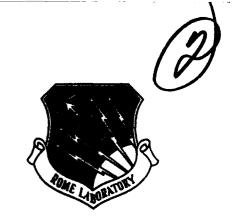


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ADVANCED COMMAND AND CONTROL ENVIRONMENT (ACCE) INTEGRATION Planning Framework

Knowledge Systems Concepts, Inc.

Paul Bell and James M. Marcinkowski



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Rome Laboratory
Air Force Systems Command
Griffiss Air Force Base, NY 13441-5700

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APPROVED:

David L. MARKS
Project Engineer

FOR THE COMMANDER:

JOHN A. GRANIERO Chief Scientist

Command, Control, and Communications Directorate

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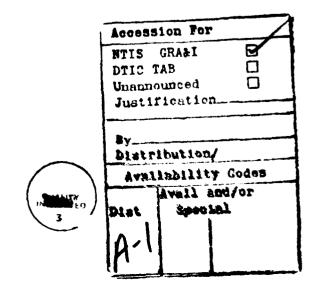
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Chapter 1

Introduction

1.1 Identification Information

This technical information report is entitled ACCE Planning Framework and provides guidelines for the incremental development of the Advanced Command and Control Environment (ACCE). Rome Laboratory established the ACCE laboratory to evaluate advanced displays and related human machine interface (HMI) technology developments in response to selected USAF command and control requirements. Knowledge Systems Concepts, Inc. has prepared the report under ELINs V002 entitled Planning Framework, V004 entitled ACCE Architecture, V005 entitled Base Line Assessment and V006 entitled Development Plan, of Contract F30602-87-D-0085/0020, "Advanced Command and Control Environment Integration". The Applied Command and Control Systems Division (COA) of Rome Laboratory (formerly Rome Air Development Center) is the contract sponsor.

1.2 Reasons for the Report

One of the objectives of the "Advanced Command and Control Environment Integration" contract was to establish a near term hardware/software baseline testbed at Rome Laboratory to evaluate display and HMI technologies for USAF command and control activities. The baseline environment was primarily made up of equipment and software that was available to the Applied Command and Control Systems Division at the time the ACCE was established. The second objective of the contract was to provide a planning framework for both the use of the ACCE, and the evolutionary development and incremental expansion of the ACCE baseline.

Knowledge Systems Concepts, Inc. provided details on the anticipated use of the ACCE in a separate technical report entitled the "ACCE Concept of Operations". The ACCE Planning Framework report completes the task by providing planning details on how the ACCE baseline can be systematically expanded. It does this by providing four substantive planning factors: an assessment of the limitations and capabilities of the current ACCE baseline; an architecture for the ACCE based on the ACCE Concept of Operations and USAF "open system architecture" guidelines; an ACCE Development Plan that shows time phased baseline improvements that will provide the advanced capabilities needed to support future command and control display and HMI requirements; and finally, recommendations concerning configuration management of the ACCE.

1.3 Organization of the Report

The ACCE Planning Framework Technical Information Report is organized into seven chapters and two appendices. Chapter 1 provides report identification information. Chapter 2 describes the ACCE baseline environment, and provides the results of an assessment of this baseline in terms of capabilities and shortfalls. Chapter 3 reviews the USAF open system architecture guidelines and their applicability to ACCE prototypes. Chapter 4 presents the design for an ACCE prototype that was developed using USAF open system architecture standards and the ACCE Concept of Operations. The design provides structure to future ACCE development activities. Chapter 5 outlines the development plan to incrementally expand the ACCE baseline. It is based on recommendations from the ACCE baseline assessment as tempered by the ACCE architecture guidelines. The Plan includes the time phased listing of implementation tasks and a development roadmap. Chapter 6 provides recommendations for ACCE configuration management. It includes ideas for configuration control, status accounting and documentation. Chapter 7 is a summary of planning framework activities. It lists the accomplishments of the planning actions, provides some conclusions that can be drawn from the planning, and recommends future actions. Appendix A provides details on three display and presentation technologies that appear to warrant future evaluation in the ACCE. Appendix B provides an alphabetical list of acronyms used in this report.

Chapter 2

ACCE Baseline Assessment

2.1 ACCE Baseline Environment

The idea for the ACCE was conceived several years prior to the start of the current ACCE effort. As a result, Rome Laboratory had obtained several hardware and software components that were available to establish the baseline ACCE configuration. The following sections review these components and assess their potential to satisfy future ACCE objectives.

2.1.1 ACCE Baseline Components

The baseline ACCE configuration available at the start of the effort was comprised of two primary systems. These systems were the Silicon Graphics workstation interfaced to a Stereographics Z-Screen display, and a Z-248 microsystem interfaced to a Bolt Beranek and Newman (BBN) SpaceGraph volumetric display. Included in the existing baseline were software packages associated with these systems and selected demonstration capabilities. The following sections provide details on these two systems.

2.1.1.1 Silicon Graphics Workstation/Stereographics Display System

The hardware environment for the baseline Silicon Graphics Workstation/Stereographics Display System consisted of a Silicon Graphics IRIS 4D/70GT workstation augmented by a Stereographics Liquid Crystal Stereoscopic Shutter (LCSS) Z-Screen 3D display, and various user input devices. The Silicon Graphics 4D/70GT workstation was configured with: 8 MB of memory; a total of 550 MB of hard disk storage; Ethernet communications; RS-232C serial interfaces; and a 60 MB removeable cartridge tape. Its MIPS R2000 CPU was rated at 12MHz, 10 Million Instructions Per Second (MIPS) and 1.1 Million Floating Point Operations per second (MFLOPS). The graphics display subsystem was rated at 400,000 vectors per second, and 40,000 polygons per second. The subsystem provided 1280x1024 pixel resolution, 48 image bit planes (24 color bit planes), 24 bit z-buffer, 16 alpha bit planes, 4 overlay planes and double buffering.

The workstation's monitor provided a color 19 inch display. The Stereographics Z-Screen display augmented the workstation's normal screen color display capability to provide 3D viewing; when three dimensional objects are properly rendered and displayed on the Z-Screen display device, a user wearing specially polarized glasses can gain a three dimensional viewing effect. User input devices on the system included a Silicon Graphics Keyboard, 3 Button Mouse, Summagraphics Digitizer with 4 Button Mouse, and a Dials and Buttons Box. The latter box consists of several programmable buttons and dials linked to various screen manipulation commands.

The system included an Ethernet local area network (LAN) Interface for high speed communications, and 10 Serial Interfaces to attach various peripherals such as terminals and printers. A Hayes 2400 baud modem was also interfaced to the system to allow users not physically connected to the Ethernet LAN to connect to the system via a communications modem.

A version of the Unix Operating System was used on the Silicon Graphics system. In addition, there was a wide variety of software already available on the system to support prototype development including a C Compiler with network interface software that included TCP/IP network protocols, and the X-Windows windowing system.

Also residing on the system was a variety of sample application software with C source code. This included the 4D Gifts Software from Silicon Graphics that highlights the Silicon Graphics 2D color graphics capability and provides executable examples of how to control and use the Silicon Graphics Display peripherals. A demonstration prototype that MITRE, Inc. developed under the 3D Display for Battle Management Program, was also available to use with the workstation. This prototype used the Stereographics Z-Screen to display 3D views of terrain scenes for an aircraft mission planning and rehearsal application.

Figure 2.1-1 lists and classifies the major resources that were available in the baseline ACCE Silicon Graphics/Stereographic System.

2.1.1.2 Baseline Z-248 / SpaceGraph Volumetric Display System

The hardware comprising the Z-248/SpaceGraph volumetric system consisted primarily of a Zenith Z-248 processor, an Enhanced Graphics Adaptor (EGA) color monitor and the BBN SpaceGraph volumetric display. The Z-248 possesses an Intel 80286 CPU operating at 8 MHz, 512 KB of RAM, 20 MB of hard disk storage, and a 360K 5 1/4 inch floppy disk drive.

The SpaceGraph volumetric display is able to display images in 3D as opposed to the two dimensions achievable with a conventional flat computer screen. The 3D effect is achieved by a flexible mirror positioned in front of a CRT that vibrates rapidly between a concave and convex shape. At the same time, the SpaceGraph volumetric software controls when certain pixels are displayed. By displaying distant points when the mirror is concave and near points when the mirror is convex, a three dimensional image can be portrayed to the viewer. Viewers can look over, under and around the sides of the image to gain different perspectives. Maximum viewing angle is approximately 30 degrees from center. Besides the SpaceGraph volumetric display, the system included a standard EGA equipped color monitor. User input devices for the system were a standard Z-248 Keyboard and a Microsoft Mouse.

Hardware Resources	Silicon Graphics IRIS 4D/70GT Workstation (8 MB memory)
	Stereographics LCSS Z Screen
	380 MB Hard Disk Storage and 170 MB Hard Disk Storage
	60 MB Cartridge Tape Drive
	3 Button Mouse
	Dials and Buttons Box
	Silicon Graphics Keyboard
	Summagraphics Digitizer with 4 Button Mouse
System Software	IRIX Operating System (Unix) and Utilities
Support Software	C Compiler
	Silicon Graphics 4D Gifts Software and C Source Code
	Unix Ethernet Software
Interfaces	Ethernet LAN Interface, 10 Serial Interfaces
	Hayes 2400 Baud Modem
Data Base	None
Application Software	MITRE 3D Display for Battle Management Program Software

ACCE Silicon Graphics/Stereographics System Resources Figure 2.1-1

The baseline Z-248 used DOS Version 3.0 from Zenith as its operating system. Development support software on the system included the Turbo C Compiler, and editors including EMACS and DOS Line Editors. The system included a 3COM Ethernet Interface and standard Serial and Parallel Interfaces.

The only way to demonstrate the SpaceGraph volumetric display capabilities was to run the BBN SpaceGraph volumetric demonstration program. This software displays a series of three dimensional images that involve simple animation.

Figure 2.1-2 lists and classifies the major components of the baseline Z-248/BBN SpaceGraph volumetric system.

Hardware	Zenith Z-248 (512 KB of memory)
Resources	BBN SpaceGraph Volumetric Display
	EGA and Color Monitor
	Z-248 Keyboard
	Microsoft Mouse
System Software	Zenith DOS Version 3.0
Support Software	Turbo C Compiler
	EMACS and DOS Line Editors
Interfaces	3COM Ethernet Interface
	Serial and Parallel Interfaces
Data Bases	None
Application Software	BBN SpaceGraph Volumetric Demonstration Program

ACCE SpaceGraph Volumetric System Resources Figure 2.1-2

2.1.2 Use of Baseline Environment

The baseline ACCE was primarily used as a demonstration environment for advanced display and presentation technology. The two applications demonstrated most frequently were the MITRE 3D Display for Battle Management prototype and the BBN SpaceGraph volumetric demonstration.

2.2 Assessment of ACCE Baseline

This section begins with a discussion of the criteria used to assess the ACCE baseline. These criteria were established to reflect the objectives stated in the ACCE Concept of Operations. The assessment criteria are then applied to the two primary ACCE baseline systems and their components to identify their strengths and weaknesses.

2.2.1 Assessment Criteria

The primary assessment involved determining how well the baseline ACCE satisfied the objectives set forth in the ACCE Concept of Operations. The primary objective of ACCE taken from the Concept of Operations document is:

"To implement a testbed laboratory environment to apply, showcase and exploit advanced display and presentation technologies that have potential impact to next generation C2 systems. The ACCE will provide a rapidly reconfigurable workbench-like environment where candidate technologies can be evaluated by engineers and users based on selected C2 requirements."

Selected major points from this objective were expanded to create more definitive assessment criteria.

ACCE will "apply, showcase and exploit advanced display and presentation technologies". To do this, the ACCE display technology must include devices and techniques that are state-of-the-art in the research laboratory. In addition, the ACCE must include sufficient equipment and software to create a demonstration prototype that will showcase the new technology. Simulations must be clear and easy to use. Moreover, they must allow the user to focus on the relative strengths and weaknesses of the targeted technologies and not be deflected by the mechanics of how to run the simulation.

ACCE will include "technologies that have potential impact to next generation C2 systems". Simulations within the ACCE must demonstrate how the application of the advanced technology solves an approved Command and Control (C2) requirement.

"ACCE will provide a rapidly reconfigurable workbench-like environment". The ACCE will be an open environment that supports the free integration and demonstration of new technology. This will allow users to directly compare competing technologies, or assess the related strengths and weaknesses of a new technology compared to what is available in the operational world today. A network backbone is a fundamental ACCE component required to interconnect the various technologies and achieve a high degree of integration. A centralized control facility is also needed to bring the networked components together into a cohesive environment, and to provide a single, consistent method for user access. In addition, ACCE use of industry accepted standards will be important to facilitate compatibility with future technologies.

ACCE "candidate technologies will be evaluated by engineers and users". Though the ACCE targets a wide user base, the initial focus of ACCE demonstrations will be the C2 user. This person has the domain expertise to evaluate the validity of a demonstration from a C2 perspective and the knowledge to definitively identify the C2-related strengths and weaknesses of a particular technology. Given favorable evaluations by domain users, ACCE demonstrations will then target engineers and technologists to identify ways to improve the technologies, and to assist with the transition of promising technologies into operational C2 systems.

The following sections discuss the relative strengths and weaknesses of the systems comprising the baseline ACCE. In these sections particular attention has been given to projecting how well these systems can support the above stated objectives of the ACCE.

2.2.2 Silicon Graphics Workstation/Stereographics System Assessment

The Silicon Graphics Workstation/Stereographics System is a system that spotlights performance, processing power, and user interaction in a state-of-the-art workstation platform. Although very advanced, the system appears to the user as a dedicated high power workstation that operates in a manner similar to conventional workstations. This perception makes the system suitable as the user platform from which a number of ACCE capabilities can be accessed.

The processor has the capability to run all the initial simulations to be performed within the ACCE. It includes a powerful and upgradeable graphics engine that can rapidly perform the complex drawing operations necessary to drive a variety of display devices. It is easily expanded through the addition of memory, processors, etc. to handle even the most intensive graphics processing and manipulation tasks. In addition to the system's hardware, the Unix operating system coupled with the C programming language and the X-Windows windowing environment can support the software implementation of sophisticated demonstration prototypes. The use of these industry standard system software components will facilitate the development of prototypes that are interoperable with other platforms running similar standard software.

The system's display capabilities include a 19 inch color monitor that is representative of today's high powered workstations. This display is augmented by the Stereographics Z-screen that can provide 3D stereoscopic depiction of 3D graphic data. The Z-Screen capability is easily turned on or off by the flip of a switch. However, this action has to be accompanied by software processes that effectively change the data values being displayed to adjust to either a 2 1/2 (two and a half dimensional) or three dimensional (3D) display mode. To obtain the 3D effect, the user must view the display screen from the proper angle (essentially head-on), and must wear special polarized glasses. If all of these display characteristics are properly orchestrated in a simulation, the system can support the direct comparison of 2 1/2D versus 3D display devices.

A variety of resources, including already developed applications, function libraries, sample routines, and hardcopy documentation was available to aid in the development of display evaluation prototypes using the Stereographics Z-Screen Display. Most notable among these resources was the MITRE, Inc. developed "Three-Dimensional Displays for Battle Management" simulation. This simulation used the system's 3D display capabilities to depict out-of-the-window cockpit views of terrain and surface objects in 3D for aircraft mission feasibility planning. This simulation was important to ACCE for two reasons. First, it satisfied the objective of using advanced display technology in a simulation directly relevant to C2 problems. Second, the simulation provided an example to developers of how to prepare images for use on a 3D display device.

Several user input devices including keyboard, 3 button mouse, and a buttons and dials box were available for use with the Silicon Graphics system. Moreover, the system could support the

addition of other such devices. This flexible input capability provided the user with a number of options to interact with a simulation.

The Silicon Graphics system appeared to the user as a powerful single user workstation. However, the system included extensive Ethernet network interface capabilities and standard network protocol software to make the system a suitable candidate to become the central controller for all ACCE simulations. In this regard, it could serve as the ACCE's nerve center to access a host of other technologies over the network to execute cohesive, well integrated simulations.

2.2.3 Zenith Z-248/SpaceGraph Volumetric System Assessment

The Zenith Z-248/SpaceGraph volumetric system is a personal computer based platform that provides an advanced, somewhat exotic 3D display capability using an overhead display and vibrating mirror.

The Z-248 processor's power appeared adequate to control the SpaceGraph volumetric display device. However, the Z-248 is not powerful enough to act as the ACCE single point of access to control integrated simulations that use many different devices.

The system is configured with an Ethernet interface, as well as the serial and parallel ports available on most PC level systems. The Ethernet interface could be useful in the future to allow the Z-248 system to communicate with the Silicon Graphics system during a simulation.

The system software environment includes PC DOS and the C programming language. This combination was found adequate for development on the Z-248 but is not compatible with the Unix based Silicon Graphics operating system. This non-compatibility required developers of simulations that tie both systems together to be familiar with both Unix and DOS.

The Z-248/SpaceGraph volumetric system provides two distinct display capabilities. With the SpaceGraph volumetric display turned off, the system provides a basic medium resolution color EGA display. With the SpaceGraph volumetric turned on and the demonstration software provided by BBN running, the system displays a series of three dimensional images in 3D. These 3D displays are provided in a medium resolution monochrome format. Association between the demonstration images and a real C2 problem is not direct; the images can only depict movement of two objects within a 3D space, or multiple vectors in 3D space.

On the plus side, 3D objects can be viewed on the Z-248/SpaceGraph without the aid of specialized glasses. And, compared to the Silicon Graphics Stereographics Z-Screen capability, the Z-248/SpaceGraph's 3D display can be viewed from most angles. These functions might be useful to ACCE developers to provide demonstration prototypes that are not specialized for the characteristics of the display and that are directly relevant to selected C2 problems. However, the demonstration software provided by the vendor was the only means of demonstrating the

SpaceGraph's volumetric 3D display capabilities. It is likely that the images and their viewing angles were specially selected to highlight the display's positive attributes.

Therefore, compared with the MITRE simulation running on the Silicon Graphics system, the Z-248/SpaceGraph volumetric demonstration had several drawbacks. The images portrayed made very limited use of animation, i.e. display of moving objects. Moreover, it appeared that this lack of animation was a design limitation inherent in the display device. In addition, the demonstration is generally non-user interactive in that the user cannot dynamically change the viewers location or distance from the 3D image. Finally, there was no evidence that more processing power or different simulation software would produce a better display.

2.3 Summary of Baseline Capabilities

Overall, the baseline ACCE configuration provides an adequate point of departure for future ACCE enhancements and implementation. The baseline ACCE systems provided the ACCE project team with an assortment of system capabilities and implementation approaches that subsequently were exploited to demonstrate advanced 3D display and user input devices and techniques.

Of the two major systems in the ACCE baseline, the Silicon Graphics system was certainly the most significant. The workstation has the capability to act as the centralized graphics engine and control point for simulations using more than one device. The system can be upgraded through the addition of processors and memory to support graphically intense operations. The display, when not operating in 3D mode, provides a good baseline to compare high quality color 2D displays. When operated in 3D mode in conjunction with appropriately developed software, the Stereographics Z-Screen provides an advanced display capability suitable for demonstration and evaluation. This type of display is innovative and is not generally found in the operational C2 world. The software on the system provides a quality development environment to support implementation and demonstration of evaluation prototypes. The software suite is in general compliance with industry accepted standards for operating systems, network interface and development languages. The 3D Display for Battle Management software is a useful simulation that matches ACCE technology with a C2 problem and provides an objective demonstration of 3D display technology.

On the other hand, the Z-248 is probably best used as a system dedicated to controlling the SpaceGraph volumetric display. It could also provide, for comparison operations, a medium resolution color display representative of 1990 IBM PC/DOS based platforms.

In summary, the baseline ACCE provided a good foundation, but a number of technology and demonstration shortcomings were found. For example, the ACCE needs to include other types of display and presentation technologies. The hardware and software components of the

baseline ACCE focus only on advanced 3D display technology and user input devices. Other major technological thrusts under the broad area of display and presentation technology need to be assessed in the ACCE. These include technologies such as multimedia presentations, large screen 3D presentations and simulations, virtual reality simulations, and large screen displays. Such technologies are innovative and offer potential payoffs for improving the understanding and solution of C2 problems.

The capability of ACCE demonstrations to show the potential solution of C2 relevant problems, needs to be improved. The 3D Displays for Battle Management simulation provides a quality demonstration that is operationally relevant, but association of the Z-248/SpaceGraph volumetric display's capabilities to operationally relevant C2 problems are left up to the viewer.

Though the baseline ACCE configuration concentrates on the demonstration and evaluation of 3D display and user input devices, the comparison of 2D or 2 1/2D to 3D is neither easy, nor direct. In addition, since the Stereographics and Z-248/SpaceGraph volumetric displays represent competing 3D display technologies, it would be valuable to be able to view both these devices in a single simulation. This would allow the ACCE staff to directly compare and assess their relative strengths and weaknesses.

A number of different user input devices are included in the baseline ACCE along with the more conventional mouse and keyboard devices. Future evaluation prototypes need to evaluate the non-standard devices and assess how they might be useful.

Finally, with the exception of the Ethernet interface, the Z-248/SpaceGraph volumetric system is not compliant with either the industry accepted standards for the operating system (Unix), or the user interface (X-Windows). Therefore, the ACCE needed to provide developers with a programming language, such as "C", that will be compatible for controlling both the Z-248 running DOS and Silicon Graphics system running Unix.

Chapter 3

ACCE Open System Architecture

3.1 Introduction

This chapter reviews open system architecture objectives and standards and provides general recommendations for the implementation of an ACCE architecture that is compliant with these guidelines.

3.2 Air Force Open System Architecture

Historically, individual C2 systems were developed to solve very specific problems within the C2 domain. These systems were typically designed and implemented by different developers under various sponsoring agencies. Often, each developer took a different approach to system design. The result was a collection of specialized systems, comprised of different architectures, interfaces, hardware and software. This led to poor interoperability and increased development, training, maintenance and enhancement costs. In response, the government has adopted the Open System Architecture guidelines. An Open System Architecture (OSA) is a computer system organization that allows software functions and hardware to be added or deleted without changing the underlying framework. This architecture can be achieved in part by adhering to structured design methodologies that result in modular systems having well defined functions and interfaces. Other OSA considerations are adherence to standards regarding the development language, computer operating system, communications methodology, data base and human machine interface.

The following outlines the primary characteristics of an OSA. The reference sources were the IDHS Architecture Newsletters published by the Air Force Intelligence Agency (1 April 1989 through 30 November 1990) and the TAF Unit-Level Open System Architecture Specification, dated 21 September 1990.

- Interoperability: The ability to provide and accept data or services from another computer system.
- **Portability**: The capability of software developed on one hardware platform to be moved or ported to other hardware platforms and reused.
- Commonality: This feature allows users to access in a consistent manner, diverse computer systems having different characteristics. Normally this is accomplished by using

standard HMI features to present users with a common look and feel across diverse systems and applications.

- Extensibility: The ability to increase the scope of an architecture. This allows for the addition of more hardware platforms to a particular site or for the inclusion of new software functionality to gain added capability.
- **Scaleability**: The ability to expand the capabilities of a single component of a system by adding increased functionality or increasing its performance to accommodate growth.
- Remote Operation: This feature allows system users to take advantage of resources that are available but not collocated with the user.

These desired characteristics are obtained through the prudent use of recognized systems standards that promote hardware independence, software portability, and application interoperability. These standards are applicable to the various components of any computer architecture including: Computer Operating Systems, User Interfaces, Network Management, and Data Bases. Standards that are of specific interest to ACCE include:

- Computer Operating Systems: The use of "POSIX" or "Unix" compliant operating systems that can be called in a standard manner.
- **User Interfaces**: The use of "X-Windows" based window managers for computer screens.
- **Network Management**: The use of industry and government accepted TCP/IP, NFS, and/or GOSIP standard communication protocols.
- **Data Bases**: The use of SQL, an industry accepted data base manipulation language, to be used by software applications that communicate with a data base management system (DBMS).

The following sections provide details on the design for the ACCE Open Systems Architecture.

3.3 The ACCE Open Systems Architecture Design

The ACCE Open Systems Architecture design must satisfy the following criteria:

- The design should adhere to the scope and objectives of the ACCE as stated in the ACCE CONOPS document. It must be in line with ACCE's primary objective: to apply, evaluate, showcase, and exploit advanced display and HMI technologies that have potential impact to next generation C2 systems. Certain operational conditions may be simulated, as long as they are realistic enough to support conduct of rigorous behavioral analysis of the technology. This means that the accuracy

and precision of the C2 functionality may not be required to highlight the strengths and weaknesses of advanced display and presentation technology and to recommend engineering modifications. If a demonstrated technique or technology shows sufficient promise as a result of an initial ACCE demonstration prototype, a second prototype that is more accurate from a C2 functional perspective could be developed.

- The design should create an open system architecture environment. The design should encourage interoperability, portability, commonality of interface, extensibility, scaleability, and access to remote operations.
- The design should use the major systems that are already assigned to the ACCE laboratory. As described in the ACCE Baseline Assessment in Chapter 2 of this report, selected advanced display and presentation devices have already been assigned to the ACCE laboratory. The ACCE architecture must accommodate these devices for cost effective technology evaluation reasons.

The creation of an open environment is an important objective in the design of ACCE resident prototypes. Because ACCE is to be an advanced demonstration and evaluation environment, it will include state-of-the-art, sometimes non-standardized, display and presentation technologies. Without the application of sound system development techniques and the use of industry and DoD accepted standards whenever possible, ACCE could easily become a hodgepodge of advanced technologies that fails to function as a cohesive environment. The OSA helps to mitigate these risks.

In some instances, exceptions to OSA standards may be required for specific innovative display and presentation technologies. Such technologies, still in their infancy, may not yet have been implemented to conform to OSA standards, or may be so innovative that they include functionality that is beyond the bounds of current industry standards. This is currently true of 3D data representations and display techniques that are not part of the X-Windows standard. In such cases it would be easy to dismiss the advanced technology out-of-hand because it is non-compliant with current OSA standards. This would be a mistake however, since some of the most innovative and potentially promising technologies would then be omitted from the ACCE without further evaluation.

Once the technology evaluation indicates potential C2 applicability, the goal should be to make the technology OSA compliant as much as possible. Even if full compliance with OSA standards is not activities able, the enhanced prototype probably could be developed using OSA techniques such as software layering, software modularity and device independence.

The following sections discuss various open system architecture related recommendations for design of the ACCE. These recommendations temper the guidelines and standards comprising

the USAF OSA model with the objectives, operational requirements, and constraints of the ACCE as stated in the ACCE Concept of Operations.

3.3.1 Computer Operating System Recommendations

The primary operating system to be used within the ACCE should be Unix. Probably the most important aspect of the USAF OSA is the selection of this POSIX compliant operating system. By adhering to this standard through the choice of Unix, adherence to other standards for communications, user interface, and data base interface standards come more naturally since TCP/IP, X-Windows, and SQL are defacto standards for communications, windowing systems, and DBMSs running under the Unix operating system.

3.3.2 User Interface Recommendations

The use of the X-windowing HMI system should be an objective of the implementation to be done within the ACCE. Well structured standard windowing systems like X-Windows support the creation of consistent user interfaces across applications.

It must also be noted however, that the very nature of the ACCE, as the environment developed to evaluate the cutting edge of display/and HMI technology, may necessitate deviation from the X-Windows standard. For example, the use of new and innovative display and HMI devices may require the use of specialized windowing and graphics functions, functions that are new and thus have not yet become part of industry accepted windowing standards. Such functions might appear as a significant library of extensions to X-Windows, or may even involve the use of all new graphic manipulation and windowing languages and libraries specialized for a revolutionary display device.

To resolve possible difficulties introduced by non-standard interfaces in state-of-the-art technology, software layering becomes of utmost importance. Layering separates application software into device independent and device dependent operations. As a result, at least the device independent functionality can be ported to other platforms.

3.3.3 Network Management Recommendations

We recommend that the TCP/IP communication protocol be used whenever possible. Network communication is an important component of the ACCE to support the demonstration and comparison of various display and HMI technology. ACCE devices (including CPUs, display devices, user input devices) must be able to interact via a network to behave as a single cohesive system. The use TCP/IP and other OSA compatible protocols such as NFS, and/or GOSIP should be a realizable objective since most of the devices in the ACCE hardware environment are envisioned to be predominantly Unix-based and therefore will include TCP/IP (and to a lesser extent NFS) communications facilities as part of the operating system. OSA compatible

communications with devices and data sources external to the ACCE should also be achievable since many of the operational Air Force systems are already TCP/IP and, to a lesser extent NFS compliant.

3.3.4 Data Base Recommendations

Data base choices probably can be deferred for the near and mid-term. This is because the ACCE focuses on the integration, evaluation, and demonstration of display and presentation technology, and in most cases the data bases used within ACCE will be simulated. When a data base is simulated, data that is normally supplied by a DBMS is instead read from and written to simple data files. With this scheme, there is typically no requirement to interface with a real DBMS and thus no requirement for a data base interface language. An exception to the statement that the data bases within ACCE will be simulated involves the possible interface to real external data sources (such as air tracking data from the Sector Operations Control Center (SOCC)). Since these data sources are external to the ACCE, the ACCE has little control over specifying and/or altering the format of the data to ensure its adherence to open system standards and guidelines.

It is envisioned that as ACCE grows in the future, it may become necessary to use a DBMS to manage and access large simulated data bases that may be necessary to drive large ACCE simulations. DBMSs and data base interfaces will have to be examined at that time to ensure that they are compatible with the ACCE's OSA specified standards.

Chapter 4

ACCE Prototype Design

4.1 Introduction

This chapter outlines a high level design for the ACCE Display Evaluation Prototype (ADEP) developed under this effort. The objectives of this design were twofold:

- To expand on the ACCE baseline outlined in Chapter 2 and create an ACCE open system architecture capable of supporting the demonstration and evaluation of advanced Display Presentation Technology.
- To implement an evaluation prototype within the ACCE that demonstrates advanced display technology applied to a C2 problem and validates the overall utility of the ACCE as an aid to research and development.

The following sections describe the prototype's operational C2 scenario, as well as the hardware and software architectures and functions of the prototype.

4.2 Operational Scenario Selection

The first step in the development of the ACCE prototype involved the selection of an operational C2 scenario that demonstrated advanced display and presentation technology. The ACCE staff selected an operational scenario that related to a system currently under development. This allowed the ACCE developers to concentrate on solving a C2 problem through the application of advanced technology rather than spend time trying to identify a problem

Several development programs and efforts were examined to identify one that contained an operational scenario suitable for the application of advanced 3D display technology. These programs included the Advanced Planning System (APS), the Survivable Adaptive Planning Experiment (SAPE), and the Air Defense Initiative (ADI).

APS was not selected to provide the scenario for an ACCE prototype due to its maturity. When APS was examined, the program was only months away from producing an operational system. Therefore, the APS was too far along to be able to benefit from research performed in the ACCE.

SAPE also was not selected, but for a different reason. Upon review of SAPE, it was determined that the problem addressed by SAPE does not currently involve a requirement that could be

supported by representing objects in a three dimensional world. Therefore, SAPE was found to be an inappropriate candidate for the application of the ACCE's resident 3D display technology.

The scenario addressed by the ADI program was selected for the application of 3D display technology. This program is investigating and evaluating approaches to an integrated C2 capability to counter the cruise missile and future low-observable advanced technology threats. Although it encompasses the functions of surveillance, engagement, and command and control, the paramount technology thrust is for broad area surveillance, particularly for assured tactical warning and attack assessment. To do this, ADI systems must be able to correlate and fuse multi-source data, in real time, to develop an integrated land, sea and air surveillance picture.

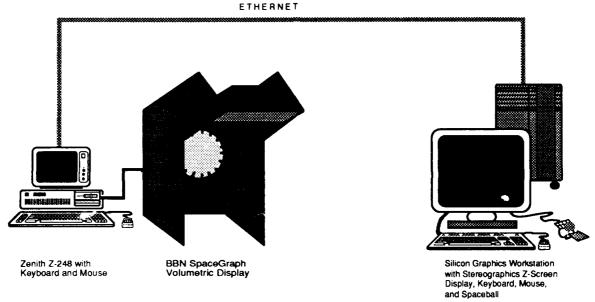
Within the broad ADI thrust, a specific prototype, the ADI Simulation for Command and Control, or ADISC2 project, was identified as containing specific display scenarios that would benefit from the application of 3D display technology. The objective of ADISC2 was to develop an integrated simulation to provide threat, surveillance, engagement and communications models that can be exercised according to approved scenarios.

The ADISC2 simulation hardware architecture in the Rome Laboratory Command and Control Technology Center (C2TC) is comprised of three Sun 3/260 workstations that communicate with each other using the TCP/IP protocol over Ethernet. Each workstation is equipped with a color bit-mapped display, a standard keyboard and a mouse. The HMI is menu driven and graphics oriented, but it was not implemented using the current industry standard for HMI called the X-Windows system. The display system allows generation of various 2D and 2 1/2D projections of the earth. The display can range from the size of a state (e.g., Texas or Massachusetts) to the entire globe. The capability also exists to overlay symbols such as ground targets, weapon detonations, missiles, over the horizon backscatter (OTH-B) radar and space based radar. The positions of these point symbols, and the earth's position due to rotation, are dynamically updated throughout the scenario.

The ADISC2 program had three characteristics that made it an ideal candidate for the application of advanced 3D display technology. First, the ADISC2 program is currently under development. It is mature enough to provide example displays and scenarios that can be simulated using 3D display technology, but is early enough in its development cycle so as to be able to benefit from 3D display technology if the prototype proves that the technology is promising. Second, the system's displays make extensive use of computer graphics that are complex, dynamic and visually interesting. Finally, the displays portray objects that possess three dimensional geometries. The earth as well as OTH and space based radar areas of coverage are three dimensional volumes that are currently depicted as two dimensional objects only because of limitations in the ADISC2 display technology. It was determined that ACCE experimentation could be conducted to gauge the benefits of applying advanced 3D display technology to an ADISC2-like problem.

4.3 ACCE Display Evaluation Prototype (ADEP) Hardware Architecture

To support the development of an advanced display and presentation prototype, a generic hardware and software architecture was developed within the ACCE. Since the baseline ACCE already included a collection of 3D display technologies, it was determined that the prototype would showcase the advanced 3D display technologies and techniques. The hardware architecture for the prototype is shown in Figure 4.3-1 and consists of the Silicon Graphic/Stereographic Z-Screen display system, the BBN Z-248/SpaceGraph volumetric display system and each system's respective hardware and software components as described in Chapter 2. The two systems were interfaced to each other via an Ethernet connection.



Hardware Architecture for 3D Display Figure 4.3-1

Analysis revealed that many of the data structures to be used in the prototype needed to be available in main memory on the Silicon Graphics workstation to optimize performance of this architecture. To support this requirement, 8 MB of memory were added to the workstation bringing the total memory to 16 MB. In addition, a 700 MB hard disk drive was added that brought the total hard disk storage capacity to 1080 MB. This increased disk capability was required to support implementation of the prototype and the concurrent storage of multiple versions of the prototype software.

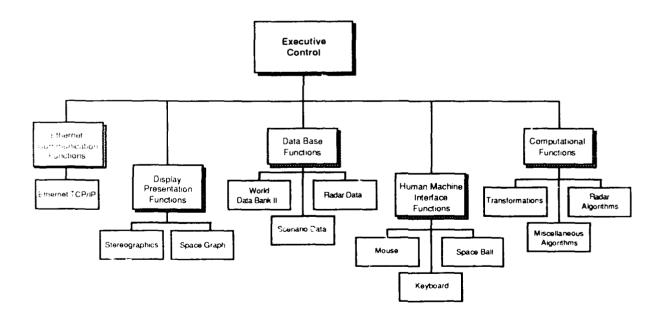
A six axis Spaceball user input device was also added to the configuration. This device was selected to provide a very intuitive means of manipulating objects displayed in 3D. The Spaceball can best be described as a trackball mounted on a stick. By twisting the ball the user is able to directly input rotation and translation commands in three dimensions.

4.4 ADEP Functional Architecture

The functional architecture of the ADEP is depicted in Figure 4.4-1. These functions include processes to:

- Provide executive software to control the overall execution of the prototype.
- Communicate display information between the SGI/Stereographic System and the Z-248/SpaceGraph volumetric display system.
- Display graphic information in 2 1/2D and 3D on the ACCE Silicon Graphic/Stereographic display System and the Z-248/SpaceGraph volumetric display system.
- Perform data base manipulation operations on World Data Bank II derived map data, radar and scenario data bases.
- Provide HMI tools to control the operations of the prototype via 2D, 3D and keyboard devices.
- Provide computational functions in the form of geographic coordinate transformations, radar algorithms and miscellaneous mathematical operations.

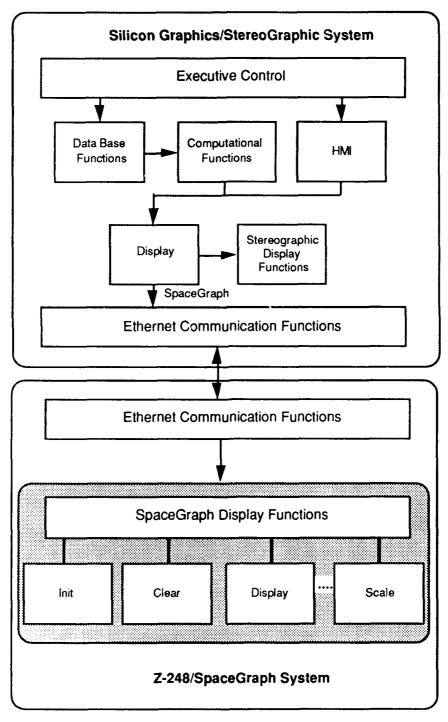
The following paragraphs provide further discussion of these functions.



ADEP Functional Architecture Figure 4.4-1

4.4.1 Executive Control Functions

The executive software controls the ADEP execution. Figure 4.4-2 depicts the ADEP's functional flow that is controlled by this executive.



ADEP Functional Flow Figure 4.4-2

The flow commences on the Silicon Graphics/Stereographic System and, if required, is passed to the Z-248/SpaceGraph volumetric system. Once activated, the executive initializes all values needed for processing including parameters for the computational functions. Next, it initializes all devices used within the operations including: the Ethernet communication device if required, display devices (Stereographic and SpaceGraph volumetric via communication), mouse and 3D Spaceball. It then opens and reads the Scenario data base, WDB II data base, and the radar data bases. The executive then graphically displays a world globe using the WDB II information via software commands to the WDB II data base, computational functions and display functions. If any radar data types are to be displayed, radar functions are processed to generate display directives for their respective area of coverage. Next, the executive waits for the user to provide direction via one of the user input devices. The executive function processes user input to generate and update the display presentation. For example, if the user selects a new geographic area of interest using the Spaceball, the Globe and radar display information are regenerated and displayed to reflect the new area of interest (AOI) position. If the user has selected the SpaceGraph volumetric display, the appropriate functions are activated to generate the display information. This information is then communicated to the SpaceGraph volumetric system. When the user chooses to terminate the process, the display is cleared, all devices and data bases are closed, and process control is passed from the executive to the underlying operating system.

4.4.2 Communication Functions

Two sets of network communication software functions have been developed for the prototype. One set of software functions operates on the SGI/Stereographic System to communicate display data to the Z-248/SpaceGraph volumetric system. The second set of software functions operates on the Z-248/SpaceGraph volumetric system and receives display data from the SGI/Stereographic System. These two network application software modules that were developed using the Unix BSD Socket Library Interface, communicate via Ethernet hardware using the TCP/IP protocol.

4.4.3 Display Functions

Two sets of display functions are provided within the prototype. One set produces data for the SGI/Stereographic System, and the other for the Z-248/SpaceGraph volumetric system. Initial processing for both systems is performed on the SGI System. For the SpaceGraph volumetric display, this data is then formatted and communicated over the Ethernet interface for display processing on the Z-248/SpaceGraph volumetric system. The SGI/Stereographic System processes both 2 1/2D and 3D data, whereas the Z-248/SpaceGraph volumetric system will process only 3D data.

4.4.4 Data Base Functions

The data bases that drive the scenario are contained in several discrete data files that can be created, manipulated and edited using a standard text editor. These files are read and used by the program at execution time. This method of simulating data interfaces was selected in accordance with an open system development approach. The format of the data files is ASCII text consisting of data element names and data element values. This file format is simple and could easily be produced by an automated DBMS, or if required in the future, by a filter that is connected to a live data interface. Three sets of data base functions were developed for the ADEP prototype: one set for the WDB II data base; one set for the Scenario data base; and one set for the radar data base.

4.4.5 Human Machine Interface Functions

The user input devices used by the prototype consist of the devices connected to the Silicon Graphic/Stereographic System and include the SGI mouse, keyboard and Spaceball. The SGI mouse is used to select menu functions. The keyboard is used to input latitude and longitude data and thereby specify a geographic area of interest (AOI). The Spaceball device is used to manipulate the position of the globe within the display and to perform other special display manipulation functions that are incorporated in the Spaceball device.

4.4.6 Computational Functions

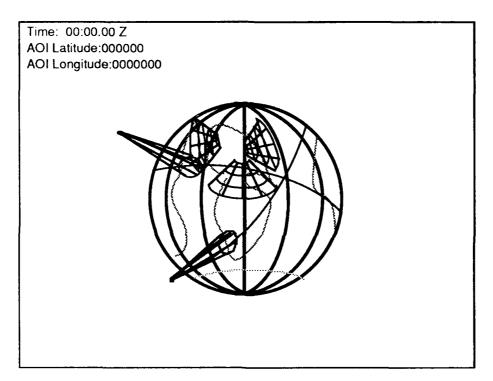
There are three sets of computational functions that are implemented in the prototype. The first set is comprised of transformation functions that convert latitude/longitude values to x,y,z coordinates and from x,y,z coordinates to latitude/longitude values. The second set of functions calculate radar coverage of OTH radar and space based radar for display presentation. Radar coverage is projected from the radar position onto the earth's surface. The third set of functions provide miscellaneous geographic computational functions. These functions include routines such as conversion of Spaceball inputs to latitude/longitude values, calculation of range and bearing between two given latitude/longitude points, etc.

4.5 ADEP Functions

ADI and specifically the ADISC2 program was selected to provide an operational scenario for the simulation and demonstration of 3D display technology. As a result of this selection, the ADI Display Evaluation Prototype (ADEP) was developed to illustrate the relative advantages of employing 3D display systems over 2 1/2D display systems. The ADEP aids in assessment of stereo-pair display technology and multi-planner volumetric display technology by applying the advanced display technology within a C2 display presentation context. The simulation operates

from the Silicon Graphic (SGI)/Stereographic workstation and is controlled via menu driven selections and data entry windows. User input is provided via keyboard, mouse and/or Spaceball input actions.

After initialization is completed, a line drawing of the world globe is displayed on the SGI workstation in 2 1/2D similar to that shown in Figure 4.5-1. Overlaying this globe are wireframe volumes representing space based radar (cone shapes) and over the horizon (fan shapes) areas of coverage. The parameters that define the number and characteristics of the radars in the simulation are read during run time from editable text files.



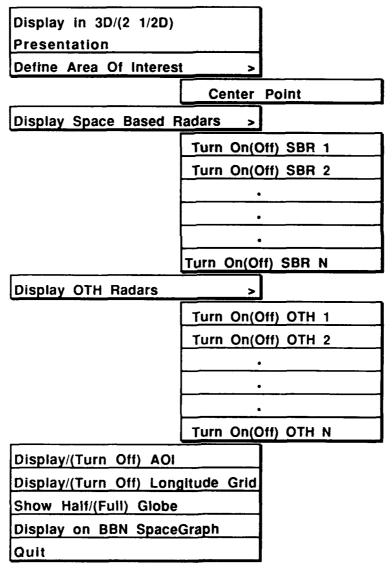
Sample ADEP Display Figure 4.5-1

In the upper left corner of this display, a digital clock is shown describing the simulated time of the prototype and the center latitude and longitude coordinate of the current AOI. The ADEP display is animated in two ways. First, the space based radars are dynamic objects that move around the globe along a designated path as time progresses. Also the user can dynamically rotate the entire globe and its associated radars by manipulating the Spaceball user input device.

Once the simulation is started the user can then control and manipulate the simulation by using a collection of menu based functions, and programmed Spaceball functions. The following sections detail the menu functions and Spaceball functions that are provided in the prototype.

4.5.1 ADEP Menu Functions

Figure 4.5-2 depicts the menu functions that are provided within the ADEP. They are accessed by dragging the mouse while holding the right mouse button down, then releasing the mouse button while the desired item is highlighted. Hierarchical menus (consisting of subitems under a main menu item) are activated by selecting the desired menu item and dragging to the right then down to the desired menu subitem and highlighting it. The following paragraphs describe the ADEP menu functions or items (and their subitems where applicable).



ADEP Menu Functions Figure 4.5.2

The Display 3D/(2 1/2D) Presentation item toggles between two modes: 3D (to be viewed with the mode switch, located at the bottom left of the monitor, set to "Stereo" and the operator

wearing polarized glasses), and 2 1/2D (to be viewed with the mode switch set to "Pseudo" without polarized glasses). This feature allows the user to directly compare and contrast how the same image appears in 2 1/2D and in 3D on the SGI Stereographic workstation. When the prototype is placed in 3D mode, the user should initially see two images placed one above the other. When the stereo button (located on the left hand side of the Stereographic Z-Screen controller located below the display monitor) is activated, these images are merged creating the 3D display. When the prototype is placed in 2 1/2D mode, the user should see only one image.

The **Define Area Of Interest** item contains a subitem that defines an area of interest (i.e., a center point expressed in latitude/longitude). The **Center Point** subitem prompts the user to enter a coordinate expressed as a latitude and longitude. When the center point of the AOI is changed, the entire world globe is rotated to position the new AOI at the front center of the screen. When the Center Point subitem is selected, the user is presented with another window that allows a latitude/longitude coordinate to be entered. Once this coordinate has been entered, the global display is altered and the new AOI is placed in the front center of the screen.

The **Display Space Based Radars** item contains subitems that control the display of Space Based Radars. Subitems **SBR 1** through **SBR N** subitems turn on the display of the selected Space Based Radar only. When these subitems are selected, the indicated Space Based Radar will be displayed, or if already on, turned off.

The **Display OTH Radars** item contains subitems that control the display of over the horizon (OTH) radars. Subitems **OTH 1** through **OTH N** display the selected OTH radar only. When these subitems are selected, the indicated over the horizon radar will be displayed, or if already on, turned off.

The Display/(Turn Off) AOI item toggles or turns on or off the display of the segmented circle depicting the area of interest or AOI. The characteristics of the AOI circle are defined to the simulation via the Define AOI menu item described above. When this item is first selected, the AOI circle is displayed. When this item is selected the second time, the AOI circle is turned off. When the AOI is displayed, information is also automatically displayed which monitors the passage of space based radars through the AOI. For instance, assume that the path of a space based radar intersects the AOI. Thus, as the simulation progresses, the space based radar will move through the AOI. When this occurs during the simulation, the latitude, longitude, and time at which the radar initially entered the AOI is automatically displayed in the upper left corner of the display below the simulation clock and AOI center point. When the radar exits the AOI, the latitude/longitude and time of the exit is also displayed. This data will remain on screen until the AOI is changed, or the radar again passes through the AOI.

The **Display/(Turn Off)** Longitude Grid item toggles or turns on and off the display of the longitude line grid. When this item is first selected, the longitude grid lines are off (not displayed). When this item is selected the second time, the longitude grid lines are turned on or displayed.

The View Half/Full Global Display item toggles or turns on and off the globe display. The full globe display shows the "hidden lines" that represent the back side of the globe. The half globe display turns off these back side of the globe "hidden lines". When this item is first selected, the back half of the globe is turned off or not displayed. When this item is selected the second time, the back half of the globe is turned on or displayed.

The **Display on BBN SpaceGraph** volumetric item sends the image currently on the SGI display to the BBN SpaceGraph and displays it. This feature allows the user to compare the display of the same data on the two display devices (i.e., the SGI Stereographic workstation and the SpaceGraph). Whenever this item is selected, the image that is currently being displayed on the SGI system will be displayed on the BBN SpaceGraph volumetric display device.

The **Quit** item allows you to exit the ACCE simulation and return to the Unix operating system. After exiting the ACCE prototype, the user should set the mode switch located on the Z-screen controller at the bottom left of the monitor to "Pseudo" to prepare for the next user session.

4.5.2 Spaceball Functions

The Spaceball input device can also be used to control/manipulate the simulation in addition to the mouse and keyboard. The Spaceball can change the AOI center point by rotating the world globe. When the user turns the Spaceball in a clockwise direction, the globe rotates in a clockwise direction. When the user turns the Spaceball in a counter-clockwise direction, the globe rotates in a counter-clockwise direction. The visual feedback from this action is immediate and twofold. First, the user can see the globe rotate and second, the center point latitude and longitude coordinate are dynamically updated in the upper left corner of the screen.

The Spaceball also has an eight button keypad that provide the following functions:

- Button number 1 reduces the Spaceball's sensitivity. When this button is used and the Spaceball is rotated, the display will rotate less quickly or the user will have to manipulate the Spaceball longer in order for the display to rotate to the desired position.
- Button number 2 increases the Spaceball's sensitivity. When this button is used and the Spaceball is rotated, the display will rotate more quickly. Thus the user will not have to manipulate the Spaceball as long in order for the display to rotate to the desired position.
- Button number 3 reduces the scale of the display. This includes the globe and all radars. When this button is used, the globe size is decreased and the effect is that the display is "zoomed out" from the user's point of view.

- **Button number 4** increases the scale of the display. This also includes the globe and all radars. When this button is used, the globe size is increased and the effect is that the display is "zoomed in" from the user's point of view.
- **Button number 5** decreases the interaxial separation of the two stereo images being displayed. This function has an effect only in the 3D mode and is used to fine tune the focus of the stereo images when "zooming in".
- Button number 6 increases the interaxial separation of the two stereo images being displayed. Again this function only has an effect in the 3D mode and is used to focus the image when "zooming out". Buttons 3 and 4 also adjust the interaxial separation in an attempt to automatically focus the display as it is zoomed in or out; buttons 5 and 6 are used only for extreme fine tuning.
- Button number 7 and Button number 8 are currently inactive and are reserved for future versions of the prototype.

In addition to the eight buttons on the Spaceball's keypad, there is a small button on the back of the Spaceball proper called the "pick" button. When the "pick" button is pressed during a simulation, the entire display is reset. The AOI latitude and longitude are set to zero latitude and zero longitude; the zoom level is set to the default value (showing the entire globe on the screen); the 3D focus is set to the default value and the Spaceball sensitivity is set to Button Number One.

Chapter 5

Development Plan

5.1 Introduction

This chapter outlines the development plan to incrementally expand the ACCE baseline. It includes the recommendations developed while assessing the current ACCE (see Chapter 2), as tempered by the ACCE architecture guidelines discussed in Chapter 3. The plan includes the time phased listing of implementation tasks and a development roadmap.

Plans for future ACCE growth are based on two primary assumptions. First, major advancements and innovations in display and presentation technology will continue to occur over the next five to ten years. This is believed to be a fair assumption based on a preliminary examination of evolving technologies such as multimedia presentations, interactive presentations, and virtual reality simulations. While these technologies are still in their infancy, they promise to provide great advancements in knowledge visualization, and thereby will convey substantive and meaningful information to a viewer. Second, it is assumed that future funding levels, for both the ACCE, and the C2 programs that can potentially benefit from ACCE demonstrations, will continue near the present level. Both are necessary conditions for the continued success of the ACCE.

5.2 Near-Term Enhancements

Near term enhancements are defined as those enhancements made to the ACCE baseline configuration described in Chapter 2 of this report, that have been completed prior to the end of this initial ACCE development effort. These improvements were made to better support ADEP demonstration activities, and to develop an initial prototype that uses the ACCE baseline technologies. A sizeable portion of the initial ACCE effort was allocated to accomplish these near term tasks. They are included in this section to establish the new baseline for the ACCE and to document the changes made to the original baseline ACCE environment presented in Chapter 2 of this report.

5.2.1 ACCE Baseline Enhancements

The first enhancements to the original baseline ACCE involved a number of additions to the environment to support prototype development, evaluation and demonstration. The original baseline environment included sufficient advanced technologies to warrant creation of evaluation

prototypes, but additional tools and interfaces were required to adequately support prototype execution. These additions included:

The Silicon Graphics Workstation Upgrade. The 4D/70GT Silicon Graphics workstation was the primary ACCE hardware component used during most of the current ACCE task. Since the workstation will also be central to all future ACCE activities, the central processing unit (CPU) of this workstation was upgraded to a Silicon Graphics 340/VGX. This provided four MIPS R3000 processors running in parallel at 33 MHz. The 340/VGX performance is rated at 117 Million Instructions Per Second (MIPS) and 31 Million Floating Point Operations Per Second (MFLOPS). As a result of the upgrade, the system now provides a graphic display capability of 1280x1024 pixels with 64 image bit planes, a 24 bit Z-buffer, up to 96 texture bit planes, 4 bit planes for overlay or underlay, and 8 bit planes for window ID. System memory was also increased to a total of 48 MB.

The Z-248 Workstation Upgrade. The Z-248 received both a hardware and software upgrade. The hardware upgrade consisted of the installation of a new Basic Input/Output System (BIOS) Controller and the addition of the following:

1 x 1.2 MB 5 1/4" Floppy Disk Drive

1 x 1.44 MB 3 1/2" Floppy Disk Drive

1 x 40 MB Internal Hard Disk

This hardware was required to support the development and integration of software tools obtained from other sources

Upgrades to the software environment consisted of the installation of MS-DOS v3.3 and Microsoft C Compiler v6.0. MS-DOS v3.3 was required to provide support for the 3 1/2" Floppy Disk Drive added under the hardware upgrade. Microsoft C was required to provide communication interface support to the ACCE prototype operating on the Z-248 workstation (see **Communication Interface** below). The software libraries required to support this interface were provided by the 3Com Ethernet interface, and the versions obtained were compatible with the available Microsoft C compilers. Microsoft C also follows the ANSI C standard more closely than the existing Turbo-C Compiler. This latter upgrade facilitates the development of ACCE prototypes that will use both the Z-248 workstation and the Silicon Graphics Workstation

The Development of a Communications Interface between the Silicon Graphics Workstation and the Z-248 Workstation. This interface was developed to support the creation of integrated cross platform prototypes. Early in the prototype development stage it was determined that the Z-248 workstation had limited processing capability compared to that of the Silicon Graphics Workstation. To take advantage of the

increased calculation and processing capabilities of the Silicon Graphics Workstation, a transparent software interface between the Z-248 and the Silicon Graphics Workstation was developed. This allowed the bulk of the graphics processing required for the Z-248 BBN Spacegraph volumetric display to be performed on the Silicon Graphics machine. By exploiting the capabilities of the Silicon Graphics Workstation and the Ethernet interface, calculation and display times for the SpaceGraph volumetric display attached to the Z-248 were improved by approximately 75%.

 The Addition of Two X-Terminals. These terminals allow multiple developers to operate on the ACCE local area network and simultaneously access the Silicon Graphics Workstation.

The added tools, libraries, and interfaces made development within the ACCE easier and more efficient. Also, since it is generally true that a better development environment produces better systems, these additions resulted in smoother running, more efficient demonstrations that were faster and easier to develop and modify.

5.2.2 Evaluation Prototype Development

An important initial enhancement to the baseline ACCE involved the development of several evaluation prototypes to demonstrate the technologies within the baseline ACCE. Specifically, it was found that the applications and prototypes within the original baseline environment did not adequately showcase the 3D display and user input technologies resident in the environment. Prototypes were needed that were directly relevant to a C2 problem. Prototypes were also required that incorporated comparisons of 3D display approaches, and comparison of 3D approaches with more conventional 2D display technology.

The ADEP provided the needed demonstration capability. Using the ADEP, a user could directly compare 2 1/2D to 3D display technology, and 3D to competing 3D display technologies in an user interactive C2 significant simulation. The simulation is controlled from a single point, the Silicon Graphics workstation, and is not scripted. This allows the user to interactively change various display characteristics as well as the position of the globe itself. The ADEP also highlights the use of multiple input devices. The simulation is manipulated by three different devices: the Silicon Graphics keyboard; the Silicon Graphics 3 button mouse; and the Spaceball device. This demonstrates to visitors the characteristics of these various user input devices.

5.3 Recommended Mid-Term Enhancements

Mid-term enhancements are defined as those occurring within two years after the completion of this initial ACCE development effort. Mid-term enhancement activities focus on widening the

ACCE technology base, enhancing initial evaluation prototypes, and on developing additional evaluation prototypes to showcase new display and presentation technologies.

5.3.1 Widening the ACCE Technology Base

Until this point, technology acquisitions within the ACCE have focused primarily on collecting advanced workstation based 3D display technology and on developing the infrastructure to better support development and demonstration of well-integrated 3D evaluation prototypes. This midterm enhancement activity seeks to expand the technology base of the ACCE to include other advanced display and presentation technologies. Technologies of interest include large screen 3D displays, multimedia presentations, and virtual reality simulations. A detailed description of these technologies is provided in Appendix A of this report.

Large screen 3D displays provide significant enhancements over current 3D display technology within the ACCE. They are viewable from a greater distance, and a wider viewing angle than more conventional workstation sized 3D displays like the Stereographics Z screen. This allows a larger audience, such as one that would be in a C2 command center, to view a 3D presentation.

Multimedia presentations offer the potential for improving the C2 decision making process. Since C2 decision making is a collaborative process involving a hierarchy of decision making, technology advancements that keep decision makers apprised of all relevant aspects of a dynamic situation are crucial, no matter what the input media.

Virtual reality systems are probably the most advanced of the three suggested mid-term technologies. These systems employ advanced miniaturized 3D display technology and eye/head tracking technology to create an enhanced simulation experience that is near reality. Using virtual reality, viewers feel they are part of the simulation rather than just watching the simulation on a computer screen. Such simulations have obvious applicability for aircraft flight and mission planning activities where it is necessary to perceive spatial relationships and terrain masking or to allow the viewer to look around within a three dimensional space.

The immediate effect of the mid-term enhancements will be to provide ACCE with a broader range of demonstratable advanced display and presentation technologies. A secondary benefit of this enhancement will be to involve a wider base of users, program managers and technologists in ACCE activities. Simply stated, not every C2 problem or system under development stands to benefit from advancements in small screen 3D display and user input technology, the current focus of the ACCE. Additionally, since advanced computer technology is a fast moving, volatile industry, a diverse collection of technologies within the ACCE will ensure the viability of the ACCE in the event any specific technology should become outdated, obsolete, or out of favor.

The physical impact of the mid-term enhancements in the ACCE environment will be moderate. Based on current display technology trends it is expected that high power user workstations with

relatively small footprints will act as the primary system platforms for these technologies. These platforms should integrate well with current ACCE components via Ethernet interfaces. Also, they are likely to be highly compliant with current open system architecture standards. All of these new display and presentation technologies do require high performance processors to load, process, and display large amounts of information very quickly. As discussed in previous enhancements, the Silicon Graphics workstation, selected to be the ACCE prototype control center, can be upgraded and/or swapped to gain the level of performance necessary to support these technologies.

Since these technological enhancements are to be performed within approximately two years, the likelihood that such technologies will be available is high. In fact there already are a few laboratory systems that advertise capabilities involving virtual reality. The specifications of some of these systems were examined under the current effort but cost constraints prevented their addition to ACCE at the time.

5.3.2 Development of New Evaluation Prototypes

Development of new evaluation prototypes will be necessary to show C2 users, project engineers and researchers how the advanced technologies within the ACCE can be applied to solve C2 problems. Since ACCE is not intended to be just a storehouse for advanced technologies, demonstration of its constituent technologies will continue to be necessary as new technologies are added to the environment. These demonstrations will be facilitated by the development of evaluation prototypes similar to those described in Section 5.2.2 of this report. The development of new evaluation prototypes will be necessary to demonstrate the applicability of newly added advanced technologies to real C2 problems. Evaluation prototypes are the glue that binds together the diverse technological capabilities in the environment into a cohesive, operationally relevant simulation. They are intended to peak the viewer's interest in technology and to make them consider including advanced technologies in future C2 efforts.

5.3.3 Extension of Existing Prototypes

Just as it is necessary to develop new prototypes to demonstrate the utility of ACCE technologies and transition promising technologies to operational C2 systems, it will also be necessary to extend already developed prototypes.

Prototype extension will allow the engineer to include new technologies in already developed prototypes. The primary impact of such an enhancement will be to compare a newly added advanced technology to current ACCE technology with a minimum of implementation effort required to modify the existing prototype. Prototype extension may also be necessary to tailor a prototype to a slightly different C2 scenario of particular interest to end users. Since many

programs and systems use similar technologies, the same prototype may be used in a variety of C2 contexts with minor modifications.

Finally, prototype extension may be necessary to further demonstrate the operational utility of a technology. The initial ACCE prototypes were limited in their implementation and major C2 functional modules and data interfaces were simulated, simplified, and/or scripted. To highlight potentially promising technologies, it may be necessary to extend the initial prototype to create a more robust, more functionally correct second generation prototype. These more realistic prototypes will facilitate the assessment of critical performance and interface issues necessary before a decision is made to use new technology in an operational system or a system development effort. The impact of such an enhancement will be to demonstrate that research and development performed within the ACCE can in fact go beyond the laboratory role of developing simplified prototype systems that, though interesting, are not operationally realistic. After peaking the interest of users with initial demonstration prototypes, the second generation prototypes can then directly demonstrate the value and feasibility of using advanced display and presentation technology to solve real C2 problems.

To create a successful second generation prototype two objectives need to be met. First, the second generation prototype needs to reflect the concerns, comments, and needs of C2 operational users. Second, the prototype needs to use more accurate and realistic models, algorithms, and data. This includes interfaces to actual data sources.

Whether this prototype extension will be done in the ACCE or as part of a separate program will be determined by the funding and operational situation at the time. For example, there is interest in extending the 3D display evaluation prototype that was developed during the initial ACCE effort to create a second generation prototype. In this instance the ACCE prototype was demonstrated to other Rome Laboratory program managers who want to transition certain aspects of the initial prototype directly into an operational system currently under development. The new prototype may include interactive manipulation of space-based radar and OTH-B characteristics, the addition of new algorithms to create three dimensional radar coverage geometries based on actual radar characteristics, and interfacing the prototype to more detailed digital cartographic data of the types produced by Defense Mapping Agency.

5.4 Recommended Long-Term Enhancements

Long term enhancements are defined as those scheduled to occur two or more years after the completion of the initial ACCE development effort. These enhancements will likely involve many future technologies and C2 simulations that are difficult to project at this time.

One technology that we believe will continue to be important in the long-term is virtual reality, specifically, those systems that will use Digital Video Interactive (DVI) technology. Significant

breakthroughs in the areas of DVI and virtual reality are likely to occur within the next few years. These breakthroughs, involving specialized high speed video capture, compression, decompression and display hardware may allow virtual reality simulations to use very high quality user interactive digital video. This technology, though still unproven, may result in virtual reality simulations that visually are undiscernible from real world experiences. Assuming DVI and Virtual Reality will remain viable technologies in the future, it will be necessary to integrate this technology into the ACCE, to develop prototypes that demonstrate the technology in C2 related simulations, and to update and extend previously developed prototypes to reflect this newly integrated technology.

5.5 Implementation Plan Tasks

The following tasks are nominated to direct the development of the ACCE in the years to come. These tasks are geared towards addressing the mid-term enhancements nominated for accomplishment within two years, and the long term enhancement nominated for accomplished beyond two years.

5.5.1 Task 1: Large Screen 3D Integration

The objective of this task is to integrate large screen 3D display technology into the ACCE and to develop and demonstrate the technology's ability to better solve C2 problems. A sub-objective within this task will be to compare and contrast the resulting large screen 3D capabilities, as well as with conventional large screen 2D capabilities.

Since large screen 3D capabilities have been used extensively in the film industry, a survey and assessment of current large screen display technology is initially required. The assessment should highlight the accomplishments, features and shortcomings of current large screen 3D display technology and review the feasibility of implementing such a capability as part of the ACCE. From this analysis, a large screen 3D display platform should be designed. Next, the various components of the platform should be procured, developed, and/or integrated. It is believed that many of the components required for such a capability already exist within the ACCE laboratory, and the C2TC. Some engineering development may be necessary to interconnect and augment already existing 2D large screen components, systems, and devices. Such a large screen 3D display capability, because of its physical size, will likely not reside within the ACCE laboratory proper. Additional space within the C2TC, possibly in the C2TC's Projection Room, may be required.

Once the basic platform has been designed and installed, attention should then focus on demonstration and evaluation. As with the small screen 3D display prototype developed under the initial ACCE effort, activities should focus on selecting a C2 problem area and developing a prototype that will showcase the technology within the C2 scenario or simulation. Since a 3D

display evaluation prototype was developed under the initial ACCE effort, a first step to developing a demonstratable system may involve revision or rehosting of the small screen 3D display prototype software to the large screen 3D display platform. Subsequent revision of this prototype could optimize this simulation for the large screen device, and revise the demonstrated scenario to reflect a currently relevant C2 scenario.

5.5.2 Task 2: Multimedia Technology Integration

The objective of this task is to integrate Multimedia technology into the ACCE and to develop and demonstrate the technology's capability to better solve C2 problems. Though multimedia is likely to be the most near-term technology area of the technologies nominated for future ACCE tasks, it may also be the technology area that offers the most benefit to the C2 problem solving process. The technology appears especially applicable for use in C2 knowledge visualize from creating softcopy briefings and preparing advanced automated training aids.

There is a great deal of attention being devoted to the study of multimedia technology in industry and academia, and various types of multimedia technologies and systems are currently being fielded in operational Air Force systems. Thus, an investigation needs to be conducted to reveal the specific areas of multimedia technology that are problematic and therefore suitable for inclusion and study within the ACCE. As a result of this investigation, a multimedia configuration that extends or augments the current ACCE configuration should be designed and implemented. This configuration will provide a platform to demonstrate and evaluate specific aspects of multimedia technology. Finally under this task, one or more evaluation prototypes need to be developed to facilitate demonstration of multimedia technology within a C2 scenario.

The primary challenge within this task involves the identification of those critical aspects of multimedia technology suitable for study using the ACCE laboratory. Currently, the areas of digital video capture, compression, decompression, and display that push the limits of what is feasible with current workstation technology appear to be the primary multimedia candidates for study within the ACCE.

5.5.3 Task 3: Virtual Reality Integration

The objective of this task is to integrate virtual reality technology into the ACCE and to develop and demonstrate the technology's capability to better solve C2 problems. The virtual world used by current systems consists exclusively of a computer generated model. Algorithms that sense inputs from the viewer are used to determine the viewer's position and viewing direction within the model. Based on these inputs, computer generated images are rendered from the 3D model to provide images as seen by the viewer.

Since virtual reality systems came about as an extension to 3D display technology, a sub-objective of this task will be to compare and contrast virtual reality's capabilities with those of 3D display technology and conventional 2D display technology.

There are many approaches to providing virtual reality. Two of the promising approaches to virtual reality are discussed in Appendix A. One approach involves purely computer generated images, and one integrates interactive video with computer generated images. Of the two approaches, the first is more likely to be available for integration into the ACCE within the two year timeframe. Critical breakthroughs in hardware video image compression and decompression are necessary before virtual reality involving video will be a viable workstation based capability.

To begin this task, a survey and assessment of current virtual reality techniques and technologies should be conducted. Analysis of virtual reality technology is important up front so that the proper type of technology is targeted for integration based on its maturity and the timeframe that integration into ACCE will be performed.

From this initial assessment, a design needs to be developed for a virtual reality system within the ACCE. As with large screen 3D display technology, this system should make maximum use of existing ACCE hardware and software. Current virtual reality systems use high powered workstations to perform the 3D graphics rendering. Thus, the Silicon Graphics IRIS 4D/340 workstation seems a prime candidate for becoming part of an ACCE virtual reality system. Head mounted computer displays and sophisticated motion tracking devices that make the viewer feel like part of the simulation would have to be acquired and integrated. With a generic virtual reality system in place, effort would then be devoted to selecting, developing and demonstrating the technology within a C2 scenario. Since virtual reality is only applicable to specific areas of C2 problem solving, careful attention should be given to selecting an appropriate C2 scenario, problem, or system to model. The C2 scenario, problem, or system must be one that can reap the benefits of the technology if the technology proves beneficial. Simulations that involve intuitive navigation within a 3D landscape are particularly suitable for application of virtual reality technology. The area of C2 flight mission feasibility planning is therefore a prime candidate.

The primary challenge within this task will be to develop a virtual reality capability on a limited budget. Typical virtual reality systems can use two or more high power workstations working in parallel as well as exotic head mounted displays as a user input device. Acquisition and integration of this technology can be very expensive. Therefore, to accomplish this capability it will be necessary to reuse existing hardware, including the Silicon Graphics workstation, and prototypes as much as possible.

5.5.4 Task 4: Enhanced Virtual Reality Integration

The objective of this task is to improve upon the basic virtual reality capability developed in Task 3, and to demonstrate the technology's capability to better solve C2 problems. The task will concentrate on improving the degree of realism achievable in virtual reality simulations possibly by using digital video images in the virtual reality simulation, as well as newly developed, innovative display and user input technology that may be available.

An initial analysis and survey will be required to assess the current state of Digital Video Interactive (DVI) and Virtual Reality (VR) technology. Early scoping of the virtual reality problem is important to this task so that the proper technological components are identified for use in ACCE. These technologies should be selected based on their maturity, capabilities, potential for benefiting the C2 problem solving process, and the integration timeframe.

From this initial assessment, a design will need to be developed that defines a hardware and software architecture to support DVI virtual reality development and evaluation. Since Task 3 has the objective of integrating an initial virtual reality system into the ACCE, this task may build upon the capabilities and technologies integrated in Task 3. It is likely that significant upgrades may need to be performed to the ACCE configuration to include the capture, storage and processing of digital video as well as improvements in head mounted display and user input devices.

Once the hardware and software platform is in place, work will then be required to select a problem suitable for the application of the technology, and to develop a prototype that demonstrates the technology within the selected problem context. It may be feasible at this time to extend the initial virtual reality prototype developed within Task 3 to compare the improved virtual reality capabilities integrated under this task.

5.5.5 Task 5: Planning and Direction

Tasks 1, 2, 3, and 4 can be grouped since they all involve the investigation, integration and demonstration of three separate but related display and presentation technologies. They all possess the common goals of integrating advanced technology into the ACCE, demonstrating how the technology can be used to solve C2 problems, and aiding in the transition of promising technology into operational Air Force C2 systems. Since some of these tasks may be conducted simultaneously, there may also be contention for valuable ACCE hardware and software resources. For these reasons, this fifth task entitled, Planning and Direction, has been created to provide the management needed for the other ACCE tasks. By creating synergy among the four other tasks and reducing duplication of effort between them, better ACCE systems and prototypes can be produced with less overall effort. Specific activities within this task include:

 Assisting with the nomination and investigation of candidate C2 scenarios, problems and systems. It is sometimes difficult for technologists to select C2 scenarios, problems, and systems suitable for the application of advanced technology. This activity strives to focus researchers toward relevant C2 problems, and to create the framework to facilitate working with C2 end users.

- Approving ACCE hardware and software additions and modifications. A small ACCE modification may have a ripple effect on other tasks, as well as already developed systems and prototypes. Because of this, this activity considers the ACCE as a whole and provides guidance and direction to the other tasks to help maintain the viability of the ACCE as a single cohesive environment.
- Scheduling and coordination of ACCE demonstrations. Promising technologies can only be transitioned into operational systems if they are demonstrated to the proper people. In effect, this activity involves the marketing of ACCE research to make sure that the demonstrations are placed in the proper context, and viewed by the correct audience.
- Scheduling and coordination of system upgrades, and resource sharing.

 As the ACCE grows there will be contention for the resources within ACCE. Scheduling will become increasingly necessary to orchestrate ACCE developments so that work progresses smoothly.

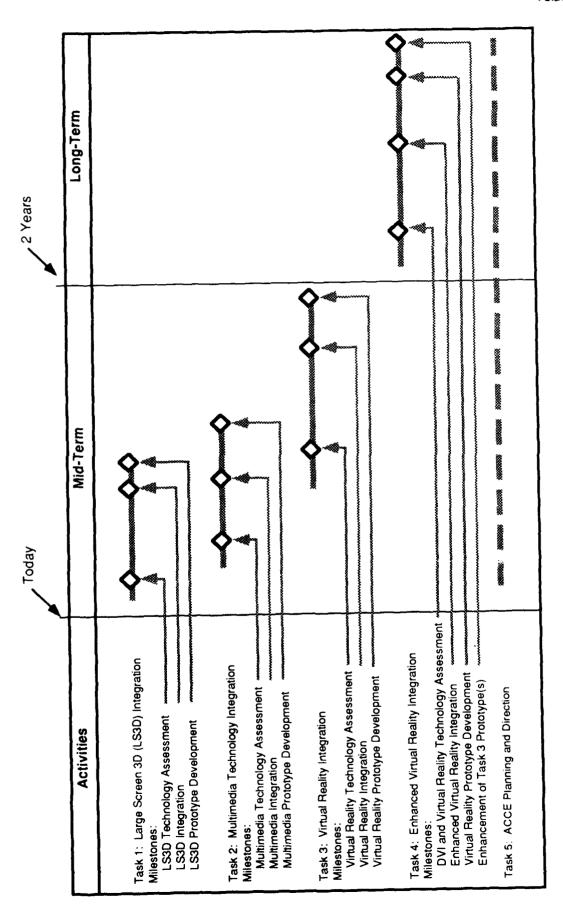
The primary challenge of this activity is to direct the technology development tasks to satisfy the ultimate goal of the ACCE: to aid in the infusion of promising advanced technology into operational systems. It is sometimes easy for technologists to become engrossed in the study of technology for technology's sake. This task oversees the technological developments within the environment and strives to keeps the work performed in the environment operationally relevant as well as technologically innovative.

5.6 Development Roadmap

A roadmap for future ACCE development is presented in Figure 5.6-1. This roadmap addresses the schedule and the milestones for enhancements to the environment.

Task 1, entitled Large Screen 3D Integration, is relatively short in duration, probably less than a year, and will be able to occur very early in the mid-term development phase due to the maturity and availability of underlying technologies. Its major milestones involve completion of the large screen 3D technology assessment, integration of a generic large screen 3D display capability, and implementation of demonstration prototypes.

Task 2, entitled Multimedia Technology Integration, is similar in duration to Task 1. It is scheduled to start slightly later than Task 1 to decrease contention for valuable ACCE development resources. Its major milestones involve completion of the multimedia technology



ACCE Development Roadmap Figure 5.6-1

assessment, integration of a generic multimedia system platform, and implementation of demonstration prototypes.

Task 3, entitled Virtual Reality Integration, is a more involved development task. It will therefore be longer in duration, probably more than a year. Task 3 is also scheduled to begin later in the mid-term development phase than tasks 1 and 2. This later start will allow time for the relatively immature technology to progress before integration into the ACCE begins. Its major milestones involve completion of the virtual reality technology assessment, integration of a generic virtual reality system platform, and implementation of any operationally relevant virtual reality prototypes.

Task 4, entitled Enhanced Virtual Reality Integration, begins where Task 3 leaves off. Its duration will probably be more than a year. Its first milestone involves completion of a second virtual reality technology assessment that also includes the investigation of DVI technology. Following this, design and integration of an enhanced virtual reality system platform will be performed. This effort may significantly augment the platform developed within Task 3. Implementation of new, operationally relevant virtual reality prototypes, as well as possible enhancement of the prototype(s) developed during Task 3 will then be completed.

Finally, Task 5, entitled ACCE Planning and Direction, is shown as a dashed task bar. Since the goal of Task 5 is to oversee all development tasks, it will extend the entire length of the timeframe for future ACCE development. Also, since Task 5 is reactive in nature it initially has no notable milestones.

Chapter 6

ACCE Configuration Management

6.1 Introduction

This chapter provides general recommendations for ACCE configuration management. These recommendations address the areas of configuration identification, configuration control and specify the types of documentation that should be maintained within the ACCE.

6.2 Configuration Identification

Configuration identification involves maintaining detailed descriptive information about the ACCE's hardware and software components. This library can be maintained either in hardcopy format or by means of an automated data base application. The following outlines the type data that should be included:

- Component Name: Brand name and model number.
- Serial Number(s): Serial numbers of all major components and sub-components.
- Component Description: A brief description of the component and its capabilities.

 This description should include items such as version numbers, installed options, and other characteristics that may not be intuitively evident.
- Vendor Identification: The name, address, and phone number of the vendor.
- **Key Points of Contact at Vendor Offices:** Names and phone extensions for sales, technical support, and maintenance.
- Acquisition Vehicle: Describes whether the component was acquired by the government or by a contractor and whether it was purchased, leased, loaned, etc. This information can be useful when tracking the history of a component.
- Purchase Price: The purchase price of the component. Even if the component was not purchased an approximate price should be included. This information is sometimes requested by people interested in acquiring and utilizing the technology being demonstrated
 - Date Delivered: When the component arrived in the ACCE.

- Date Installed: When the component became operational within the ACCE.
- Warranty Information: Duration and terms of any equipment or software warranty.
- List of Related Documentation: Include the names of hardware/software manuals, products brochures, etc. related to the component. This information helps direct people to more detailed information on the component.
- Repair and Revision Log: This log provides a running list of the dates and descriptions of all component repairs, revisions or upgrades and by whom they were performed.

6.3 Configuration Control

The ACCE is a dynamic environment in that systems and prototypes under development need to coexist with already developed systems and prototypes. Therefore, configuration control is critical to manage the activities and to assure that the ACCE remains both a viable development and demonstration environment. Once it has been determined that a hardware or software addition or enhancement is required, a formal change request should produced. Processing these requests and assessing their impact on other ACCE components are management activities detailed in Section 5.5 of this report.

It is also important to be able to demonstrate capabilities currently under development to users, managers and other technologists whenever the opportunity arises. To facilitate this demonstration capability, the initial ACCE effort maintained two versions of the developing prototype; a tested version for demonstrations and the ongoing development version. Once the development version of the prototype had progressed to a point where a logical, demonstratable portion of functionality is completed, it was used to replace the old demonstration version. It is suggested that this approach be used in future ACCE prototype development activities.

6.4 Documentation

A variety of documentation needs to be maintained for users of the ACCE. This documentation includes the configuration identification information discussed in Section 6.2, plus detailed descriptions of the commercial-off-the-shelf components such as technical manuals, user manuals, and commercially produced sales brochures.

Documentation of the systems, technology demonstration platforms and prototypes that are developed within the ACCE also needs to be maintained. This includes background information of the type contained in requirement specifications, the ACCE Concept of Operations and system design documents. When a prototype is developed, documentation must be prepared that

describes the prototypes components, functions, and the appropriate demonstration procedures. This includes all of the software inputs, processes and outputs.

Maintaining this information using an automated data base application would further increase the accessibility of this data for future developers. KSC has developed an automated software library that runs on a Macintosh workstation, that is populated with data describing the prototype developed under the initial ACCE Task. A listing produced by this library that describes all functions, inputs and outputs of the delivered prototype will be provided in the ACCE Final Technical Report document.

Finally, it is critical that the ACCE staff be able to demonstrate the installed prototypes while other work in the ACCE is progressing. For this reason, a formal written test procedure must be supplied with each delivered prototype to allow ACCE personnel to check the prototype to verify it is operating correctly. The formal test procedure should list the key areas of the prototype that are to be spotlighted and include detailed explanations of the anticipated results of each operation or function. Since ACCE development is ongoing, these test procedures must be executed periodically to verify that the existing prototypes have not been negatively impacted by development modifications to the ACCE hardware and software configuration.

Chapter 7

Planning Framework Summary

7.1 Introduction

This chapter provides a summary of this planning framework document and the planning framework activities that were performed. These activities began with an assessment of the hardware and software components in the baseline ACCE. From this assessment, various enhancements to the baseline configuration were recommended to better support implementation and evaluation of advanced technology prototypes. A hardware and software architecture was then developed to demonstrate advanced 3D display technology. Finally, future enhancements were nominated and organized into a series of tasks comprising a development roadmap for the ACCE. The following sections summarize the major accomplishments of each of these planning framework activities.

7.2 ACCE Baseline Assessment

At the beginning of the initial ACCE task, the baseline ACCE configuration was examined and assessed. Two advanced display technology systems within the baseline configuration were selected for evaluation: the Silicon Graphics workstation paired with the Stereographics Z-screen; and the Z-248 system that is interfaced to a BBN SpaceGraph volumetric display. The Silicon Graphics workstation was found to possess a reasonable 3D display capability, plus ample CPU and graphics processing power to support prototype development and execution. The Z-248, because of its limited processing capabilities, was found to be suitable exclusively for use in controlling the BBN SpaceGraph volumetric display device.

A variety of conclusions were derived from the baseline assessment. First, it was found that sufficient advanced 3D display technology did exist within the baseline environment to warrant development of a demonstratable prototype. Second, it was determined that the future prototype should attempt to use advanced user input device technology, such as the Spaceball, as well as the advanced display technology of the BBN SpaceGraph volumetric and Stereographics Z-Screen displays. It was also found that the baseline lacked the necessary infrastructure to interface display systems and to support prototype implementation and demonstration. To solve this problem, the ACCE contractor made specific recommendations regarding the installation of hardware and software, program development software and software function libraries.

The ACCE staff determined that the 3D display technology prototypes already within the baseline lacked applicability to specific C2 scenarios. In many cases it was up to the viewer to make the association between a particular 3D technology's capabilities and the C2 problems that the technology could be applied to solve. The conclusion drawn from the assessment was that future prototypes need to directly demonstrate advanced technological capabilities within operationally relevant C2 situations.

7.3 ACCE Architecture

Early in the development of the ACCE architecture, research was performed to gain an increased understanding of USAF open system architecture goals and guidelines. It was determined that various design approaches and standards could be employed in the ACCE architecture to meet many of the open system goals in the areas of interoperability, portability, commonality, extensibility, scaleability, and remote operation. However, the open system architecture approach was tempered with the realization that ACCE advanced technology, by its very nature, won't always conform to accepted architecture standards. In fact, there won't be any standards for some innovative state-of-the-art technology approaches.

Several factors were considered in designing the ACCE architecture. First, it needed to adhere to the scope and objectives of the ACCE, as stated in the CONOPS, to apply, evaluate, showcase, and exploit advanced display and presentation technologies that have potential impact to next generation C2 systems. Second, the design needed to incorporate open system architecture characteristics such as interoperability, portability, commonality of interface, extensibility, scaleability, and remote operation. Finally, the design had to include the major systems that were already available to the ACCE laboratory. For the latter, it was necessary to develop a prototype using these technologies and assess them, before additions to the baseline configuration could be justified. As a result, a hardware architecture was developed to support the demonstration and evaluation of 3D display technology. The architecture uses the Silicon Graphics system with the Stereographics Z-Screen display, and the Z-248 system with the BBN SpaceGraph volumetric display. An Ethernet local area network was acquired and installed to allow communication between the two systems.

The ADI Simulation for Command and Control (ADISC2) project was selected to provide the operational scenario for the ACCE demonstration. The ADISC2 project was suitable since it is currently implements C2 scenarios involving the portrayal of objects and the spatial relationships among those objects. The ACCE staff modified the ADISC2 scenario to portray the world as a three dimensional globe. This display is overlayed with wireframe volumes representing space based radar and over the horizon radar areas of coverage. A variety of functions were designed to provide user interactive manipulation of the display via the mouse, keyboard, and Spaceball user input devices. These functions support the direct comparison of the globe display shown in two

dimensions on the Stereographics Z-Screen, the globe display shown in three dimensions on the Stereographics Z-Screen, and the globe display shown in three dimensions on the BBN SpaceGraph volumetric display.

7.4 ACCE Development Plan

A development plan for the overall ACCE project was created. This plan outline enhancements recommended to take place in the near-term (prior to completion of the current ACCE task), midterm (within 2 years after the completion of the current task), and long-term (beyond two years). These enhancements are comprised of activities that address three objectives of ACCE development:

- To integrate new display and presentation technologies into the ACCE.
- To develop new prototypes that showcase advanced display and presentation technologies.
- To enhance existing prototypes for further demonstration and evaluation.

Most of the recommended near-term objectives were met prior to the completion of the current ACCE task. A series of four future tasks were proposed to accomplish recommended mid-term and long-term objectives. These tasks include integration and prototyping activities in promising technology areas such as Large Screen 3D displays, Multimedia Presentations, and Virtual Reality Simulations. The fifth task would provide management and direction to the other ACCE technology development tasks. A schedule for completing these five tasks was prepared that outlines the important milestones.

7.5 ACCE Configuration Management

An important component of this planning framework document involves recommendations for the management of the ACCE configuration. These recommendations address the areas of configuration identification, and configuration control, as well as specifying the types of documentation that should be developed for and maintained within the ACCE.

First, it is recommended that a library be maintained that describes the many components of the ACCE configuration. This library would contain information describing the environment's components, contacts for sales, technical, and maintenance information, and a chronological record of the history of each component.

Second, it is recommended that formal procedures for configuration control be established. One suggested procedure involves the maintenance of two prototype software versions. One would be a demonstration version, and the second the development version that is actively modified,

revised and enhanced during implementation of prototypes. Also, it is recommended that the decision making process for hardware and software configuration modifications be centralized and managed. Proposed enhancements to the ACCE configuration must be carefully evaluated to assess their potential impact on the ACCE as a whole. Such a procedure will allow ACCE developers to fully consider the ripple effects of a modification before it is implemented.

Finally, it is recommended that documentation on contractor delivered systems, platforms, and prototypes be maintained in the ACCE. This should include detailed hardware and software information like that contained in the Concept of Operations document, functional specifications, and design documents. Also documentation detailing the software architectures, functions and data bases should be created by the developers and maintained within the ACCE. This type of documentation will facilitate the reuse of existing software and data, a technique that is essential to help reduce implementation costs. Also, since the ACCE is a demonstration environment, documentation must be maintained that describes the demonstration procedure for each prototype. This documentation would contain the steps an operator would take to execute the prototype to showcase its capabilities.

Appendix A

Future Display and Presentation Technologies

Display and presentation technologies include a host of hardware, and software techniques that transform information processed by, or residing in a computer system, into a format that a user can visually interpret. An important goal of future display and presentation technologies will be to provide knowledge representations that can be easily assimilated and understood. The following sections discuss various advanced display and presentation technologies that have been nominated as potential candidates for future integration into the ACCE.

A.1 Large Screen Three Dimensional (3D) Displays

Large screen 3D technology seeks to improve the viewing characteristics of 3D presentations by displaying them on very large wall sized displays. Typically large screen 3D displays are stereoscopic. Stereoscopic techniques involve presenting two representations of the same image slightly offset from one another to the viewer. The offset simulates the perspective views as seen by each eye. Alternate views of the images must be presented to each eye of the viewer at a rate that minimizes or removes observer flicker. The brain combines this image pair into a single image that is perceived as having depth. To obtain the stereoscopic effect however, depending upon the particular approach, special glasses must be worn that synchronize the particular image with either the left or right eye accordingly. Various approaches to these glasses have been developed to cause 3D. These include: eyeglasses with mechanical motor driven rotating shutters; liquid crystal filled goggles; and polarized glasses. Besides having to wear cumbersome glasses, some drawbacks of stereoscopic displays include synchronization of the glasses with the images, restricted viewing zones, image flicker, image clarity and visual fatique.

The large 3D display format is accomplished using computer projection displays that, instead of displaying an image on a CRT screen, project the image onto a large wall-mounted screen. By utilizing two of these projection devices to simultaneously display two rendered images that are slightly offset, a stereoscopic 3D viewing effect can be realized. This effect is similar to that which is achieved on smaller CRT-based devices like the Stereographics Z-Screen. The benefits of a large screen format involve improved viewing characteristics. First, since the scale of the display is much larger, many viewers can be positioned to view the 3D display simultaneously. By increasing the number of people who can view the 3D image, the technology facilitates collaborative problem solving.

A.2 Virtual Reality

Several more advanced display technologies are being researched that may hold promise for C2 applications of the future. One of particular interest is the idea of the virtual reality or 3D virtual space. First conceived in 1958 by the Philco corporation, this idea takes 3D to another level. Instead of viewing a 2D image on a screen, the viewer puts on a headset containing a head mounted stereoscopic viewer to actually experience the effect of being within a 3D space. In this virtual space the viewer is fully engulfed in a computer generated 360 degree stereoscopic image. To achieve this phenomena, the image must be presented to the viewer at very high speeds (up to 30 frames per second), and must include both the viewer's forward and peripheral range of sight. By employing head tracking technology, the virtual experience is enhanced to effectively allow viewers to look around in the 3D space simply by turning their head in that direction; left, right, up or down. Also, by integrating other advanced HMI techniques that monitor hand movements, the user can interact with the virtual environment by using hand movements to manually manipulate objects in the virtual space around.

This technology appears to have the greatest application potential to activities that demand close interaction with the surrounding environment. For example, due to the scale of the environment, flight simulation seems better suited to this technology than C2 situation assessment. In a flight simulator, a pilot would sit in a computer generated cockpit operating the vehicle through its controls. The pilot could experience a sense of control since the virtual environment would be responding to his commands. In situation assessment, the scale is significantly smaller. The viewer would be in an expansive environment attempting to analyze an extensive battlefield area, and may feel lost in his surroundings. Thus, the value of virtual space can only be realized when the scale is increased to a point where the immediate world may be experienced.

The sophistication of virtual world technology with its complex interfaces and highly demanding data processing requirements make its immediate use in C2 applications a challenge. Continued research in laboratories like the ACCE is needed to determine how the technology could be applied to solve C2 related problems. This research is also needed to drive continued advancements in hardware and software that are necessary to make virtual reality a viable technology for operational systems of the future.

Several approaches to achieving virtual reality are being research. The first involves using high powered computer workstations to produce a computer generated depiction of the virtual space. This approach typically begins with the use of three dimensional modelling software. With this software, the characteristics of objects within the virtual space are defined. This three dimensional model is then used by other software that senses user inputs from head tracking and hand tracking devices to render the proper viewer perspectives on the three dimensional model. The

result is a computer generated view of the three dimensional world. Objects can appears as wireframe models, or a solid shaded objects.

A second, more realistic approach to achieving virtual reality involves the use of Digital Video Interactive technology or simply DVI. Virtual Reality systems using DVI seek to improve the quality of the images being provided to the viewer by using digital video that is captured a priori. With this approach, video cameras with special wide angle fish eye lens are used to capture a real world scene in full motion video. With sophisticated storage and indexing schemes, selected portions the captured video frames are played back to the viewer in real time. This yields very high quality virtual reality images for presentation to the viewer. This typically requires very large storage devices to store the images and special image compression/decompression hardware are needed to compress and capture and decompress and display high quality digital video. This approach alone is only applicable to simulations in that the real world situation being simulated can be filmed prior to playback. To overcome this limitation, additional research may be necessary to be able to overlay the real world digital video images with computer generated images and graphics. This would allow the captured video scenes to form a high quality backdrop for dynamic complex situations that can not, or may not be feasible to film in real life.

A.3 Multimedia

A rapidly evolving technology, that stemmed largely from the motion picture industry, is multimedia. Multimedia incorporates several media types such as text, graphics, audio, animation and video in a single computer display. The feature that distinguishes multimedia from common video is that it is interactive. A user can control the presentation and navigate through it on a path of his choosing. Multimedia is another data communication technology that can be applied to various activities within the C2 process. Two areas where it is particularly well suited are for commanders' briefings and training tools.

To keep up to date with the current situation, commanders and their staff rely on presentations assembled by their subordinates. Reports are generated for commanders' briefings from status information collected and combined by duty officers at the lower echelons. Data for these reports is derived from such sources as maps, data bases, observations made by analysts, manuals and collateral intelligence messages, to name a few. Multimedia provides a medium for integrating this information plus intelligence extracted from such sources as news reports, videotaped events and digital image data bases into a single coherent presentation. Multimedia presentations used with advanced display devices such as high definition TV or large screens can provide the commander with information vital to the decision making process. Also, communication effectiveness can be increased by incorporating 3D and virtual world display techniques into presentations. Combined, these technologies can give the commander and his staff a seat in a battle that is being fought thousands of miles away.

Multimedia also may be employed to train soldiers in the use of sophisticated weapons or computer systems. The combination of visual and audio effects can essentially replace human instructors. For example, a presentation may be developed that teaches a weaponeer how to apply weapons to various types of targets. Video sequences may be used to display candidate targets. Audio can increase communication effectiveness and eliminate the need for the trainee to read textual messages. Simulations may be built that respond accordingly to actions performed by the trainee. These simulations could run against several realistic scenarios so that the airman could learn how to react under a range of circumstances.

Appendix B

List of Acronyms

2 1/2D Two and a Half Dimensional

3D Three Dimensional

ACCE Advanced Command and Control Environment

ADEP ACCE Display Evaluation Prototype

ADI Air Defense Initiative

ADISC2 ADI Simulation for Command and Control

AOI Area of Interest

APS Advanced Planning System

BBN Bott Beranek and Newman

C2 Command and Control

C2TC Command and Control Technology Center

COA Applied Command and Control Systems Division

CPU Central Processing Unit

DBMS Data Base Management System

DVI Digital Video Interactive

EGA Enhanced Graphics Adaptor

Volume III

НМІ

Human Machine Interface

LAN

Local Area Network

LCSS

Liquid Crystal Stereoscopic Shutter

MFLOPS

Million Floating Point Operations per second

MIPS

Million Instructions Per Second

OSA

Open System Architecture

OTH-B

Over the Horizon Backscatter

SAPE

Survivable Adaptive Planning Experiment

SGI

Silicon Graphic

SOCC

Sector Operations Control Center

VR

Virtual Reality

MISSION

OF

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