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DIGITAL AIRCRAFT DAMAGE ASSESSMENT
AND REPAIR

Gail A. Hudson
Donald L. Thomas

LOGISTICS AND HUMAN FACTORS DIVISION
Wright-Patterson Air Force Base, Ohio 45433-6503

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This paper describes a preliminary effort to develop and evaluate a computer-based system to provide specialized technical data for use by technicians in assessing damage to aircraft resulting from accident or battle damage. The system uses two- and three-dimensional computer graphics to represent aircraft structures and systems. The graphics provide information to aid the technician in identifying damaged components. The system also provides ready access to parts and repair information. A prototype was developed using off-the-shelf equipment and evaluated by having technicians and engineers use the system for a series of assessment exercises. The results indicate that the concepts tested have significant potential to improve the damage assessment process. However, advances in hardware and software technology are required to make such a system practical.

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Gail A. Hudson
Donald L. Thomas

LOGISTICS AND HUMAN FACTORS DIVISION
Wright-Patterson Air Force Base, Ohio   45433-6503

SUMMARY

This paper is a summary of work done by McDonnell Aircraft Company who was contracted to develop and demonstrate the Digital Aircraft Damage Assessment and Repair (DADAR) system. DADAR is a computer hardware and software system which presents three-dimensional graphic displays. The user is given the capability to interactively manipulate the graphic for the purpose of obtaining information needed for assessing aircraft damage and/or performing maintenance. The functions available include displaying a different orientation of the graphic, enlarging or shrinking the graphic, moving the graphic to another position on the screen, adding or removing a component layer of the graphic, selecting a volume of possible damage for parts identification, and selecting Technical Order remove and replace instructions.

A demonstration and system evaluation was conducted at Warner Robins Air Logistics Center (WR-ALC), Robins Air Force Base, Georgia, in November 1986. Damage assessors, technicians, mechanics, and engineers evaluated the system with regard to functionality and ease of use. The results are discussed in Section IV.

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PREFACE

The research described in this paper was funded by the Department of Defense Computer-Aided Acquisition Logistics System (CALS) office and the Air Force Human Resources Laboratory (AFHRL), by adding this and other additional work to contract F33615-84-C-0061 with Systems and Applied Sciences Corporation (SASC). SASC subcontracted a portion of the contract to McDonnell Aircraft Company (MCAIR), McDonnell Douglas Corporation, under SASC subcontract 85-7065-60004.

The purpose of this effort was to develop, demonstrate, and evaluate a functional "test" computer hardware and software system to present "peel-away graphics" techniques for aircraft damage assessment using state-of-the-art computer technology with emphasis on graphics. Portability was also an issue, but at this preliminary stage, had second priority to the graphics.

An advisory panel was established to provide technical assistance to MCAIR in the areas of combat logistics, aircraft battle damage assessment, F-15 C/D depot maintenance, and human factors. Members of the working group included Mr. Bruce Lepisto from the DOD CALS office; Mrs. Gail Hudson and Dr. Don Thomas from AFHRL; and the following personnel from Warner Robins Air Logistics Center (WR-ALC): Mr. Eddie Achord, Directorate of Materiel Management; Mr. Mark Cundiff and Mr. Roger Thompson, Directorate of Maintenance; and SSgt John Young, Combat Logistics Support Squadron.

The authors of this working paper have extracted material from the DADAR Contract Compliance Report provided by MCAIR and have expanded it to more completely discuss how computer graphics may aid in aircraft maintenance activities. The appendices were provided by MCAIR and are published as received with only formatting changes.

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DIGITAL AIRCRAFT DAMAGE ASSESSMENT AND REPAIR

I. INTRODUCTION

The task of evaluating damage to an aircraft caused by an aircraft accident or inflicted by hostile actions in combat is a very difficult one. The damage assessor must identify all damaged components (that may be severely deformed or missing), determine the criticality of each item, identify essential systems which may be affected by the damage, and obtain the information necessary to acquire replacement parts or suitable repair materials. Currently, technicians performing the assessment task are forced to rely upon their knowledge of the aircraft and its systems and upon technical data provided in conventional technical orders (TOs). Unfortunately, the required information frequently is scattered throughout the TOs, making location of essential information a very time-consuming process. A method of rapidly providing the assessor with the essential information is needed to speed up the assessment process, especially for combat operations.

Recent developments in computer graphics technology provide a potential solution to this problem. Advanced computer graphics provide a capability to represent the structure and components of an aircraft to aid the assessor in identifying damaged components and retrieving pertinent information about the components. With computer graphics, it is possible to manipulate the drawings to provide information that cannot practically be provided in a paper-based medium. For example, it is possible to rotate the graphic to see the area of interest from a different angle or to remove a layer of components to see what components may be hidden behind the layer. In addition, with a computer system, it is possible to use information from the graphic to directly call up pertinent information such as a part number or repair instructions from a data base. For example, using a computer-based system, the technician would be able to identify the damaged component in the graphic, and the computer would respond by presenting the complete parts information in a few seconds. The current procedure requires searching through the TO to find an illustration of the component, obtaining the nomenclature for the item, and then going to the Illustrated Parts Breakdown to locate the parts information. The Digital Aircraft Damage Assessment and Repair (DADAR) project was implemented to further develop this computer graphics concept and to develop and evaluate an initial prototype.

The development of the system was accomplished by McDonnell Douglas Corporation (MCAIR) with guidance provided by an advisory panel composed of a representative of the Department of Defense Computer-Aided Acquisition Logistics Systems Office, engineers and maintenance personnel from the F-15 C/D depot at the Warner Robins Air Logistics Center (WR-ALC), a battle damage assessor from the Combat Logistics Support Squadron (CLSS) at Robins AFB, and representatives of the Air Force Human Resources Laboratory (AFHRL). The results of this project are described in the following sections. It is important to stress that the purpose of this effort was to evaluate the concept of a DADAR system and not the hardware/software used in the evaluation.

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II. SYSTEM DEVELOPMENT

In developing the system, emphasis was placed on designing a system that meets the damage assessor's needs for information; is easy to use; and makes full use of state-of-the-art computer graphics technology, computer-aided design (CAD), and logistics support analysis (LSA) data. To meet these goals, a thorough analysis was made of the assessor's information requirements. Existing CAD and LSA data were examined and techniques were developed to convert the data for use with the DADAR system. Techniques for interacting with the system were developed, and the necessary hardware and software were developed/adapted. Data were then developed for a section of the F-15 C/D aircraft for use in testing the system.

In designing the system, emphasis was placed on developing and evaluating techniques for creating and presenting information for damage assessment. System development was limited to the use of off-the-shelf hardware. No attempt was made to develop or modify hardware for the system. It was recognized that the computational requirements imposed by the graphics techniques to be used would reach the limits of the capabilities of state-of-the-art microcomputers currently available. Thus, the current state of the art could not result in a sufficiently rugged, portable system for implementation as a battle damage assessment aid. However, the development of a similar system for depot level damage assessment where the hardware could be maintained in a semi-controlled environment was considered to be feasible.

Defining Information Requirements

The initial step in developing the DADAR system was to determine the assessor's information requirements.

The primary source of requirements for battle damage assessment information needs was a study sponsored by AFHRL and conducted by McDonnell Douglas (Wilper, Eschenbrenner, & Payne, 1983) that provided a thorough analysis of the battle damage assessment process and identified information requirements. Additional information was provided by the CLSS representative on the advisory panel. Information requirements for peacetime damage assessment were developed with the aid of the engineers and technicians on the advisory panel and in discussions with other engineers and technicians at WR-ALC.

Information requirements for battle damage assessment and peacetime damage assessment were found to be similar. The primary difference was in emphasis. Battle damage assessors are primarily concerned with determining what may be damaged, the impact of the damage (both operationally and on other systems), the quickest repair to return the aircraft to service (at least temporarily), and the time required to return the aircraft to operation. The peacetime damage assessor is more concerned with identifying and obtaining specific information (such as part numbers) on the damaged or missing components so that the aircraft can be restored to a "like new" condition.

Data Development

One of the goals of the DADAR effort was to demonstrate and test the
feasibility of using/adapting existing digitized technical data for an
automated damage assessment and repair aid. MCAIR has extensive digital
technical data on the F-15 C/D aircraft. These data are developed and
maintained in their Computer-Aided Design/Computer-Aided Manufacturing
(CAD/CAM), LSA, and Integrated Logistics Support (ILS) systems. These
systems are integrated in the proprietary MCAIR Digital Document
Creation/Revision (DDCR) system. The DDCR uses the data to develop TOs. The
data used by the DDCR contains most, if not all, of the information required
for the DADAR system. MCAIR developed techniques to use the DDCR system to
convert the data for use with the DADAR system. Direct transfer of some data
was possible. However, some modification by human operators was required for
some data (e.g., alteration of some graphics using the CAD system). The
techniques used were necessarily designed for use with MCAIR's proprietary
CAD/CAM, LSA, and ILS systems; however, they could be adapted for use with
similar systems used by other manufacturers.

For this effort, data were developed for a 1-cubic-foot zone (zone 27)
of the F-15 C/D aircraft. Zone 27 is located behind and slightly above the
right wing. This zone was selected because it contains a variety of
components representing six aircraft systems and the aircraft structure. It
was deemed to be sufficiently complex so as to provide a fair test of the
system and small enough to permit complete data development with the
available funds.

Software and Hardware Development

Where possible, MCAIR used existing software for the DADAR system.
Software required for functions such as display and rotation of a graphic
was adapted from existing software. New software development was required
for functions such as integrating the different types of data (e.g., graphics
and parts information) and controlling the user/system interaction.

The initial software development and DADAR demonstration were
accomplished using MCAIR's mainframe computer system. This software was
refined and ported to an Evans & Sutherland CAD system for further
refinement and for the first DADAR demonstration. The software was then
ported to a Silicon Graphics microcomputer-based graphics workstation for the
remaining demonstrations and field test.

Off-the-shelf hardware was used for the DADAR system. Portability was
not a requirement, as the focus of the work was on the content and
functionality of the software. The hardware for the first demonstration was
an Evans & Sutherland CAD system which was a component of the larger MCAIR
CAD system. The hardware for the second demonstration was a Silicon Graphics
Iris microcomputer. The hardware for the final DADAR demonstration and field
test system was a stand-alone system selected specifically for the DADAR
project. This hardware was selected after an extensive survey of available
microcomputer-based graphics workstations. Initially it was thought that the
system would run on an advanced personal computer. However, as system
development progressed, it was determined that the DADAR system would require

a computer system with significantly greater capabilities than the personal computers available at the time. The system would require the capabilities of a sophisticated graphics "engine." A number of microcomputer systems initially thought to be suitable for the DADAR system were found to be inadequate due to an inability to process the complex graphics within time constraints. It was finally determined that the Silicon Graphics Iris (Model W3030) graphics workstation most nearly met the criteria for the DADAR system. Therefore, the Iris workstation was selected as the DADAR presentation hardware. This hardware is described in the following section.

III. SYSTEM DESCRIPTION

The complete DADAR system is composed of data creation and presentation hardware and software, and technical data. These components, the functional capabilities of the system, and documentation provided with the system are described in this section.

Hardware

MCAIR's DDCR system was used to create the data for the DADAR system. This hardware is composed of a large mainframe computer working in conjunction with specialized computer-aided design equipment.

The Silicon Graphics Iris Model W3030 graphics workstation was selected for the DADAR presentation system hardware. The workstation is an integrated raster image system. It includes a Motorola 68020 microprocessor, 8 megabytes of random access memory, a 70-megabyte hard disk drive, a 15-inch color display monitor for both graphics and narrative data, a mechanical mouse device for interacting with the display, and an 83-key keyboard for data entry. A Digital LA50-RA desktop dot-matrix printer was included with the system to provide a hard copy capability. This system provides the capability to exercise all of the DADAR functions.

Software

The DADAR software and data base design concept is illustrated in Figure 1. The necessary technical data were generated by MCAIR's proprietary DDCR system. These technical data are organized and formatted into a digital document suitable for DADAR via a DADAR Interface Module developed for the project. The digital document is transferred to DADAR via either direct online data transfer or a magnetic cartridge tape. The DADAR Interface Module consists of two major programs. The DADAR Editor provides interactions with graphics data and narrative data to organize them by view, and part identifier. The DADAR Translator provides the format conversion to the digital document format required for presentation on the DADAR system.

The DADAR presentation software is composed of software adapted from existing MCAIR computer-aided graphics systems and software developed specifically for this effort. The specially developed software includes software to access the DADAR data base and control the interaction between the user and the system.
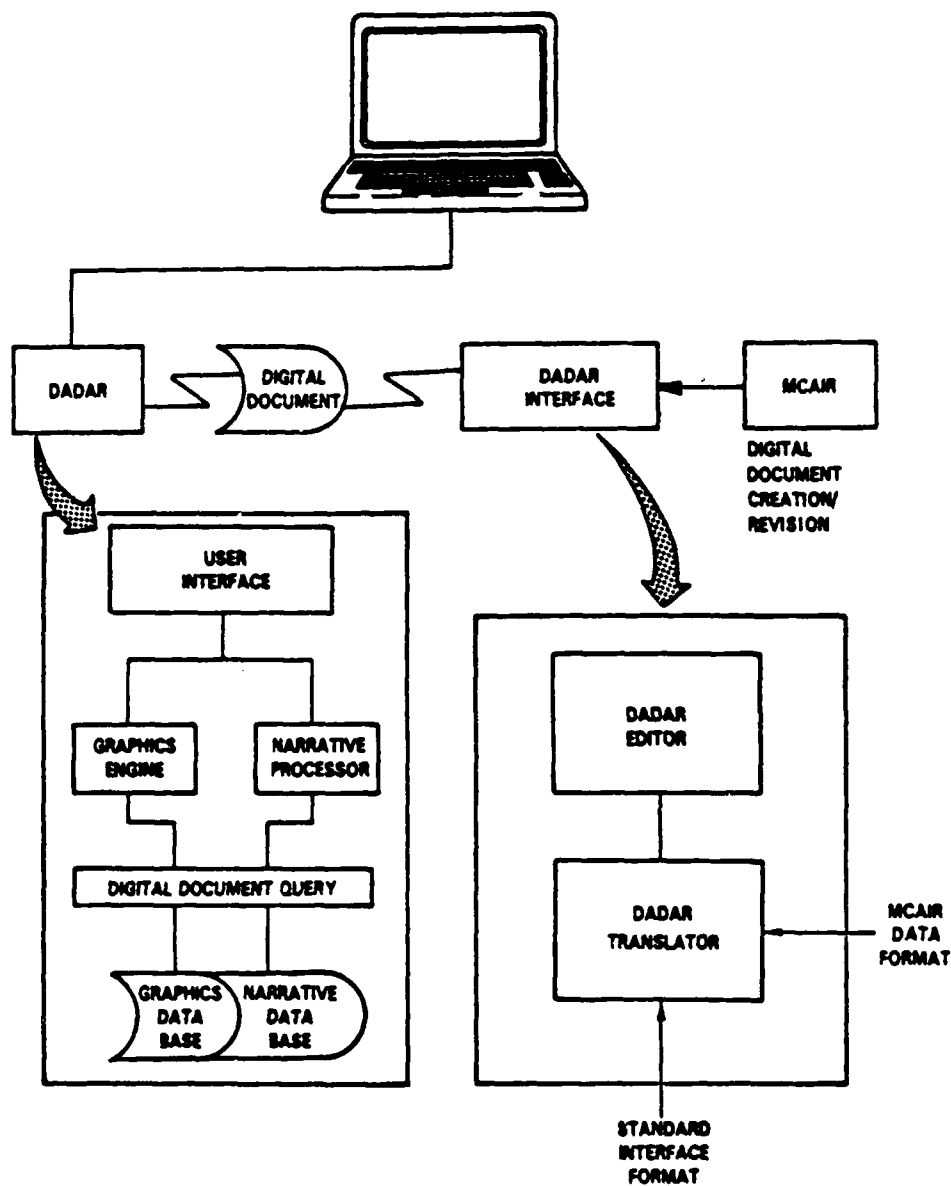
Figure 1.   Software Design Concepts.

Technical Data

To provide a means of demonstrating and testing the system, technical data were developed for Zone 27 of the F-15 C/D aircraft using the DDCR system and transferred to the DADAR presentation system. Data from the DDCR were modified as necessary to meet the requirements of the DADAR system. These modifications primarily involved reworking some illustrations to satisfy DADAR display requirements. The data developed included detailed three-dimensional illustrations of the components located in Zone 27, parts information on each component, and remove and replace instructions. (Note: Due to the memory constraints of this system, the TO data for the test system were limited to the Environmental Controls subsystem. This amount of data was sufficient to demonstrate the concept.)

DADAR Capabilities

DADAR is a menu-driven system. Initially, the user is presented an illustration showing an exterior view of the aircraft. The illustration identifies different zones of the aircraft. The user can retrieve information on the zone of the aircraft containing the damage by moving the cursor (using a mouse device) to the damaged zone and pressing the SELECT button on the mouse. The system responds with a detailed graphic of the complete zone. The graphic is initially presented in an illustration mode (hidden lines are removed) with a viewing orientation of DOWN (from the top of the aircraft), FORWARD (looking toward the front of the aircraft), and INBOARD (looking from the outside to the inside of the aircraft). The user may interact with the system in a number of ways to retrieve the information that he or she desires using the following functions.

Change View. The user may select from a set of eight predefined orientations to view the same graphic from a different viewpoint. This is helpful when the usual access to a particular area is restricted. The eight orientations are DOWN; UP; INBOARD; OUTBOARD; FORWARD; AFT; DOWN, FORWARD, and INBOARD; and UP, FORWARD and INBOARD.

Change Scale. To identify damaged components, it is often necessary to have a very detailed view of a given component. The initial display of the graphic often does not provide enough detail of specific components to allow identification. The user may have the area around the item of interest redrawn to a predefined scale to provide a global or detailed closeup view of the specific component. Enlarging the current graphic by a factor of two, three, or five will bring small parts into view and present them in detail. Shrinking the current graphic by one-half, one-third, or one-fifth will reduce the size of the graphic to give the user a global reference for the position of parts.

Change Window. When a graphic is enlarged, the display area remains the same size. Therefore, some of the original data are eliminated. However, the currently enlarged graphic and the previous graphic are both centered in the display area. The move function allows the item of interest to be centered on the display to prevent its loss when the graphic is redrawn at a larger scale. Also, this feature may be used with any graphic to shift the position of the graphic so that a point of interest that is outside the display area may be moved into view.

Change Layer. The graphic is organized into layers of component systems of the aircraft. The layers are organized in a particular order which is roughly equivalent to the spatial order from the skin to the structure of the aircraft. The user has the capability to remove one or more layers. The resulting graphic redrawn for the user will be the layers which are left in the zone. For example, it is not possible to remove the fifth layer without removing the four layers in front of it. It is also not possible to replace the second layer without also replacing all other layers behind it at the same time. This capability allows the user to see graphically behind components for the purpose of assessing damage without taking the aircraft apart.

Request Parts Information. The user may recall information on a specific part by moving the cursor to touch a component on the illustration and then pressing the SELECT key. The system will display the specific part nomenclature, part number, and other essential part information, such as what parts are connected to the identified part.

Parts List. The parts list function allows the user to compile a list of part numbers. Part numbers may be added or deleted from the list. A print option is available which will print the parts information described above on the printer for the part numbers on the list.

Part ID. The user may request that a part be identified by either keying in a part number on the keyboard causing the component to be highlighted on the graphic or by placing the cursor on the graphic and pressing the SELECT key for the part of interest causing the part number to be displayed.

Change Display Mode. The graphics for this system are available in two modes: the illustration mode and the wire frame mode. The wire frame mode displays all lines as if the components were transparent. The illustration mode (default display mode) displays the graphic in a more realistic view. Components that are closer to the observer block the view of components behind them. To save the amount of memory required to store all the graphics, the data which are not visible in the illustration mode were actually removed. Therefore, this mode cannot be used for the Change View or Select Parts by Volume functions. The Change Display Mode feature allows the user to change the display mode to/from illustration mode and wire frame mode, depending upon which is active.

Select Parts by Volume. The damage area resulting from the passage of a projectile through a section of an aircraft can be approximated by the shape of a cone. This function allows the user to define a truncated cone by specifying the two diameters and points of entry and exit. The system provides parts information for parts that are entirely or partially included within the defined volume.

Select Technical Data Information. After the assessor has identified the damaged parts and obtained the necessary parts information, he may wish to remove and replace one or more of the parts. If so, he may select "Remove and Replace Instructions" from the menu and the DADAR system will respond by presenting the technical data information.

Change Zones. The zoned F-15 C/D graphic is displayed. The user can then select another zone. (Note: The system provides the capability to change zones. However, data are available for zone 27 only.)

Documentation

Based upon the results of this project, MCAIR developed documentation for use in further research on the damage assessment problem using the DADAR system and for the development of a more advanced DADAR system. The documentation developed includes:

1. DADAR Draft System Design Specification (DADAR Contract Compliance Report, McDonnell Douglas Corporation, 1986). The specification provides detailed recommendations for DADAR application in an operational environment. It describes a system that is generically applicable to a range of functional users, organizations, and aircraft weapons programs. It identifies interfaces between the contractor's CAD/CAM and ILS data bases, and identifies major nodes for receipt, storage, and distribution of digital logistics and technical data within the Military Departments.

2. Software documentation.

   a. A modularity design specification detailing the infrastructure of the system is included in the "DADAR System Specifications" (see Appendix A).

   b. A structured programming logic definition that describes the software design methods and a user interface standard that describes the interactions of the user with the system and system feedback are included in the DADAR Contract Compliance Report.

3. User Documentation.

   a. A training manual describing console procedures is included in the "DADAR Quick Training Procedure" (see Appendix B). This was used as a script for the evaluation at WR-ALC. The results of this evaluation are discussed in Section IV.

   b. The DADAR Contract Compliance Report includes three users manuals.

      (1) Overview. This manual is a broad, comprehensive view of the DADAR system.

      (2) System Operation. This manual describes how to power on the hardware and boot the software.

      (3) User's Manual. This manual includes the System Operation Manual and also describes the functions of the software and how to exercise them.   .

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IV. DEMONSTRATIONS AND EVALUATION

Demonstration I: Initial System Design and Proof of Concept

Demonstration I was held at MCAIR, St. Louis, on 27 March 1986 (4 months after contract). The purpose of this demonstration was to present the initial design for the DADAR system and to demonstrate the concepts to be incorporated into the system. The demonstration was presented to the members of the DADAR Advisory Panel.

The demonstration consisted of the presentation of graphics of the type planned for the DADAR system. The graphics provided several views of the components located in Zone 27 of the F-15C/D. Proposed techniques for generating and presenting the graphics were discussed with the Advisory Group. The results of this discussion provided direction for the DADAR system design.

For the demonstration, the DADAR graphics and technical data were displayed on an Evans & Sutherland PS300 terminal. The demonstration materials included:

1. A three-dimensional model of the selected F-15 C/D section with the Structure and Internal Cooling System merged.

2. A three-dimensional model with the Structure and Internal Cooling System separated, with the capability to interrogate part numbers. Interrogation was performed through a screen-displayed option menu. Options included system part numbers or individual part numbers for either the Structure or Internal Cooling System.

3. The basic DADAR user interface techniques.

Even though the Evans & Sutherland terminal has color capability, the demonstration was presented in monochrome, since it was anticipated that the system would be ported to a personal computer which would have only monochrome capability.

At the time of this demonstration, it was not yet clear how the layers of components would be organized. It was first thought that each layer would be a specified depth from the skin and thus be a slice of whatever components fell within this area. It was later determined that implementing this concept would be complex, time-consuming, and costly. MCAIR already had data in their CAD/CAM computer organized by aircraft system. Therefore, after this demonstration, it was decided that layers would include only one system per layer and be organized in the order which roughly parallels its spatial position in the test zone from aircraft skin to structure. The final design includes seven layers: Internal Cooling System, Electrical System, Environmental Control System, Hydraulics System, Leak Detection System, Primary Control System, and Structure.

Demonstration II: Modified System Design

Demonstration II was held at MCAIR, St. Louis, on 30 July 1986 (8 months after contract). This demonstration was presented to the DADAR Advisory Panel and provided a final design review prior to the development of the final DADAR prototype system.

This second demonstration displayed the full capabilities of the proposed design. It included presentation of technical graphics of selected parts and allowed selection of view and/or viewing scale. All parts could be selected for interrogation of part identification.

After an extensive review of available equipment, MCAIR had determined that the personal computer technology was not sufficiently developed to provide the speed needed to process graphics for DADAR. A decision was made to use the Silicon Graphics Iris graphics workstation for the final prototype system. MCAIR made an agreement with Silicon Graphics to provide a workstation for the final demonstration.

For this second demonstration, the graphics models, manipulations, and interrogations were presented on the Evans & Sutherland PS300 terminal in monochrome and then on the Silicon Graphics Iris terminal in color to show the difference between the monochrome graphics and the color graphics. This provided the Advisory Group with an opportunity to evaluate the capabilities of the proposed system.

During discussions following the demonstration, the design was finalized and approved. In addition, plans were made for the third and final demonstration and evaluation to be conducted at WR-ALC.

Demonstration III: Final Prototype

The DADAR prototype system was shipped in November 1986 to WR-ALC from MCAIR, St. Louis, for Demonstration III and for the DADAR system evaluation to follow the demonstration. The system was installed in a hangar office area adjacent to the maintenance bay. This location was chosen because it provided a clean, safe area close to the work areas of the technicians who would be participating in the evaluation.

This demonstration had two objectives:

1. To demonstrate that the system data base could be easily updated at a location distant from the MCAIR DDCR which was used to create the data.

2. To provide an opportunity for senior Air Force maintenance managers and computer system developers to evaluate the damage assessment capabilities of the system in an operational environment.

The system update capability was demonstrated using a magnetic cartridge tape. Two changes were made. An aircraft part with a different number and configuration was incorporated into the data, and a new function to measure distances was added to the DADAR system. These changes could have been made by a telephone linkage from WR-ALC to MCAIR. However, this was not done because of the cost of installing the necessary telephone line at WR-ALC.

The system demonstrations were given during the first two days following system installation, to managers and supervisors of those participating in the evaluation. Impromptu demonstrations were conducted for the directorate chiefs, division chiefs, branch chiefs, and section chiefs from the Directorate of Maintenance (MA) and the Directorate of Materiel Management (MM) at WR-ALC who came to the DADAR system in small groups. Engineers, mechanics, electricians, and technicians who were not participating in the evaluation also attended the demonstrations.

Evaluation

Those participating in the evaluation were encouraged to wait until the evaluation period to see the system. Overview booklets were distributed to the participants a week before the evaluation period. The participants were volunteers from MA, MM, and the 2955th CLSS who were interested in spending some time with the system and providing information about the system's potential uses in their jobs.

A total of 40 people participated in the subjective evaluation. Four were from the 2955th CLSS. Nineteen were from the Aircraft Division of MA (MAB), of which 10 were from the Engineering/Planning Branch and 9 were from the Production Branch. Two were from the Quality Control Division (MAQ) and there was one participant from the Resources Management Division (MAW). There were 14 participants from MM, of which 3 were from the Engineering Division (MME), 2 from the F-15 C/D Technical Management Division (MMF), 1 from the Materiel Management Division (MMM), 1 from the Electronic Warfare Division (MMR), and 7 from the Systems Program Management Division (MMS).

The participants were given an exercise to follow which fully utilized all functions of the DADAR system (see Appendix C). On average, the participants spent about 1/2 hour using the DADAR system, with only minor assistance from an observer (only when requested). The observer was an engineer from AFHRL who was trained in the operation of DADAR and in the collection of data from the participants. After the participant completed the training exercise, the observer interviewed the participant by asking nine questions (see Appendix D). The observer recorded the verbal responses.

The jobs of the participants included mechanical, structural, and electrical repairmen; technicians; planners; schedulers; quality assurance specialists; crash damage assessors; and engineers. Many had never been exposed to computers. None had extensive experience with computers.

All participants said that DADAR would be useful to do their jobs. They indicated that parts identification is the information most needed. Another is a cross-reference from part number to national stock number to facilitate the ordering of parts identified by DADAR. Those who work very closely with complex TO drawings preferred the wire frame pictures. Those who had jobs which did not require the analysis of complex TO drawings preferred the illustration drawings. The participants indicated that DADAR drawings are better than TO drawings. The colors are helpful for identifying parts and parts may be looked at from different views.

The participants indicated that the removal of layers and the removal of a part were the best features of DADAR. Many indicated that the speed at

which parts information may be obtained is also a good feature. A few
mentioned that DADAR's presentation of all component systems in one picture
(unlike the TOs) is a good feature.

Some of the worst features mentioned were difficulty of learning how to
use the computer, difficulty of precisely picking a spot on a line, and the
use of color not being significant to those who are color blind. Also, the
cost of the system was indicated by a couple of people to be the worst
feature, even though cost was never discussed.

In general, comments were favorable. The participants were anxious to
have a similar system expanded to the whole F-15 C/D aircraft and to other
aircraft as well, and made available in the shop and workplaces.

Each participant was also requested to complete a written questionnaire
containing 28 Yes/No questions, two multiple-choice questions, and one
short-answer question. Appendix D contains a list of the questions, along
with the tabulated reponses.

V. DISCUSSION

The DADAR project successfully demonstrated that the development of a
computer graphics-based system to aid in the assessment and repair of damaged
aircraft is feasible. Further, it demonstrated that aircraft damage
assessors and others involved in the repair of damaged aircraft are likely to
be able to effectively use such a system, and that they are receptive to the
implementation of such a system for operational use. Engineers and
technicians who participated in the evaluation expressed very positive
attitudes toward the system and a strong desire to see a similar system
implemented for operational use. In addition, the project demonstrated that
it is possible to use data from CAD, LSA and similar digital data bases to
create data for an automated damage assessment aid.

Although this limited demonstration of a DADAR system was successful,
further research and development is needed before such a system can be
practically implemented for operational use. Specific examples are as
follows:

1. Define the graphics requirements for the system. Determine what
types of graphics are most appropriate and effective for the damage
assessment application (e.g., 3-D graphics versus 2-D graphics, illustration
graphics versus wire frame graphics, etc.). Determine the value and
necessity for features such as rotation, scroll, and zoom of graphics, etc.
Find effective ways of reducing the need for graphics (i.e., find ways to
present the same information without the expense of using graphics).

2. Develop more cost effective ways of developing DADAR data. This
study demonstrated that it is possible to use data from existing data bases
to develop DADAR data. However, the procedures used were not a direct
transfer. A significant amount of human intervention was needed to adapt the
data. Techniques which will permit direct transfer are needed to make such a
system cost effective for operational use.

3. Develop more powerful, ruggedized computer systems. The DADAR prototype used one of the most powerful computer graphics workstations available. However, this system was barely able to meet the requirements for processing the DADAR graphics. System response times were judged to be adequate for a demonstration system, but were much slower than desirable for an operational implementation. The DADAR prototype hardware was an "office system" not suitable for hangar or flightline use. An operational system must be sufficiently rugged for use under austere environmental conditions and must be much smaller than the DADAR prototype hardware.

4. Develop improved human/computer interface (HCI) techniques. The DADAR HCI was adequate for a demonstration system. However, there are several questions related to the HCI which require study (e.g., which is the most effective technique for the user to provide input to the computer--mouse, touch panel, keyboard; what is the best way to define "layers" for graphics).

5. Determine the importance of color. Do color-coded illustrations improve performance of damage assessors? Does any advantage provided by a color display and color-coded graphics justify the cost?

Although there is much work remaining to be done, this work has made a contribution to the development of an operational automated damage assessment aid.

The potential of such a system for improving the capability of the Air Force to efficiently repair damaged aircraft in peacetime is great. However, the potential of such a system is even greater for the support of combat operations when rapid repair of damaged aircraft is critical. It is essential that work be continued to resolve the issues discussed above and to develop an assessment aid that is suitable for operational use under the most austere conditions.

REFERENCES

McDonnell Douglas Corporation (1986). DADAR Contract Compliance Report. Unpublished manuscript. Wright-Patterson AFB OH: Logistics and Human Factors Division, Air Force Human Resources Laboratory.

Wilper, B. L., Eschenbrenner, A. J., Jr., & Payne, W. T. (1983, December). Assessing aircraft battle damage: Information and support requirements (AFHRL-TR-83-25, AD-B078 865L). Wright-Patterson AFB, OH: Logistics and Human Factors Division, Air Force Human Resources Laboratory.

APPENDIX A: SYSTEM SPECIFICATIONS

General Description

The DADAR system has been uniquely designed to provide quick access to
data bases containing aircraft information, using computer graphics. This
quick access to the data base provides the user with the necessary
information needed to repair an aircraft. Specifically, DADAR has been
designed for the F-15 C/D repair stations. The numerous interactive DADAR
functions are unique to this system in the way they are presented to the user
and the way the access to the data bases is accomplished.

The premise for the design of DADAR was to provide user-friendly
functions that require minimum user effort to quickly extract the needed
information about the aircraft. The software routines were designed to
provide these requirements. In addition, the system was designed to allow
for future enhancements and the expansion of the interactive functions and
the data base.

The DADAR system was first developed on the McDonnell Douglas
Computer-Aided Design Drafting (CADD) system. It was required by contract
that the system be transferred to a stand-alone system. The stand-alone
system chosen is a Silicon Graphics Iris W3030 workstation. The speed,
accuracy, and resolution of the graphics on the workstation far exceeded
those of the CADD system. The current capability of the workstation met all
the requirements of the DADAR system to be implemented. In addition, it
provided for future growth of the program through further enhanced functions
and increased data storage.

Basic Capabilities

The DADAR system has many functions which allow for appropriate and easy
retrieval of aircraft information. The functions that are currently
available include: part information, parts list, select parts by volume,
part ID =, change view, change scale, change window, change display to wire
frame/illustration, change layer, change zone, and home. Two of these
functions, select parts by volume and change view, are available only in the
wire frame display mode. The DADAR system is composed of ten different
components (see Figure A-1).

Data Base Structures

Tables A-1, A-2, and A-3 provide the structures for the data bases used
by the DADAR software.

Software Concepts

1. Volume. Given two endpoints in the world coordinate system and the
diameter at each endpoint, the volume of a cone can be defined (see Figures
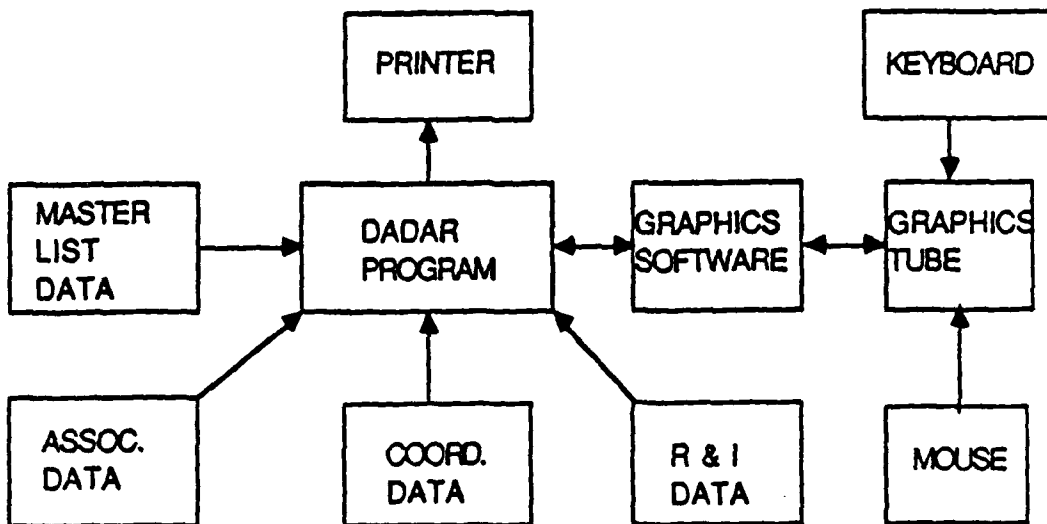A-2, A-3, and A-4).

Figure A-1. DADAR System Components.

Table A-1. Coordinate, Removal and Installation Data Bases Structure

line	
1	Center point data
2	Viewport data
3	Window limit data
4	4 x 4 matrix for the view matrix data
.	
.	
.	
8	Part no.
9	1 or 2 (1 = look for vector data, 2 = look for character data)
10	number of points in segment (n)
11+n	x coord, y coord, z coord (coordinates of a point)
12+n	size of text in graphics coordinates
13+n	x coord, y coord, z coord
14+n	pullout statement (text)
15+n	-1 (signifies end of part data)

Table A-2. Master List Data Base Structure

```
part name
color code
none     Contains the filename to removal procedure or none
none     Contains the filename to installation procedure or none
  .
  .
  .
part name
color code
none
none
  .
  .
  .
n part name
```

Table A-3. Associated Data Base Structure

```
        $part name
            text
            text
              .
              .
              .
        $END
        $part name
            text
              .
              .
              .
        $END
          .
          .
          .
        $part name (n)
```

r_1 = radius at first endpoint (A-1)

r_2 = radius at second endpoint (A-2)

a = the unit vector along vector P_1P_2 (A-3)

alng = length of vector from point 1 to point 2 (A-4)

x-component of vector P_1P_2: $a[0] = P_2[0] - P_1[0]$ (A-5)

y-component of vector P_1P_2: $a[1] = P_2[1] - P_1[1]$ (A-6)

z-component of vector P_1P_2: $a[2] = P_2[2] - P_1[2]$ (A-7)

sqrt = the square root function (A-8)

length of vector P_1P_2:

$$alng = sqrt\ (\ (a[0])^2 + (a[1])^2 + (a[2])^2\ )$$ (A-9)

x-component of unit vector: $a[0] = a[0] / alng$ (A-10)

y-component of unit vector: $a[1] = a[1] / alng$ (A-11)

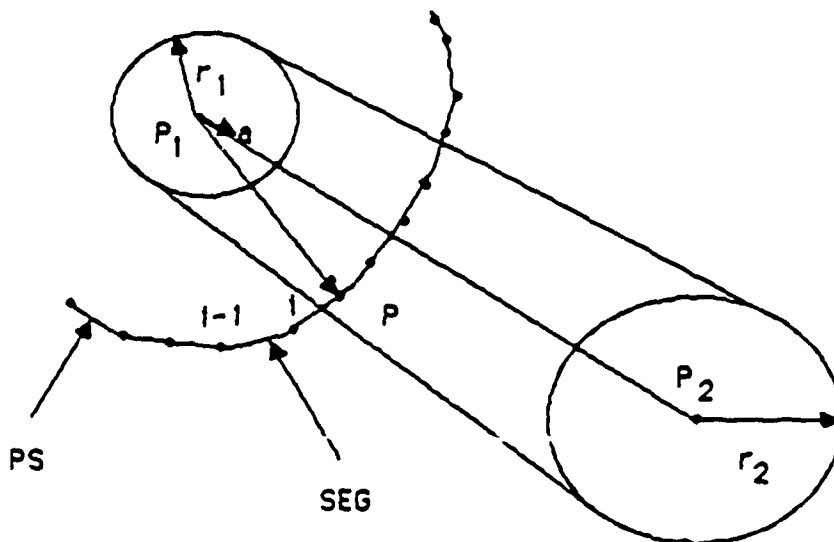z-component of unit vector: $a[2] = a[2] / alng$ (A-12)

Figure A-2. Segment Drawing for Volume Calculations.

seg = unit vector from point i on segment to point i-1 on segment   (A-13)

slng = length of vector seg before seg became a unit vector   (A-14)

 inc = number of points to be checked along segment   (A-15)

pchk = coordinates of point to be checked   (A-16)

x-component of segment vector: $seg[0] = x[i] - x[i-1]$ (A-17)

y-component of segment vector: $seg[1] = y[i] - y[i-1]$ (A-18)

z-component of segment vector: $seg[2] = z[i] - z[i-1]$ (A-19)

$slng = sqrt ((seg[0])^2 + (seg[1])^2 + (seg[2])^2)$ (A-20)

x-component of unit vector along segment: $seg[0] = seg[0] / slng$ (A-21)

y-component of unit vector along segment: $seg[1] = seg[1] / slng$ (A-22)

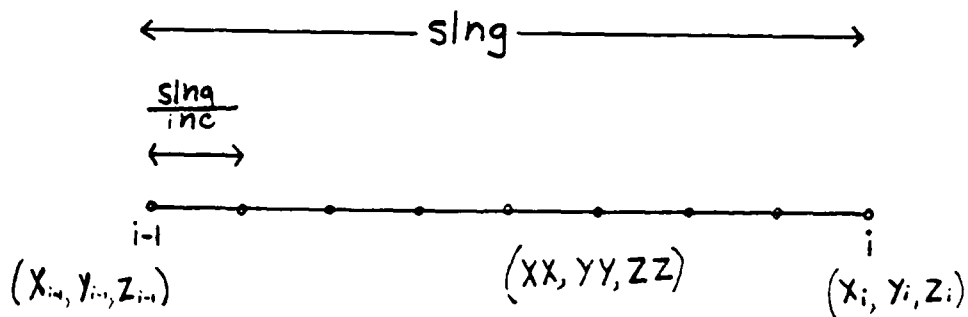z-component of unit vector along segment: $seg[2] = seg[2] / slng$ (A-23)

Figure A-3. Incremental Diagram of Segment Length.

$$inc = \text{number of incremental subdivisions of the segment} \qquad (A-24)$$

$$J = \text{integer index, value ranging from 1 to (inc - 1)} \qquad (A-25)$$

$$xx = x[i-1] + (\; slng * seg[0] * J) \,/\, inc \qquad (A-26)$$

$$yy = x[i-1] + (\; slng * seg[1] * J \;) \,/\, inc \qquad (A-27)$$

$$zz = z[i-1] + (\; slng * seg[2] * J \;) \,/\, inc \qquad (A-28)$$
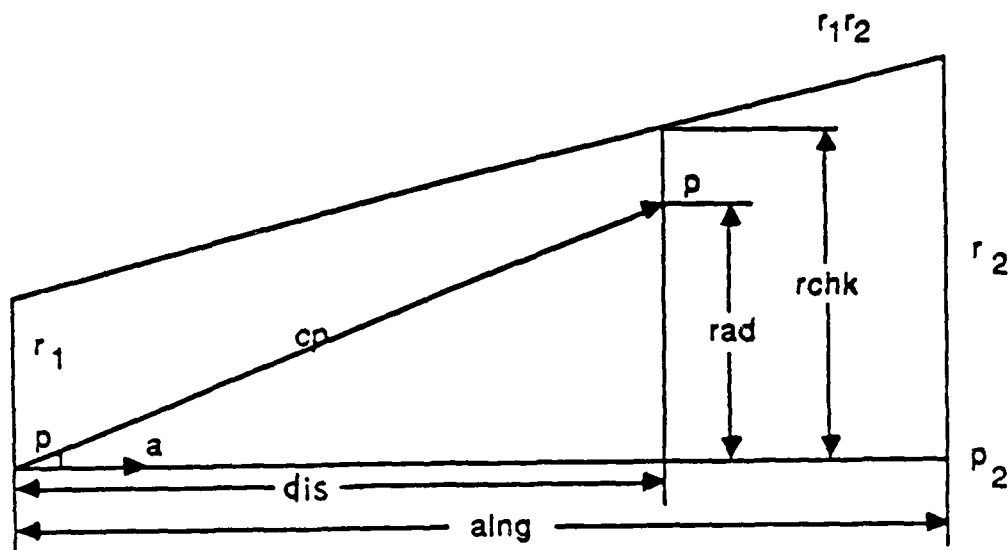
Figure A-4. Vector Drawing for Volume Calculations.

$$cp = \text{vector from first end point to point to be checked} \qquad (A-29)$$

$$apar = \text{length of cp vector squared} \qquad (A-30)$$

$$rad = \text{length of line perpendicular to vector } p_1p_2 \text{ at point p} \qquad (A-31)$$

$$rchk = \text{length of line perpendicular to vector } p_1p_2 \text{ at } r_1r_2 \qquad (A-32)$$

$$fabs = \text{the floating point absolute value function} \qquad (A-33)$$

$$dis = \text{the distance from } p_1 \text{ to p along } p_2 \qquad (A-34)$$

$$x\text{-component of vector } cp: \qquad cp[0] = xx - p_1[0] \qquad (A-35)$$

$$y\text{-component of vector } cp: \qquad cp[1] = yy - p_1[1] \qquad (A-36)$$

$$z\text{-component of vector } cp: \qquad cp[2] = zz - p_1[2] \qquad (A-37)$$

$$apar = (cp[0])^2 + (cp[1])^2 + (cp[2])^2 \qquad (A-38)$$

$$rad = sqrt \ (\ fabs \ (\ (dis)^2 - apar \ ) \ ) \qquad (A-39)$$

$$rchk = r_1 + (\ (\ r_2 - r_1 \ ) * apar \ / \ alng \ ) \qquad (A-40)$$

If rad is less than rchk and apar is greater than zero but less than alng, then the point is within the user-defined volume. Hence, the part lies within the volume.

2. Scale. The scale is modified by manipulating the window limits. The window limits are multiplied by the scaling factor to achieve the new limits (see Figure A-5).

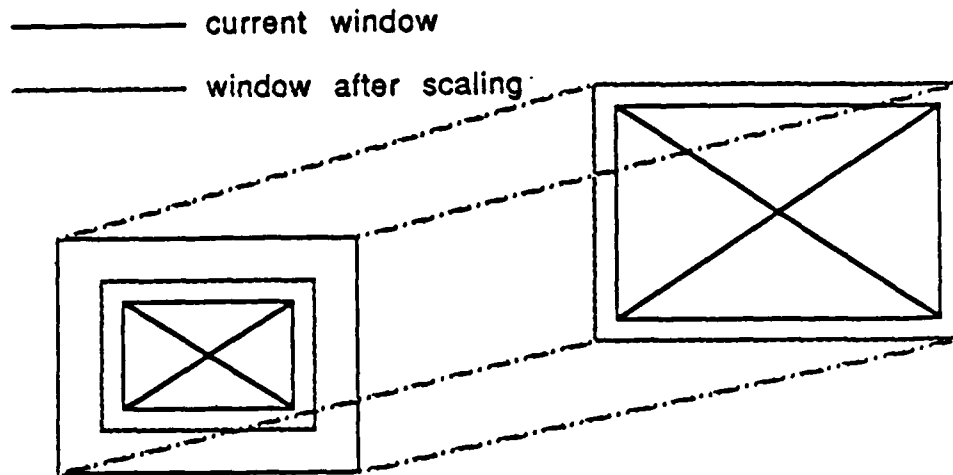Figure A-5. Window Projections for Scaling.

$$\text{left window limit (WXL):} \qquad gsrwin[0] = scale * gsrwin[0] \qquad (A-41)$$

$$\text{right window limit (WXR):} \qquad gsrwin[1] = scale * gsrwin[1] \qquad (A-42)$$

$$\text{bottom window limit (WYB):} \qquad gsrwin[2] = scale * gsrwin[2] \qquad (A-43)$$

$$\text{top window limit (WYT):} \qquad gsrwin[3] = scale * gsrwin[3] \qquad (A-44)$$

3. Window. The pick point on the screen is transformed to the coordinates that are usable by the window routines. Once these coordinates are found, the basic translation is implemented (see Figure A-6). The x, y, and z coordinates of the pick point are used to find the new window limits which define the view window.
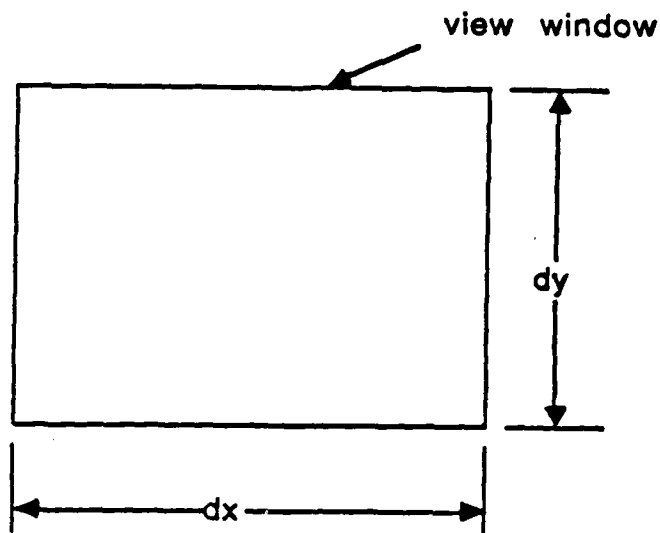
Figure A-6. Definition of View Window.

$$dx = (\, gsrwin[1] - gsrwin[0] \,) \, / \, 2.0 \quad \text{(A-45)}$$

$$dy = (\, gsrwin[3] - gsrwin[2] \,) \, / \, 2.0 \quad \text{(A-46)}$$

Window limits are manipulated as follows (see Figure A-7).

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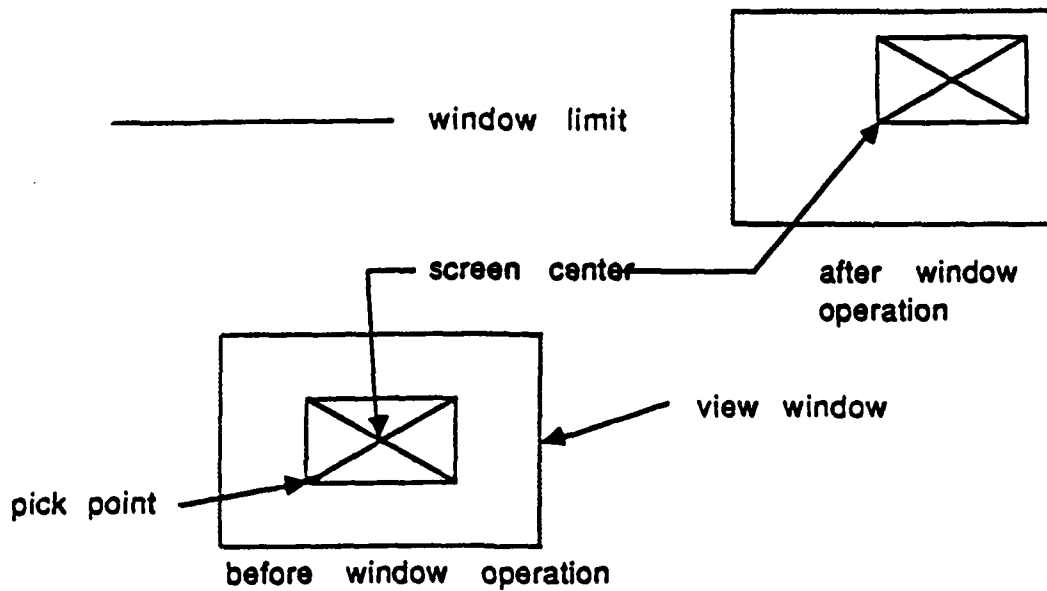
Figure A-7. Manipulation of Window Limits.

left window limit (WXL):	$gsrwin[0] = x - dx$	(A-47)
right window limit (WXR):	$gsrwin[1] = x + dx$	(A-48)
bottom window limit (WYB):	$gsrwin[2] = y - dy$	(A-49)
top window limit (WYT):	$gsrwin[3] = y + dy$	(A-50)

APPENDIX B: DADAR QUICK TRAINING PROCEDURE

The following exercises are provided for the purpose of training and familiar- ization of DADAR. The document "DADAR Overview" (DADAR Contract Compliance Report) should have been read prior to proceeding with these exercises.

Exercise: Basic DADAR Operations

1. Begin by turning the DADAR hardware on:

   a. Power on the controller switch.

   b. Power on the monitor switch.

   c. Power on the printer switch.

   d. Note message on the screen: IRIS>. Wait about one minute.

   e. Type in a lower-case letter "b" (without quotes) and press the RETURN key.

   f. Wait until the DADAR main menu and the zone picture are displayed on the screen.

2. The system will be ready for use when the mouse position indicator is green in color. The mouse indicator will appear somewhere on the screen. To easily locate it, move the mouse and observe the moving indicator on the screen.

3. Examine the screen.

   a. From left to right, along the top edge of the screen are the menu items: PART INFO, PARTS LIST, and PART ID= .

   b. From left to right along the bottom edge of the screen, are the menu items: CHANGE SCALE, CHANGE WINDOW, CHANGE DISPLAY TO WIREFRAME, CHANGE LAYER, CHANGE ZONE and HOME.

   c. Each of these menu items are set apart from the other and represent operations which can be performed using DADAR. Each operation is a "tool" that can be used to determine information about the portion of the aircraft which is being displayed.

4. The mechanical mouse is a small off-white colored box with three black buttons on the top and three ball bearings on the bottom. It is moved about on a pad. Move the mouse. Observe the green indicator on the screen. Practice moving the mouse indicator to a desired location on the screen until you are proficient. Better response will be achieved if you allow your hand to rest on the top of the mouse.

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5. "Picking" is a term which will be commonly used in these exercises. Picking indicates to the system that a specified item or information is to be acted upon. The item under the mouse indicator will be selected or "picked". DADAR is a menu-driven system. This means that most operations are performed by a series of "picks". To complete a pick, follow this procedure:

a. On the screen, locate the mouse indicator over the item to be picked.

b. Depress the SELECT (right-most) button on the top of the mouse.

6. As a practical exercise:

a. Place the mouse indicator over the CHANGE ZONE menu item, located on the lower-right of the screen. NOTE: The term "menu item" will be used when referring to textual screen information.

b. Depress the select button on the mouse.

c. An easier way to express steps a. and b. is to say: "Pick the CHANGE ZONE menu item."

7. The resulting display represents the entire F-15 C/D aircraft. DADAR is a demonstration system. Therefore, only the detailed information for Zone 27 is available. A production version of DADAR would contain all of the zones of the F-15. The Zoned F-15 C/D display allows you to select the zone for which detailed information is needed. Pick on the menu item Zone 27.

8. The resulting display represents the parts which are contained in Zone 27. In this case, the skins have been removed. Please indicate your answer to the following questions by circling one of the choices:

a. How difficult was the DADAR power-on procedure?   EASY   HARD

b. Did you have problems using the mouse?   YES   NO

c. Are the pictures interesting?   YES   NO

d. Are the pictures useful?   YES   NO

9. The picture being displayed will be referred to as the "zone picture".

a. Pick the menu item CHANGE SCALE. Note the message: "PICK NEW SCALE FACTOR" that is displayed below the zone picture and the numbers (scale factors) that are displayed above the CHANGE SCALE menu item.

b. Pick the scale factor "2". The resulting display of the zone picture is two times as large as the previous display of the zone picture.

c. Pick the menu item CHANGE SCALE.

d. Pick the scale factor "1/2". The resulting display of the zone picture is reduced to one-half of the previous display size; i.e., it is back to the original size! This 4-step exercise illustrates how the CHANGE SCALE

function works. That is, the current zone picture is either enlarged or reduced by the selected scale factors.

10. Scale factors, such as 2 1/2 (5/2) can be formed by two scale changes:

a. Enlarge the scale by 5. (Pick the scale factor "5").

b. Reduce the scale by 1/2. (Pick the scale factor "1/2").

c. The resulting picture is 5 X 1/2 = 2 1/2 times the original scale. The rule to remember is that the final scale factor after a series of scale changes is the product of all the scale factors used in the series of scale changes.

11. Exercise: CHANGE WINDOW.

a. Pick the CHANGE WINDOW menu item which is located to the right of the SCALE menu item on the lower-left screen edge. Note the message: "PICK POINT WHICH WILL BE MOVED TO SCREEN CENTER".

b. Move the mouse indicator to the upper-right corner of the screen.

c. Pick on this portion of the zone picture by depressing the SELECT (right-most) button on the mouse. The portion of the picture which was in the upper-right corner of the screen has been moved to the center of the screen. This picking procedure is described more simply by saying: "Pick a screen location."

d. Use the same procedure to bring the large yellow ellipse (oval) to the center of the screen. Note: If the large yellow ellipse is not visible, then pick on anything that you want.

12. The CHANGE WINDOW operation can be used repeatedly to move the zone picture anywhere on the screen.

a. Use the CHANGE WINDOW menu item to bring any part of the dark blue color-coded electrical wire bundle to screen center.

b. Observe where the blue electrical wire bundle becomes invisible at one of the edges of the screen.

c. Bring that portion of the blue electrical wire bundle to screen center using the CHANGE WINDOW menu item.

d. Continue this process to follow the blue electrical wire bundle to its end.

e. Follow the blue wire bundle back to the other end.

13. Please indicate your answer to the following questions by circling one of the choices:

a. Do you understand the SCALE menu item?   YES   NO

b. Is the SCALE function useful?   YES   NO

c. Is the SCALE function easy to learn?   YES   NO

d. Is the SCALE function easy to use?   YES   NO

e. Did you have problems using the mouse?   YES   NO

f. How does using DADAR feel?   BAD   NONE   GOOD

g. Are the pictures useful?   YES   NO

h. Do you want to continue?   YES   NO

i. Can you see any use for DADAR in your job?   YES   NO

14. This exercise will illustrate the option of picking items from the zone picture rather than the menu items. This exercise illustrates that the zone picture is really an assembly of parts similar to the manner of assembly in the real F-15 C/D aircraft.

a. Position the mouse indicator over some of the light blue portion of the zone picture.

b. Depress the SELECT button. The entire part represented by this light blue portion of the picture is now flashing in the color white. The part number is displayed in the upper-right corner of the screen next to the menu item: PART ID=. The part number is displayed in the color light blue. This entire procedure is simply stated: "Pick a Part."

c. Pick another part. Note the flashing white display and the part number at the upper-right corner of the screen.

d. Pick several parts of different colors.

15. Use SCALE and CHANGE WINDOW to see the entire zone picture.

16. Pick four different parts, one after the other.

17. Write down the part number displayed in the upper-right corner of the screen. This entire procedure is described simply by saying "Key in a part number." Note on the display, the flashing white portion of the picture. This is the same response as if you had picked the part. This is the procedure for finding a known part number on the picture.

a. Pick menu item: PART ID=. Note the light blue part number disappears and is replaced by a flashing white bar. This is a signal to use the keyboard to enter text or numbers.

b. Enter the part number which you just wrote down by depressing the proper keys on the keyboard like you were using a typewriter. Note: the number keys are on the top row of the keyboard; the alphabetic keys are on the lower three rows; the dash (-) is on the upper right of the top row. If

an incorrect key is used, the BACKSPACE key on the top row can be used to backup and correct the error.

c. When the part number is correctly entered, push the RETURN key that is located on the middle right portion of the keyboard.

18. Find part number 69A332002-2024. Is the forward
bulkhead now flashing?   NO   YES

19. Examine: CHANGE DISPLAY MODE TO WIRE FRAME menu item.

a. Pick the menu item: CHANGE DISPLAY TO WIRE FRAME.

b. Examine the display which now appears on the screen.

c. Notice at the lower-left of the screen the new menu item: CHANGE VIEW. At the top-center of the screen: SELECT PARTS BY VOLUME menu item is displayed. The display is now in the Wire Frame picture mode. It is similar to the Illustration mode pictures used up to now, but may appear less "natural" to you. This picture has been developed as though the parts are all made of glass and are transparent. You are able to see behind objects. The display probably appears more cluttered to you, but it allows you to view more "hidden" details of the zone picture.

20. Center the picture in the screen using the CHANGE WINDOW menu item.

21. Enlarge the picture to twice its size using the CHANGE SCALE menu item.

22. Example: CHANGE VIEW. The change view function demonstrates the fact that the DADAR pictures are not flat (two dimensional). They are three dimensional.

a. Pick the CHANGE VIEW menu item. Note the series of words above the CHANGE VIEW menu item:

DOWN
UP
INBOARD
OUTBOARD
FORWARD
AFT
DOWN FORWARD INBOARD
UP FORWARD INBOARD

These items are the view options that are available. Notice the message: "PICK NEW VIEW".

b. Pick the DOWN view option.

c. Center the picture. (Hint: Use CHANGE WINDOW.)

d. Examine the picture. Notice that it is considerably different from the previous one. The picture is what would be seen looking down.

e. Pick the CHANGE VIEW menu option. Notice that the DOWN view option is highlighted in the color green. This is how you can determine the current view of the display.

f. Pick view option UP.

g. Examine the picture. The picture is what would be seen looking up.

h. Change the view to INBOARD. Notice the highlighted view option.

i. Change the view to OUTBOARD.

j. Change the view to FORWARD.

k. Change the view to AFT.

l. Change the view to DOWN FORWARD INBOARD. Note: This is the view which existed when you began changing views.

m. Change the view to UP FORWARD INBOARD.

23. Please indicate your answer to the following questions by circling one of the choices:

a.	Is the Wire Frame picture useful?	YES	NO	
b.	Can you see a use for DADAR in your job?	YES	NO	
c.	The mouse is hard to use.	TRUE	FALSE	
d.	Does the CHANGE VIEW menu item help you to understand the picture?	NO	YES	
e.	The CHANGE VIEW menu item not needed.	TRUE	FALSE	
f.	Can you use DADAR?	BARELY	OK	WELL
g.	Does using DADAR make you feel uncomfortable?	YES	NO	
h.	Is the keyboard easy to use?	YES	NO	
i.	Do you need to know part numbers to do your job?	YES	NO	
j.	Must you know what is inside the F-15 C/D to do your job?	NO	YES	

24. Change the view to: DOWN FORWARD INBOARD.

a. Pick menu item: CHANGE LAYER. Examine the words which appear above the menu item CHANGE LAYER:

INTERNAL COOLING SYS
ELECTRICAL
ENVIRONMENTAL CONTROLS

```
HYDRAULICS
LEAK DET SYS
PRIMARY CONTROLS
STRUCTURE
```

Note the message: "PICK LAYER TO BE ADDED OR REMOVED." Notice that this list of layer options is color-coded to match the display of the parts in the zone picture.

b. Pick the menu item: INTERNAL COOLING SYS.

c. Examine the display. Notice that the INTERNAL COOLING SYS has been removed from the assembly. The part numbers are added and the picture is now centered on the display to help you to see the zone and the moved items.

d. Pick CHANGE LAYER.

e. Examine the list of layer options; i.e., the options displayed above CHANGE LAYER menu item. Note that the INTERNAL COOLING SYS layer option is now displayed in the color white. This indicates that this layer has been removed.

f. Pick the layer option: PRIMARY CONTROLS.

g. Examine the display. Notice the PRIMARY CONTROLS layer is shown removed and only the structure is visible in the picture.

24. a. Pick part number: 68A610025-1005 CABLE.

b. Pick the forward bulkhead. Does the
PART ID= 68A332002-2024?   YES   NO

c. Move 68A332002-2024 to screen center.

d. Increase the scale by 1 1/2 times.

25. a. Pick CHANGE LAYER menu item.

b. Again, examine the list of layer options above CHANGE LAYER. Notice that all the options above the PRIMARY CONTROLS layer, as well as PRIMARY CONTROLS, are displayed in the color white. This indicates that they were also removed with the PRIMARY CONTROLS.

26. a. Examine layer option: ELECTRICAL. Notice that it is white, indicating that it has been removed.

b. Pick the layer option: ELECTRICAL.

c. Examine the picture. Notice that everything is in place except the INTERNAL COOLING SYS.

d. Pick CHANGE LAYER.

e. Examine the list of layer options. Note that all systems below ELECTRICAL are now shown color-coded.

The layer function demonstrates that the zone picture is organized into layers, like an onion, and can be disassembled and reassembled in only one way. To remove a layer, all layers above it will be removed. To replace a layer, all layers below it will be replaced.

27. a. Pick CHANGE DISPLAY MODE TO ILLUSTRATION menu item.

b. Examine the picture. Notice that the same layer is removed.

28. a. Remove layer ENVIRONMENTAL CONTROLS.

b. Examine the picture. Notice that the ENVIRONMENTAL CONTROLS components are exploded.

29. Please indicate your answer to the following questions by circling one of the choices:

a.	Is this paper hard to read?	YES	NO
b.	Can layers be removed?	YES	NO
c.	Is removing a layer necessary in your job?	YES	NO
d.	Could you use a break right now?	YES	NO
e.	Is this is a good system?	YES	NO
f.	Do you like the Illustrated pictures most?	YES	NO
g.	Are the Wire Frame pictures useful?	YES	NO
h.	Do you understand the term: Aircraft System?	YES	NO
i.	Is the way DADAR has layers bad?	YES	NO
j.	Can you easily locate a part by sight?	YES	NO

30. Remove all of the layers except the structure layer.

31. Pick the PART INFO menu item.

32. a. Pick the forward bulkhead. Is the part number 68A332002-2024?   YES   NO

b. Examine the display. Notice all the "mate with" (MATE W/) and fastener information. This menu item provides a list of associated parts in Zone 27 which are required to install this piece of structure.

33. Pick the HOME menu item at the lower right of the screen. Remember that HOME takes you back to Step 1 of any procedure of DADAR. When you get

confused and don't know where you are in the DADAR system, HOME will take you to Step 1 of anything that you want to do.

34. a. Pick menu item PARTS LIST.

    b. Pick the forward bulkhead.

    c. Examine the display below the menu item: PART INFO.

    d. Is the orange part number 68A332002-2024?   YES   NO

35. a. Pick a second part from the structure.

    b. Examine the Parts List. A second part number has appeared to the right of the first.

36. Pick a third, fourth, and fifth part from the structure.

37. Pick the forward bulkhead again. Notice that this part is not added again to the Parts List.

38. a. Pick a sixth part from the PRIMARY CONTROLS. (Shown in green.)

    b. Examine the Parts List. Notice that the part numbers are color-coded with the same color as the part in the zone picture.

39. a. Pick the REMOVE menu item.

    b. Note the message at the bottom of the screen: "PICK PARTS LIST ENTRY TO REMOVE".

    c. Pick the part number that is color-coded green. Notice that it is removed from the Parts List.

    d. Remove the first entry in the Parts List. (Hint: Pick REMOVE first).

    e. Notice that the Parts List is shifted to fill the hole where the removed part number was displayed.

    f. Pick the CLEAR menu item. Notice that all Parts List items are removed.

    g. Add five parts to the Parts List.

    h. Pick the PRINT menu item.

    i. Notice that the printer is now printing. When it is done, tear off th printed material. Notice that the associated data for each part in the Parts List is printed. The rule to remember is: The Parts List is a kit which you can add to or remove from at any time. A printed listing can be obtained when desired.

40. Please indicate your answer to the following questions by circling one of the choices:

a.	Is the information available in DADAR useful?	YES	NO
b.	Should there be more information available?	YES	NO
c.	Is the system easy to use?	YES	NO
d.	Do you like the Wire Frame pictures most?	YES	NO
e.	Will DADAR save you time on your job?	YES	NO
f.	Will DADAR make your job better?	YES	NO

41. Pick the Home menu item.

42. Pick CHANGE DISPLAY TO WIRE FRAME.

43. To find all parts inside a given volume which is shaped like a cone:

    a. Pick the: SELECT PARTS BY VOLUME menu item.

    b. Notice the message: "PICK FIRST END POINT."

    c. Pick a part from the structure near where the near end of the cone is. Imagine this location as the entry point of a bullet.

    d. Notice the message: "KEY-IN DIA". Using the keyboard, key-in a number equal to the diameter in inches and depress the RETURN key.

    e. Notice the message: "PICK SECOND END POINT." Pick a part from the structure where the far end of the cone is located. Imagine this location as the exit point of a bullet.

    f. Notice the message: "KEY-IN DIA." Using the keyboard, key-in a number equal to the diameter in inches and depress the RETURN key. After a short delay, notice that the printer is now printing a list of parts and the associated data for all parts which fall inside the cone.

44.   a. Install all layers (INTERNAL COOLING SYSTEM).

    b. Find part number: 189320-3-1.

    c. Pick menu item: PART INFO.

    d. Pick INSTALL MAINT PROC menu item.

    e. Examine the display. Note that the Installation Procedure for this part is shown on the screen.

    f. Pick anything on the display.

    g. Note the message: "NO ADDITIONAL INFORMATION AVAILABLE."

h. Pick REMOVE MAINT PROC.

i. Note that the Removal Procedure is shown.

j. Pick anything on the display.

k. Pick HOME menu item. Note that several parts of the ENVIRONMENTAL
CONTROLS have the Removal and Installation procedure information available,
but no other parts.

45. Please answer the following questions:

a. What other types of information would be useful?

b. What is the best feature of DADAR?

c. What is the worst feature of DADAR?

46. Congratulations!! You are now a DADAR operator. Continue to use DADAR,
as you desire, to evaluate its usefulness to you in your job.

APPENDIX C: EVALUATION PARTICIPANT VERBAL QUESTIONS

1.   What kind of job do you do?

2.   Do you or have you worked with computers before?

3.   Is the information available in DADAR useful/necessary to do your job?   What information do you most often need?   What other types of information would be useful?

4.   Which do you like best: the illustrated pictures or the Wire Frame pictures?   Why?   Which are most useful to the tasks accomplished?

5.   How do the graphics look on the screen as compared to the TO?   Which is better?

6.   What is the best feature of DADAR?

7.   What is the worst feature of DADAR?

8.   Do you have any general comments?

APPENDIX D: EVALUATION PARTICIPANT RESPONSE QUESTIONS

		YES	NO
1.	Do you use Illustrated pictures to do your job?	35	2
2.	Must you know the position and location of parts inside of the F-15 C/D to do your job?	32	7
3.	Do you need to know part numbers to do your job?	34	5
4.	Did you have any problems using the mouse?	7	32
5.	Do you understand the function of the SCALE menu?	40	0
6.	Is the SCALE function easy to learn?	39	1
7.	Is the SCALE function easy to use?	38	2
8.	Is the SCALE function helpful?	40	0
9.	Did the ability to selectively remove illustrated pictures help you complete the task?	40	0
10.	Were you able to identify aircraft components from the illustrations?	40	0
11.	Does the CHANGE VIEW menu help you understand the picture?	39	0
12.	Can the layers be easily removed?	39	0
13.	Would removing a layer help you do your job?	37	1
14.	Can you easily locate a part by sight without using layers?	16	23
15.	Was the information presented in an easy-to-use format?	37	1
16.	Was the speed of the system satisfactory?	36	2
17.	Was the display readable?	39	1
18.	Was the keyboard easy to use?	40	0
19.	Were the graphics legible?	39	0
20.	Were the graphics helpful in locating and identifying components on the aircraft?	40	0
21.	Did the Illustrated pictures provide enough detail?	35	4

		YES	NO

22. Did the Wire Frame pictures provide enough detail? **YES** 36 **NO** 3

23. Will DADAR save you time on your job (help you do your job quicker)? 39 0

24. Will DADAR save you effort on your job (make your job easier)? 38 0

25. Does DADAR make it more difficult to do your job? 0 38

26. Was this training procedure difficult to read and understand? 4 36

27. Do you like the use of color to highlight the various parts shown? 39 1

28. Would DADAR be useful to assess aircraft battle damage? 40 0

29. For what assessment tasks might DADAR be particularly useful? See below for

responses.

		A	B

30. Which would be better for a novice assessor? **A** 23 **B** 13

   a. Illustrated pictures
   b. Wire Frame pictures

31. Which would be better for an experienced assessor? 10 25

   a. Illustrated pictures
   b. Wire Frame pictures

RESPONSES TO QUESTION 29

Participant

1. Would be helpful to access any and all tasks on the F-15 C/D.

2. Material estimates and cost.

3. No response.

4. Crash damage/fire damage.

5. I don't know.

6. No response.

7. Crash damage parts assessment.

8. Engine bay fire.

9. When assessing battle damage, it requires numbers of TOs and various amounts of blueprints which are not always available without ordering. This would be everything all in one.

10. Identification of parts and hardware.

11. Making sure you had the right parts and you would not have to order parts that were not damaged or ones you did not need.

12. F-15 wings component parts location and identification.

13. A quick reference of part numbers. A quick assessment of damage done. A quick assessment of missing parts. DADAR would be useful to assess aircraft battle damage only to the extent that a person knows what zone to access and doesn't have to search the entire aircraft.

14. I work mostly with facilities and equipment. A layer by layer drawing of various aircraft facilities would be helpful.

15. Locating part numbers of missing items due to projectile path.

16. Identifying parts that are completely destroyed.

17. Fire and crash damages, general depot assessment, and repairs.

18. (1) everyday job, (2) ABDR.

19. Parts identification.

20. Battle damage.

21. Establish material requirements.

22. Damage located under skin panels.

23. Checking system for parts.

24. Actual pictures of damage to compare would be very useful.

25. No response.

26. Troubleshooting.

27. Building a material requirement list (MRL).

28. Helping to build an MRL for an aircraft structural repair program.

29. No response.

30. No response.

31. No response.

32. Location of parts and systems and installation and removal procedures.

33. If adapted to the right uses, DADAR would help in practically every aspect of damage repair. It is now geared toward field maintenance ones but could be easily expanded for engineering analysis.

34. (1) Identify next higher assembly, (2) identify part number and nomenclature, (3) cross-reference part number to stock number, (4) list fasteners to attach parts, (5) capability to remove individual parts from assemblies.

35. Battle damage assessment, survivability analysis, TO preparation (tasks and illustrations).

36. Hydraulic, electrical, pneumatic.

37. No response.

38. Being unfamiliar with assessment of aircraft I can only project my thoughts as it could be used on the subsystems that I handle. But to this length would be economically unfeasible.

39. Aircraft maintenance fields. Can be used for damaged aircraft being put back together. Location of parts, part numbers, Illustrated Parts Breakdown (IPB).

40. For all systems within any aircraft.