ASSESSING THE PREFERENCE OF TWO OR
THREE DIMENSIONAL COMPUTER GRAPHICS
ANIMATION DISPLAYS ON THE AIR BASE
OPERABILITY DECISION MAKING PROCESS

THESIS

Captain James P. Morris, USAF

AFIT/GIR/LSM/90D-8

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The opinions and conclusions in this paper are those of the author and are not intended to represent the official position of the DOD, USAF, or any other government agency.

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ASSESSING THE PREFERENCE OF TWO OR THREE

DIMENSIONAL COMPUTER GRAPHICS ANIMATION

DISPLAYS ON THE

AIR BASE OPERABILITY DECISION MAKING PROCESS

THESIS

Presented to the Faculty of the School of

Systems and Logistics of the Air Force

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Requirements for the Degree of

Master of Science in Information Resource Management

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Preface

In all the universe the one thing I dreaded the most to do was a thesis. Now that it has past me by without too many scars, I wish to deeply thank those who had help in easing the dreadful pain. A most sincere thanks is given to my advisor, teacher, and friend, LT Donald McNeeley, USN, for his patience, motivation and enthusiasm he gave me when my computer animation idea first sprouted. I would like to thank my mother, Diana Lewis, for saving my thesis by re-typing it when my hard disk drive crashed in the hour of need. Also great thanks for my program director, Lt Col D. J. McBride. Thanks also to those in my class who kept me cheerful. Thanks to Mary for her support and I hope future contributions. And finally, I thank all those who helped in participating in the ABO experiment. Without them I would not have had any data to compare!

James P. Morris

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ABSTRACT

This study investigated the preference of two types
of computer animation graphics displays -- two and three
dimensional. A preference was determined based on how well
they supported the decision making process within the Air
Base Operability organization (ABO). The procedure used
was the true experiment method to compare the two different
display types and the standard Air Base Operability display
to see if there was a significant difference. The
experiment was conducted on a personal home computer with a
color graphics capability. Subjects were randomly assigned
to one of the three groups using a particular display.
The basic objective of the experiment scenario was to find
damaged areas inflicted on a simulated Air Force base. The
results from the experiment indicated no significant
difference between the two dimensional and three
dimensional graphics displays. However, there was a
significant difference between the three dimensional
display and the standard ABO display. The conclusions
drawn from this experiment shows that not enough data was
collected from the experiment to prove a significant
difference between the displays. The primary
recommendation made by this researcher is to reconduct the
experiment with a more substantial sample population from
each group.

ASSESSING THE PREFERENCE OF TWO OR THREE DIMENSIONAL COMPUTER GRAPHICS ANIMATION DISPLAYS ON THE AIR BASE OPERABILITY DECISION MAKING PROCESS

I. Introduction

Overview

Chapter one provides background information on the general issue of determining the preference between two types of computer graphics animations. This chapter will also state and explain the study's specific problem statement, its purpose and justification, its specific research objectives and the scope of the application using computer graphics animation.

Background

Over the last two decades, computer graphics has improved its development from simple displays of monochromatic mathematical wire diagrams to a very sophisticated system of multiple color processed images with filled in faces. In these newer systems, the operator can now interact with these display devices to better assist and improve programming and decision making. As one researcher, Brian Berry states:

> The 1960s have been characterized as the era of computer numbers, the 70s as the era of computer

words, and the 80s as the era of computer graphics. Computer graphics has extended traditional data processing methods by providing ways of communicating information pictorially. (3:xv)

Interactive computer graphics is the first step toward a more common man-machine interaction. Computer communication has developed into a technology for converting virtually unlimited information into visual images. One researcher defines computer graphics as 'a consciously managed and documented technology directed toward communicating information accurately and descriptively' (10:398).

When the first personal computers were developed there arose great expectations as to how the computer could improve the display of information. In earlier years, computer graphics were expensive due to labor costs for data input, the time consumed with generating the graphics, the rate of calculating and manipulating the data, and the large memory capacity and disk space required (22:21-24). Now, inexpensive personal computers can begin to fulfill those expectations. Low-cost microcomputers, such as one owned by this researcher, allow graphics to be a generally available resource. Faster microprocessors have been developed which generate a computer graphic animation in 1/10th of the time formerly required. Additionally, file compression methods have made animations easier to store on disk. Angell states:

Until recently, all but the most trivial computer graphics was the province of specialized research groups. Now with the introduction of reasonably priced graphics devices, the subject will reach many more users and its full potential can realized. Computer-produced pictures always impress the layman, and the 'mysterious' techniques used for drawing them have gained a [false] reputation for complexity. (1:vii)

In part, computer graphics has entered almost every field of endeavor including business and industry. Research must continue to pursue how much computer graphics can enhance organizations. Therefore, it is necessary first explain why computer graphics has entered into the management field.

Computer Graphics In Management

The prominent reason for this increased usage of computer graphics in management is due to the increased utilization within the decision-making area (3:xvi, 7:463, 8:40, 16:764, 20:757). Computer graphics has been found by decision makers as an available and powerful device for passing information to people in any kind of circumstance. Beyond the simple display of the graphic image itself, these pictures can be used in the context of an elaborate information system to bring about augmented analytic and descriptive capacities for users. One example is illustrated by Berry:

A geographic information system (GIS) allows a user not only to display results pictorially, but also to

perform a number of analytic operations on the data, interface other existent data bases, and enjoy a general-purpose data-creation capability. (3:xvi)

One researcher's (18:57-67) investigation concerning graphics usage noticed a significant trend in the use of computer graphics by users in organizations. Other surveys, performed by Lehman in 1984 and 1986, determined the impact of computer graphics on the MIS. From his 1986 research he concludes:

At this time, microcomputer-based graphics and mainframe-based graphics are not just technological alternatives. They are not integrated into existing information system to the same degree and their users report different advantages and disadvantages which mirror the distinctions between MIS-oriented and user-oriented systems or between organizational and personal computing. (17:139)

Therefore, prior to 1986, graphics was not a viable decision support system alternative. Since 1984, however, there has been a rapid growth of computer graphics in areas such as the decision-making process. One reason for this rapid growth has been the availability of environmental data for regional planning and civil engineering (3:66). This is just one example and other examples will be illustrated in the literature review chapter. One particularly important reason for using computer graphics in the decision-making arena is that it saves time; a most valuable commodity. It is extremely easy for computer graphic systems to manipulate various information into charts, maps, and graphs. The building of various charts, maps, and graphics assist in the explanation and

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dissemination of complex sets or groups of data. Complex sets of information can be comprehended more easily when visually represented. Additionally, tendencies and peculiarities in the information data are often perceived more easily when it is generated in a graphical image as opposed to displaying the information through tables and charts. This ability to spot alterations in the data is needed by decision makers to better describe, sort out, validate and exclude any wrong information. Through computer graphics, decision makers are also provided with the ability to ask questions to test alternative scenarios and then depict the results graphically, in a quick and efficient manner. Decision makers will turn toward such systems for assistance as these information systems become more generic and the man/machine interface becomes simpler.

Currently, there two different means of displaying graphics. These two means are two dimensional and three dimensional computer graphics, and both will be thoroughly explained in the literature review chapter.

Specific Problem Statement

Organizations, when in need of improvement, can turn to computers for assistance in their decision-making process, and a portion of that assistance could be derived from computers graphics. The addition of computer graphics

technology can increase the decision-making abilities of the managers. Now that an organization has the means, what choices does it have? What type of graphic display will best assist an organization with its decision-making process? While there are many solutions available, the wrong choice is assured to be costly.

In order to determine what graphic display method could improve the decision-making process for a particular organization, it is necessary to conduct research using a specific organization's decision-making environment.

The complex battlefield environment, with rapid tactical decisions made by military commanders on the basis of multiple sets of rapidly changing data, is one such environment. This environment causes extreme difficulties, since decisions are based on data presented and absorbed through using conventional maps, charts, photographs, and other graphical aids such as plotting boards. Such media are inflexible, difficult to update, and hard to interpret if cluttered with data not relevant to the decision-making process. Using either two or three dimensional computer animation graphics might prove beneficial. The need for new techniques for which the application of computer graphics might be worthwhile, is suggested by Schachter:

> A hostile environment may include as many as 30,000 potential targets including such major items as tanks, armored personnel carriers, artillery tubes, air defense systems, command posts, and logistics centers. Of the total, about 1,000 of these may be high priority targets. It is immediately apparent that

there is a significant disparity between the large
number of tactical elements present and the major
items of concern to the commander. Traditional
methods involving the use of hand-delivered paper
reports and paper maps with Plexiglas overlays for
grease pencil annotation are not well-suited for a
rapid flow and culling of information. New techniques
are needed to enable commanders to absorb and analyze
the mass of information they receive so that they can
make decisions which are both timely and correct.
(27:xiii)

Therefore, one possible decision-making arena in the

Air Force which could benefit from computer graphics is the

Air Base Operability (ABO) damage assessment organization.

The ABO function is to accurately record and report all

damage inflicted from enemy attack on an airfield and

surrounding area. The ABO decision maker then decides

whether those locations assessed are worthy of continued

use or requires repair. This researcher proposes

investigating the decision making process utilizing either

two or three dimensional computer animation graphics within

the Air Base Operability (ABO) decision-making environment.

The ABO environment poses as an excellent environment in

which to conduct the proposed research and compare

different computer graphics techniques. First, because the

ABO environment currently utilizes graphics data as input

based on damaged areas to buildings, runways, etc., to make

important decisions. Secondly, the Air Force is currently

developing a Future Airfield Damage Assessment System

(ADAS), as explained in the literature review chapter, to

assist in processing airfield damage data. Thus the

prospect of conducting research to determine which type of graphics display for the ABO decision maker is important. The correct graphics display would better assist those who assess the damage and conduct briefings to keep commanders informed on he situation to make important decisions. An in depth explanation of how the ABO operation is conducted and what its mission consists of is explained in chapter II. Therefore, the ABO operation makes an ideal case to use for research to determine which computer graphic animation would most benefit the ABO decision-making process. An understanding of how a specific display impacts the ABO decision-making process would further assist research on computer displays for additional decision making arenas. The problem statement for this study is:

Which type of computer animation graphic display, either two or three dimensional, would be most beneficial for any decision making process?

Purpose

The purpose of this study is to investigate the impact of two and three dimensional computer graphics displays on the ABO decision-making process. This investigation will attempt to determine which graphic display best improves the ABO decision making process and will examine the differences between the two types of graphics with respect to the existing method used.

Specific Objective

The specific objective of this research is to develop and test two different types of computer animation graphic displays. The first consists of a two dimensional graphic animation and the second consists of a three dimensional graphic animation display. These two displays will then be tested in an experiment given identical criteria, and their results will be compared by analysis of variance to determine if there are any differences from the current display method.

Hypothesis and Investigative Questions

The hypothesis that this research hopes to prove is that there is a definable difference between the two computer graphics displays and that three dimensional computer animation graphics will best improve any decision-making process. The above specific objective will be met by answering the following investigative questions:

1. Is there a significant difference with using two dimensional or three dimensional computer animation graphics in the ABO decision-making process?

2. What ABO information can or cannot be presented with each type of animation graphic display?

3. What time constraints are applicable with the production two dimensional or three dimensional animation graphics for the decision maker?

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4. What finances are associated with the acquisition of a computer graphics display system and will it be cost effective?

Investigative questions 1 and 2 will be answered.

through the methodology and analysis of the data discussed in Chapters III and IV. Investigative questions 3 and 4 will be answered in the literature review in Chapter II.

Scope

The scope of this research will cover the best set of criteria necessary for the decision-making process. In order to determine the effectiveness of the computer animation graphic display, one specific functional area, such as Air Base Operability, was chosen. The decision support area will cover the damage assessment phase during the post-attack period on an air force base. Further research into other areas should be accomplished to determine if they, too, may also be benefited by the addition of computer graphics. However, for purposes of this research, only the damage assessment phase will be used.

II. Literature Review

Overview

There are two different types of computer graphics available for managerial functions and decision support systems - two dimensional or three dimensional computer generated images or animations. The purpose of this literature review is to discuss the capabilities of two dimensional and three dimensional computer graphics in management and prior research which has been conducted. First, an overview of some of the trends in graphics definition of two dimensional and three dimensional graphics as defined by other researchers will be discussed. Following this, examples of how computer graphics have enhanced certain applications in the decision support area will be presented. And finally, this review will examine how the Air Base Operability decision-making process functions during its damage assessment phase during the post-attack period.

Computer Graphics Trends

Numerous researchers have noted a tremendous growth with computer graphics. As mentioned before, this growth seems to exist because of the decreasing costs for computer systems. This is verified by DeSanctis when he stated:

The computer graphics industry is estimated to be
growing at an annual rate of 60 to 70 percent.
Rapidly declining hardware costs, flexible easy-to-use
software, and increased availability of graphics
technology for microcomputers and office workstations
account for this trend. (7:463)

In 1989, Lehman mentioned in the previous chapter on

graphics trends, conducted an analysis of the two surveys

he did earlier and declared some basic findings for

computer graphics:

- Considerable penetration has occurred since 1984,

- Graphics have become better integrated into the
  overall organizational information system,

- Factors in the success of computer graphics remain
  the same: ease of use and data availability, and

- Applications have shifted from support to decision
  making to support of communications. (18:67)

DeSanctis and others suggested, however, that 'little

research is available on the impact of graphics on decision

making...'(7:463) Therefore, investigation of the research

on computer graphics is in order, since decision support

organizations are starting to realize the importance of

computer graphics-based systems. Then, it will be necessary

to review important research findings of how computer

graphics have benefited decision making.

Computer Graphics Research

Research developments have concluded that certain

computer graphics outputs are helpful in the decision

making process (7:482, 8:44, 16:772). One example is an

experiment conducted by Izak Benbasat pertaining to color

graphics (2:1104). Benbasat concluded that color graphics,

as opposed to tabular display outputs, played an important

role in the decision-making process, but only to a certain

extent. The limitation was that while color graphics was

excellent in making short, quick judgements, for a long

term scenario, however, tabular outputs were better. An

important finding of the experiments was that the benefits

of color-coding were more strongly associated with

graphical rather than tabular display formats. The most

important finding was the influence of color in relation to

interaction with the cognitive style of the decision maker

(2:1102). Color also appeared to assist the decision maker

under a time constraint or during the early stages of

problem solving. Also evident was that graphical

presentations enhanced decision-making speed, but only if

the report was designed in a form which directly assisted

with the problem solving heuristic. While graphs were

found most helpful in calculating and comparing values of a

general region, they were not helpful for exact data values

required for optimization.

Computer Graphics Usage

Computer graphics have come a long way from their

first usage. Computer graphics were first used as an aid

to designing objects. Computer-aided-design (CAD) has

provided a means for creating all types of architectural

plans and drawings. For example, CAD programs can describe

any machine part in three dimensions. Another example is

that architects are using building layouts produced by CAD

methods as design aids for housing sales (23.143-150). Two

dimensional floor plans are used to design room

arrangement, door and window placement, or the location of

various facilities. Three dimensional displays are used to

view the appearance of a single building design or to test

the appearance of a complex arrangement of buildings (a

mall, university campus, or an air force base).

Computer graphics techniques are also used by artists.

Animated cartoons and movies are produced with the aid of

graphics displays. One example is 'TRON', one of the first

motion pictures made which used computer generated images

for most of its backgrounds and special effects

(27:vi). These effects appeared almost life-like, giving

the audience a better understanding of what it could be

like inside a computer. Workers in many areas are relying

on computer graphics as an important integrated tool for

studying the characteristics of systems.

In addition to models, computer generated graphs and

charts are used to interpret mathematical relationships or

to study trends in the behavior of systems. These graphs

produced from the graphics data inputted into computers can

take a variety of forms. Two dimensional weather maps, for

example, can be constructed by graphics systems from data supplied by satellite observation stations. In another example (3:xix), pressure or temperature variations over geographical areas was compared in three dimensional plots.

Similar techniques are used in many business and government applications. These applications represent one of the largest groups of computer graphics users. Various types of line graphs and bar charts are used for summarizing financial and statistical data. While three dimensional pictures and graphs are used to show multi dimensional information, these pictures and graphs are often generated for managerial reports, for consumer information bulletins, or for visual aids to be used during presentations. Besides the basic uses of line, bar, and charts used to display information, there are other uses in computer graphics which fully utilize its potential applications.

In the 1970s, computer graphics were just an alternative means to huge amounts of hole punch cards and paper output (14:146). Even as late as 1982, there were only three types of monitor display technologies available for graphics (22:6), which were RGB, composite and separated. Only eight colors were available for graphics pictures and the memory to display graphic animations was exhaustive and not enough for most computers consisting of only 512 kilobytes of Random Access Memory (RAM). Today,

graphics can consist of 4096 or more different colors displayed all at once. Additionally, there is a new technique called color cycling, which imitates animation of motion and uses small amounts of memory. Computer graphics has made a tremendous leap ahead from its first usage.

Development of microcomputer technology has led to the design of small-scale computer systems with a broad range of graphics capabilities. Desk-top computers can be configured for graphics uses in the office, in research and design and in schools and as personal computers. Their low cost, compact size and versatility make them highly suitable for a wide variety of graphics applications. The research conducted and the graphics displays shown for this thesis utilizes a personal computer, the Amiga 2000. But to utilize some of the new potentials of computer graphics, an understanding is necessary of what different types of computer graphics there are.

Computer Graphics Systems

The basic components of a computer graphics system comprise of a CPU (Computer Processing Unit), keyboard, video monitor, and the necessary graphics programs. Most computers additionally allow peripheral equipment such as digitizers, as input or output devices.

Because computer graphics are mainly involved with the video display monitor, it is an important component to

understand. All computer monitors are some type of Cathode Ray Tube (CRT). These CRTs can be designed to function as random-scan or raster-scan devices. The type of function used makes a difference of how clearly a picture is shown. Each has its own advantages and disadvantages making the picture look better or worse depending on the cost. A home TV is an example of a raster-scan CRT. Techniques other than the basic CRT design have been used for constructing video displays. These devices include plasma panel displays (26:3-29), laser scan displays, light-emitting diodes (LEDs), and liquid-crystal (LCD) systems. Each presents a different clarity in the graphic picture being displayed. With an understanding of the video display monitor in hand, let us turn now to how a graphic picture is presented on the monitor, and what a picture is comprised of.

Display Graphics Concepts

Graphics systems are often characterized by the number of available colors and by the number of points - referred to as the resolution -- that can be plotted on the screen. Resolution for graphics systems is given in terms of the number of horizontal and vertical display points available. These numbers are set by the graphics computer system, but are also dependent on the type of video display device used. Systems using a standard TV monitor have an upper

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limit of about 512 points horizontally and 256 points vertically. Special graphics terminals and monitors are capable of a 2000 by 2000 pixel resolution today.

Each character displayed on a video screen takes up a small rectangular space. This space is divided even further into smaller rectangles. These smaller rectangles are called pixels (13:30). A simple character can be several pixels in size depending on the computer system. When a computer graphics program is active, it accesses the pixels directly. The graphics pixels are simply "turned on" when needed and a specific color is chosen. Pixel locations are referenced by a coordinate system (X,Y). The horizontal distance is measured by X, and the vertical distance by Y and start from the top left of the display monitor going from left to right, top to bottom. The number of pixels plotted per centimeter (cm) is referred to as resolution, and is commonly used to describe the clearity of a graphic image. Display monitors have the ability to show different resolutions, depending on the graphic program, but how large a display monitor one might have has little importance on resolution. It depends only on the capability of the monitor to change resolutions. The different resolution modes are described in three categories - Low (displaying fewer points), Medium and High resolution (showing the most pixels/cm).

With the basic components of a computer graphics system explained, it is now essential to explore the two different types of computer graphics generated -- two and three dimensional.

Two Dimensional Graphics

Two dimensional graphics are the viewing of a computer generated picture with only 2 degrees of freedom (15:42). This freedom consists of its axis running horizontally and the Y axis running vertically on the screen. To create a two dimensional graphic picture is to first determine which parts of the model or object are to be displayed and whether or not any overall adjustments to the picture are to be made as a whole. Eventually, when creating a two dimensional graphic picture, the developer must decide which side of an item the viewer is to see and which other items lying within the area are drawn. Examples of two dimensional pictures would be top views or side views, such as maps or photographs. Finally, the user must decide on the details concerning the appearance of the object, such as size, color, or location on the screen.

When drawing the picture, several effects can be used to create realism. A two dimensional object can appear to be three dimensional, but do not be fooled. Through a technique called anti-aliasing, a graphic image can be made to seemingly stick out of the picture. Anti-aliasing is

the process of adding several grey scale colors to the side
of the image produced starting with a light grey to
eventual black, creating the effect that the object appears
to stand apart from its background. Anti-aliasing can also
be used to give an object more detail and not seem
cartoonish. Using darker shades of the same color, an
object can have indentations and dimensions within itself
again, adding more realism. Another effect which is very
useful in two dimensional graphics is color cycling. Color
cycling involves shifting a designated color over one pixel
or color address to another (28:215). If the color address
range is not too extreme, the effect gives the graphic
picture a simulated animation effect. An example would be
to cycle a torch flame. The color range would be from
yellow to red and the effect would give the torch movement.

There are several benefits to using two dimensional
graphics as a type of decision support display. One
benefit is the storage size. Two dimensional graphics have
relatively small file sizes, and therefore take up very
little disk space. If a user is required to prepare a
briefing consisting of multiple computer graphics pictures,
two dimensional graphics pictures would take less disk
storage room, thus more pictures could be presented.
Another benefit is the ease of digitizing an image from a
photograph or video picture to a two dimensional graphic.
This allows for any user to become an artist simply by

pointing a video camera at an object, hitting a key, and through a computer program the object picture is transferred into computer memory and displayed on the monitor. This image can then be readily changed with respect to color, size, and even aspect using anti-aliasing.

There are some disadvantages to two dimensional graphics. One disadvantage is trying to get more information from the graphic than is available. If a user wanted to see the other side of the object, it would be an impossible task, unless a totally separate picture had been generated. Another disadvantage is that two dimensional graphic pictures tend to give more information than is believed (28:217). Two dimensional pictures deceive the user to interpret more information about the picture. Additionally, user freedom to move around the graphic picture is limited. A two dimensional graphic picture has boundaries, by and which the user can not proceed beyond it. A two dimensional graphic can be zoomed in or out, but the information on the object remains essentially the same.

Three Dimensional Graphics

Three dimensional graphics involve adding a third dimension to the picture, the Z axis. It is important to understand that all computer images produced on a graphics screen are always two dimensional; thus when three

dimensional graphics are mentioned, the term refers to the underlying model used to generate a picture, not the picture itself (15:30). There are, however, new technologies arriving in which the display of three dimensions will be possible (i.e., use of special optics glasses). This is somewhat different from holographic images, but along the same guidelines. The computer stores in its memory the three dimensional data points or vertices, of the object being rendered into a two dimensional picture. From these points polygons are generated producing surfaces of different colors specified by the user. Various textures can also be achieved on these polygons, such as a mirror like texture, glass, or metal. When creating a three dimensional graphic, the user must include all possible information on the object to insure accuracy of the object being presented. When rendering the graphic in three dimensions, the computer will also generate the aliasing effects of the object as seen from a particular view. These effects are the result of a three dimensional light source inserted by the user at a given three dimensional coordinate. Multiple light sources can also be given for added illumination to the different sides of an object for depth perception.

The primary benefits of three-dimensional graphics is the amount of information that can be obtained from the picture. More than one side of an object can be displayed.

The object can be zoomed in or out to see if there is more information involved with it. Another benefit is the realistic and photo-like quality which a three dimensional graphic presents through ray tracing. Ray tracing is a technique used for generating shaded images on the object being created (29:96). Ray traced three-dimensional objects add an even higher resolution than two-dimensional graphics, because it produces images in a high resolution mode of over 4096 colors. This powerful technique produces astounding images that no picture created in two dimensional could produce.

One major disadvantage of three-dimensional graphics is the amount of disk storage required. In addition to the disk space needed to store the picture or animation rendered from three dimensions, the computer must also maintain the object or objects in question on disk storage. Furthermore, it is also required that a computer have available a large amount of memory in random access memory (RAM) to produce the three dimensional graphic. The three dimensional graphic image generated in this thesis required five megabytes of RAM. This is due to the processing of the object in three dimensions and what its appearance will be from a particular reference point. One other disadvantage to three-dimensional graphics is the time involved to generate a picture. A three-dimensional picture can take from one minute to as much as one week to

generate, depending on speed of the computer. Some
projects may require several weeks to be generated,
depending on the microprocessor speed. An organization
will not normally wait this long for graphic results to
assist in the decision-making process. But as mentioned
before with the technology available, an organization can,
provided it has a sufficient budget, purchase a fast enough
microprocessor to produce the graphics in minutes. With
these two different types of computer graphics having now
been explained in detail, it is appropriate to discuss some
current applications.

Computer Graphics Applications

As mentioned before in the first chapter, there are
many applications for either two or three dimensional
computer graphics. Dr. Tony Diment, a graphics expert, has
said: 'There now seems to be no area of human endeavor
that cannot be enhanced by the application of computer
graphics' (19:8). One example is the applicability of real
time, three dimensional images for mass market products.
In an article written by Plummer (23:143-150), a research
prototype of a kitchen designer is presented. The article
compares the differences between using a two dimensional or
three dimensional computer graphics system. Plummer
explains the differences:

Real time three dimensional graphics allows much greater interaction. A conventional two dimensional system will allow images to be presented on the screen and choices made. A three dimensional system allows exploration in a manner which does not have to be precisely anticipated by the designer of the application package. Furthermore, the world being explored can be imaginary and its structure may have been influenced by the user. (23:143)

Another application of computer graphics is with simulations. One such simulation is the Advanced Battle Simulation (ABS) used for Command and Control practice with the U.S. Army (4:51-55). ABS is an extension of an even more elaborate simulation Network (SIMNET) Defense Advanced Research Projects Agency (DARPA) - Army project (24:60-64). SIMNET and ABS utilize both two and three dimensional graphics, with each playing an important part to ensure the user gets only the pertinent information.

Computer graphics for training individuals has strong potential. One application in training is the use of three dimensional graphics in air weapons controlling of three dimensional graphics in air weapons controlling (11:1-37). The research used a simulated three dimensional display system as a supplemental training guide to benefit air weapons controllers.

Another application which is particularly important for decision support systems, is one created by a thesis student involving adaptive design (12:1-165). Gfeller designed a computer based decision support system for evaluating a post-attack chemical contamination of an air

base. This system utilized two dimensional computer graphics to aid the decision making process.

From the two types of computer graphics explained in this research paper, it is important for the designer to understand what is the organization's ultimate objective. Both types have their advantages and disadvantages dependent cn the type of information being presented. Computer hardware is also an important f.ctor to take into account when deciding which graphic presentation is feasible. Production cost is also important. Each of these factors must be examined carefully, and research is needed to determine in greater detail the differences and possible measurements for determining what can be the best choice. As computer graphics technology continues to improve and become cheaper, faster and more efficient, the applications using computer graphics will widen even further. An understanding of why a specific display is beneficial for an organization or decision support system will assist in determining where and what type can be used in other arenas. Using the ABO environment is one such example. Air Base Operability is an excellent environment to demonstrate the use of computer graphics displays because of its mission. The next section will describe how ABO operates and how it can utilize computer graphics animation.

Air Base Operability

The ABO mission is to provide Air Force commanders information concerning the capability to survive, recover and operate under attack conditions (5:A1-2). One of the key objectives is to rapidly recover from the effects of an enemy attack on the air base. The Survival Recovery Center's (SRC) primary function in the ABO is to advise the wing commander and higher headquarters on the status of the air bases' facilities. In order to do this, the SRC plots attack damage on a map, transmits the direction for recovery efforts and recommends priorities for recovery. The ABO'S recovery mission is to assess the damaged areas, reduce the hazards found (unexploded ordinance; nuclear, biological, and chemical contamination; fire), repair the damage to critical resources, and return the air base to maximum combat status in the minimum amount of time.

Organization of ABO

All Air Base Operability (ABO) operations are controlled by the wing commander or equivalent. Assigned forces operate through the Wing Operations Center (WOC) using the battle staff and existing telephone and radio. The combat support group commander is responsible for directing the activities in the SRC. He also coordinates the efforts of the supporting staff to analyze, collect, prioritize, display, and report information on the status

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of the base" (5:A2-8). The SRC works under the Wing

Operations Center and is the center for marking and

identifying all base damage. After all damage has been

located, the SRC is then responsible for devising a

recovery strategy. The WOC then approves this plan and

implements the recovery activity. It is the SRCs

responsibility to determine the extent of the damage to

facilities, keeping track of personnel status, resources,

etc. From the SRC, the Base Civil Engineer (BCE) will send

out damage assessment teams to determine the extent of

damage (6:2-7). He will also receive, review and evaluate

damage assessment reports. The BCE will also assist the

commander in building and achieving the base recovery

strategy.

Damage Assessment

The ABO team obtains a damage assessment immediately

after an attack has occurred. Damage assessment consists

of two types - Rapid Runway Repair (RRR) and facility

damage (6:3-1). For purposes of this thesis, only facility

damage will be covered. Facility damage involves the

evaluation of damage caused to buildings, POL sites, and

other utilities.

There are two types of information - location of

pavement damage caused by bombs, cannon fire, etc., and

locations of UXOs which are transmitted to the SRC. All

UXOs must be marked within 300 feet of buildings or aircraft operating surfaces. Camouflet craters, very deep craters with no apparent rupture to the surface of a road, must be reported. The maps presented must be scaled to show the 300 foot UXO radius-of-effect around buildings. The damage must be recorded once it is evaluated, then immediately reported to the SRC for damage plotting. The complete understanding of the information being relayed is important to the speed of reporting and strict adherence to radio discipline by SRC and Damage Assessment Team (DAT) personnel. The areas to be evaluated according to their importance are 'the takeoff and landing (TOL) surfaces; access routes; maintenance, reloading, refueling areas; and other areas directed by the SRC' (6:3-11). In each of these areas, all craters and unexploded ordinances must be included in the report.

Damage Assessment Information

The following materials are used for damage assessment inside the Survival Recovery Center (SRC):

- **Base Map** (Scale 1:4800)
  This is a base layout map to indicate the location of UXOs, Damage and contamination.
- Airfield map (Scale 1:1200)

- Clear plastic crater template (Scale 1:1200)

- Colored pencils.

- MOS windows - clear plastic rectangles representing MOS length and width (Scale 1:1200)

- **Chart Selection Tables**
  Depicting status of equipment, resources and
  personnel.
- Surface roughness charts for determining MOS size
  and crater repair quality.

- Chart holding box

- EOD time and bomb damage repair worksheets
                                    (6:4-12)

The damage assessment in the SRC is conducted in 4

phases. However the last two, evaluation and

recommendation to commander, will only be discussed as it

is only pertinent to this research dealing with the

post-attack recovery phase. The evaluation phase consists

of assessing a damaged areas to determine the worst impact

and selecting MOS (Minimum Operating Surfaces) for aircraft

to operate. Damage to buildings must be evaluated in case

of evacuation if necessary. The final phase is reporting

to the wing commander to inform him so that implementation

of repairs or evacuation can be started as soon as

possible. These last two phases are directly involved in

the decision making process. These two phases will be

initiated when conducting the research to determine which

computer graphic is more beneficial.

Future Airfield Damage Assessment System

There are two systems being developed for the ABO

decision making area. The first is the airfield damage

assessment system (ADAS) and the second is named CRISIS.

The ADAS is composed of an airborne subsystem and a ground

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assessment subsystem (6:3-15). Developmental testing

occurred during the 'Salty Demo' (April-May 1985).   When

the system becomes fully automated, it will lead to a

computer aided MOS (Minimum Operating Surface) selection

process for determining Rapid Runway Repair (RRR).   The

CRISIS system was developed at the Air Force Academy

(12:8).   It serves a similar purpose for the SRC (Survival

Recovery Center) by determining damage assessment, chemical

contamination, etc.   Both these systems demonstrate the

practical application of two or three dimensional animation

graphics to the decision making area.

Conclusion

It has been determined that the use of either two or

three dimensional computer animation graphics into the

decision making area of ABO is practical.   The next chapter

will discuss the methods for comparing both types of

graphics in the ABO environment.

III. Methodology

Overview

This chapter describes the steps which will be taken to answer the investigative questions given in chapter I. It will also thoroughly describe the procedures taken to conduct the experiment to determine the preference between two or three dimensional computer graphics. Thus answering investigative questions 1 and 2. The specific objective will be to determine if there is a significant difference between the different computer animation graphics displays and which will be more beneficial for the Air Base Operability decision making process. The specific method chosen for this research was the true experimental design for comparing three different types of ABO displays.

Decision Support Systems

In order to conduct and compare the two and three dimensional computer animation graphics displays in a decision making environment, as mentioned in chapter II, a feasible application such as Air Base Operability was necessary. It was also necessary to design a decision support system based on the ABO process using both types of graphic displays, because ABO is planning on utilizing a system such as CRISIS (12:5) for their decision making. Therefore, in order to compare the preferences in decision

making ability, this researcher designed a two and three dimensional DSS (Decision Support System). These DSSs are designed to meet the mission requirements of ABO - - locating facility damage during the post-attack phase of base recovery. These two systems also allow the user to scan through the simulated air base and locate the damaged areas, thereby making decisions whether a building, POL depot, or runway needs to be evacuated, repaired, or rerouted. Although many of the items included on the storyboard was not be used for this experiment, it was necessary to include for purposes of demonstrating the importance of how a decision support system operates.

Evaluation Importance

Evaluation of the ABO DSS is necessary to be certain that it will determine the preference of between the two or three dimensional computer graphics. Again the specific method suggested to evaluate the ABO decision support system will be to conduct a true experiment. The research method would involve testing a group of individuals exposed to the proposed ABO graphics decision support system or the existing ABO decision method currently using maps, charts and tables. Each subject would have hands on exposure to one or the other systems. The current ABO decision method

would act as a control mechanism to determine if the ABO decision support system really has an impact to the decision making process.

Evaluation Criteria

It is important to evaluate the ABO decision support system based on how specifically related to the operational environment for which it is intended as well as how well the users cognitive skills are enhanced by the DSS's graphical interface. The following operational evaluation items are considered for testing (some suggested by researcher Andrew Sage) based on the storyboard and concept map already designed:

1. Is the ABO decision support system logically sound and stable? (25:88)

2. Is the ABO DSS transparent to the user? Is it simple to use and idiot proof? Does it have an easy to understand help reference system?

3. Is the ABO Decision support system intuitive? Does it present the user with the right information when and where he/she needs at the right time?

4. Are there minimal keystrokes in the ABO DSS? Is the graphics interface to the control screen simple, fast and quick to run for user commands?

5. Is the DSS closely matched up to the operational and organizational situation environment of the actual Air Base Operability (ABO) decision making process? (25:88)

6. Does the ABO DSS support the variety of cognitive skills, styles and knowledge to the user operating the system? (25:88)

7. Does the ABO DSS assist the user with the aid of developing and using their own cognitive skills, styles and knowledge? (25:88)

8. Is the ABO DSS sufficiently flexible for allowing adaptability in use for users with differing cognitive skills, styles and knowledge? (25:88)

9. Does the ABO DSS encourage users to bring in specific job experiences into the system to allow more effective solutions to unstructured problems and will they still meet the political and institutional acceptability constraints of the ABO organization? (25:88)

10. Will the ABO DSS promote effective long term management, i.e. future organizational goals, mission statements, procedures? (25:88)

Other Objectives for Evaluation

Besides identifying the criteria to determine if the ABO decision support system is successful or not, it is appropriate to look at other objectives as well. These other objectives are such things as determining the most useful strategy for employment of the ABO DSS when conducting the experiment.

Questioning the subjects after the experiment has been conducted may be appropriate. The users could be asked about their conceptions to the graphical interface of the ABO decision support system. The questionnaire could also find out the behavioral or human factor effectiveness of the ABO DSS. It is also important to make sure there is an appropriate balance between the Air Base Operability decision support system evaluation and the control group using the current ABO decision process during the

experiment. Evaluation of the ABO DSS using the four Ps
(Productivity, Process, Perception, Product) is important
also.

In examining the productivity of the DSS one should
ask - How productive is the ABO DSS to accomplishing the
specific task of identifying base facility damage? The
process of making the decision is important - Does the
decision making process change at all with the DSS as
compared to the existing methods used? This criteria has
already been mentioned before with some of the above
criteria. The perceptions of the decision maker when
he/she uses the ABO decision support system is important.
Again this might be determined with the help of questioning
the user after he has been exposed to the ABO DSS. And
finally the product of the ABO DSS - Is it cost effective
to use this DSS over the existing system? Will the DSS be
capable of running on existing systems used by Air Base
Operability? All of these other objectives could help even
more to evaluate the ABO decision support system.

Evaluation Criteria Effects on Storyboard

The evaluation criteria could possibly change the
structure and appearance of the preliminary storyboard
designed for the ABO decision support system. It is
doubtful however that the evaluation criteria will affect
the concept map of the ABO DSS. This is because the

concept map was designed based on existing procedures in the Air Base Operability organization. These will only change if the ABO organization drastically changes its mission statement or reporting procedures.

The evaluation criteria might change the storyboard in some way. If after conducting the experiment, the users might use one of the display presentations more than the other, i.e. using the three dimensional graphic presentation over the two dimensional graphic presentation of facility damage, this would result in taking out that portion of the decision support system. If one animation graphic is more preferable to the user then both should not be included into the ABO DSS.

Some other changes to the storyboard might be the explanation of some of the display screens. Since these are to be included in the help menu section of the DSS, if the user has difficulty in understanding how a particular menu function works, then better explanation is needed to solve that misconception or misunderstanding.

Overall this researcher believes there will be very little changes needed to the storyboard. Although it is somewhat certain that the deletion of either the two or three dimensional animation display will occur since the primary reason for this ABO decision support system is to determine which display is more preferable.

Variables of Measurement

In order to determine the preference between the different ABO displays, it is necessary to identify the measurement variables. These are dependent variables which will be used in determining a statistical significant difference. Here are some areas to consider:

1. The average time it took each group to assess the damage in the model.

2. How well each subject assessed the damage in the display (i.e. number of damaged facilities).

3. How well each subject correctly assessed the seriousness of the damaged facilities.

4. Any behavioral traits that might arise when the subject is using the ABO decision support system.

Therefore based on the above items, the following variables of measurement are created to be tested during the experiment:

Variable 1 - DAMAGE TYPE: This variable will consist of the type of damage done to a facility. It will measure the accuracy of how the subject correctly identified the type of damage. The different types of damage shown on the displays are: Craters, Cracks and UXOs.

Variable 2 - SEVERITY: This variable consists of the type of seriousness of the damage. It will measure how well the subject correctly assessed the damaged area and identified its severity. This variable also measures how well the subject identifies it by color coding. Each type of severity is color coded as follows:

MINIMAL - BLACK

MEDIUM   - DARK RED

CRITICAL - BRIGHT RED

Variable 3 - LOCATION: This variable consists of the location of the damaged area. It will measure how accurately the subject is able to pinpoint a damaged area's true location based on what the subject sees on the graphic display. The location choices in the experiment are: North, South, East, West and Top (for Buildings).

Variable 4 - AREA: This variable consists of the type of location the damaged area lies on. It will not only measure again how accurately the subject is able to determine the location of the damaged area, but how well the subject can see the damaged area on a particular graphic object. The area choices available are: Wall, Ground and Roof.

All the variables of measurement were compiled together in a questionnaire sheet (See Appendix B). This questionnaire explains to the subject the mission objective of the ABO scenario and the variables he/she must look for. The questionnaire also gives an example.

Data Collection Procedures

The variables of measurement to be analyzed in this research experiment will be collected from each of the

experiment groups. Each subject will mark their answers on a computerized answer sheet from the above mentioned questionnaire. Next, the answers will be read into a computer for statistical analysis. There must be at least thirty subjects tested all together. This meets the criteria for the Central Limit Theorem in statistics that thirty sample data points will be sufficient to represent the group population (9:291). Each subject will be randomly chosen to utilize one of the three DSS displays. The two and three dimensional DSS displays will be presented through an Amiga 2000 computer system. This system was chosen by the researcher because of his familiarity with designing computer animation graphics on the Amiga. Each subject will look at the display and given a maximum time of fifteen minutes, determine the amount of damage the simulated air base has been attacked. Each subject will record the amount of damage that has occurred to the air base by filling out a computerized answer sheet. This sheet contains all buildings, POLs, and runways necessary for the damage recording. It also contains the spaces available for type of damage, severity of the damage, location and area as seen on the DSS display.

Specification of Variables

An attempt will be made to control the variables in the experiment to assure external validity. Each subject

will receive the same instructions for completing the specified mission task. Each of the variables for each group are exactly the same. It will be appropriate to determine whether these variables might affect other variables in some way. The group tested by the standard ABO display will serve as a control group against the other two groups of experimental displays. The examination occurs during the post-test phase of the experiment. There will be no pretest on the subjects due to using the standard ABO display as a control group.

Experimental Design and Conditions

As mentioned above, the experiment will consist of three different types of DSS displays, the standard display currently used by ABO, the two dimensional display, and the three dimensional display. All three displays will hold the same damage data in order to assure internal validity for all the Decision Support Systems. Internal validity is threatened if there are any changes between the observations or measuring instruments. Therefore, all model displays will represent the same simulated air base. All models will have exactly the same predefined damaged areas to facilities for the subjects to locate and identify. After the DSS displays were designed, they were examined by local experts who were familiar with computer graphics, decision support systems, or Air Base Operability

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procedures. These experts were Lt Col Dorthy McBride, Lt Col John Valusek and Capt Polasek. All the experts were satisfied that these DSS displays were sufficient to use for the experiment. After the displays were examined the next step was to add damage to the simulated air base. Following this a trial test was conducted again to ensure each DSS display would operate correctly for each subject while tested. The following briefly describes each DSS display.

Simulated Air Base

First, each DSS display had to be constructed from a single air base. This simulated air base was built in three dimensions. Three dimensional models can be constructed in many ways, through digitizing, data base input or Computer Aided Design (CAD), as mentioned before in Chapter II. The experimental air base this researcher built was constructed with the help of a CAD program called SCULPT 4D. The dimensions of each building, runway and POL facility were constructed with x, y and z coordinates ie, length, width and height. After the air base was fully constructed, objects representing craters, UXOs and building cracks were added. These objects were also in different colors representing the extent of the damage ie, bright red represents a critical damage point and the facility must be evacuated. The color coding will be

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explained in detail later. The entire air base model including the damaged objects consisted of 8,000 points and 21,000 polygons. This required over 3.5 megabytes of RAM (Random Access Memory) for the Amiga computer to hold the entire air base in memory and generate the required computer graphic pictures.

ABO Standard Display

This display is based on the standard display currently used by Air Base Operability. The SRC mainly charts their damage area information on a large blueprint of the air base. As mentioned in Chapter II, they receive reports from damage assessment teams (DATs) and then record them on this air base blueprint. Therefore it was necessary to construct a similar blueprint of the simulated air base from this experiment. A top down view was generated from the Amiga computer. This picture, after constructed, was a wire frame only and showed no damaged areas. The graphic picture display dimensions were 2500 X 2500 pixels in width. This was necessary in order to create a blueprint paper hardcopy of equivalent size compared to the standard ABO map used.

After the blueprint was constructed, it was necessary to create a DAT report document for the subject to examine for recording the damage onto the blueprint. This report listed all the damaged areas that occurred during the

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attack on the simulated air base. Nothing was omitted for the purpose of validity. The damage entries on the report were placed in random order and the subject was to assume they were listed in order of time reported (See Appendix C).

The procedure for reporting damage in this display was to examine the DAT report, accurately record a damaged area onto the air base blueprint and then record the damaged area onto the computerized answer sheet. In order for a successful recorded damaged area to count, it must be recorded on both the air base blueprint and the answer sheet. This approximately estimated the time it takes for an SRC representative to decode an incoming DAT report and then record it onto their air base map.

Two Dimensional Display

The two dimensional display represented a top down view of the simulated air base. This measured the characteristics of two dimensions as mentioned in Chapter II. The two dimensional decision support system constructed begins with an overall top down view of the entire air base. This overall view was generated by looking down on the three dimensional air base model at a simulated height of 1000 feet. The view was generated after the air base was damaged. Therefore, some damaged areas were visible and the subject could already ascertain

some answers based on this view. From here the subject is then able to get a closer detailed two dimensional look at a facility. The DSS is designed to show a zoomed in 2-D picture by just selecting (left button on a mouse controlled input device) a the particular facility. After selecting the desired facility, the two dimensional graphic picture is shown. This picture was again generated from the three dimensional air base model and shows a top down view only of the facility, at a height of approximately 300 feet. After viewing the zoomed in picture, the subject can go back to the overall view by simply pressing the 'Esc' button on the computer keyboard.

The procedure for this display is for the subject to accurately find and record the damaged areas on the air base. The subject is also informed he/she must first locate the most serious damaged areas (based on color coding). If the subject sees a damaged area from the overall top down view, then he/she is instructed to view the closer two dimensional view. After all damaged areas are perceived from the overall view, the subject is then recommended to look at other facilities to check if any damaged areas were missed. After locating a damaged area the subject is to correctly record it on the computerized answer sheet.

The two dimensional graphic display contains all the
damaged areas. Similar to the standard ABO display and for
the purpose of validity, no damaged areas were omitted.

Three Dimensional Display

Finally, the three dimensional ABO display consisted
of a three dimensional view of the simulated air base.
Each facility had its own computer generated graphic
animation view. This view entailed an animated view
starting from the top view of the facility, moving downward
for a north view, then rotated clockwise to view the
facility until returning back to the north view. All of
the 3-D animation graphics are constructed from the same
simulated air base. All the three dimensional views of
facilities were accessed in the same manner as the two
dimensional display. The subject from the beginning saw an
overall top down view of the simulated air base. In order
to view a three dimensional animated view of a facility,
the subject selected that facility, by moving the mouse
and clicking. The top down view is identical to the two
dimensional top down view. When the animation was viewed
of a particular facility, the subject had some control of
how the animation is presented. This control consisted of
the ability to change the speed of the animation; pause the
animation at any time; or restart the animation back to the
beginning.

The procedure for this display was exactly the same as the two dimensional display. The subject was to identify the most seriously damaged areas, first picking areas from the overall top down view, then working on other facilities not so obvious. After a damaged area had been identified, the subject then should have correctly recorded that information on the computerized answer sheet.

Explanation of the Controls

Each display group consisted of a random number of individual subjects. All subjects were randomly selected into one of the display groups as they arrived for testing. All the subjects were given a pretrial briefing to explain the mission scenario for ABO, the objective to that mission, and procedures for recording onto the computerized answer sheet. Each subject were not be exposed to any other display other than the one they were assigned to.

Criteria for Selection

There was no specific criteria for selection of the subjects for the experiment. This researcher posted announcements concerning the experiment to all who might be interested in participating. The only criteria for

non-selection was be if the subject was severely color blind, because the variables mentioned above involved color coding for severity of damage.

Data Analysis Procedures

Data analysis first involved associating the data statistically to ensure normality of the data. All three data groups were analyzed together to ensure a normal sample size of the population and distribution has occurred. This was done using a univariate analysis of the data. It was then determined whether the appears to be any statistical relationship between the answered data in the three display groups. Similarities and differences within and between the three data groups were detected by use of the parametric statistical procedure known as Bonferroni's multiple comparison procedure for analysis of variance (ANOVA). With the use of ANOVA, several assumptions must be made and followed about each group population from which the data is gathered:

1. The observations must be independent.

2. The populations from which the data are generated all are normally distributed with standard deviations and means which may or may not be unique.

3. The level of the data obtained from the computerized answer sheets will be at least interval.

4. The data is gathered in a random and independent process.

The Bonferroni procedure will effectively compute an interval length as a function of the mean square error of the data. Where the sample means differ by more than the value of the computed interval, the difference in the true mean is stated to be statistically significant. If the sample means are different by a value less than the computed interval, the difference will be considered significant (21:865). The data analysis will be conducted through the use of the computer facilities at the Air Force Institute of Technology (AFIT), Wright Patterson Air Force Base, Ohio. The statistical analysis program used for testing by the Bonferroni procedure is called the SAS software system. SAS's PROC ANOVA procedure will be used with the BON (Bonferroni) option. This will be used for the variance of means computations.

The independent variables will be compared from the group class to determine significance. The damage, severity, and location variables will be compared from all three groups. If there is a statistical significant difference in the mean scores of each of these variables then there will be a preferencial difference.

Reporting Analysis of Data

Chapter IV involves the implementation of the experiment proposed in this chapter and the analysis of the data collected. Chapter V will contain the summary of the

finding and conclusions drawn from the analysis. These two chapters will determine wnether the proposed hypothesis is true or not and determine the preference between the two or three dimensional computer graphic displays.

IV. Analysis of Data

Overview

The previous chapter described the methodology for conducting the true experiment. This chapter analyzes the data compiled from the true experiment to determine if there is a significant difference between the three displays -- three dimensional, two dimensional, and the standard ABO Display.

Collection of the Data

The data from each subject was collected on a computer answer sheet as mentioned before in Chapter III. After all subjects were tested, the data was then compiled together into separate groups of the designated variables. A separate variable group was also assigned just for interest sake which identified the total number of responses each subject made whether correct or not.

Frequency Analysis

Each variable group was analyzed by frequency and cumulative frequency to compare the highest and most frequent number of correct answers (See Tables 1-12). The variable names for each dependent variable were: TOT - for Total number of responses the subject entered; DAM - for total number of correct responses the subject made for type of damage identified; SEV - for total number of correct

responses the subject made for type of severity of the
damage; and LOC - for total number of correct responses the
subject made for the location of the damage on the airbase.
A number also followed the variable for each group that
variable belonged to: 3 for three dimensional display; 2
for two dimensional; and 1 for ABO standard display map.
There were 14 subjects tested for the three dimensional
display, 11 subjects for the two dimensional display, and
11 for the standard ABO display. The Mean, standard
deviation, maximum and minimum values are shown for all
data group variables together in table 1 below. Appendix C
shows a frequency listing of each variable group
separately.

Table 1 - Mean Data of a Group Variables

Variable	N	Mean	Std Dev	Minimum	Maximum
TOT3	14	16.43	3.72	8.00	23.00
TOT2	11	16.55	3.11	11.00	21.00
TOT1	11	12.09	5.24	3.00	21.00
DAM3	14	16.07	3.34	8.00	20.00
DAM2	11	13.55	3.11	10.00	20.00
DAM1	11	11.64	5.05	3.00	20.0C
SEV3	14	10.57	3.88	2.00	17.00
SEV2	11	10.00	3.49	5.00	16.00
SEV1	11	9.27	4.69	2.00	17.00
LOC3	14	14.00	4.30	8.00	21.00
LOC2	11	13.55	4.91	3.00	20.00
LOC1	11	11.09	5.03	2.00	20.00

Some of these frequencies are close to higher than
the mean of each variable. It was also important to view
the data with each dependent variable group combined --

that is, combine all the data together and compare the distribution by each dependent variable separately. Table 2 shows the Mean data of the dependent variables with 36 data points. This combined group data allows ANOVA comparisons later on in the chapter. The group dependent variables named are: TOTAL - for Total responses; DAMAGE - for correct type of damage identified; SEVERITY - for correct type of damage severity identified; and LOCATION - for correct location of damage identified.

Table 2 - Combined Group Mean Data

Variable	N	Mean	Std Dev	Minimum	Maximum
TOTAL	36	15.14	4.47	3.00	23.00
DAMAGE	36	13.94	4.21	3.00	20.00
SEVERITY	36	10.00	3.96	2.00	17.00
LOCATION	36	12.97	4.75	2.00	21.00

Frequency Bar Charts

To get a better and clearer observation of how evenly distributed the dependent variable groups were distributed, it was necessary to look at them by creating frequency bar charts. Figures 5-16 (see Appendix D) show the distribution for each dependent variable group. It became obvious since each variable group had a small sample size that the bell shape of the bar charts was not apparent in all. In fact some of the charts were skewed to the left or

right. It may be possible that if more data was added, the
bell shape would be more apparent thus showing an even
distribution.

Again it is important to view the data grouped
together with each dependent variable viewed separately.
These next charts (Figures 1-4) show a more evenly
distributed sample size. This corresponds to the Central
Limit Theorem stated in Chapter III.
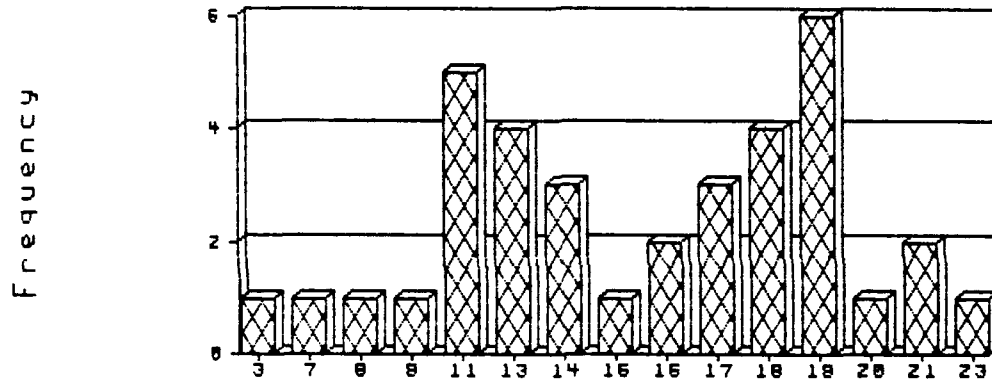
Figure 1.   Bar Chart of Total Responses
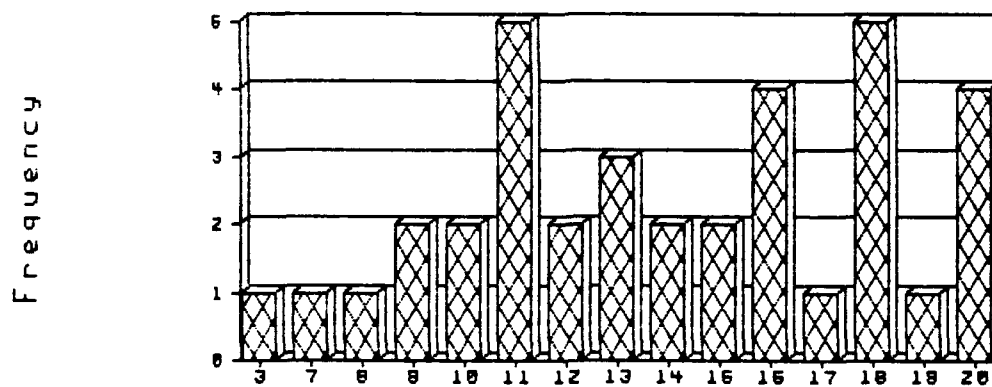
Figure 2.   Bar Chart of Correct Damage

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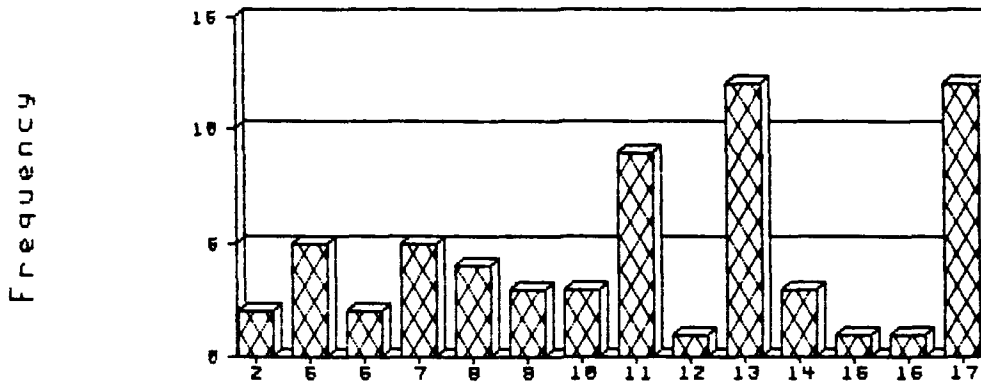
Figure 3. Bar Chart of Correct Severity
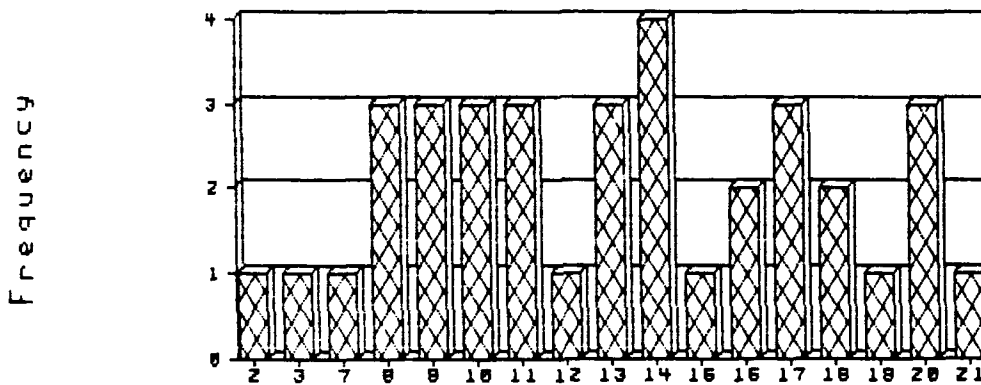
Figure 4. Bar Chart of Correct Location

Univariate Procedure

Next it is necessary to view each dependent group of
individual data for normality. By conducting a univariate
study on each dependent variable, the analysis can prove
that the sample groups are from a normal population. The
univariate test performs different tests for normality
depending on the sample size of the data. The univariate
procedure consists of using the Wilk-Shapiro test for
normality for sample sizes less than 51.   The following
test was conducted for each dependent variable group. Each

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figure shows a different dependent variable group with two
types of output. The first type shows descriptive
statistics for calculating the Wilk-shapiro normality test.
The second portion contains one plot, the normality plot.
The Normality plot shows asterisks (*) which represent the
sample data and plus signs (+) which represent a straight
line. if the sample is from a normal distribution, the
asterisks and plus signs will overlap. A large number of
plus signs indicate a nonnormal distribution of sample
data. By rejecting the null hypothesis (Ho) the sample
size will not represent a normal population distribution.
The combination of these two indications checked the data
for normality.

In figures 5-16, a univariate procedure was
accomplished on each of the data groups. Following each
procedure, a hypothesis test for normality was conducted
based on the information supplied from the univariate data.
Conclusions are drawn from each hypothesis test to
determine if each group was normally distributed.

```
                    Variable=TOT3

                       Moments

N                   14  Sum Wgts           14
Mean          16.42857  Sum               230
Std Dev       3.715131  Variance      13.8022
Skewness       -0.5632  Kurtosis     0.974162
USS               3958  CSS          179.4286
CV            22.61384  Std Mean     0.992911
T:Mean=0      16.54587  Prob>|T|       0.0001
Num ^= 0            14  Num > 0            14
M(Sign)              7  Prob>|M|       0.0001
Sgn Rank          52.5  Prob>|S|       0.0001
W:Normal      0.961315  Prob<W         0.7032

               Normal Probability Plot
  23+                                    + + * + + +
    :                               + + * + +
    :                          *  *  * + * + +
    :                       *  * + + + + +
    :                   * + * + + +
    :              * + + * + +
    :         + + + + + +
   9+    + + + + + *
    +----+----+----+----+----+----+----+----+----+--
        -2       -1        0       +1       +2
```

Figure 5.   SAS Univariate Procedure for TOT3

Test for Normality on TOT3

    The data consist of a random sample X1, X2 ... , Xn
of size n = 14 for the TOT3 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

        Ho: Group samples are from a normal population.

        Ha: Group is nonnormal.

TEST STATISTIC:

        TS: W = 0.961315

        alpha = .05

REJECTION REGION:

W < 0.874

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the TOT3 data group. Therefore the sample population is normally distributed for the purposes of this experiment.

```
                      Variable=TOT2

                          Moments

     N                   11   Sum Wgts            11
     Mean           16.54545   Sum                182
     Std Dev        3.110101   Variance      9.672727
     Skewness        -0.4553   Kurtosis      -0.84559
     USS                3108   CSS           96.72727
     CV             18.79731   Std Mean      0.937731
     T:Mean=0       17.64414   Prob>|T|        0.0001
     Num ^= 0             11   Num > 0             11
     M(Sign)             5.5   Prob>|M|        0.0010
     Sgn Rank             33   Prob>|S|        0.0010
     W:Normal       0.935988   Prob>W          0.4541

               Normal Probability Plot
   21+                                  + + + + * +
     ¦                        *    * + + + + + *
     ¦                    * + * + + + +
     ¦                + * + * + + +
     ¦            + + + * + +
   11+      + + + + + * +
     +----+----+----+----+----+----+----+----+----+----+--
         -2        -1         0        +1        +2
```

Figure 6.   SAS Univariate Procedure for TOT2

Test for Normality on TOT2

The data consist of a random sample X1, X2 ... , Xn of size n = 11 for the TOT2 group.

ASSUMPTIONS: The sample is a random sample.

58

HYPOTHESIS:

Ho: Group samples are from a normal population.

Ha: Group is nonnormal.

TEST STATISTIC:

TS: W = 0.935988

alpha = .05

REJECTION REGION:

W < 0.850

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the TOT2 data group. Therefore the sample population is normally distributed for the purposes of this experiment.

```
                          Variable=TOT1

                               Moments

        N                      11   Sum Wgts                 11
        Mean             12.09091   Sum                     133
        Std Dev          5.243177   Variance           27.49091
        Skewness         0.201824   Kurtosis           -0.10124
        USS                  1883   CSS                274.9091
        CV               43.36462   Std Mean           1.580877
        T:Mean=0         7.648227   Prob>:T!             0.0001
        Num ^= 0               11   Num > 0                  11
        M(Sign)               5.5   Prob>:M!             0.0010
        Sgn Rank               33   Prob>:S!             0.0010
        W:Normal         0.948855   Prob>W               0.6069

                    Normal Probability Plot
       21+                                              * + +
         :                                        * + + + +
         :                                    * + + + +
       15+                              + + + +
         :                        + + + +  *
         :               *  + * + *  *
        9+            * + + +
         :        * + + +
         :     + + + +
        3+     + + + *
         +----+----+----+----+----+----+----+----+----+----+--
             -2        -1        0        +1        +2
```

Figure 7.   SAS Univariate Procedure for TOT1

Test for Normality on TOT1

        The data consist of a random sample X1, X2 ... , Xn

of size n = 11 for the TOT1 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

            Ho: Group samples are from a normal population.

            Ha: Group is nonnormal.

TEST STATISTIC:

            TS: W = 0.948855

60

alpha = .05

REJECTION REGION:

W < 0.850

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the TOT1 data group. Therefore the sample population is normally distributed for the purposes of this experiment.

```
                      Variable=DAM3

                        Moments

         N                  14    Sum Wgts            14
         Mean          16.07143   Sum                225
         Std Dev       3.338915   Variance      11.14835
         Skewness      -1.01274   Kurtosis      1.130162
         USS               3761   CSS           144.9286
         CV            20.77547   Std Mean      0.892363
         T:Mean=0      18.00998   Prob>:T:        0.0001
         Num ^= 0            14   Num > 0             14
         M(Sign)              7   Prob>:M:        0.0001
         Sgn Rank          52.5   Prob>:S:        0.0001
         W:Normal      0.906152   Prob>W          0.1374

                  Normal Probability Plot
    21+                                        *+++++*
      :                              *  *  *+*+*+*++
      :                           *++++++++
    15+                     *+*+++++
      :               *++*++++
      :          ++++++
     9+ ++++++  *
       +----+----+----+----+----+----+----+----+----+----+--
           -2       -1        0       +1       +2
```

Figure 8. SAS Univariate Procedure for DAM3

Test for Normality on DAM3

The data consist of a random sample X1, X2 ... , Xn

of size n = 14 for the DAM3 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

Ho: Group samples are from a normal population.

Ha: Group is nonnormal.

TEST STATISTIC:

TS: W = 0.906152

alpha = .05

REJECTION REGION:

W < 0.874

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the DAM3 data group. Therefore the sample population is normally distributed for the purposes of this experiment.

```
                    Variable=DAM2

                       Moments

       N                  11  Sum Wgts            11
       Mean         13.54545  Sum                149
       Std Dev      3.110101  Variance      9.672727
       Skewness     0.861048  Kurtosis      0.026558
       USS              2115  CSS           96.72727
       CV           22.96048  Std Mean      0.937731
       T:Mean=0     14.44493  Prob>|T|        0.0001
       Num ^= 0           11  Num > 0             11
       M(Sign)           5.5  Prob>|M|        0.0010
       Sgn Rank           33  Prob>|S|        0.0010
       W:Normal     0.884731  Prob>W          0.1158

              Normal Probability Plot
  21+                                      *      +++++
    :                                      +++++
    :                             *  *++++*+++
    :                            *+++++
    :                       ++*+*+
  11+            *      *++++++*
    +----+----+----+----+----+----+----+----+----+----+
        -2       -1        0       +1       +2
```

Figure 9. SAS Univariate Procedure for DAM2

Test for Normality on DAM2

     The data consist of a random sample X1, X2 ... , Xn of size n = 11 for the DAM2 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

        Ho: Group samples are from a normal population.

        Ha: Group is nonnormal.

TEST STATISTIC:

        TS: W = 0.884731

        alpha = .05

REJECTION REGION:

W < 0.850

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the DAM2 data group. Therefore the sample population is normally distributed for the purposes of this experiment.

```
                        Variable=DAM1

                          Moments

N                    11    Sum Wgts            11
Mean            11.63636    Sum                128
Std Dev          5.04525    Variance      25.45455
Skewness        0.203869    Kurtosis      -0.34869
USS                 1744    CSS            254.5455
CV              43.35762    Std Mean        1.5212
T:Mean=0        7.649463    Prob>:T:        0.0001
Num ^= 0              11    Num > 0             11
M(Sign)              5.5    Prob>:M:        0.0010
Sgn Rank              33    Prob>:S:        0.0010
W:Normal         0.95886    Prob>W          0.7368

                 Normal Probability Plot
   21+                                         *++++
     :                                      *  ++++
     :                                   *  ++++
   15+                                 ++++
     :                              ++++*
     :                          +*+*
    9+                     *+*+
     :                  *+++
     :              ++++
    3+       +++*
      +----+----+----+----+----+----+----+----+----+--
         -2        -1        0        +1        +2
```

Figure 10. SAS Univariate Procedure for DAM1

Test for Normality on DAM1

The data consist of a random sample X1, X2 ... , Xn of size n = 11 for the DAM1 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

Ho: Group samples are from a normal population.

Ha: Group is nonnormal.

TEST STATISTIC:

TS: W = 0.95886

alpha = .05

REJECTION REGION:

W < 0.850

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the DAM1 data group. Therefore the sample population is normally distributed for the purposes of this experiment.

```
                    Variable=SEV3

                        Moments

        N               14    Sum Wgts            14
        Mean       10.57143    Sum                148
        Std Dev    3.877237    Variance      15.03297
        Skewness   -0.55373    Kurtosis      0.539776
        USS            1760    CSS           195.4286
        CV         36.67657    Std Mean      1.036235
        T:Mean=0   10.20177    Prob>|T|        0.0001
        Num ^= 0         14    Num > 0             14
        M(Sign)           7    Prob>|M|        0.0001
        Sgn Rank       52.5    Prob>|S|        0.0001
        W:Normal   0.967496    Prob>W          0.7979

                Normal Probability Plot
    17+                                      + + * + +
      :                              *   * + + * + +
      :                            * + * + + +
      :                       *   * + * + +
      :                *   * + * + + +
      :              * + + + + +
      :          + + + + +
    3 +     + + + + + *
      +----+----+----+----+----+----+----+----+----+--
          -2        -1        0        +1        +2
```

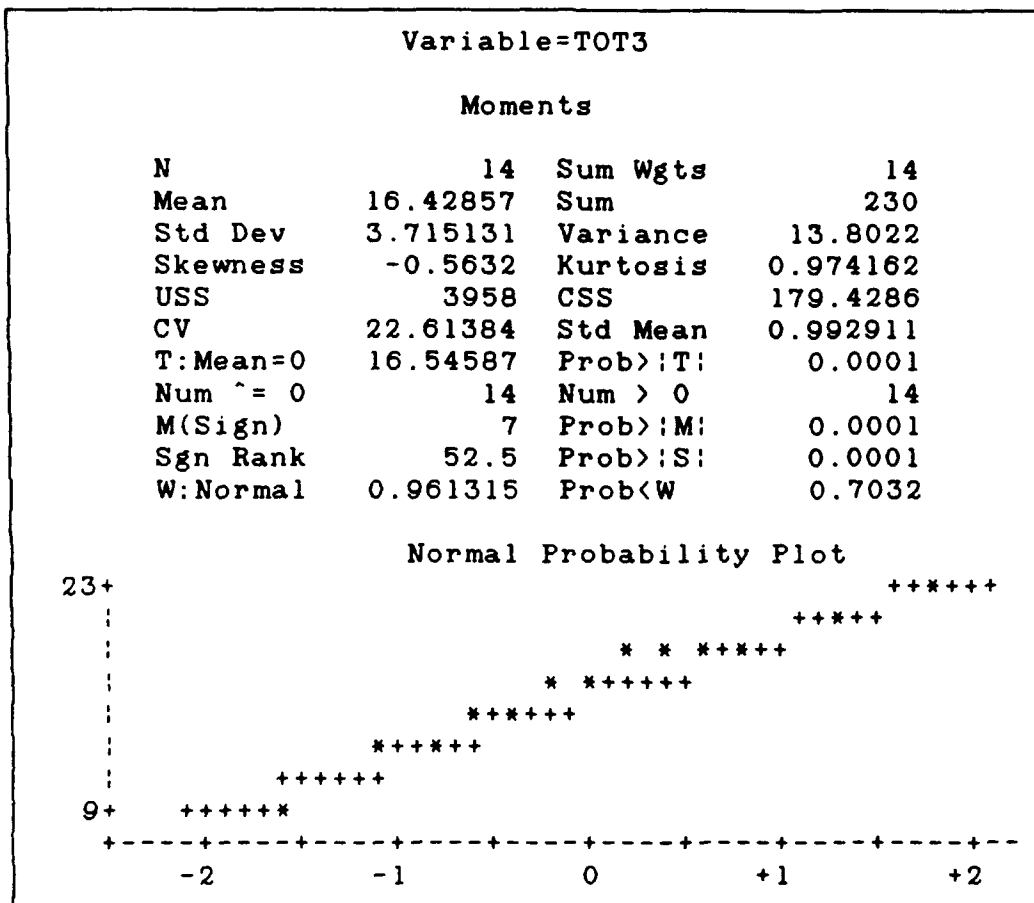**Figure 11.   SAS Univariate Procedure for SEV3**

Test for Normality on SEV3

   The data consist of a random sample X1, X2 ... , Xn
of size n = 14 for the SEV3 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

        Ho: Group samples are from a normal population.

        Ha: Group is nonnormal.

TEST STATISTIC:

            TS: W = 0.967496

            alpha = .05

66

REJECTION REGION:

$$W < 0.874$$

CONCLUSION:

There is insufficient evidence to reject the null
hypothesis for the SEV3 data group. Therefore the sample
population is normally distributed for the purposes of this
experiment.

```
Variable=SEV2

                        Moments

      N                    11   Sum Wgts           11
      Mean                 10   Sum               110
      Std Dev         3.49285   Variance         12.2
      Skewness       0.464649   Kurtosis     -0.57243
      USS                1222   CSS               122
      CV              34.9285   Std Mean     1.053134
      T:Mean=0       9.495469   Prob>|T|       0.0001
      Num ^= 0             11   Num > 0            11
      M(Sign)             5.5   Prob>|M|       0.0010
      Sgn Rank             33   Prob>|S|       0.0010
      W:Normal       0.953292   Prob>W         0.6642

                Normal Probability Plot
    17+                                      *  +++++
      :                                  *+++++++
      :                            +*+++++
    11+                      ++*++*
      :              *  *++*+
      :         *+++++
     5+     +*++++
      +----+----+----+----+----+----+----+----+----+--
          -2        -1         0        +1        +2
```

Figure 12. SAS Univariate Procedure for SEV2

Test for Normality on SEV2

The data consist of a random sample X1, X2 ... , Xn
of size n = 11 for the SEV2 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

Ho: Group samples are from a normal population.

Ha: Group is nonnormal.

TEST STATISTIC:

TS: W = 0.953292

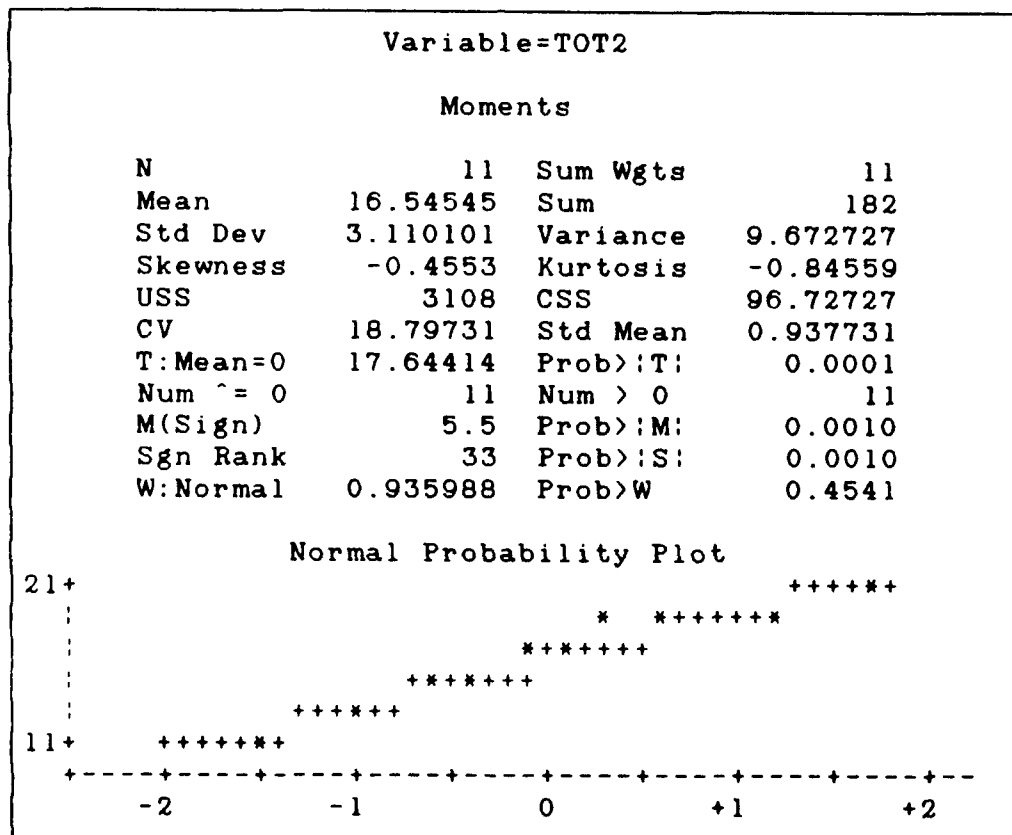alpha = .05

REJECTION REGION:

W < 0.850

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the SEV2 data group. Therefore the sample population is normally distributed for the purposes of this experiment.
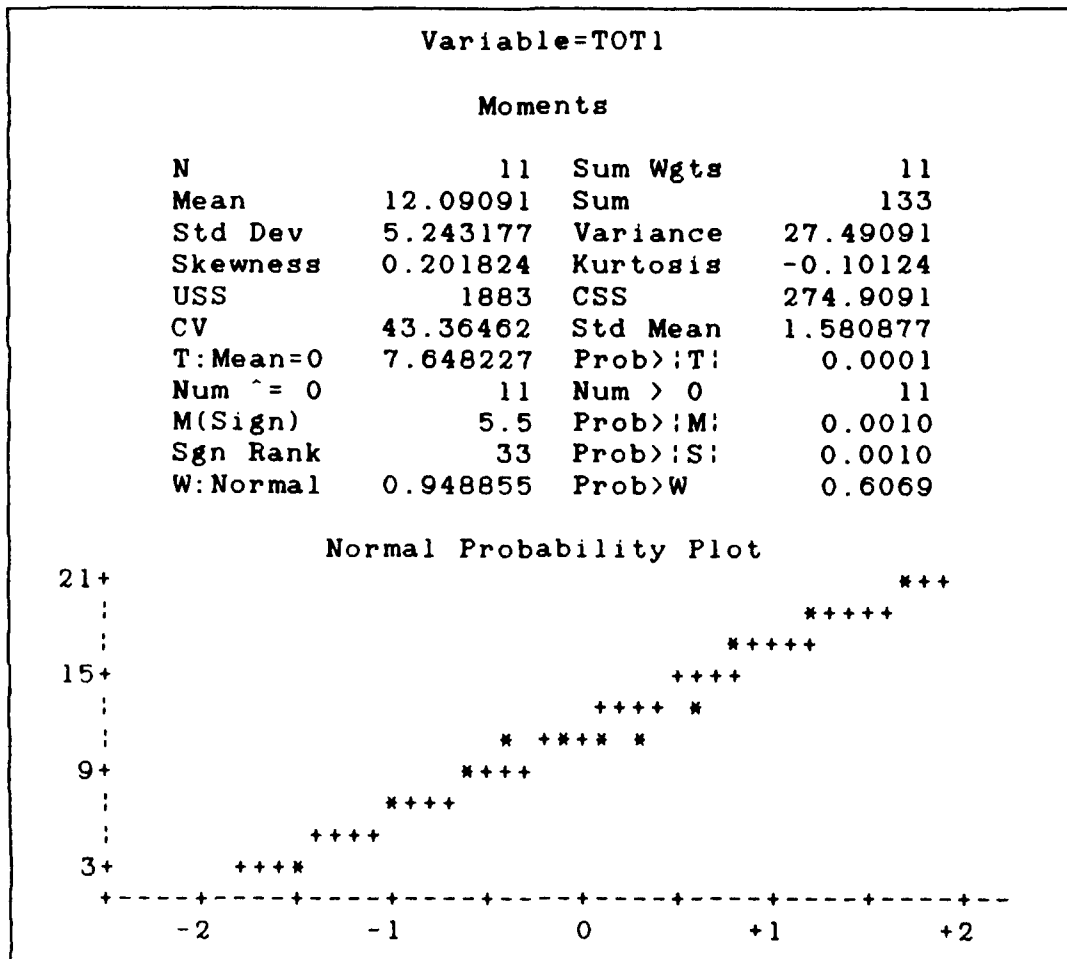
```
                        Variable=SEV1

                           Moments

         N                   11   Sum Wgts            11
         Mean           9.272727   Sum                102
         Std Dev        4.692354   Variance      22.01818
         Skewness       -0.00399   Kurtosis      -1.14653
         USS                1166   CSS           220.1818
         CV             50.60381   Std Mean      1.414798
         T:Mean=0       6.554101   Prob>|T|        0.0001
         Num ^= 0             11   Num > 0             11
         M(Sign)             5.5   Prob>|M|        0.0010
         Sgn Rank             33   Prob>|S|        0.0010
         W:Normal       0.929086   Prob>W          0.3835

                  Normal Probability Plot
       17+                                        +*++
         :                                   ++++
         :                              *+*++++*
         :                         *  *+++
         :                      ++++
         :                  ++++*
         :            *++++ *
        3+      *++++
         +----+----+----+----+----+----+----+----+----+--
            -2        -1        0        +1        +2
```

Figure 13. SAS Univariate Procedure for SEV1

Test for Normality on SEV1

        The data consist of a random sample X1, X2 ... , Xn

of size n = 11 for the SEV1 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

        Ho: Group samples are from a normal population.

        Ha: Group is nonnormal.

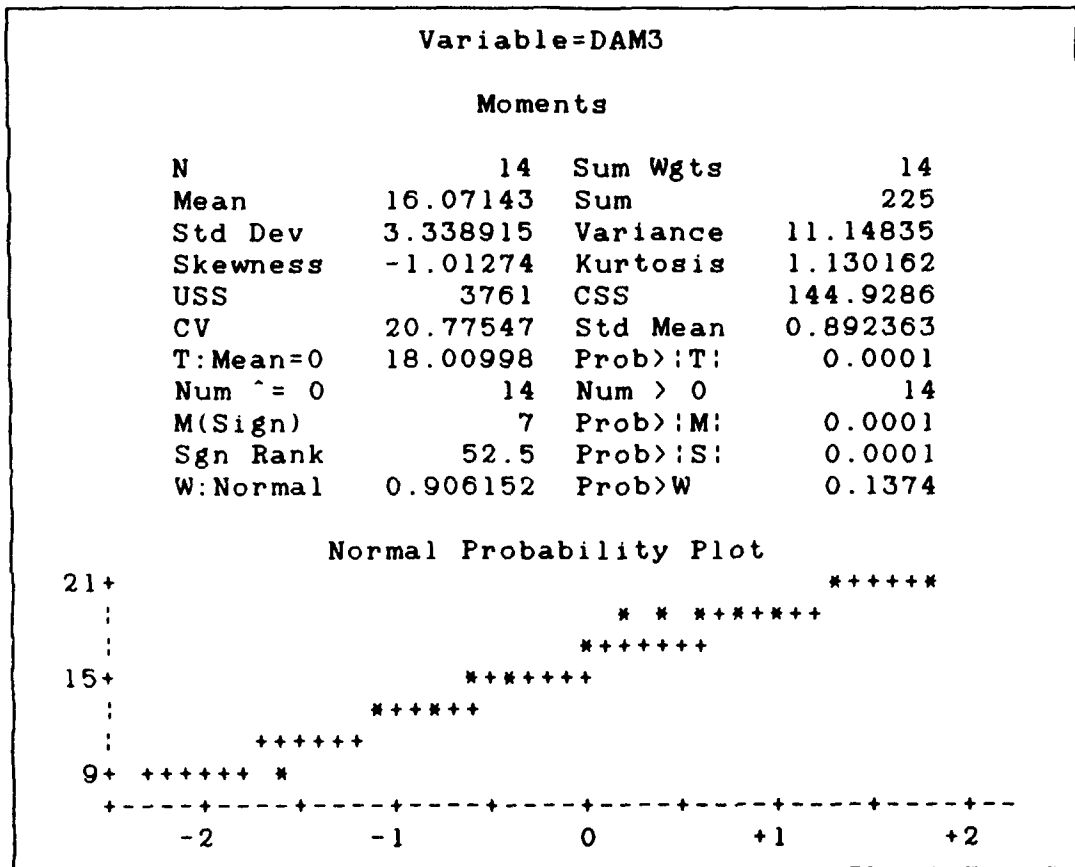TEST STATISTIC:

        TS: W = 0.929086

        alpha = .05

REJECTION REGION:

$$W < 0.850$$

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the SEV1 data group. Therefore the sample population is normally distributed for the purposes of this experiment.
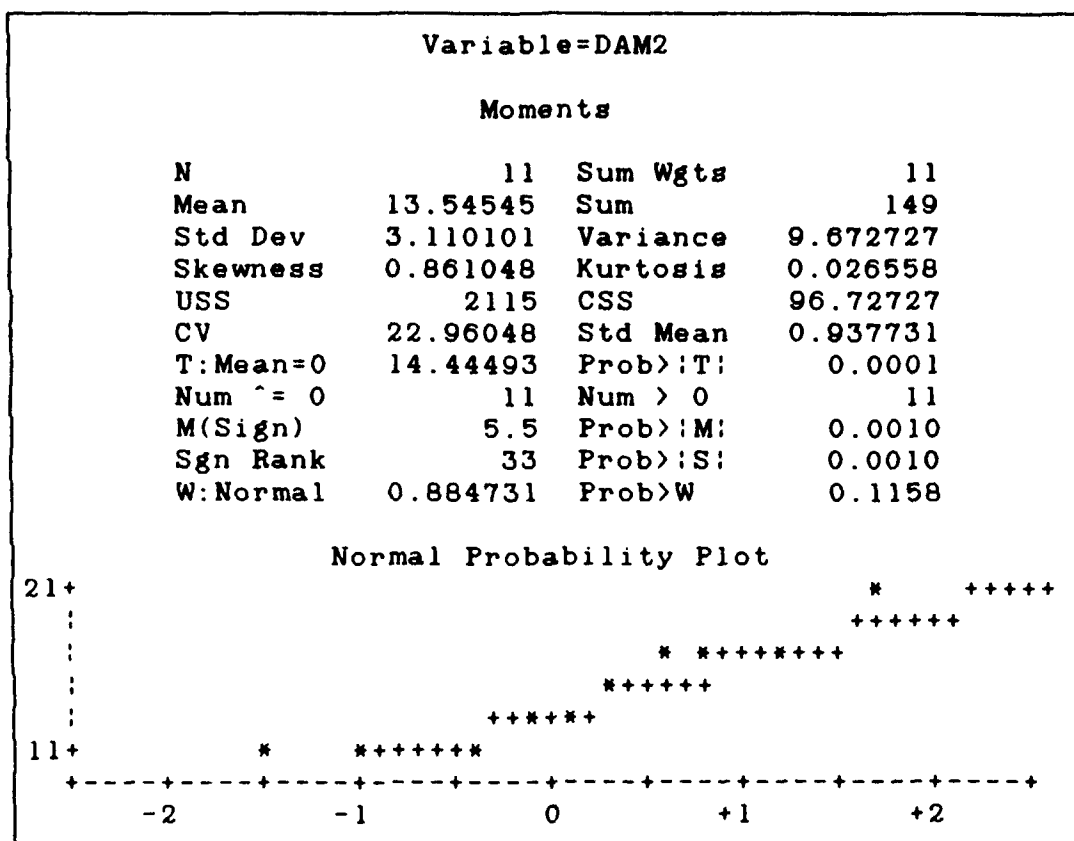
```
                        Variable=LOC3

                           Moments

      N                 14   Sum Wgts            14
      Mean              14   Sum                196
      Std Dev     4.296689   Variance      18.46154
      Skewness    -0.06109   Kurtosis      -0.89806
      USS             2984   CSS                240
      CV          30.69064   Std Mean      1.148339
      T:Mean=0    12.19153   Prob>|T|        0.0001
      Num ^= 0          14   Num > 0             14
      M(Sign)            7   P- >/|M|        0.0001
      Sgn Rank        52.5   Prob>|S'        0.0001
      W:Normal    0.936639   Prob>W          0.3627

                  Normal Probability Plot
   21+                                    *  ++++*+
     :                                *++++
     :                            *+*++
   15+                    *  *+*+*+
     :                  *++++
     :             ++*++
    9+        *    +*++*
     +----+----+----+----+----+----+----+----+----+--
        -2        -1         0        +1        +2
```

Figure 14.   SAS Univariate Procedure for LOC3

Test for Normality on LOC3

The data consist of a random sample X1, X2 ...   Xn of size n = 14 for the LOC3 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

Ho: Group samples are from   mal population.

Ha: Group is nonnormal.

TEST STATISTIC:

TS: W = 0.936639

alpha = .05

REJECTION REGION:

W < 0.874

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the LOC3 data group. Therefore the sample population is normally distributed for the purposes of this experiment.
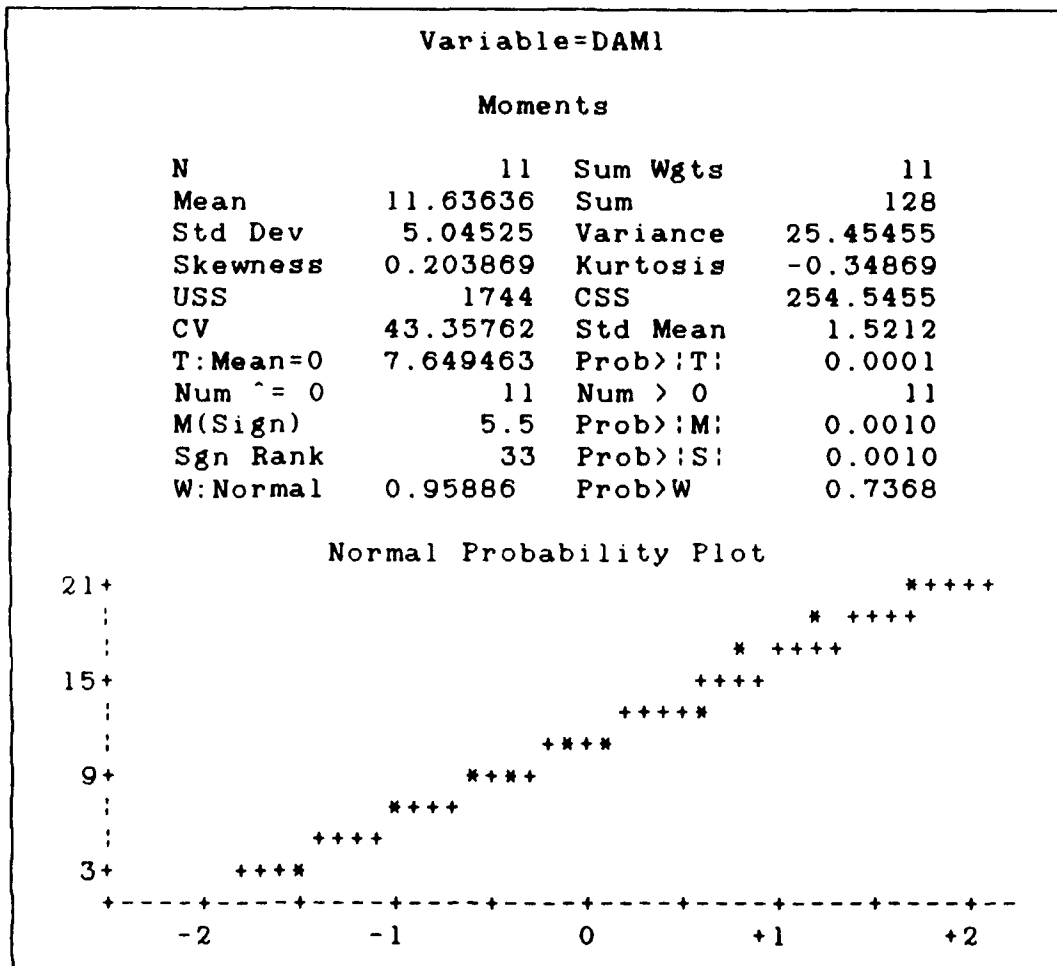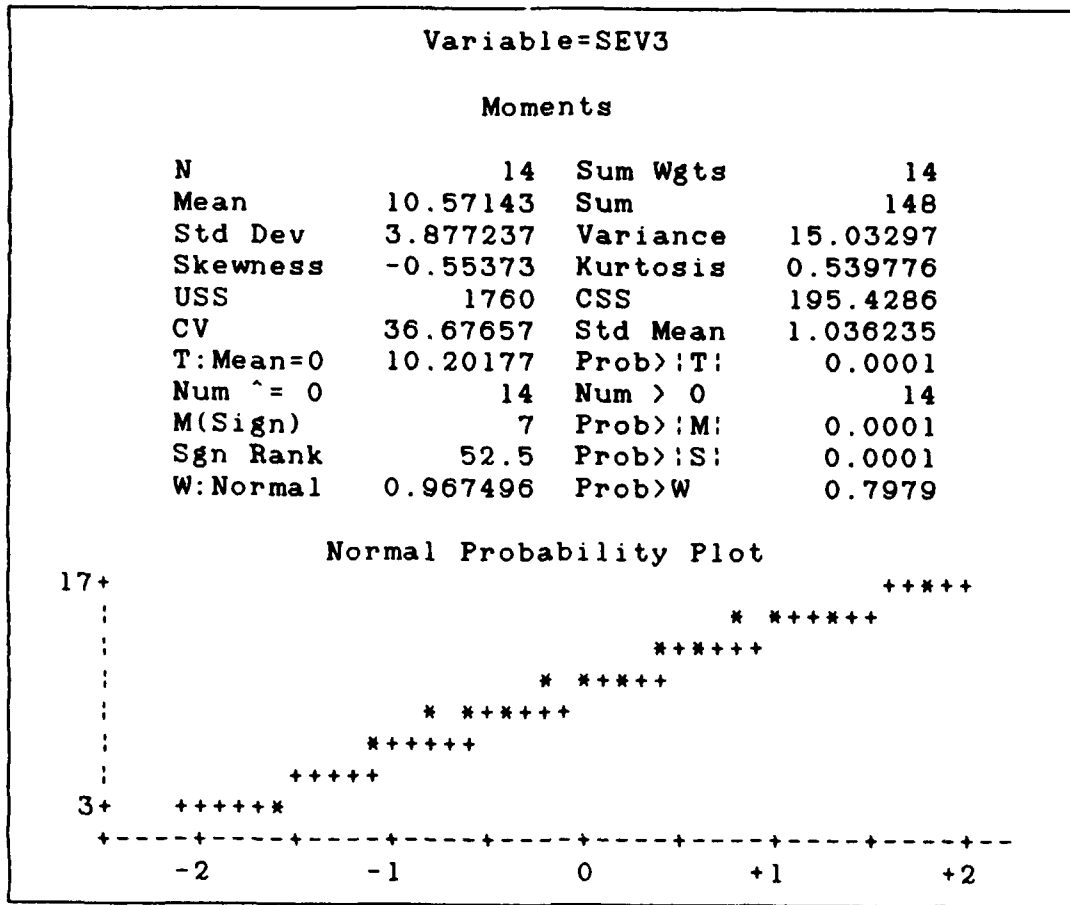
```
                    Variable=LOC2

                         Moments

   N                 11  Sum Wgts            11
   Mean         13.54545  Sum                149
   Std Dev      4.906397  Variance      24.07273
   Skewness     -0.75097  Kurtosis       0.75494
   USS              2259  CSS           240.7273
   CV           36.22172  Std Mean      1.479334
   T:Mean=0     9.156453  Prob>:T:        0.0001
   Num ^= 0           11  Num > 0             11
   M(Sign)           5.5  Prob>:M:        0.0010
   Sgn Rank           33  Prob>:S:        0.0010
   W:Normal     0.934284  Prob>W          0.4359
```

Normal Probability Plot

```
21+                                        + + * +
  :                                      + * + +
  :                             *    * + + + +
15+                                + + + + +
  :                            + * + *
  :                     *    * + + +
9 +                   + + + +
  :               + + + +
  :        + + + +
3 +    + + + +     *
  +----+----+----+----+----+----+----+----+----+--
       -2        -1         0        +1        +2
```

Figure 15.   SAS Univariate Procedure for LOC2

Test for Normality on LOC2

    The data consist of a random sample X1, X2 ... , Xn

of size n = 11 for the LOC2 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

          Ho: Group samples are from a normal population.

          Ha: Group is nonnormal.
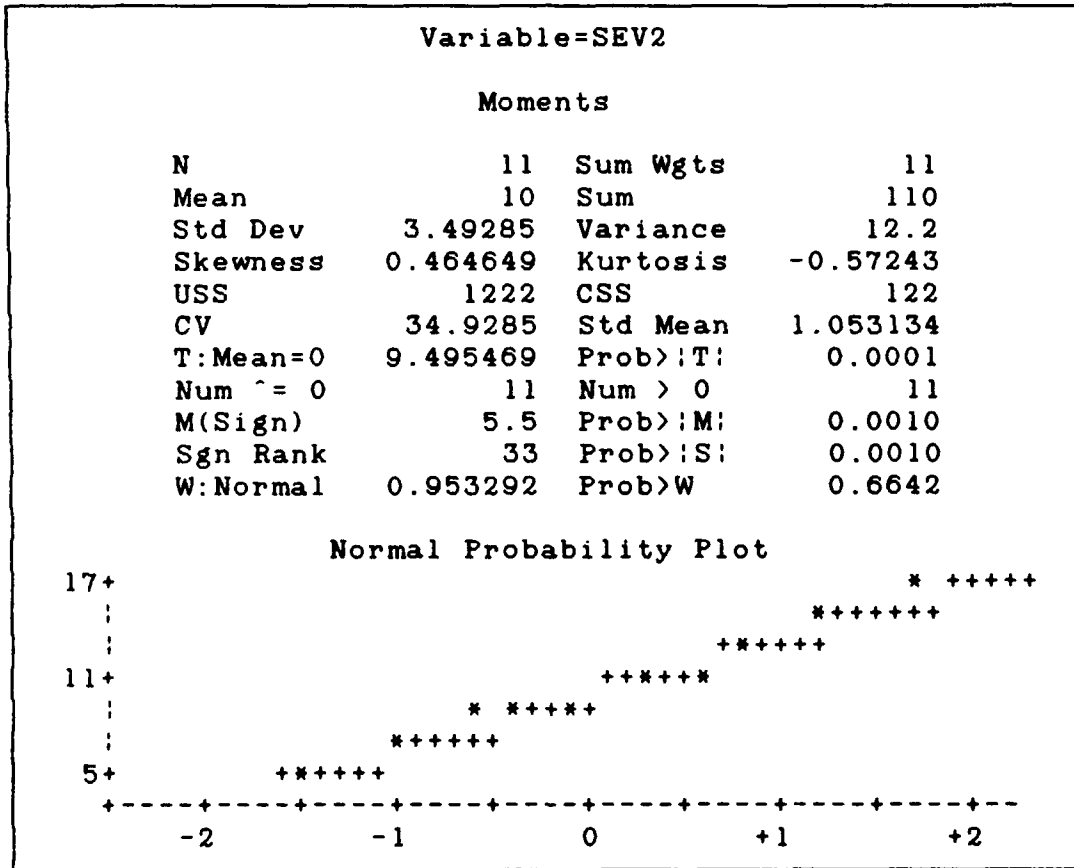
TEST STATISTIC:

$$TS: W = 0.934284$$

$$alpha = .05$$

REJECTION REGION:

$$W < 0.850$$

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the LOC2 data group. Therefore tne sample population is normally distributed for the purposes of this experiment.
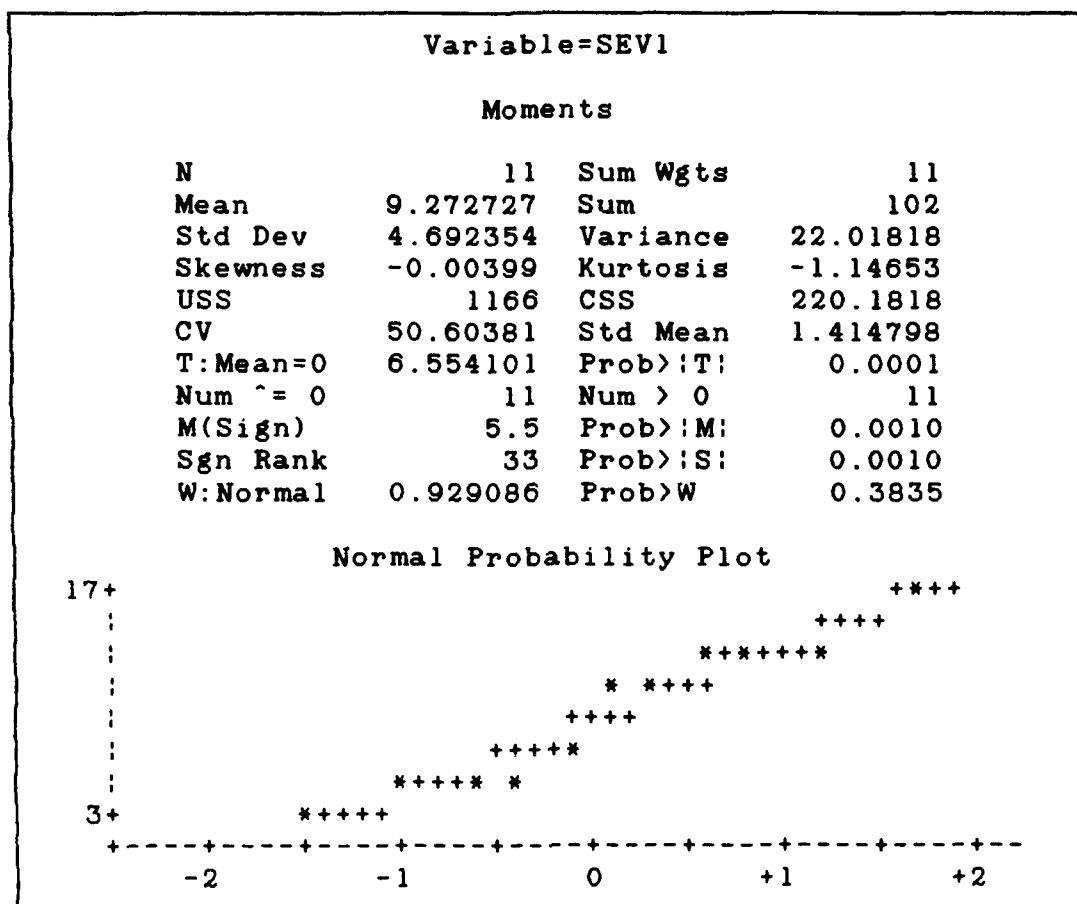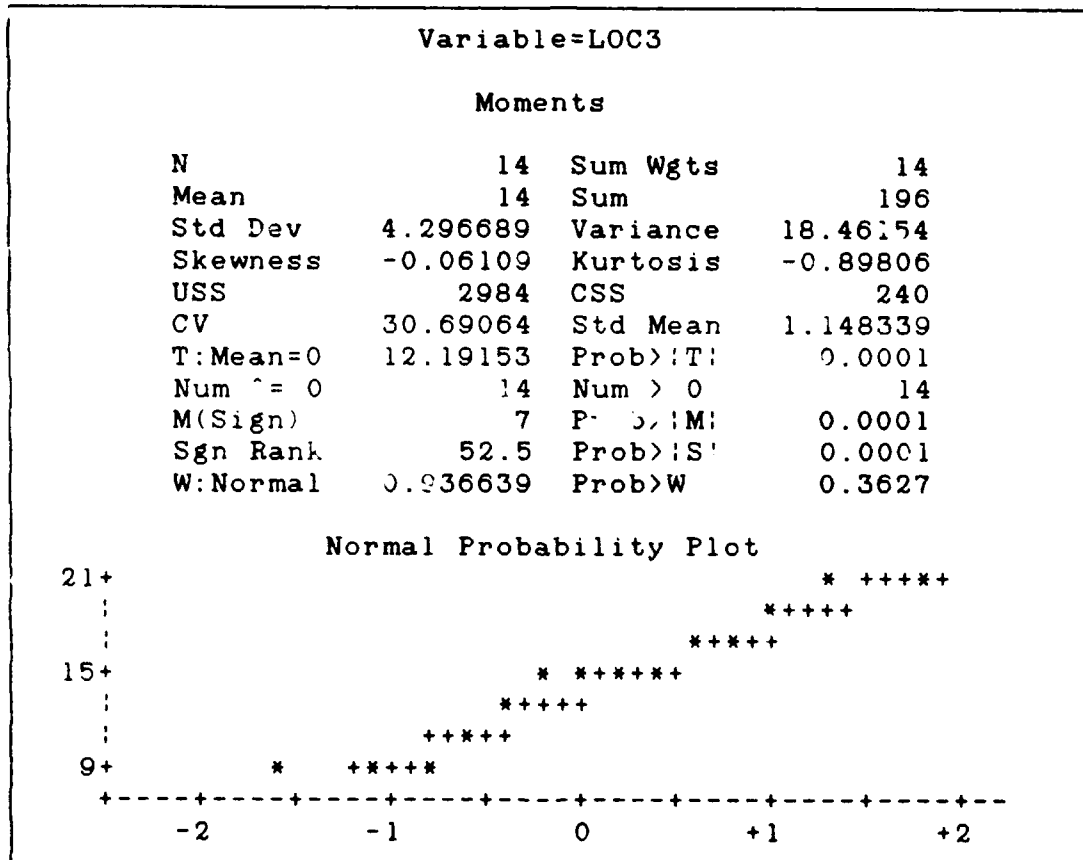
```
                        Variable=LOC1

                            Moments

          N                11    Sum Wgts            11
          Mean        11.09091    Sum                122
          Std Dev      5.029007   Variance       25.29091
          Skewness     0.211426   Kurtosis        0.371294
          USS              1606   CSS             252.9091
          CV           45.3435    Std Mean        1.516303
          T:Mean=0     7.314443   Prob>!T!         0.0001
          Num ^= 0           11   Num > 0             11
          M(Sign)           5.5   Prob>!M!         0.0010
          Sgn Rank           33   Prob>!S!         0.0010
          W:Normal     0.957196   Prob>W           0.7152

                    Normal Probability Plot

      21+                                        *  ++++
        :                                     *    ++++
        :                                   ++++
      15+                               +*++
        :                          +++*
        :                       ++*+*
       9+                   *+*+*
        :               *++++
        :            ++++
       3+       ++*+
        +----+----+----+----+----+----+----+----+----+----+--
           -2        -1        0        +1        +2
```

Figure 16.   SAS Univariate Procedure for LOC1

Test for Normality on LOC1

   The data consist of a random sample X1, X2 ... , Xn

of size n = 11 for the LOC1 group.

ASSUMPTIONS: The sample is a random sample.

HYPOTHESIS:

          Ho: Group samples are from a normal population.

          Ha: Group is nonnormal.

TEST STATISTIC:

TS: W = 0.957196

alpha = .05

REJECTION REGION:

W < 0.850

CONCLUSION:

There is insufficient evidence to reject the null hypothesis for the LOC1 data group. Therefore the sample population is normally distributed for the purposes of this experiment.
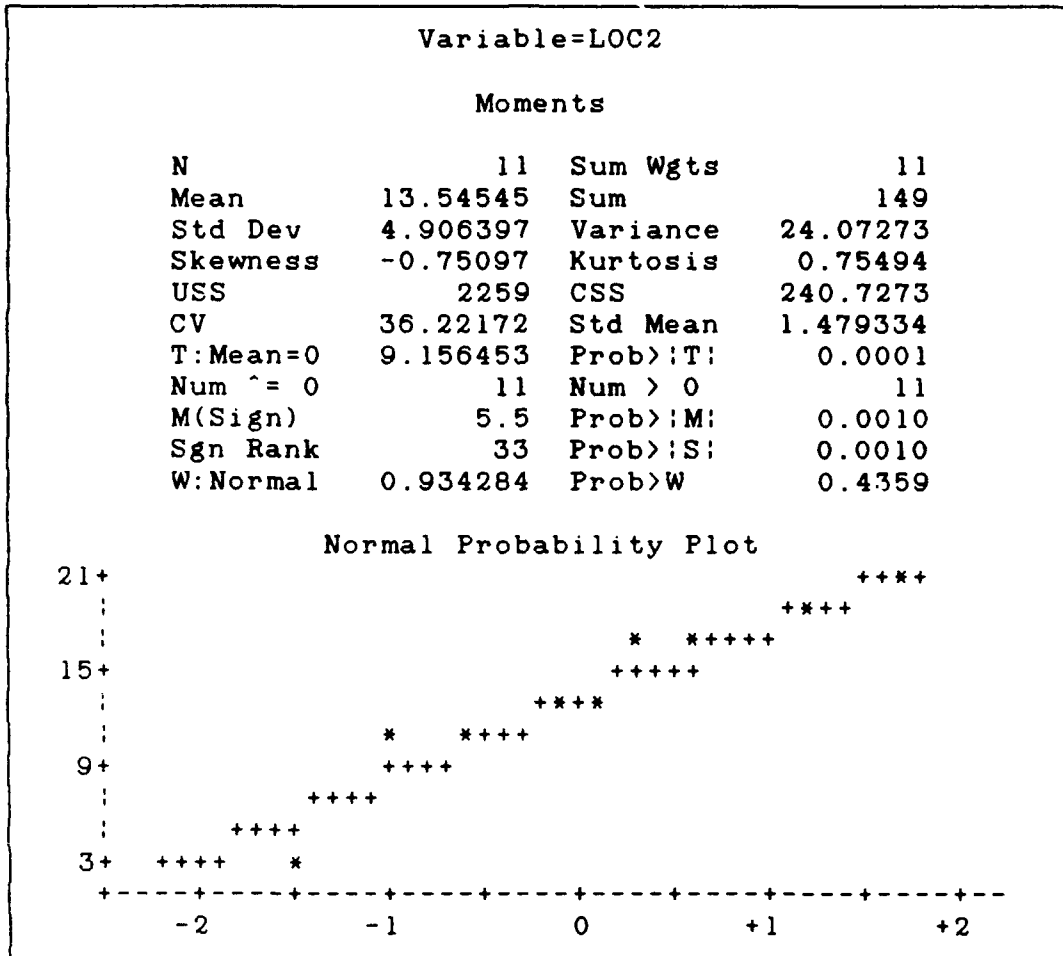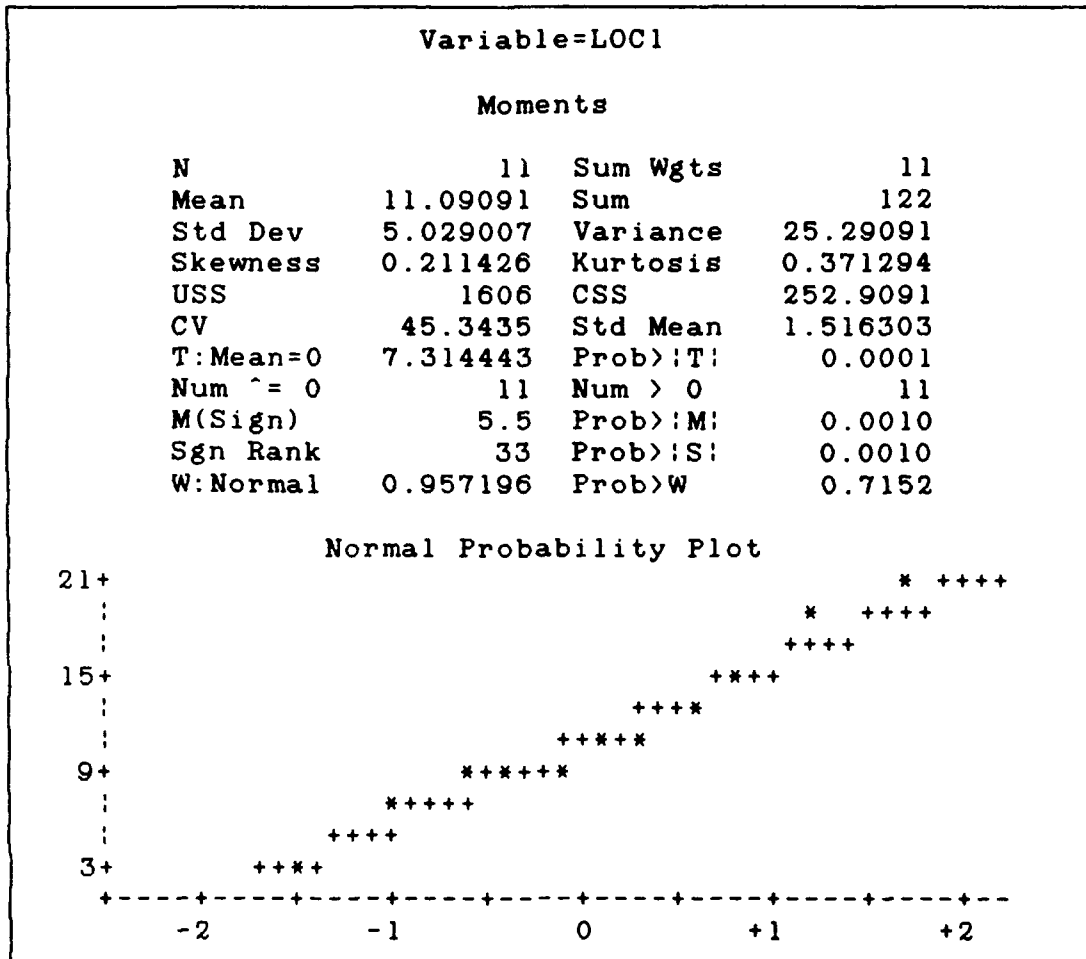
Performing an Analysis of Variance

It is necessary to perform an analysis of variance on the independent data groups. All the data has proved to be normally distributed, meaning all data groups failed to reject the null hypothesis. It must now be determined if there is a significant difference between the groups. Tables 3-5 give the name of the dependent variable compared, the degrees of freedom, the p-value for significance and other statistical data. The p-value is extremely important and will be compared to the reference probability value of 0.05 significance. If the p-value is lower than the reference p-value, then it can be concluded that the mean is significantly different among the different display groups; three dimensional, two dimensional and the standard ABO display. Finally by using

the Bonferroni option with the ANOVA test, the data groups
will be compared against each other. The output will
indicate any difference between each pair of means. It
also indicates a confidence interval for the difference,
and will indicate when the groups are different by three
asterisks (***). Tables 3-5 show the SAS ANOVA output
followed by a hypothesis test to either accept or reject
the null hypotheses that the means are significantly
different.

Table 3 - ANOVA Test on Correct Damage Groups

General Linear Models Procedure

Dependent Variable: DAMAGE

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	123.68759019	4.11	0.0254
Error	33	496.20129870		
Corrected Total	35	619.88888889		

R-Square	C.V.	DAMAGE Mean
0.199532	27.80806	13.9444444

Source	DF	Type I SS	F Value	Pr > F
GROUP	2	123.68759019	4.11	0.0254

Source	DF	Type III SS	F Value	Pr > F
GROUP	2	123.68759019	4.11	0.0254

Bonferroni (Dunn) T tests for variable: DAMAGE

NOTE: This test controls the type I experiment wise error rate but generally has a higher type II error rate than Tukey's for all pairwise comparisons.

Alpha= 0.05 Confidence= 0.95 df= 33 MSE= 15.0364
Critical Value of T= 2.52221

Comparisons significant at the 0.05 level
are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
3	- 2	-1.415	2.526	6.467	
3	- 1	0.494	4.435	8.376	***
2	- 3	-6.467	-2.526	1.415	
2	- 1	-2.261	1.909	6.079	
1	- 3	-8.376	-4.435	-0.494	***
1	- 2	-6.079	-1.909	2.261	

Conducting ANOVA F test on DAMAGE Variable group

HYPOTHESIS:

      Ho: The means of each group are equal.

      Ha: at least two treatment means differ.

TEST STATISTIC:

      TS: $F = 4.11$

      p-value $= 0.0254$

CONCLUSION:

Reject the null hypothesis that the means of the sample groups are equal. Therefore at least two treatment means differ. By looking at the bonferonni option, the two groups that differ are the three dimensional group and the standard ABO group.

Table 4 - ANOVA Test on Correct Severity Groups

General Linear Models Procedure

Dependent Variable: SEVERITY

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	10.38961039	0.32	0.7292
Error	33	537.61038961		
Correct Total	35	548.00000000		

R-Square	C.V.	SEVERITY Mean
0.018959	40.36239	10.0000000

Source	DF	Type I SS	F Value	Pr > F
GROUP	2	10.38961039	0.32	0.7292

Source	DF	Type III SS	F Value	Pr > F
GROUP	2	10.38961039	0.32	0.7292

Bonferroni (Dunn) T tests for variable: SEVERITY

NOTE: This test controls the type I experiment wise error rate but generally has a higher type II error rate than Tukey's for all pairwise comparisons.

Alpha= 0.05   Confidence= 0.95   df= 33   MSE= 16.29122
Critical Value of T= 2.52221

Comparisons significant at the 0.05 level
are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit
3	- 2	-3.530	0.571	4.673
3	- 1	-2.803	1.299	5.400
2	- 3	-4.673	-0.571	3.530
2	- 1	-3.614	0.727	5.068
1	- 3	-5.400	-1.299	2.803
1	- 2	-5.068	-0.727	3.614

Conducting ANOVA F test on SEVERITY Variable group

HYPOTHESIS:

> Ho: The means of each group are equal.

> Ha: at least two treatment means differ.

TEST STATISTIC:

> TS: F = 0.32

> p-value = 0.7292

CONCLUSION:

Fail to reject the null hypothesis that the means of the sample groups are equal. Therefore, none of the treatment means differ. By looking at the bonferonni option, there are no groups that differ. There is no significant difference in the sample means for the correct severity.

Table 5 - ANOVA Test on Correct Location Groups

General Linear Models Procedure

Dependent Variable: LOCATION

Source	DF	Sum of Squares	F Value	Pr > F
Model	2	57.33585859	1.29	0.2889
Error	33	733.63636364		
Corrected Total	35	790.97222222		

R-Square	C.V.	LOCATION Mean
0.072488	36.34704	12.9722222

Source	DF	Type I SS	F Value	Pr > F
GROUP	2	57.33585859	1.29	0.2889

Source	DF	Type III SS	F Value	Pr > F
GROUP	2	57.33585859	1.29	0.2889

Bonferroni (Dunn) T tests for variable: LOCATION

NOTE: This test controls the type I experiment wise error rate but generally has a higher type II error rate than Tukey's for all pairwise comparisons.

Alpha= 0.05 Confidence= 0.95 df= 33 MSE= 22.2314
Critical Value of T= 2.52221

Comparisons significant at the 0.05 level
are indicated by '***'.

GROUP Comparison		Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit
3	- 2	-4.337	0.455	5.246
3	- 1	-1.882	2.909	7.701
2	- 3	-5.246	-0.455	4.337
2	- 1	-2.616	2.455	7.525
1	- 3	-7.701	-2.909	1.882
1	- 2	-7.525	-2.455	2.616

Conducting ANOVA F test on LOCATION Variable group

HYPOTHESIS:

Ho: The means of each group are equal.

Ha: at least two treatment means differ.

TEST STATISTIC:

TS: F = 1.29

p-value = 0.2889

CONCLUSION:

Fail to reject the null hypothesis that the means of the sample groups are equal. Therefore, none of the treatment means differ. By looking at the bonferonni option, there are no groups that differ. There is no significant difference in the sample means for the correct location.

Summary

This chapter presented a great deal of data collected and analyzed for determining the preference of the displays. The data was analyzed for normality and then compared against each other through the ANOVA procedure to see if the sample group means were significantly different. The following chapter will give conclusions and recommendations from this analysis. Chapter V will also answer all the investigative questions posed in Chapter I.

V. Conclusions and Recommendations

Overview

The previous chapter analyzed the data compiled from the true experiment to determine if there was a significant difference between the three displays -- three dimensional, two dimensional, and the standard ABO Display. This chapter discusses the results of that analysis and the possible conclusions and recommendations for further research.

Conclusions (Investigative Question # 1)

Investigative question # 1 asks: Is there a significant difference with using two dimensional or three dimensional computer animation graphics in the ABO decision-making process?

The data analyzed in the methodology chapter indicated no <u>significant</u> difference between using two dimensional or three dimensional computer animation graphics in the ABO decision-making process. However, there was a significant difference between using the three dimensional graphics display as opposed to using the standard ABO map technique. The significant difference was in determining the correct type of damage indicated on the simulated air base. The significance value of this difference is .025. This value is below the reference value of .05 for a notable difference therefore, it is

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justified to report this difference. It is possible that there might have been a notable difference between the other means of the different display groups if more data points were available for the sample. It is believed by this researcher that there were not enough data points collected in the experiment for a significance to appear.

Conclusions (Investigative Question # 2)

Investigative question # 2 asks: What ABO information can or cannot be presented with each type of animation graphic display?

After inspecting the answers obtained from the questionnaires in the experiment, it was noted by some subjects that the two dimensional graphics display could not accurately present damage which occurred to a facility on its side. The two dimensional graphics display could only present damaged areas which appeared on the tops of facilities. Subjects who used the two dimensional display had difficulty identifying the damaged areas located on the side of a facility and thus scored poorly because of it. They did however, according to their scores, correctly identify damaged areas which were on the side of a facility. This suggests that possibly not enough side damaged areas were entered into the simulated air base for a significant conclusion. Because the means did not differ significantly, it is difficult to prove otherwise.

Also a very important observation to note was the use of colors for both displays. The use of bright red and dark red in the two graphic displays was a mistake. Subjects using both displays repeatedly remarked about having difficulty in determining the severity of a damaged area. This is justified by observing the mean data for each group on correct severity. Al. the means appear below the other areas tested. A suggestion was made to change dark red to yellow to represent medium severity for better identification.

The three dimensional graphic display was able to present all the information needed for the mission of ABO. There were some difficulties as to location of a damaged area. For example, although subjects located a crater on the runway, they had difficulty deciding if it was in the center of the runway, south east, or south west. To solve this possible problem, a grid system could be incorporated in the graphic system to locate damaged areas by grid coordinates instead of cardinal references.

Conclusions (Investigative Question # 3)

Investigative question # 3 asks: What time constraints are applicable with the production two dimensional or three dimensional animation graphics for the decision maker?

As mentioned earlier in the literature review,
Chapter II, the production of a three dimensional computer
graphic animation takes some time. Each damaged facility
animation on the three dimensional display took an average
time of five hours to generate on the Amiga 2000 computer.
The Amiga computer processor clock speed was 7.4 Mhz. This
is comparatively slow compared to newer Amiga machines
presently running at speeds up to 50 Mhz. With this new
technology, the creation of a graphic animation would be
reduced ten fold. What would take an hour to produce with
the old model machine would take less than five minutes
with the newer model. Thus, one damaged facility animation
would take approximately twenty five minutes or less to
create. Even more sophisticated and powerful machines in
the market today could produce an animation graphic even
quicker.

A two dimensional graphic display is relatively quick
to produce since only one picture (the top down shot) is
necessary. The time it takes to produce a damaged facility
picture is less than 30 seconds. This time constraint is
based on the assumption that the two dimensional graphic
display is created in the same manner in which it was
created in the experiment. Other methods of two
dimensional picture creation could be used as described in

Chapter II which could possibly take more time. The time

necessary might involve human (manual) intervention to

touch up the graphic picture.

Conclusions (Investigative Question # 4)

Investigative question # 4 asks: What finances are

associated with the acquisition of a computer graphics

display system and will it be cost effective?

The finances involved in acquiring a computer

graphics display system could be costly.   A computer

graphics display system consists of what was mentioned in

Chapter II: A powerful computer processor, a high

resolution graphic display monitor, a moderate amount of

RAM to create the images, and any graphics input and output

devices needed. Whether those costs are justified is a

difficult question to answer. Based on the analysis from

Chapter IV, the three dimensional display did prove to be

significantly more effective in determining the type of

damage a facility incurred after a post-attack from enemy

forces. If the ABO mission or any other organization's

mission demands that this be critical, then the costs

associated to purchasing a computer graphic system are

justified. It is also extremely important to note that

this system will not just be used for one application.

Multiple applications are apparent for this type of system.

The cost effectiveness of a three dimensional computer graphic system will go up as more and more applications are brought to its use.

Overall Conclusions

As mentioned before, there was a significant difference noted in determining the type of damage a facility incurred with the three dimensional graphic display and the standard ABO map display. Although there was not a significant difference between two and three dimensional computer animation graphics, the data analyzed indicates a preference for three dimensional computer animation graphics over the standard ABO display. While observing some of the subjects using two or three dimensional graphics, the researcher noted some frustration with the subjects using the two dimensional display. This seems to be due to the lack of information presented with the two dimensional picture. If we assume the adage that ˙More is better˙ one could be lead to believe that the three dimensional graphic animation is better. But that fact cannot be proved conclusively with this present data.

Recommendations for Future Research

Future research in the area of two and three dimensional computer animation graphics is strongly advised. Future research involving the preference between

two and three dimensional graphics in other applications is recommended. However, as mentioned before the samples sizes of each display group should have been larger. It is recommended that future research be conducted with a larger sample size from each display group. A sample size for each group should be about 30 or more. The new sample size groups might show a more defined difference between the displays.

If similar research is to be conducted using the ABO decision-making process application, then correction of the problems encountered with this experiment should be accomplished.

Summary

This thesis attempted to determine the preference between two computer animation displays -- two and three dimensional. By using the ABO decision-making process as an environment, three displays were created. Subjects were then randomly selected to use one of the three displays and their data was compared and analyzed. The results suggested a significant difference between the three dimensional display and the standard ABO display currently being used for determining the preference in a particular display. The results, however, did not show a significant difference between two and three dimensional displays. Therefore there was no significant preference between the

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use of two or three dimensional computer animation displays
on the air base operability decision making process.

APPENDIX A: ABO Damage Listing Report

Damage Type	Severity	Building #	Location
UXO	MEDIUM	100	North-West (Ground)
CRATER	MINIMAL	103	East (Ground)
UXO	MEDIUM	Runway 27	East End
UXO	MEDIUM	106	Center (Ground)
CRACK	MEDIUM	105	Top (Roof)
UXO	MEDIUM	Hangers	Between 1 & 2
CRATER	MINIMAL	POL Dome	South (Pad)
UXO	MEDIUM	104	East (Ground)
CRACK	MEDIUM	108	North (Wall)
UXO	MEDIUM	110	East (Ground)
CRATER	MINIMAL	110	North (Ground)
CRATER	CRITICAL	Hangers	# 3 South
CRACK	MINIMAL	101	West (Wall)
CRACK	MEDIUM	105	North (Wall)
CRATER	MINIMAL	107	West (Ground)
CRACK	MEDIUM	108	South (Wall)
CRATER	MINIMAL	Runway 18	North-West
CRATER	MEDIUM	100	South (Wall)
CRACK	CRITICAL	102	East (Wall)
UXO	MEDIUM	106	North-West (Ground)
CRATER	MINIMAL	Hangers	#1 East
CRATER	MINIMAL	Runway 18	South-East

Damage Type	Severity	Building #	Location
CRACK	CRITICAL	104	Inside (Wall)
CRATER	MINIMAL	107	Top (Building)
CRACK	MINIMAL	109	Top (Building)
CRATER	MINIMAL	Runway 27	North-Center
CRACK	CRITICAL	111	North (Wall)
CRATER	MINIMAL	Runway 18	West-Central

For each building, identify the total number of
damaged areas, the type, location and severity of each
damaged areas. Some buildings may have damage, some may
not, others may have more than one damaged area. None of
the facilities will have more than three damaged areas.

EXAMPLE:

You find building 105 has a black crater on its south wall.
Look for the question number corresponding to building 105
and fill in the necessary spaces on the answer sheet.

10. Building 105

TYPE	SEVERITY	LOCATION	AREA
1 = CRATER	1 = MINIMAL (BLACK)	1 = NORTH	1 = WALL
2 = CRACK	2 = MEDIUM (DARK RED)	2 = SOUTH	2 = GROUND
3 = UXO	3 = CRITICAL (BRIGHT RED)	3 = EAST	3 = ROOF
		4 = WEST	
		5 = TOP	

Starting then with row number 10, the following is filled.

10. (1) (2) (3) (4) (5)   For Type

20. (1) (2) (3) (4) (5)   For Severity

30. (1) (2) (3) (4) (5)   For Location

40. (1) (2) (3) (4) (5)   For Area

For location you may answer more than one space, for
instance a crater is located North-West (NW) therefore you
fill in North and West together, numbers 1 & 4.

COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4
TYPE	SEVERITY	LOCATION	AREA
1 = CRATER	1 = MINIMAL (BLACK)	1 = NORTH	1 = WALL
2 = CRACK	2 = MEDIUM (DARK RED)	2 = SOUTH	2 = GROUND
3 = UXO	3 = CRITICAL (BRIGHT RED)	3 = EAST	3 = ROOF
		4 = WEST	
		5 = TOP	

FOR ANSWER SHEET

1. Building 100	2. Building 100	3. Building 100
4. Building 101	5. Building 101	6. Building 101
7. Building 102	8. Building 102	9. Building 102
10. Building 103	41. Building 103	42. Building 103
43. Building 104	44. Building 104	45. Building 104
46. Building 105	47. Building 105	48. Building 105
49. Building 106	50. Building 106	81. Building 106
82. Building 107	83. Building 107	84. Building 107
85. Building 108	86. Building 108	87. Building 108
88. Building 109	89. Building 109	90. Building 109
121. Building 110	122. Building 110	123. Building 110
124. Building 111	125. Building 111	126. Building 111
127. POL Dome	128. POL Dome	129. POL Dome

TYPE	SEVERITY	LOCATION	AREA
CRATER	MINIMAL (BLACK)	NORTH	WALL
CRACK	MEDIUM (BROWN)	SOUTH	GROUND
UXO	CRITICAL (BLACK)	EAST	ROOF
		WEST	
		TOP	

For Runway 27

TYPE	SEVERITY	LOCATION	AREA
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

For Runway 18

TYPE	SEVERITY	LOCATION	AREA
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

For Hangers 1-North, 2-Middle, 3-South

TYPE	SEVERITY	LOCATION	AREA
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

APPENDIX C: Frequency Tables

Table 6 - Frequency of 3D Total Responses

TOT3	Frequency	Percent	Cumulative Frequency	Cumulative Percent
8	1	7.1	1	7.1
13	2	14.3	3	21.4
14	1	7.1	4	28.6
15	1	7.1	5	35.7
16	2	14.3	7	50.0
18	3	21.4	10	71.4
19	2	14.3	12	85.7
20	1	7.1	13	92.9
23	1	7.1	14	100.0

Table 7 - Frequency of 3D Correct Damage

DAM3	Frequency	Percent	Cumulative Frequency	Cumulative Percent
8	1	7.1	1	7.1
13	2	14.3	3	21.4
14	1	7.1	4	28.6
15	2	14.3	6	42.9
16	1	7.1	7	50.0
18	4	28.6	11	78.6
19	1	7.1	12	85.7
20	2	14.3	14	100.0

Table 8 - Frequency of 3D Correct Severity

SEV3	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2	1	7.1	1	7.1
6	1	7.1	2	14.3
8	2	14.3	4	28.6
9	1	7.1	5	35.7
10	2	14.3	7	50.0
11	1	7.1	8	57.1
12	1	7.1	9	64.3
13	1	7.1	10	71.4
14	3	21.4	13	92.9
17	1	7.1	14	100.0

Table 9 - Frequency of 3D Correct Locations

LOC3	Frequency	Percent	Cumulative Frequency	Cumulative Percent
8	3	21.4	3	21.4
10	1	7.1	4	28.6
13	1	7.1	5	35.7
14	3	21.4	8	57.1
15	1	7.1	9	64.3
16	1	7.1	10	71.4
17	1	7.1	11	78.6
1	1	7.1	12	85.7
20	1	7.1	13	92.9
21	1	7.1	14	100.0

Table 10 - Frequency of 2D Total Responses

TOT2	Frequency	Percent	Cumulative Frequency	Cumulative Percent
11	1	9.1	1	9.1
13	1	9.1	2	18.2
14	2	18.2	4	36.4
17	2	18.2	6	54.5
18	1	9.1	7	63.6
19	3	27.3	10	90.9
21	1	9.1	11	100.0

Table 11 - Frequency of 2D Correct Damage

DAM2	Frequency	Percent	Cumulative Frequency	Cumulative Percent
10	1	9.1	1	9.1
11	3	27.3	4	36.4
12	2	18.2	6	54.5
14	1	9.1	7	63.6
16	3	27.3	10	90.9
20	1	9.1	11	100.0

Table 12 - Frequency of 2D Correct Severity

SEV2	Frequency	Percent	Cumulative Frequency	Cumulative Percent
5	1	9.1	1	9.1
6	1	9.1	2	18.2
8	2	18.2	4	36.4
9	2	18.2	6	54.5
10	1	9.1	7	63.6
11	1	9.1	8	72.7
13	1	9.1	9	81.8
15	1	9.1	10	90.9
16	1	9.1	11	100.0

Table 13 - Frequency of 2D Correct Locations

LOC2	Frequency	Percent	Cumulative Frequency	Cumulative Percent
3	1	9.1	1	9.1
10	1	9.1	2	18.2
11	2	18.2	4	36.4
12	1	9.1	5	45.5
13	1	9.1	6	54.5
16	1	9.1	7	63.6
17	2	18.2	9	81.8
19	1	9.1	10	90.9
20	1	9.1	11	100.0

Table 14 - Frequency of Standard Total Responses

TOT1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
3	1	9.1	1	9.1
7	1	9.1	2	18.2
9	1	9.1	3	27.3
11	4	36.4	7	63.6
13	1	9.1	8	72.7
17	1	9.1	9	81.8
19	1	9.1	10	90.9
21	1	9.1	11	100.0

Table 15 - Frequency of Standard Correct Damage

DAM1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
3	1	9.1	1	9.1
7	1	9.1	2	18.2
9	2	18.2	4	36.4
10	1	9.1	5	45.5
11	2	18.2	7	63.6
13	1	9.1	8	72.7
17	1	9.1	9	81.8
18	1	9.1	10	90.9
20	1	9.1	11	100.0

Table 16 - Frequency of Standard Correct Severity

SEV1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2	1	9.1	1	9.1
5	3	27.3	4	36.4
7	1	9.1	5	45.5
11	2	18.2	7	63.6
13	3	27.3	10	90.9
17	1	9.1	11	100.0

Table 17 - Frequency of Standard Correct Locations

LOC1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2	1	9.1	1	9.1
7	1	9.1	2	18.2
9	3	27.3	5	45.5
10	1	9.1	6	54.5
11	1	9.1	7	63.6
13	1	9.1	8	72.7
14	1	9.1	9	81.8
18	1	9.1	10	90.9
20	1	9.1	11	100.0
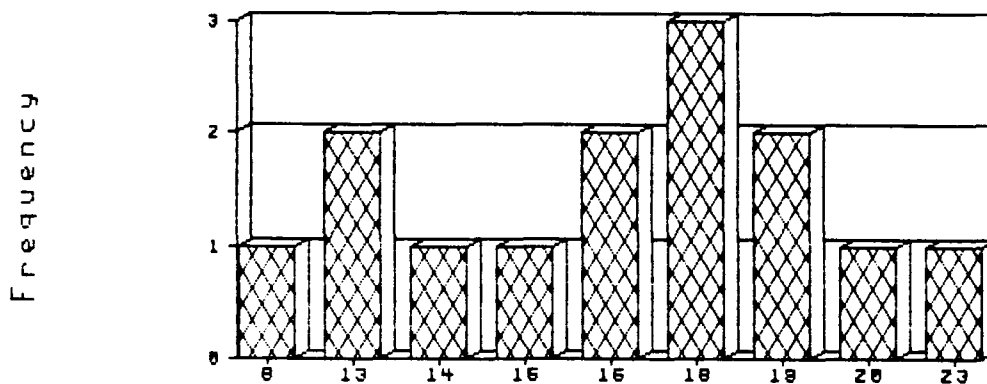
Figure 17.   Bar Chart of 3-D Total Responses
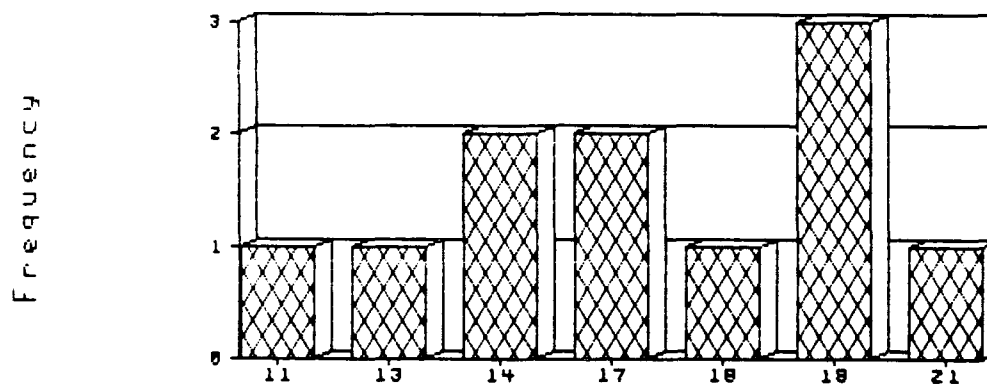
Figure 18.   Bar Chart of 2D Total Responses
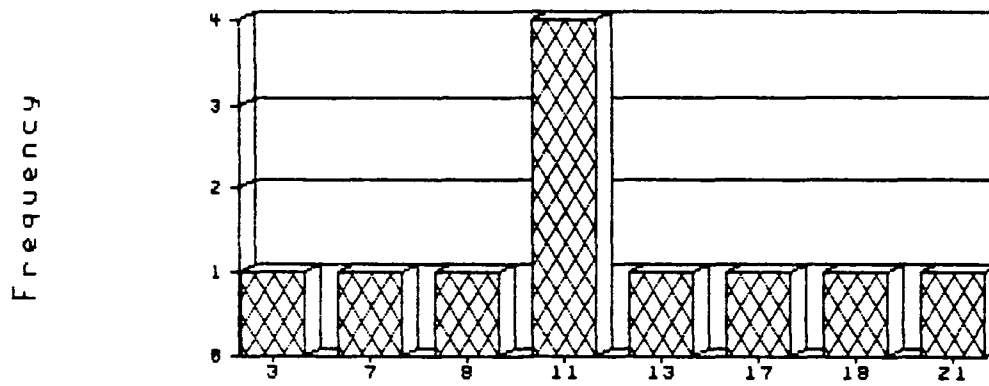
Figure 19. Bar Chart of Total ABO Standard Responses
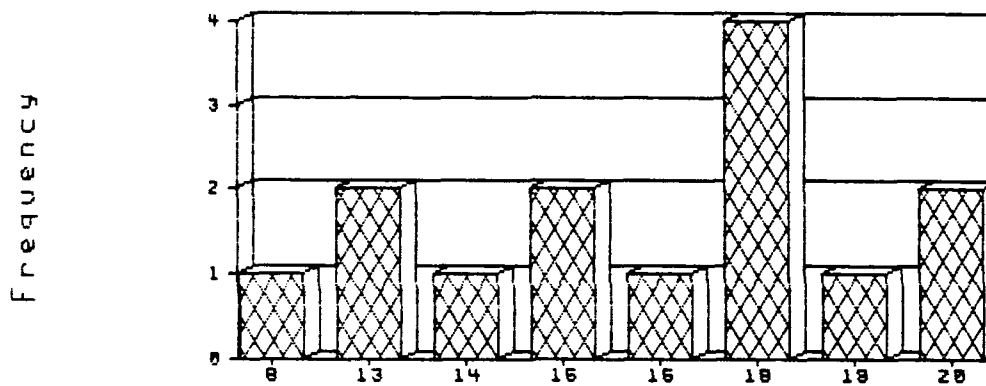
Figure 20. Bar Chart of 3D Correct Damage
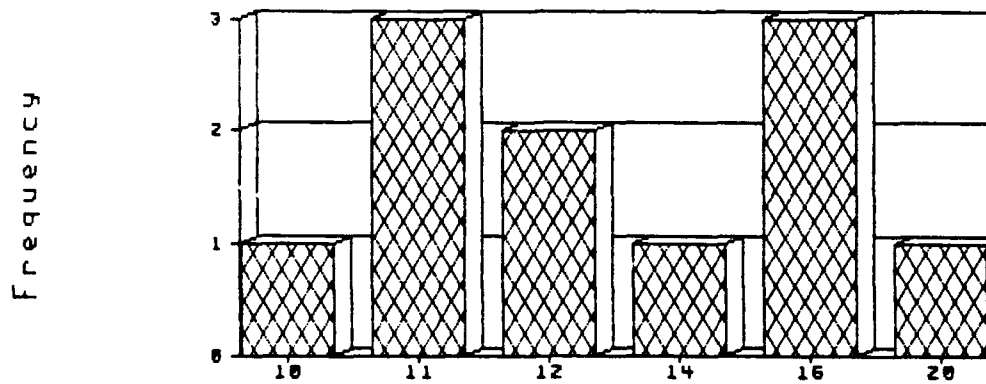
Figure 21. Bar Chart of 2D Correct Damage
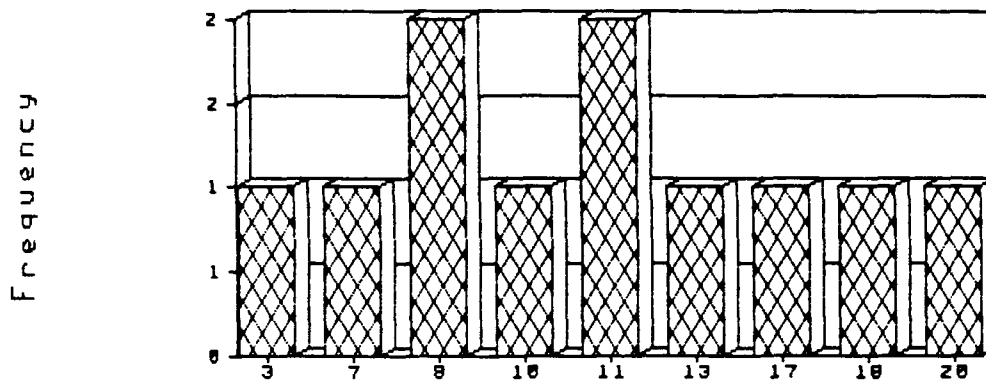
Figure 22. Bar Chart of ABO Standard Correct Damage
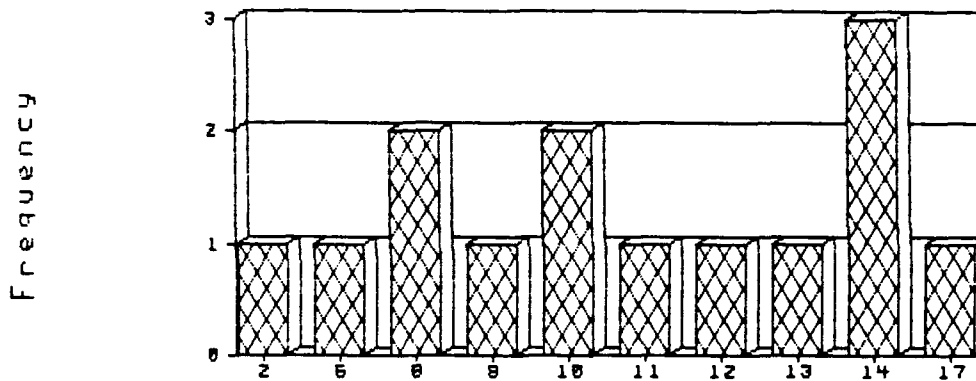
Figure 23. Bar Chart of 3D Correct Severity
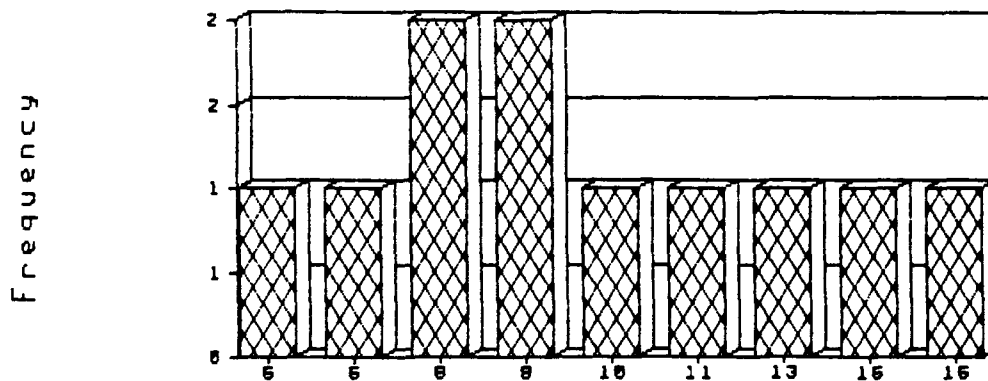
Figure 24. Bar Chart of 2D Correct Severity

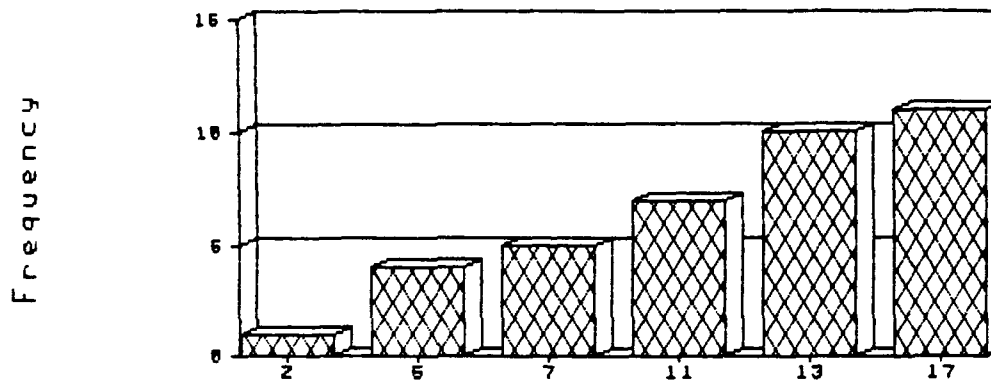102
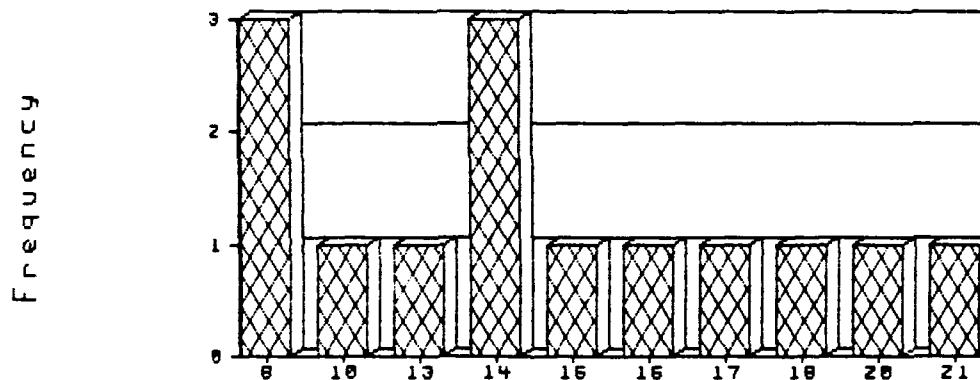
Figure 25.   Bar Chart of ABO Standard Correct Severity

Figure 26.   Bar Chart of 3D Correct Location
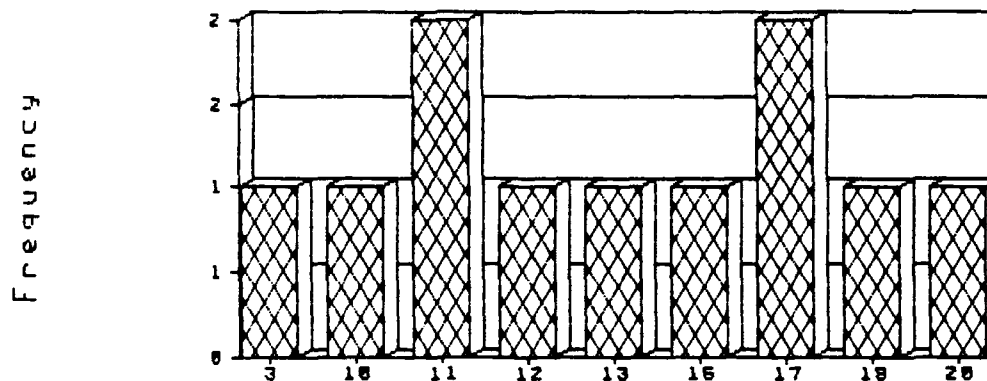
Figure 27.   Bar Chart of 2D Correct Location

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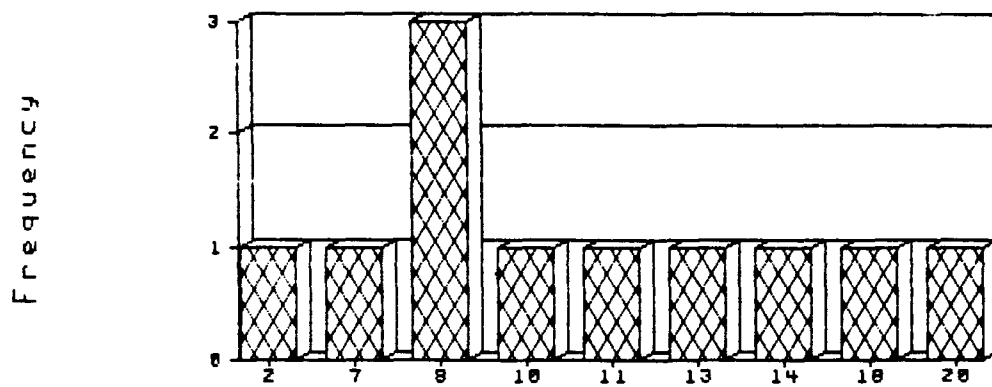
Figure 28.   Bar Chart of ABO Standard Correct Locations

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ASSESSING THE PREFERENCE OF TWO OR THREE DIMENSIONAL COMPUTER GRAPHICS ANIMATION DISPLAYS ON THE AIR BASE OPERABILITY DECISION MAKING PROCESS

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13. ABSTRACT (Maximum 200 words) This study investigated the preference of two types of computer animation graphics displays -- two and three dimensional. A preference was determined based on how well they supported the decision making process within the Air Base Operability organization (ABO). The procedure used was the true experiment method to compare the two different display types and the standard Air Base Operability display to see if there was a significant difference. The experiment was conducted on a personal home computer with a color graphics capability. Subjects were randomly assigned to one of the three groups using a particular display. The basic objective of the experiment scenario was to find damaged areas inflicted on a simulated Air Force base. The results from the experiment indicated no significant difference between the two dimensional and three dimensional graphics displays. However, there was a significant difference between the three dimensional display and the standard ABO display. The conclusions drawn from this experiment shows that not enough data was collected from the experiment to prove a significant difference between the displays. The primary recommendation made by this researcher is to reconduct the experiment with a more substantial sample population from each group.

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