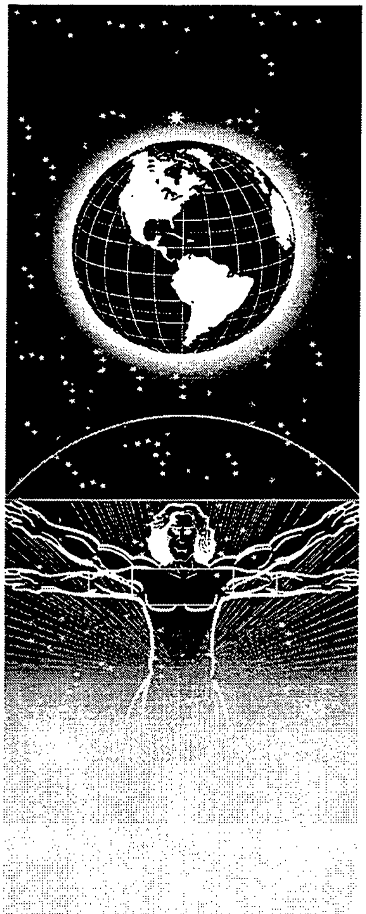
AFRL-HE-WP-TP-1998-0023



UNITED STATES AIR FORCE RESEARCH LABORATORY

Task Filtered Display of Functional Diagrams for Flightline Maintenance

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March 1998

Interim Report for the Period June 1993 to January 1997

19980728 035

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AFRL-HE-WP-TP-1998-0023

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

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

FOR THE COMMANDER

for THOMAS J. MOORE, Chief
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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
March 1998

3. REPORT TYPE AND DATES COVERED
Final - June 1993 to January1997

4. TITLE AND SUBTITLE
Task Filtered Display of Functional Diagrams for Flightline Maintenance

5. FUNDING NUMBERS
C - N/A
PE - 62202F
PR - 1710
TA - D2
WU - 01

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory, Human Effectiveness Directorate
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Air Force Materiel Command
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Wright-Patterson AFB OH 45433-7604

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory, Human Effectiveness Directorate
Crew Survivability and Logistics Division
Air Force Material Command
Logistics Readiness Branch
Wright-Patterson AFB OH 45433-7604

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFRL-HE-WP-TP-1998-0023

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This paper discusses a proposed design of the display of simplified schematics and writing diagrams in Interactive Electronic Technical Manual (IETMs) to support flightline maintenance. The paper reviews current theoretical and applied solutions to the display of large diagrams on small screen devices. A selected technique is implemented from a users perspective in demonstration software. The design is discussed with suggestions for future research.

14. SUBJECT TERMS
IETMs, Maintenance, Wiring Diagrams, Technical Manuals, Schematic Diagrams, Troubleshooting

15. NUMBER OF PAGES
21

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Standard Form 298 (Rev. 2-89) (EG)
Prescribed by ANSI Std. 239.18
Designed using Perform Pro, WHS/DIOR, Oct 94

PREFACE

A current initiative to use computer-based or interactive electronic technical manuals (IETMs) is being adopted by all services in the Department of Defense. Although initial tests and applications of the IETM demonstrated greatly improved performance and potential cost savings, problems have been experienced in presenting one type of information, schematic and wiring diagrams, on small computer screens. This paper discusses a proposed design for the display of IETM schematics and wiring diagrams to support flightline maintenance. This approach will overcome some of the problems experienced. The paper reviews current theoretical and applied solutions to the display of large diagrams on small screen devices. A selected technique was implemented from a users perspective in demonstration software. The design is discussed with suggestions for future research.

Special thanks goes out to the following individuals for their support during the development of the TFD Concept: Johnnie Jernigan of NCI Corp, Capt. Eric Carlson and Brian Smith of the Armstrong Laboratory, Logistics Research Division (AL/HRGO) for their technical expertise; Harry English, Chuck Matteny, Bill Norton, Sgt Duncan and Sgt Farcus of the F-16 Special Program Office (SPO) for their F-16 technical expertise and technical manual support; J.B. Schroder and Gary Smith of Flight Dynamics Laboratories for their demonstration of the Flight Control Maintenance Diagnostic System (FCMDS) and suggestions for improvement. Without the help of all of these individuals, this project would not have been possible.

The principal investigator for this research was Jeff L. Wampler. This research was conducted under AL/HRGO Work Unit 1710-D2-01, Technology for Logistics Information Systems. The work also supported the Integrated Maintenance Information System (IMIS) program, project 2950.

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INTRODUCTION

As modern aircraft have become more complex, so has the maintenance data required to support the aircraft. For example, the United States Air Force F-16 requires approximately 250,000 pages of technical manuals to support flightline maintenance. Flightline maintenance is responsible for keeping the aircraft in fighting form through both scheduled maintenance (e.g. oil changes) and unscheduled maintenance (diagnosis and repair of system failures). The maintenance personnel are a team of mechanics and managers whose primary mission is to maintain and repair the aircraft as quickly and effectively as possible with available resources. Without effective flightline maintenance, the fighting capability of the Air Force would be severely hindered.

To improve overall mission effectiveness, aircraft systems are employing computers to assist flightline maintenance. One such concept, the Integrated Maintenance Information System (IMIS), will provide computers to store, manage and present literally all of the information required to support the flightline maintenance effort (Link, et al., 1987). The IMIS is the product of a research and development effort at the Human Resources Directorate of Armstrong Laboratories (AL/HRG) , completed in 1994. Ward , et al. (1995) provides a description of the IMIS demonstration system, and Thomas (1995) provides an description of the IMIS field study and the test results. The IMIS concept is being adopted by most modern weapon systems, including the F-16 and F-22.

Under the IMIS concept, technicians will use IETMs presented on portable computers, called portable maintenance aids (PMAs), instead of bulky paper technical manuals. In addition to presenting IETMs, the PMA will be used for several other functions. Work forms will be completed on the PMA and transmitted to maintenance data bases for electronic storage. Parts will be ordered over a computer network. Maintenance managers will have access to electronic flying/maintenance schedules and status boards on the PMA instead of paper schedules and "grease board" status boards. Radio communication technology will provide rapid transmittal of information, via computer, to all team players as required.

The IETM concept and technology were developed as part of the IMIS program and are being adopted by all services in the Department of Defense. A set of Military Specifications has been developed as guidelines in the development and procurement of IETMs (MIL-D -87269, 1992; MIL-M -87268, 1992, MIL-Q -87270, 1992).

The IETM portion of the IMIS concept has been demonstrated in a series of field studies (Thomas, 1995; Link, et al., 1990; Carlson, et al., 1992). In these studies, technicians were compared using computer-based technical manuals vs. paper-based technical manuals to troubleshoot a series of simulated aircraft faults. On all occasions the technicians performed better with the electronic media than with paper technical manuals. These studies provided a wealth of information on the development, presentation, and use of electronic technical manuals. One finding of these studies was that better methods are needed for presenting schematic and wiring diagrams.

Frequently troubleshooting on modern aircraft involves electronic components where the technician performs a series of voltage and/or continuity checks. In a recent study performed on a Navy F/A-18 (Carlson, et al., 1992), the schematic diagrams were omitted and wiring diagrams were replaced with simplified versions of the wiring diagrams contained in paper technical manuals. The wire diagrams were boxes (representing Line Replaceable Units (LRUs)) with plug/jack numbers, pin numbers and door locations.

User comments reflected the need to provide more detailed system information such as schematics and wiring diagrams to support troubleshooting in an operational environment (Quill, et al., 1992). Furthermore, schematic and wiring diagrams are not thoroughly specified in the IETM MIL-SPECS. Based on this information, and the importance of the information presented in schematics and wiring diagrams, better techniques for presenting the information must be developed.

This paper discusses a proposed design for the display of simplified schematics and wiring diagrams in IETMs to support flightline maintenance. The paper reviews current theoretical and applied solutions to the display of large diagrams on small screen devices. A selected technique is implemented from a users perspective in a proof-of-concept software prototype. The design is discussed with suggestions for future research.

Background

During flightline maintenance, electronic technicians are primarily in a box swapping mode. In other words, the technician is looking for a faulty component (LRU), electrical wire or connection. Once a fault is found, the faulty component, connection or wire is replaced with a working component, connection or wire. If the system checks out, the faulty component is sent back to the shop to be fixed while the aircraft flies another mission. This has been the most effective way to keep the aircraft mission ready.

Graphics are an integral part of all aircraft technical manuals. Due to the complexity of modern weapon systems, schematic diagrams for flightline maintenance are often simplified to contain just enough information for the technician to gain an understanding of the inner workings of a component.

The "simplified" schematic diagrams and wiring diagrams are typically fold-out pages (11"x 17"). These diagrams often have references to other drawings when the information can not fit on a single page. The result is that several pages are needed to depict a single system, its component, and connections.

Display size and dot pitch hinder attempts to display such diagrams on a portable computer. In the early 1990s, many portable computers were developed with a relatively small display (8" x 6") with a dot pitch of at least 81 dots per inch. The majority of these displays are flat panel Liquid Crystal Displays (LCDs) which are typically inferior to Cathode Ray Tubes (CRTs) in image quality (Travis, 1991).

The minimum image size required to easily read the displayed information on a computer display is much larger than that of paper. The recommended minimum-sized font is 16 min of arc for tasks in which legibility is important (ANSI, 1988). This corresponds to a character height of approximately .11 inches (based on a viewing distance for desktop CRTs, approximately 24 inches). On the flightline, the technician may interact with the technical data while kneeling in front a portable computer. The viewing distance for kneeling increases to around 3 feet for the 95th percentile male. Based on this information, MIL-M -87268 recommends a minimum font size of .17 inches for IETMs. The result of limited display technology and larger text requirements is much less information per square inch on the computer than on paper. When dealing with a 6" x 8" display, only a portion of the diagram can be displayed at one time. For complex sub-systems which require several 11"x 17" schematic diagrams, the electronic counterpart would require many screens of data.

As stated by Mitta (1992), the typical way of handling images larger than the display is to provide scrolling and/or zooming functions. Both scrolling and zooming have the disadvantage of allowing the user to "get lost" in the position of the viewable image with respect to the overall diagram. Additionally, the user interface controls for scrolling were designed to be operated with a freeform positioning device, such as a mouse. The portable computers used on the flightline usually have trackball, finger pad or touchscreen type input devices, which often are difficult to control. Easier-to-use controls are needed to permit the technician to conveniently manipulate the cursor and control the display of information on the screen.

Presentation of Large Diagrams

A review of current research for the display of complex visual information by Quill (1992), describes the fisheye concept (Furness, 1986 and Mitta, 1989) and the transparency/blur concept (Colby and Scholl, 1991) as potential user oriented solutions to presenting functional diagrams (schematic diagrams) on a small computer display. Both concepts take advantage of human perceptual and cognitive capabilities to filter the data into meaningful chunks of information with reference to the surrounding components/systems.

The fisheye presentation system uses a series of weighting algorithms to determine the importance of each item in a schematic to the others. With the fisheye concept, the technician is able to select for viewing a focus point or those portions of graphics or sub-graphics in which he/she is most interested. These items are presented in more detail, while surrounding items of less interest are presented in less detail (Mitta, 1992).

Transparency and blur can be used to fade in and out detail based on its belongingness to a set of common elements. Sets can be layered so that the user can select a layer of information for viewing.

Quill recommends a combination of fisheye and transparency/blur for the display of functional diagrams. In addition, these techniques are potential solutions to displaying other large diagrams such as schematics. However, more research is needed to validate the usefulness of such a technology. Both techniques require extensive task analysis data to determine weights and relationships between elements in each diagram, an effort whose costs may outweigh its benefits for large complex systems.

Task Filtering

Another approach to presenting technical diagrams is to break down the larger diagram into sub-diagrams which represent only the information required to perform the current troubleshooting task (Hatterick, 1985). Many of the tasks performed by flightline technicians involve checking the connections between two components. For these tasks, the information on the schematic or wiring diagrams not related to the current task can be distracting. This information can be filtered out to provide only the relevant data.

Technical writers for the F-16 have broken down the schematic diagrams as a way to chunk a complex system into several pages. Many references are drawn between diagrams which make using the diagrams cumbersome, since the technician must find the referenced page and then find the desired information on that page. In an electronic presentation, the references can be made automatically. However, when all the required information is displayed at one time, the diagram is huge with much information not pertinent to the task at hand. For example, the Inertial Navigation Set (INS), which is a moderately complex system, has two 11"x 17" papers depicting its simplified schematics. On these two pages, there are six references to other schematics. To get a complete picture of the simplified schematics for the INS and related components, the technician may need to refer to eight 11"x 17" diagrams. Likewise, F-16 wiring diagrams contain every wire and pin location for each connection to/from a component. For example, the INS wiring diagram is contained on one 11"x 17" page in an extremely small font. On this page there are nine references to other wiring diagrams. Again, to get a complete picture of the INS wiring, ten 11"x17" pages are required.

Field technicians for the Navy F/A-18 created "cheater sheet" schematic diagrams which are a combination of the simplified schematics and wiring diagrams. These diagrams were hand-drawn representations of a subset of a schematic for a particular troubleshooting task. This concept allows the schematics to be drawn with only the applicable components (and wires) in each diagram for a particular troubleshooting task.

A combination of the simplified schematics employed by the F-16 technical manuals and the cheater sheet concept developed by F/A-18 field engineers seems to have a potential application to the electronic presentation of schematic and wiring information.

Flight Control Maintenance Diagnostic System (FCMDS)

Flight Dynamics Laboratory has developed a demonstration wiring diagram system which supports the information filtering concept. The FCMDS (Bursch, 1993) was developed from a fault isolation perspective for the flight control system of the F-16 aircraft. FCMDS filters the data for troubleshooting, in that the fault isolation manuals require the technician to check a single voltage and/or continuity at a time. FCMDS displays one wire at a time with components (LRUs), wires, connectors and any intermediate connections displayed in a generic graphic. The information associated with a component, connector or wire is displayed in a data display area as the cursor is placed on that part of the wiring diagram. FCMDS has been successfully field tested with F-16 technicians.

Several shortcomings of FCMDS are readily apparent. The system provides no overall picture of the systems being investigated (such as those provided in the functional block diagrams, simplified schematics and complete wiring diagrams). There is no doubt that the technician can only trace one wire at a time. However, without showing multiple connections simultaneously, the technician does not see integrated relationships between components.

There is no signal flow information between components and no schematics for internal components of LRUs. Without the schematic information, the technician has no support information to help gain an understanding of "how the system works." The necessity for schematic information in technical manuals for flightline maintenance has been disputed by developers and technicians alike. One anonymous technician stated "we don't want to become a bunch of box-swapping monkeys" when referring to the lack of schematic information in IETMs.

The generic graphic used to depict components and connections requires the user to provide manual inputs to obtain information which could be continuously displayed (actual LRU name, plug/jack numbers, pin numbers and wire numbers). The generic graphic may be easier to develop (especially with large complex systems), but may not be the best representation of the data for the technician. This problem may be overcome by a more unique display of the data for each diagram.

Finally, support information such as theory of operation and locator diagrams for LRUs, bulkhead connectors and wire harnesses are not readily available. During free-form troubleshooting, information such as location diagrams for LRUs and connections, bulkhead connections and plug/jack pin maps may be required.

Based on user comments, the principal investigators of FCMDS suggested several enhancements to their system which are intended to alleviate several of these shortcomings. However, the FCMDS team contends that the flightline technician does not need to see schematic information internal to LRUs.

PROPOSED DESIGN

A design for the display of schematic and wiring diagrams (functional diagrams) for flightline maintenance was developed using concepts from the research and development discussed in the previous sections of this paper. The F-16 Inertial Navigation Set (INS) was the system selected for concept demonstration.

Task Filtered Display of Functional Diagrams (TFD)

The TFD concept breaks down the functional diagrams based on typical tasks performed by the technician. In order to determine the information required by technicians, a task analysis was performed with the assistance of aircraft technicians and troubleshooting experts. The following sections summarize the actions and information requirements for flightline troubleshooting.

Information Requirements

With the paper-based manuals, several sources of information are used to support troubleshooting. The following outlines a typical troubleshooting scenario: 1.) Fault isolation (FI) manuals are used to perform a deductive series of tests based on given symptom(s). Simplified schematics and locator diagrams are referenced in the FI manuals to locate aircraft components and electrical connections. The schematic diagrams are at a relatively high level and display component to component connections. Additionally, the schematics portray all of the pertinent internal electrical and hydraulic components of each LRU. 2.) Job guides are referenced in the FI manuals when a component must be removed/replaced to conduct a test. 3.) When a test leads to potential faulty wiring, detailed wiring diagrams are available for each LRU showing its connections to other aircraft components. Intermediate connectors between components at fuselage stations (bulkhead connectors) are also depicted in the wiring diagrams. 4.) When the faulty wire or connector is isolated, the technician is referred to the wire/connector repair procedures in yet another technical manual. 5.) If the technician exhausts all tests in the FI manual and the problem persists, free-form troubleshooting occurs where the technician uses his/her knowledge of the system along with available technical data to isolate the problem. During the free-form troubleshooting, the technician must have access to all Functional Block Diagrams, schematics and wiring diagrams and Illustrated Parts Breakdown (IPB) manuals associated with the suspected system.

At each step in the troubleshooting process, certain information should be readily available to the technician. The detailed information requirements for the technician are outlined in Table 1. Information requirements were derived from technicians using F-16 Technical Manuals.

Table 1 Troubleshooting Information Requirements and Sources

Information Required	Source of Information
1. Standard Troubleshooting	
1.1. Symptom	Built-in Test (BIT) or observed by human
1.2. System being diagnosed	Fault Isolation Manuals
1.3. Test/Procedures to be performed	Fault Isolation Manuals
1.4. Location of LRUs.	Front of Fault Isolation Manuals
1.4.1 Ground connections on each LRU.	Fault Isolation Manuals or Wiring Diagram Manuals
1.5. Location of test points (Plug/jack)	Fault Isolation Manuals
1.5.1 Number of pin on plug/jack	Fault Isolation Manuals
1.5.2 Location of pin on plug/jack	General Vehicle (GV) Manuals
2. Component Remove/Replace	
2.1 Remove and replace procedures	Job Guide Manuals
3. Wire/Connector Repair	
3.1 Wire Numbers	Wiring Diagrams
3.2 Wiring repair and replace procedures	GV Manuals
4. Free-form Troubleshooting	
4.1 System Interconnectivity	GV Manuals - Functional Block Diagrams
4.2 Theory of operations	GV Manuals
4.3 Signal flow (voltages and directions) between and within LRUs	Fault Isolation Manuals - Simplified schematics
4.4 Internal schematics	Fault Isolation Manuals - Simplified schematics
4.5 Location of intermediate connectors.	Wiring Diagrams or IPB Manuals

TFD Description

The TFD prototype will potentially contain all of the INS simplified schematic and wiring diagram information extracted from the eighteen 11"x 17" fold-out schematic and wiring diagrams in the F-16 Technical Manuals. However, one of the beauties of IETMs is how referenced documents are transparent to the user. To reference another information source, the user simply selects an item from a menu (vs. searching another manual in the paper technical manual world). For the sake of brevity, this paper contains a subset of screens which are representative of the TFD capability. The TFD demonstration software was developed using Toolbook V5.3 software by Assymetric Corporation.

The data displayed in the TFD demonstration software has two uses. The first use is in conjunction with the fault isolation tasks. In this case, the fault isolation procedures may lead the technician to isolation of the fault. Some of the prescribed fault isolation tests may be wiring checks which require use of a simplified wiring diagram. The signal flow and wiring diagrams provided by the TFD prototype would support these graphic requirements.

The second use of the TFD is to support free-form troubleshooting when the fault isolation does not lead to a solution and the technician is forced into a free-form troubleshooting mode. In this case, the technician will select the sub-system of choice and browse the diagrams associated with the selected sub-system.

When the technician uses the prototype in free-form mode, he/she will select the suspected system from a hierarchical list or graphic menu. Let's assume the INS was selected. The INS system and its connections are depicted in a connectivity block diagram (Figure 1). These diagrams show some of the information contained in the high level block diagrams and can help the technician gain an understanding of interrelationships among aircraft components.

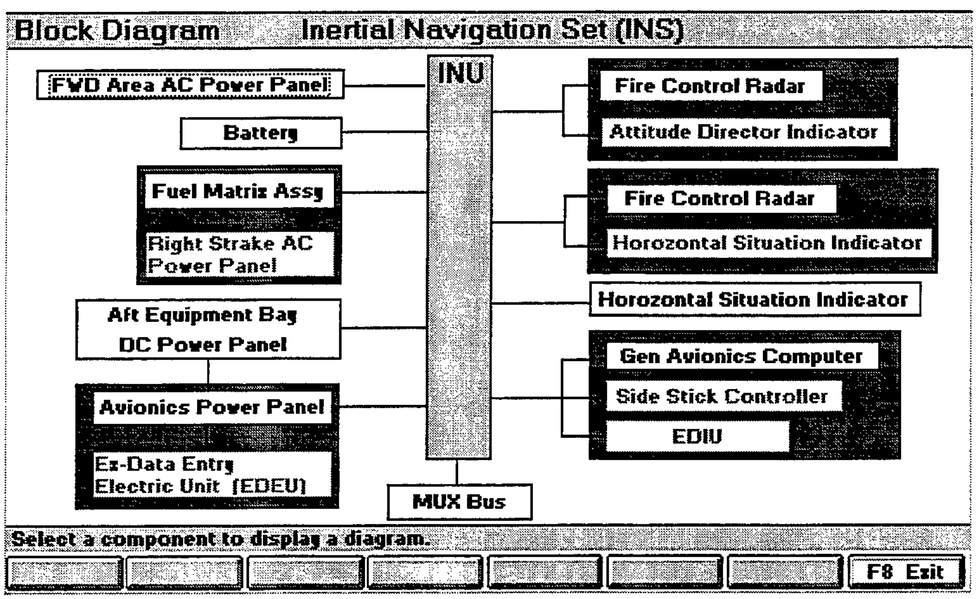

Figure 1: Inertial Navigation Set (INS) Connectivity Block Diagram

The displays for the TFD prototype conform to the layout for IETMs as specified in the MIL-SPECS. Each screen has (from top to bottom) a title bar, a content region, a message line and function keys used for navigation through the system.

This high level block diagram depicts the INU and all of its related components. The components are grouped in gray blocks to show when several components are displayed together in a single diagram. To view any of the diagrams, the user simply selects a block.

After selecting a block, the signal flow diagram is displayed (Figure 2) in the form of a simplified schematic similar to a portion of the current F-16 diagrams. The signal flow diagrams provide voltages and signal names for each connection between LRUs. LRUs are depicted as gray boxes with labels on top. Plug/jack connectors and pin numbers are displayed for each connection. Simplified schematics are used to depict transformers, circuit breakers, relays, filters, etc. within LRUs. This diagram can be considered a simplified schematic sub-diagram. This diagram shows all connections between three LRUs: Right Strake Aircraft Power Panel, Fuel Matrix Assembly and INU, giving the technician an integrated representation of the relationship between components.

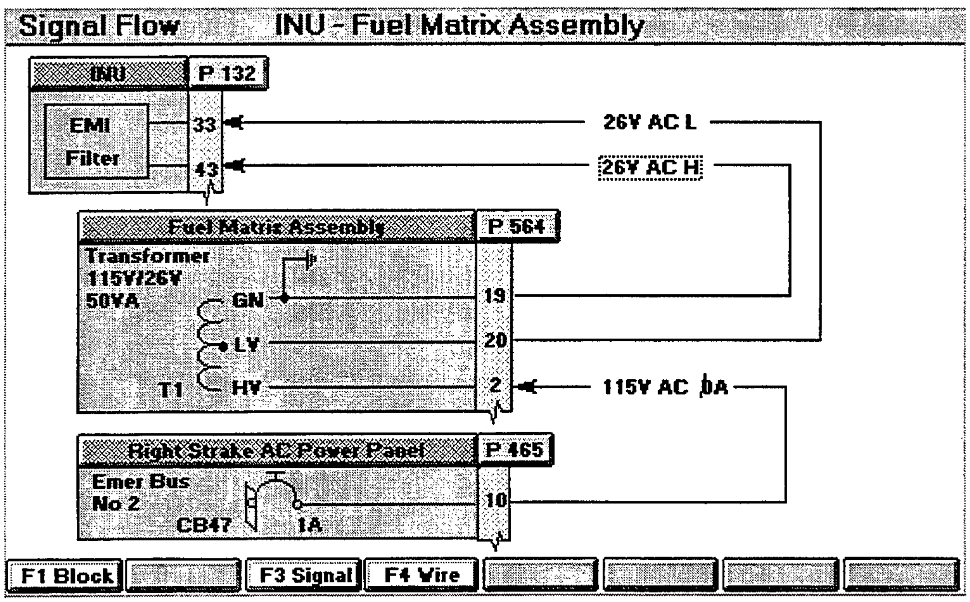

Figure 2: Simplified Schematic Sub-Diagram

By selecting the "F3 Wire" function key, an overlay is depicted on the LRUs which is similar to a portion of the wiring diagrams. The signal information is removed and bulkhead connectors and wire numbers are displayed for each connection (Figure 3). Notice that a majority of the required information is displayed to the technician without requiring input (actual LRU name, plug/jack numbers, pin numbers, bulkhead location, and wire numbers). Unlike FCMDS, the wiring diagrams show all wires between components in one display.
Some sub-diagrams may require more than one screen to depict the wiring diagrams.

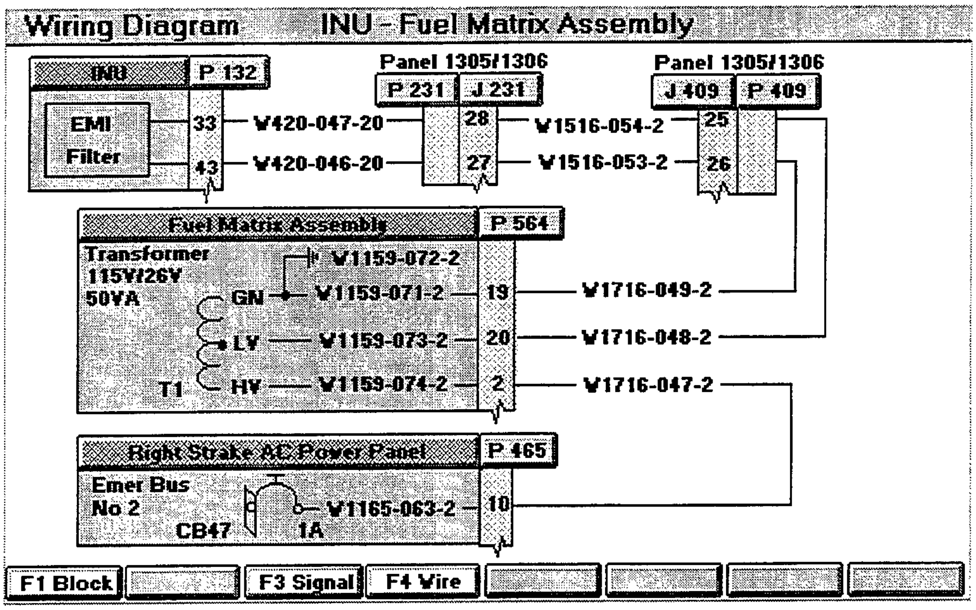

Figure 3: Wiring Sub-Diagram

Figure 4 represents the connections between the INU, Fire Control Radar (FCR) and Attitude Direction Indicator (ADI). All components are displayed due to the splicing of wires between components.

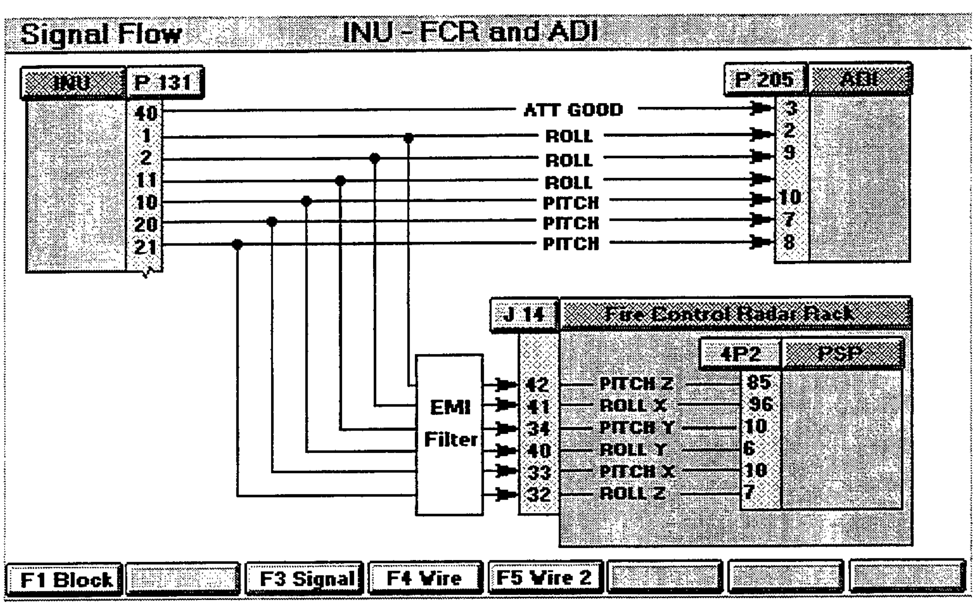

Figure 4: Simplified Schematic Sub-diagram

The wiring diagram for the INU, FCR and ADI (Figures 5 and 6) runs through a matrix assembly and requires two screens. The function keys on the bottom of the display have "Wire" and "Wire 2" keys representing the two connected wire diagrams. On the first screen (Figure 5), components continued on the second wiring display (ADI and FCR) are displayed as light gray boxes without wiring detail to provide the context of system connectivity to the technician. The right hand plugs from the Forward Interface Matrix Assembly are redisplayed on the second diagram (Figure 6) to help provide continuity between the diagrams.

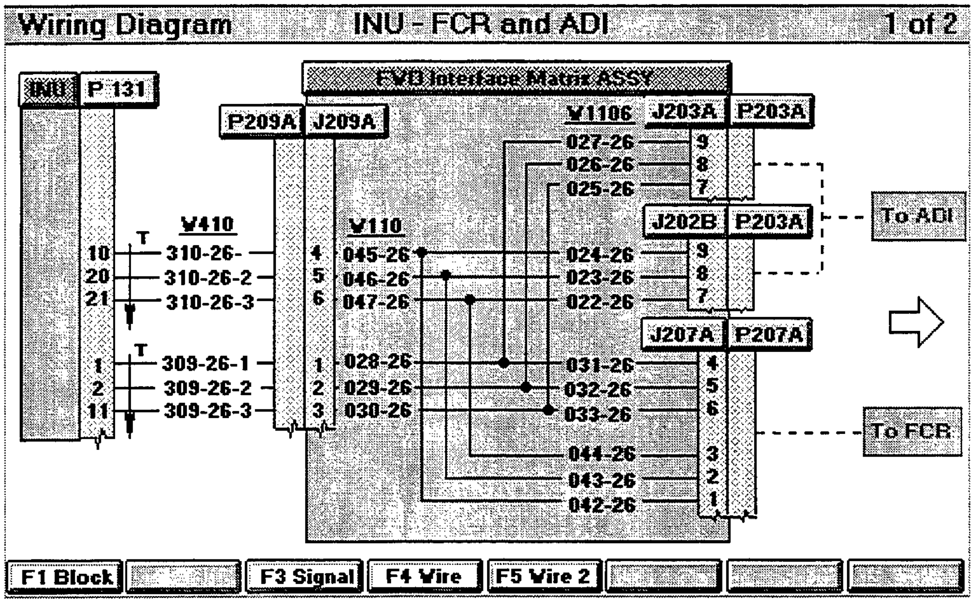

Figure 5: Wiring Sub-Diagram Screen 1

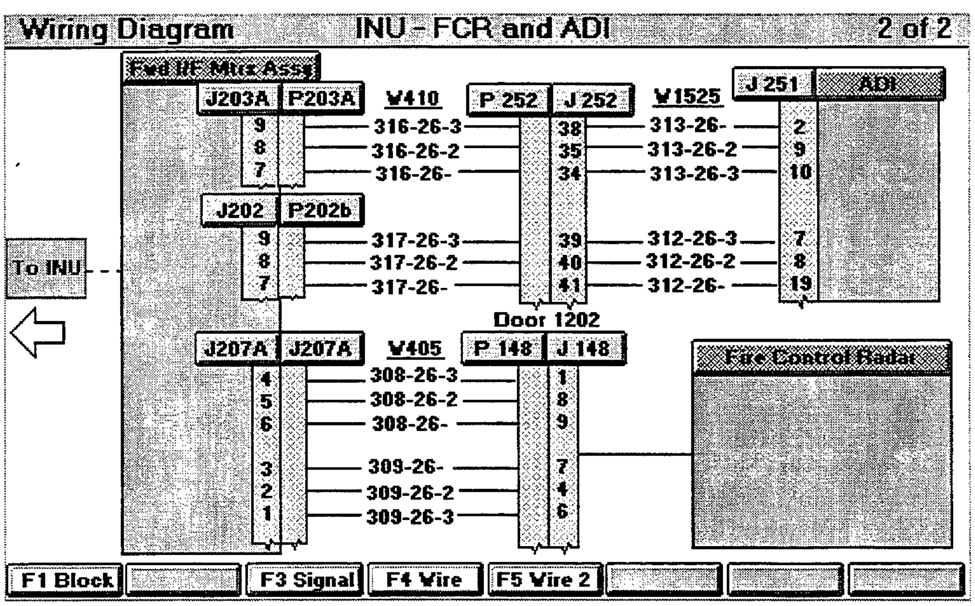

Figure 6: Wiring Sub-Diagram Screen 2

In any of the signal flow or wiring diagrams, the technician can obtain supporting information by selecting the component of interest. If the user selects a LRU title, the information associated with the LRU can be accessed (Figure 7). The menu contains the following for a LRU: locator diagrams, schematic diagram of internal components, ground connections, repair/replace procedures, and theory of operation.

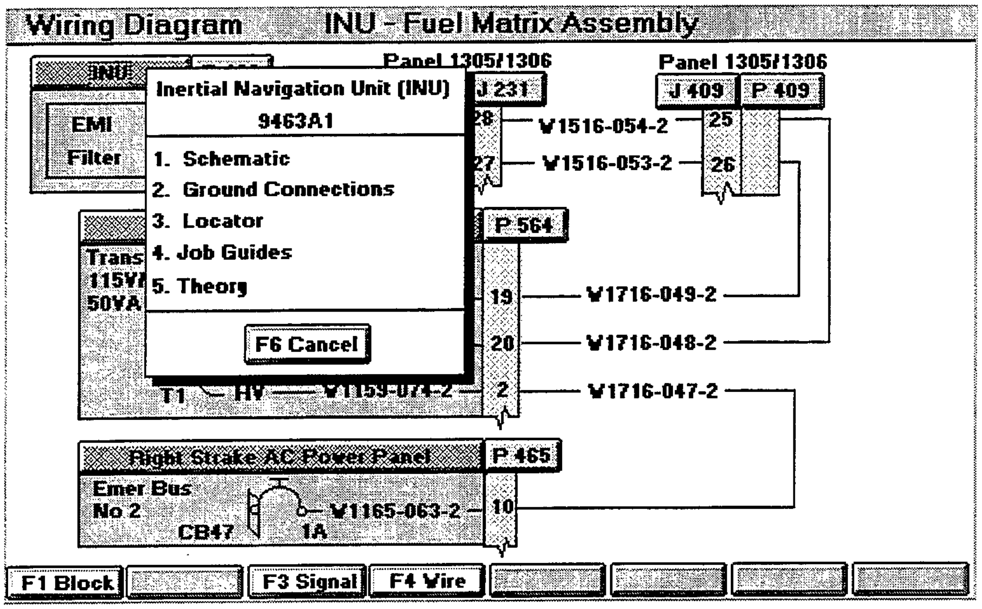

Figure 7: LRU Support Information

A Schematic diagram of the internal components of an LRU is shown in Figure 8. Components external to the ADI are de-emphasized (light gray), while still showing connectivity between the ADI's pins.

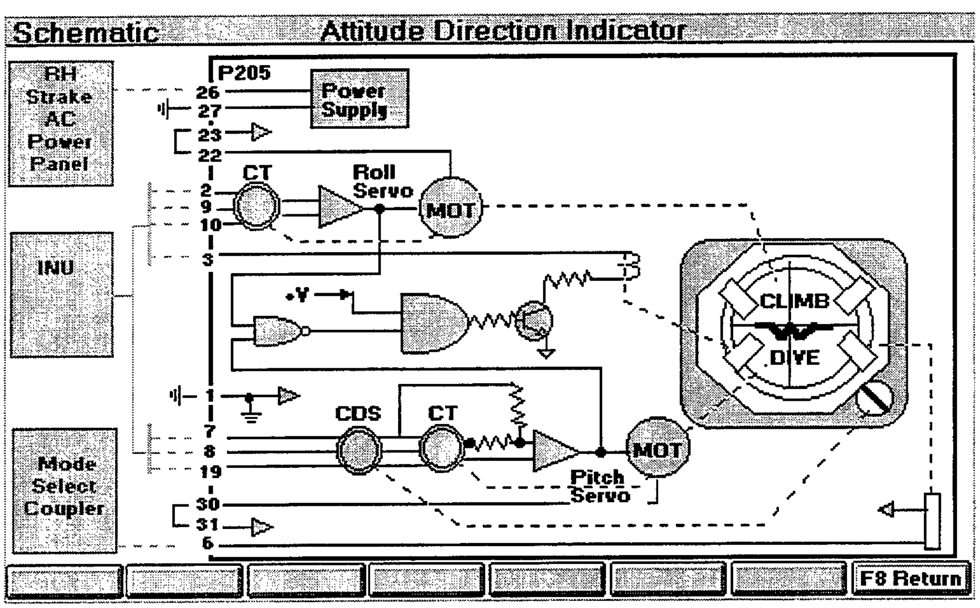

Figure 8: LRU Schematic Diagram

Ground connections for the INU are shown in Figure 9. This information is scattered in the fault isolation manuals and wiring diagrams in paper based technical manuals. Repair/replace procedures and Theory of Operations for the LRU are displayed in a similar fashion. The theory of operation for the INU is shown in Figure 10.

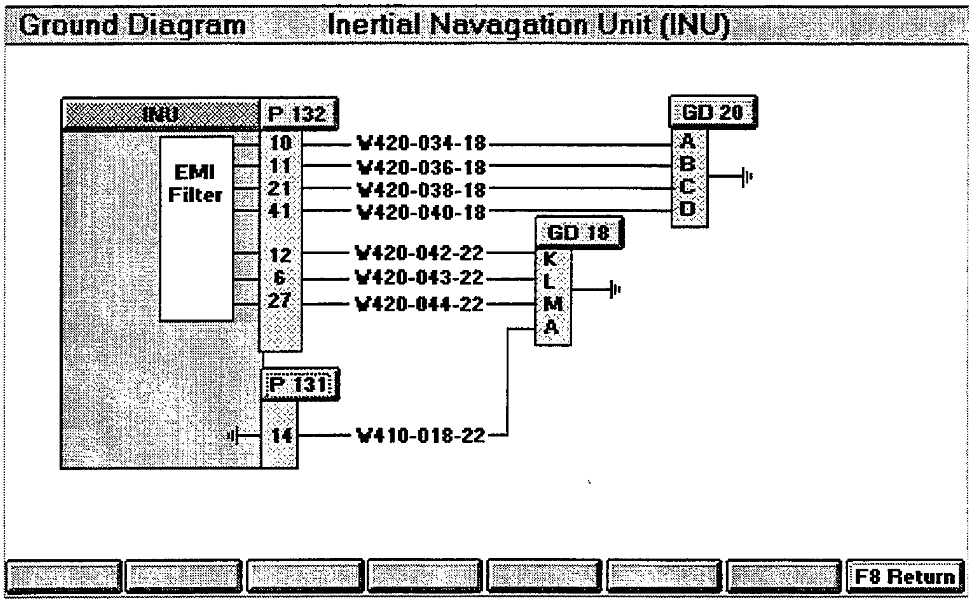

Figure 9: LRU Ground Connection Diagram

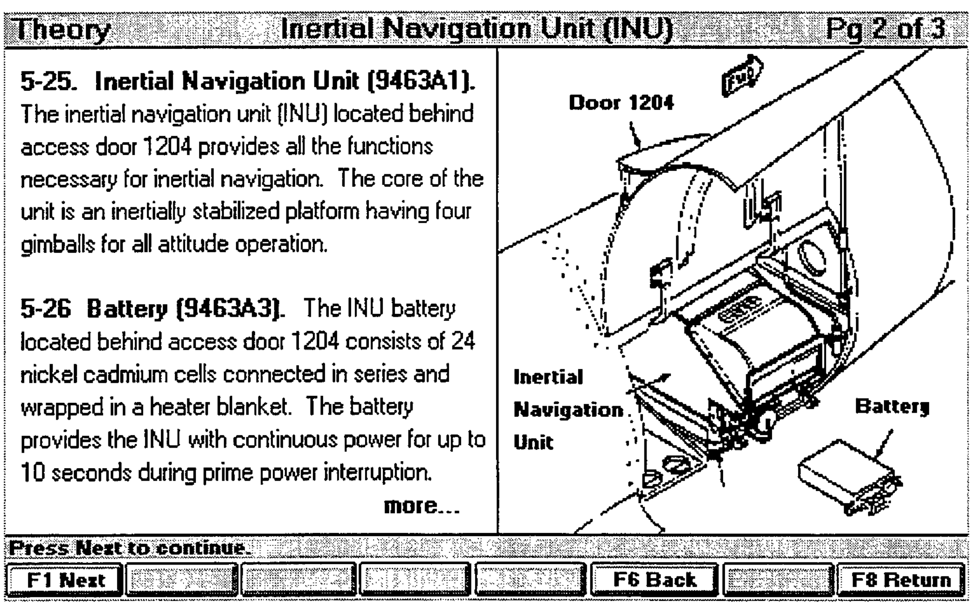

Figure 10: Theory of Operations for a LRU

Plugs and Jacks can be selected (Figure 11) to obtain part information, locator diagrams, repair procedures (Job Guides) and pin map diagrams. The pin map diagram approach was employed in the IMIS F/A-18 test and may be useful when the connector pin/socket numbers have worn off (Figure 12).

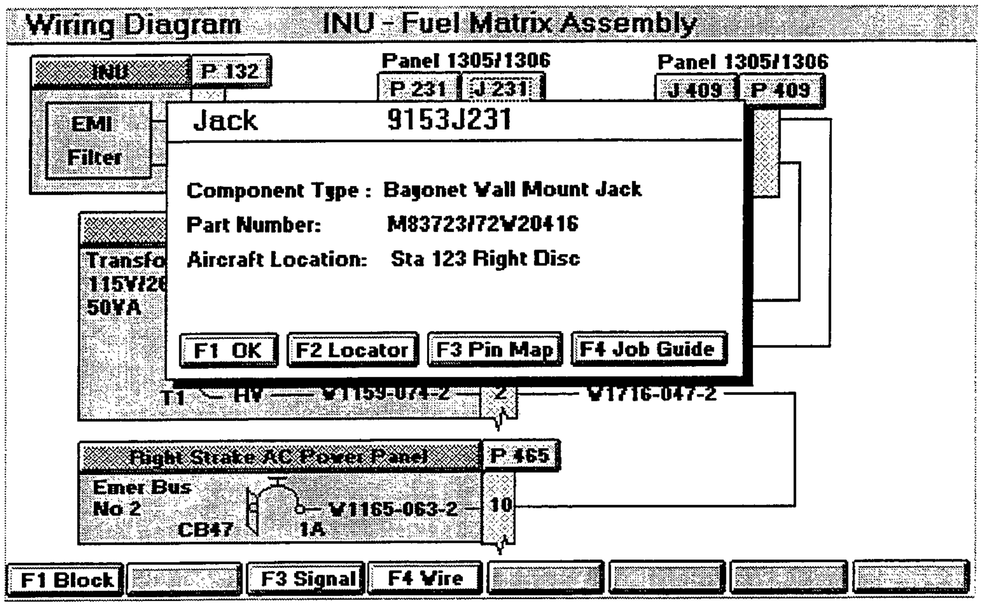

Figure 11: Connector Support Information

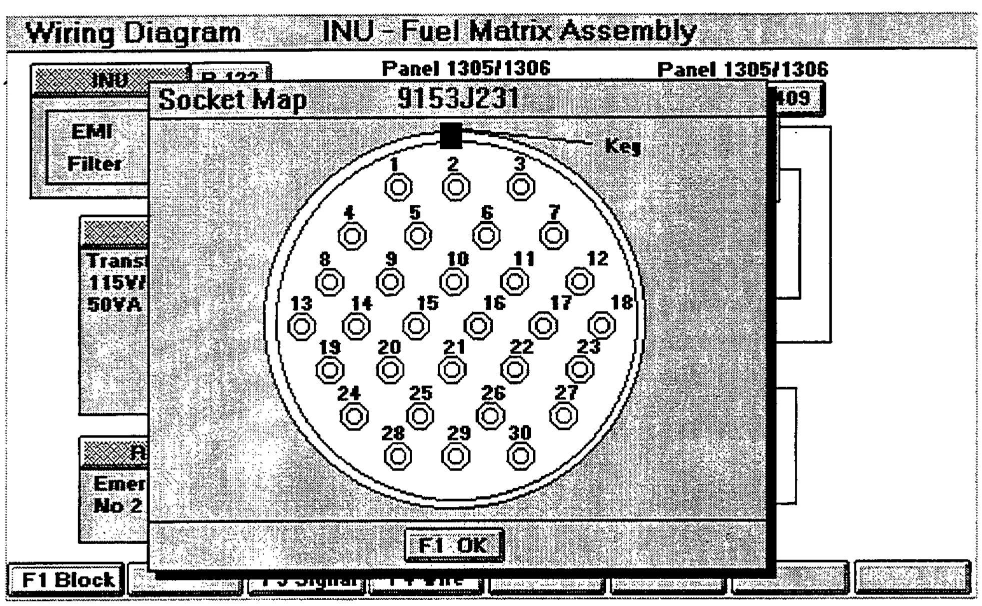

Figure 12: Pin/Socket Map for Electrical Connector

Wires can be selected to obtain detailed legend information found in the GV Manuals (Figure 13), location diagram for the wire harness and wire repair procedures. The legend information for wire numbers is similar to that employed by FCMDS.

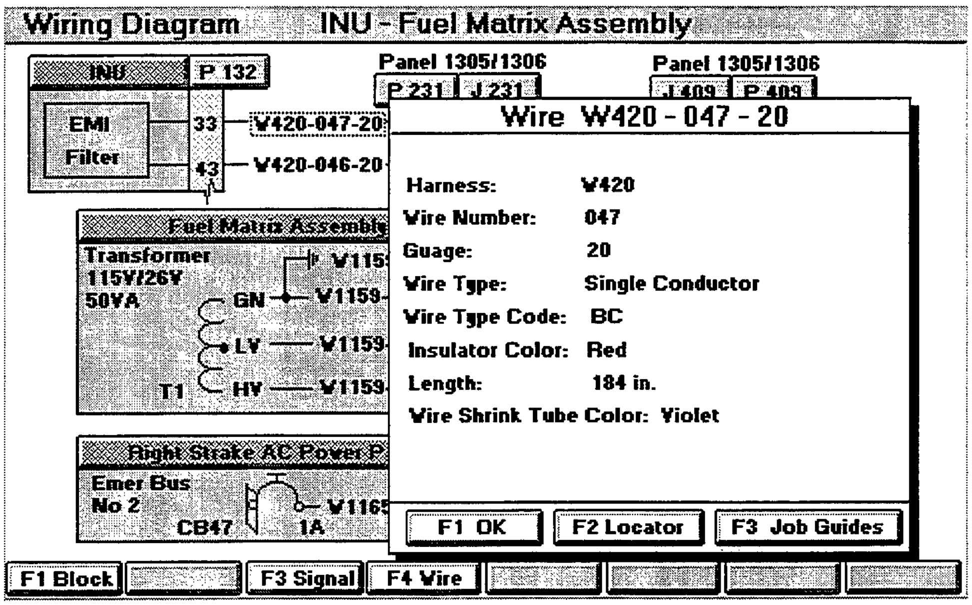

Figure 13: Wiring Support Information

As has been demonstrated in this section, the TFD concept overcomes some of the complexities associated with displaying large functional diagrams on a portable computer display. Additionally, the TFD concept overcomes some of the noted problems with a single wire system, such as used by FCMDS.

DISCUSSION

There are several areas of research which must address the dilemma associated with displaying schematic and wiring diagrams on a portable computer. These issues can be divided into presentation issues and data issues.

Presentation Issues

The presentation system for TFD was designed for a specific screen size (8"x6"). Ideally, a presentation system would allow the sub diagrams to increase in size if more display area were available.

Obviously, the INU is not the most complex sub-system in the F-16. The Flight Control System is much more complex and would require several pages of block diagrams to depict all sub-diagrams. Additionally, several components may have numerous connections (more than can fit on a screen) and would require several screens. Further research is needed to evaluate the ability of the TFD approach to support maintenance of more complex systems.

Large schematics still pose a problem, especially of large, complex sub-systems. These diagrams should be evaluated to determine if further simplification would be satisfactory for flightline use. Display of these diagrams will require several screens which must be interconnected. The Fisheye concept appears to be promising, but remains unproven.

The fisheye concept was applied to an F-18 Hydraulic system schematic diagram (Mitta, 1992). Likewise, the TFD approach needs investigated for the display of hydraulic components and connections.

Several features could be added to the TFD system to improve its effectiveness. Wire tracing functions which would allow the technician to traverse the sub-diagrams via connectivity would be useful. During free-form troubleshooting, Plug/Jack queries allowing the technician to go straight to a plug/jack in a sub-diagram would allow immediate access to the required information for further troubleshooting. Allowing the technician to "check off" sub-diagrams in a free-form troubleshooting mode would eliminate redundant troubleshooting.

Data Issues

Source data for the implementation of an operational TFD is a concern. Existing CAD/CAM systems used in engineering design of aircraft must be investigated to determine how much data can be obtained "for free" and how much must be created. For example, exact location art for the location and doors/panels for bulkhead connectors may not exist. Pin numbers for all pins on a particular connector do not exist. These types of data would have to be created to support a TFD system. Some of the FCMDS limitations are based on the unavailability of such data.

The layout of the sub-diagrams must be authored. The simplified schematics for the F-16 Paper Technical Manuals were authored for paper presentation. Likewise, a sub-diagram perspective must be taken by the future technical writers for IETMs. With the help of technical experts, the schematics may be "broken up" to better fit on portable computer screens.

Once the data is available, how it is represented is another challenging issue. All of the technical aspects associated with data representation for IETM schematic and wiring diagrams are beyond the scope of this paper. However, the user information requirements should drive the data requirements. These requirements, once specified, should be incorporated into the MIL-D-87269 for future procurements.

CONCLUSIONS

The TFD prototype system is an example of how complex diagrams can be segmented into functional groups for electronic display. Concepts from both theoretical and applied approaches to displaying functional diagrams were applied. The TFD was developed using technician information requirements to filter the data so that only the information required to perform a specific troubleshooting task is presented. Supplemental information which may be required to support the task is readily available.

The TFD prototype is an initial version and must be validated by flightline technicians to assure its usability. Continuing work with technicians from the F-16 SPO will provide user support for later versions of the demonstration software.

Before the TFD concept can be implemented in specifications for an operational environment, many issues must be resolved. Ongoing efforts to support the electronic display of schematic and wiring diagrams for flightline maintenance must continue to address the challenges associated with displaying large functional diagrams on a portable computer.

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ACRONYMS

ADI	Attitude Director Indicator
AL	Armstrong Laboratory
BIT	Built-in Test
CRT	Cathode Ray Tubes
FCMDS	Flight Control Maintenance Diagnostic System
FCR	Fire Control Radar
FI	Fault isolation
GV	General Vehicle
IETM	Interactive Electronic Technical Manual
IMIS	Integrated Maintenance Information System
INS	Inertial Navigation Set
INU	Inertial Navigation Unit
IPB	Illustrated Parts Breakdown
LCD	Liquid Crystal Displays
LRU	Line Replaceable Units
PMA	Portable Maintenance Aids
SPO	Special Program Office
TFD	Task Filtered Display of Functional Diagrams