DOCUMENTED BRIEFING

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Multifunctional Information Distribution System (MIDS) Program Case Study

Daniel Gonzales, Daniel Norton, Myron Hura

Project AIR FORCE

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PREFACE

This documented briefing examines the Multifunctional Information Distribution System (MIDS) program and the challenges that the Air Force and the MIDS International Program Office (IPO) will likely face as the program moves into the production phase. A number of options are presented that could help the Air Force, the other U.S. military services, and the MIDS international partners meet future challenges. This case study should be of interest to Air Force planners and program managers involved in the development and upgrade of U.S. Air Force aircraft and those involved in the development and acquisition of future tactical data communication systems for ships, aircraft, air defense sites, and command and control centers.

This study, part of *the Interoperability of Allied and U.S. Air Forces in Future Operations* project, was conducted in the Aerospace Force Development Program of Project AIR FORCE.

PROJECT AIR FORCE

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We also thank Maj Gen Hawley (ret., AC2ISRC/CC), Brig Gen Nagy (SAF/AQI), and Brig Gen McFarland (ESC/CV) for their helpful comments and insights. We have done our best to capture their observations accurately in this case study, but any errors or omissions are our fault alone.

Finally, we thank Phillip Feldman of RAND and Tim Bonds, Director of the RAND Project AIR FORCE Aerospace Force Development Program, for their insightful and comprehensive review of this document.

ACRONYMS AND ABBREVIATIONS

2R	Class 2 terminal
ABL	Airborne Laser
AC2ISRC	Aerospace Command and Control and Intelligence, Surveillance, and Reconnaissance Center
AWACS	Airborne Early Warning and Control System
C2	command and control
CNAD	Conference of National Armaments Directors
COE	Common Operating Environment
CONOPS	Concept of Operations
DAB	Defense Acquisition Board
DCAOC	Deployed Coalition Air or Operations Center
DDR&E	Defense Research and Engineering
DGS	Deployable Ground Station
DII	Defense Information Infrastructure
DTDMA	distributed time-division multiple access
ECP	Engineering Change Proposal
EMD	Engineering and Manufacturing Decision
FAA	Federal Aviation Administration
FDL	Fighter Data Link
FDL	terminal variant of LVT
I/O	input/output
ICD	Interface Control Document
IFF	Identification Friend or Foe
IOC	Initial Operational Capability
IPF	Intermediate Pulse Frequency

IPO	International Program Office
IPS	interim power supply
ISR	Intelligence, Surveillance and Reconnaissance
JMOA	Joint Memorandum of Agreement
JPO	Joint Program Office
JSTARS	Joint Surveillance and Target Attack Radar System
JTRS	Joint Tactical Radio System
LOC	lines of code
LRIP	low rate initial production
LVT	Low Volume Terminal
MIDS	Multifunctional Information Distribution System
MP	message processor
MUX	multiplexer
NATO	North Atlantic Treaty Organization
NTE	not to exceed
ORD	Operational Requirements Document
P3I	planned project product improvement
PEC	Program Executive Council
PEO	Program Executive Officer
PMOU	Program Memorandum of Understanding
RTI	real-time interface
S2	Supplement 2
SATCOM	satellite communications
SEM-E	Standard Electronic Modules Format – E
SHAR	The Rockwell-Collins Sea Harrier
SIO	Systems Integration Office
SP	signal processing
SPAWAR	Space and Electronic Warfare

STANAG	standardization agreement
TDMA	time-division multiple access
TDP	Technical Data Package

Multifunctional Information Distribution System (MIDS) Program Case Study

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INTRODUCTION

Maj Gen John Hawley (ret.), then commander of the Aerospace Command and Control and Intelligence, Surveillance, and Reconnaissance Center (AC2ISRC), requested that we conduct a case study on the multifunctional information distribution system (MIDS) program in the Interoperability of Allied and U.S. Air Forces in Future Operations project, of which he was a co-sponsor.

MIDS is a major U.S.-led international program in which Link 16 compatible data communications terminals are being developed by a multinational group of companies. In this report, we define Link 16 as the designation for Joint Tactical Information Data System (JTIDS) waveform and protocol compatible radios that transmit and receive data messages in the TADIL J message catalog.[1] The countries funding the development of MIDS are the United States, France, Germany, Italy, and Spain. The MIDS program is led by the U.S. Navy with a U.S. Navy captain as program manager. The MIDS International Program Office (IPO) is located at the U.S. Navy Space and Electronic Warfare (SPAWAR) command in San Diego, California. By international agreement, the deputy program manager is a French military officer. This management arrangement

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[1]We define Link 16 as an encrypted high-capacity, jam-resistant, nodeless tactical digital data link network established by JTIDS-compatible communication terminals that transmit and receive data messages in the TADIL J message catalog.

reflects the cost shares of the international program partners, with the United States and France contributing the largest share of program costs.[2]

The MIDS program provides an important case in which some of the advantages and disadvantages of achieving interoperability with coalition partners can be examined. Experience from recent NATO operations indicates that it would be desirable to have interoperability between U.S. and NATO forces at several levels.

Possible levels of interoperability between coalition forces range from command and control procedures and doctrine down to the physical interfaces between communications systems. Compatible command and control procedures, training, message formats, and interoperable communications equipment should all help to facilitate more efficient and effective NATO operations. Levels of communications equipment interoperability can include (1) physical interfaces such as connectors, electrical power requirements, form factors, and cooling requirements, and (2) air interface characteristics, which include frequencies, radiated power levels, waveforms, and communications protocols. Interoperability at the lower physical level does not imply interoperability at the air interface level, and vice versa. Note that functional communications interoperability requires compatible air interfaces and message formats but not compatibility at the level of physical interfaces, although the latter might offer some benefits, such as the possibility of more streamlined, combined logistics.[3] As we shall see, the MIDS program established requirements for interoperability at multiple levels.

However, cooperative programs such as MIDS that have international partners may have longer schedules and greater costs than comparable U.S.-only programs. Such consequences may arise from the program requirement that ensures that all program members have a significant share in key technology and manufacturing aspects of the program. At a more detailed level, such potential sources of cost and schedule consequences include (1) the complex financial arrangements that are needed to ensure that all nations participating in the program are satisfied with their shares of the technology development and manufacturing, (2) the increased technical coordination and testing that is required when systems and sub-systems are being developed by multiple parties, and (3) the higher coordination costs of international projects (because of such factors as travel costs and the need to translate documents into

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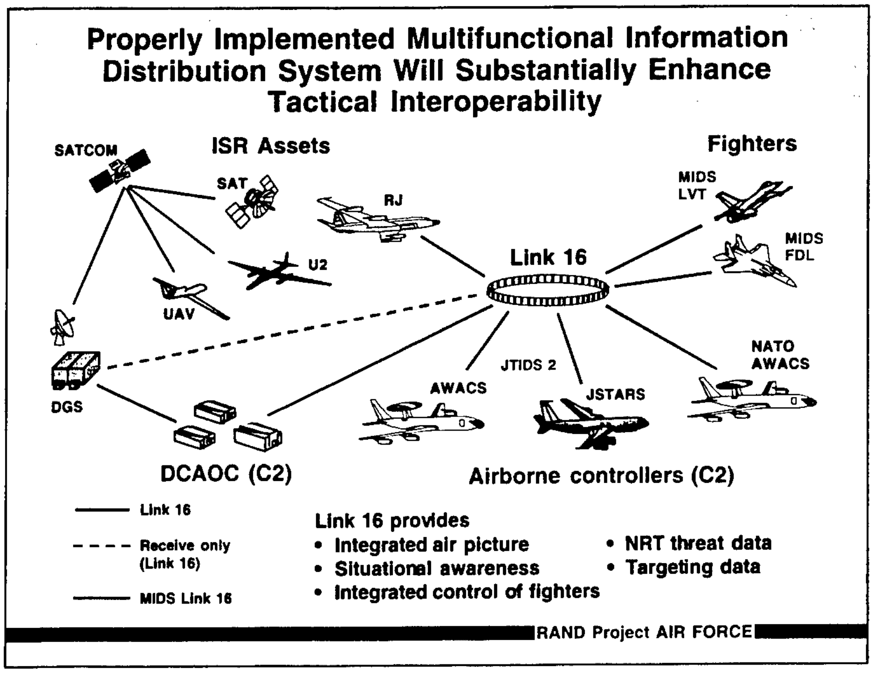
[2]Program costs and cost shares are discussed on pp. 34ff.

[3]Message formats are not considered part of air interfaces because message content processing does not take place in communications hardware or software.

multiple languages). Because coordination and testing costs depend strongly on the required levels of interoperability, a successful and cost-schedule-efficient international interoperability program must choose its interoperability requirements with care.

Despite these drawbacks, cooperative programs such as MIDS that include the transfer of technology and joint manufacturing agreements may be the only way to gain agreement between NATO allies on the characteristics and the acquisition of systems with high levels of interoperability. Significant operational benefits can be obtained by achieving high levels of interoperability using systems like MIDS developed in cooperative efforts with NATO allies.



MIDS will provide interoperable data communications that will link fighter aircraft to airborne controllers, ISR collection assets, and ground-based command and control (C2) nodes, such as a Deployed Coalition Air or Operations Center (DCAOC). Today, most U.S. Air Force and NATO fighter aircraft have only voice or very limited data communication capabilities that can connect only selected aircraft to each other.

Link 16 data communications standards and technology were originally developed in the U.S. JTIDS program that began in 1975. However, JTIDS terminals were originally deployed only on U.S. command and control aircraft such as the Airborne Early Warning and Control Systems (AWACS) and Joint Surveillance and Target Attack Radar System (JSTARS). Because of their high cost and large size, the original JTIDS terminals were never deployed onto U.S. fighter aircraft on a fleetwide basis. The MIDS program was created to put small, lightweight, Link 16 terminals on U.S. and NATO fighter aircraft. With Fighter Data Link (FDL) and Low Volume Terminal (LVT) MIDS terminals, Link 16 communications networks can include all critical airborne assets involved in air combat, including the links that connect U.S. F-15, F-16, and F/A-18 aircraft. Link 16 will provide a range of important information to U.S. combat aircraft: an integrated air picture that includes the locations, velocities, and headings of friendly and hostile aircraft, general situation awareness data (e.g., waypoints and landmarks), and amplification of data on air and ground targets that will allow the integrated control of fighters by either ground-based or airborne controllers. It will also provide the capability to transmit in near-real-time threat and targeting data to U.S. combat aircraft, thereby enabling new concepts of operation for the use of off-board sensor data in attack operations.

Scope

This case study endeavors to highlight the promises, pitfalls, and programmatic complexities of a cooperative initiative designed to achieve datalink interoperability among coalition forces at several levels. These levels are: (1) air interfaces (i.e., waveform standards); (2) physical interfaces with aircraft avionics buses; (3) message formats; and (4) command and control procedures. At the request of one of the co-sponsors, this case study focuses on the MIDS program and one short-term alternative to MIDS, the JTIDS Class 2R terminal, which was under development by the Air Force in the mid 1990s. In this case study, we assess the advantages and disadvantages of the MIDS program and examine whether the JTIDS Class 2R terminal would have provided a more cost effective and timely solution than MIDS to the urgent operational requirements of the U.S. Air Force.[4]

The MIDS program is one of the few international system development programs that has enjoyed sustained international support for an extended period of time. However, one of the drawbacks of MIDS is that it is based on JTIDS, an aging system design that takes limited advantage of recent technology developments. This case study does not address the issue of whether this program will support all fighter data link needs in future military operations. As discussed in our past work (Hura et al., 1998), additional research on this larger issue is warranted. More capable and more technologically advanced data link systems, such as the Joint Tactical Radio System (JTRS) are under development by the DoD. These systems may meet the more stressing far-term needs of the services. However, JTRS will not be available in the near term and has not been offered by the United States to NATO allies. On the other hand, if the MIDS program can be transitioned without major delays into the production phase, the urgent data link requirements of the MIDS program member nations can be satisfied in the near term while still enabling U.S.-NATO datalink interoperability. For these reasons, this case study did not examine the alternative programmatic option in which the United States abandons MIDS and accelerates the acquisition of JTRS for all U.S. platforms requiring Link 16.

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[4]The JTIDS Class 2R terminal was designed specifically for the U.S. Air Force F-15. The Class 2R terminal was not offered to NATO allies.

We also did not examine the range of long-term alternative approaches that the United States and NATO could choose to achieve interoperability at various levels by using advanced technologies.[5] As alluded to above, there appears to be no near-term alternative to MIDS for the full range of air and ground platforms that will be equipped with MIDS terminals. However, in the long term interoperability could be achieved on a number of levels if MIDS were cancelled and a more advanced datalink system were developed by the United States and NATO. These long-term options range from agreeing on: (1) common datalink air interface standards; (2) common message formats; (3) hardware interface standards for datalink terminals and the avionics buses of NATO air and ground platforms; and (4) cooperative development and acquisition programs for an advanced datalink terminal.

However, agreement over such standards and formats (options 1–3 above) may not guarantee interoperability because individual NATO nations must still commit funds and resources to produce and integrate such datalink terminals in NATO platforms. To assess the advantages and disadvantages of such long-term options, economic analyses of many redundant national advanced datalink programs should be made and compared with an equivalent analysis of a international cooperative advanced datalink program.[6] A parallel interoperability requirements analysis could then be linked with this economic analysis. Such economic and interoperability requirements analyses are beyond the scope of this case study.

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[5]An example of a technologically advanced datalink program is the U.S. National JTRS program.

[6]Such analysis would determine whether independent national datalink programs would be in the economic interests of all, some, or none of the NATO member nations, given specific assumptions concerning the levels of interoperability such a system would provide.

Research Questions

- What is the status of the MIDS EMD program?
- What problems have occurred?
- What are the risks and prospects for success?
- What are the cost implications of any problems?
- Can the MIDS IPO management and Air Force MIDS terminal-platform integration process be improved to reduce future risks?

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We sought to address several research questions. The first was to investigate the status of the MIDS Engineering and Manufacturing Decision (EMD) program.[7] The second was to identify any problems encountered in the program and to determine the nature of those problems (for example, schedule delays, cost increases, or terminal-platform integration problems). The third was to assess the risks and prospects for success of the program in the production phase in light of any problems identified in the EMD phase. The fourth was to assess the costs associated with the EMD and production phases of the MIDS program, the potential cost implications of any problems identified in our research, and to determine the net cost to the Air Force of proceeding with MIDS instead of the JTIDS Class 2R terminal program. All these issues are addressed to determine the trade-offs in time and in funding incurred by the DoD in promoting U.S.-NATO interoperability by means of a multinational acquisition program such as MIDS. Finally, we look to the future and address how management of the MIDS program and Air Force management of the MIDS-platform integration process can be improved to reduce future risks of program delays and cost increases.

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[7]The EMD program phase typically precedes low-rate or full-scale production of a system. At the conclusion of the EMD phase, the system design is frozen and the producibility of key components has been demonstrated by prospective manufacturers.

Outline

- MIDS program goals and architecture
- History, schedule, and management structure
- MIDS and JTIDS Class 2R program costs
- Summary and concluding observations
- Suggested actions

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The outline for the remainder of the briefing is as follows. First, we discuss European goals for U.S.-NATO cooperative programs, the goals of the MIDS program, and the MIDS terminal architecture. Next, we discuss the history of the MIDS program over the last decade, including how MIDS grew out to the original Air Force-led JTIDS joint service program, and review the projected schedule for the MIDS program. We then discuss projected costs of MIDS production terminals and compare those costs to the possible costs of JTIDS Class 2R production terminals if the latter program had proceeded as originally envisioned by the Air Force. Finally, we end with a summary of the issues for the MIDS program, concluding observations, and suggested actions the Air Force could take to ensure the success of the MIDS program.

MIDS PROGRAM GOALS AND ARCHITECTURE

It is important to understand the full range of goals European NATO member nations have in pursuing cooperative development programs with the United States. In particular, when it comes to interoperability programs and agreements such as the MIDS program, European nations typically have three major goals. The first goal is operational: to provide interoperable C2 or surveillance capabilities. In the particular case of data links, the goal is to have interoperability between NATO aircraft and ground- or ship-based C2 centers. In addition, because of the position location reporting and identification capabilities of Link 16 terminals, it was realized in the mid 1990s (when the MIDS program began) that MIDS could provide aircraft Identification Friend or Foe (IFF) information that originally would have been provided by the NATO MK XV IFF transponders. Furthermore, if aircraft position location, identification, and status information could be communicated quickly and accurately by means of a data communications network, it could help overcome language barriers between NATO pilots of different nationalities and help to effectively integrate the air forces of NATO member nations.

Second, European allies in NATO shared a desire for international cooperation and technology sharing with the United States, especially because the United States is rightfully viewed as the leader in many military technologies. However, few international cooperative development programs that include the United States and other NATO partners have proceeded successfully into the production phase. One such example is the NATO MK XV IFF program, which started during the 1970s when the identification of friendly and hostile aircraft in European air space was a major concern. NATO allies at that time had a strong desire to field a highly capable combat aircraft IFF system so they could replace the old and vulnerable IFF systems that were in use. An international cooperative development program was started with U.S. participation. However, as this program progressed the system grew in complexity and its cost escalated. The program was eventually canceled at the behest of the U.S. Air Force, causing tension between the United States and its European partners.

Finally, European nations have a common goal to preserve and strengthen the European industrial base, especially in an era of reduced defense spending. Cooperative development programs are especially attractive to European member nations because of the relatively small size of their military forces and the consequent small size of their military industrial firms. Consequently, although many NATO nations desire a Link 16 capability, they are reluctant to buy JTIDS terminals off-the-shelf from U.S. industry. Since the end of the Cold War, defense spending has declined significantly in Europe as well as in the United States. Thus, budget pressures and European desires to gain access to American military technology have led the Europeans to favor international acquisition programs that involve cooperative development of systems by U.S. and European defense companies. MIDS is a prime example of a program that satisfies these three European goals.

The rationale for engaging in international cooperative development programs is more limited from a U.S. point of view. The U.S. military industrial base is relatively large and the United States still enjoys a technological advantage in many types of military systems. However, interoperability at various levels between U.S. and NATO forces is nevertheless in the U.S. interest. If U.S. and NATO forces are not interoperable, it may be more difficult to carry out coalition operations effectively and achieve integrated command and control of coalition forces. NATO air operations in Kosovo illustrate the problems that can result from non-interoperability. Therefore, high-level interoperability with the forces and C2 centers of European allies is a high-priority U.S. goal.

MIDS Program Goals

- **Modular, "open" terminal architecture**
- **Terminals that can be readily tailored to "any" platform**
  - ***initially compatible with a limited set of platforms***
- **Small, lightweight, and affordable terminal that can fit on any aircraft**
- **Guarantee interoperability between U.S. and allied platforms**
  - ***by ensuring that Europeans acquire an interoperable jam-resistant airborne data link capability***

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To realize the interoperability and cooperative development goals of many NATO member nations, the MIDS program was structured in a way that would allow cooperative development and acquisition of Link 16 terminals that could be used in NATO aircraft and C2 centers. Thus, the original goals of the MIDS program, established by the participating member nations, were first to develop and use a modular open terminal architecture. An open architecture makes it easier to integrate MIDS terminals into dissimilar platforms built by different contractors. This "open" architecture predates the Defense Information Infrastructure (DII) common operating environment (COE) and is distinct from it, in that it is not specifically based on a set of open software or hardware standards. However, it is partially based on commercial standards for real-time processing systems and on the use of widely available commercial components, such as the Motorola 68040 microprocessor. We will discuss the MIDS architecture in more detail.

A second goal of the program was to develop a terminal that could be readily tailored to fit any military platform. Initially, MIDS terminals would be developed for integration into a set of platforms specified by participating member nations. Originally, the U.S. Navy F/A-18 was the only U.S. aircraft included in the MIDS program. However, the MIDS architecture can be and has been modified to accommodate additional U.S. aircraft. This goal has been only partially realized. As described in more detail later, the integration of a single type of common datalink terminal into a range of combat aircraft and ground C2 centers requires the development and adoption of multiple common hardware and software interface standards. Because of the many platform and avionics bus standards involved, the integration of MIDS terminals into aircraft and C2 centers can introduce new complexities and costs into platform upgrade programs. For example, the U.S. Air Force has incurred unanticipated costs in tailoring MIDS terminals to the planned upgraded packages for the F-16 and F-15 platforms.[8]

A third goal of the MIDS program was shared by the Air Force JTIDS Class 2R terminal program: to produce a small, lightweight Link-16 compatible terminal that could fit in any aircraft (including the fighter aircraft of participating member nations) and still be affordable. In the early days of the MIDS program, the smallest aircraft in the inventory of MIDS member nations was the F-16. Compatibility with aircraft like the F-16 has been a driving program requirement because of the volume, power, and coolant requirements it imposes on the terminal.

The final and operationally most significant goal of the program was to provide interoperable C2 data communication links between U.S. and allied platforms, regardless of whether they were ground-based C2 nodes, ships, airborne C2 nodes, or fighter aircraft. Such interoperability would be ensured by MIDS because participating member nations would be required to acquire MIDS terminals for their military forces.

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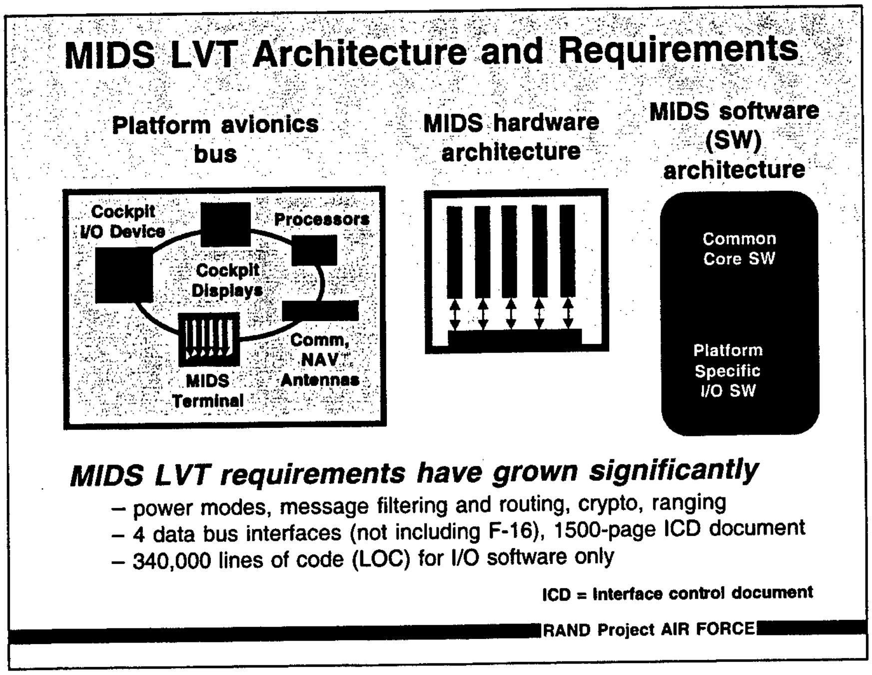
[8]The costs of modifying the MIDS terminal for integration into the F-16 will be paid for entirely by the U.S. Air Force. Some European countries, such as the Netherlands, possess F-16s. However, these countries are not participants in the MIDS EMD program. Only after the U.S. Air Force rejoined the MIDS program to equip U.S. F-16s with MIDS and the necessary MIDS terminal design changes were identified did these European countries decide to procure MIDS production phase terminals for their F-16s. In fact, the integration of MIDS terminals into European F-16s will be managed by the U.S. Air Force F-16 Special Program Office (SPO) and not by the MIDS IPO.



Shown above are key elements of the MIDS architecture for the Low Volume Terminal (LVT), the original terminal of the MIDS program. The LVT-platform integration approach is illustrated in the left-hand figure. The LVT is connected to the platform avionics bus (e.g., the 1553 bus of an F-16). Through the bus it exchanges information with platform systems, including cockpit input/output (I/O) devices such as numeric keypads, cockpit displays showing air threats or targets, communications and navigation antennas, and onboard processors. The MIDS architecture enables the LVT to exchange information with such systems on the specified platforms of participating member nations (the list of LVT compatible platforms, hereafter termed LVT platforms, is shown in the next chart).

The MIDS LVT hardware architecture is illustrated in the middle figure. The LVT chassis is common to all MIDS platforms. The chassis holds up to nine standardized electronic cards, or Standard Electronic Modules Format-E (SEM-E), each with specific functionality such as voice or message processing. The cards can easily be replaced in the event of failure or if a specific functionality is desired. A significant goal (but not a requirement) of the MIDS program is for terminals to be interoperable at the card or SEM-E level (i.e., to have the ability to take a card from the MIDS terminal on a European aircraft and place that card into a MIDS terminal on a U.S. aircraft and have that terminal function correctly). This potential outcome is not an official interoperability goal of the MIDS program because it is perceived as a high-risk endeavor. However, if MIDS card-level interoperability is realized, it could increase the logistics flexibility of NATO aircraft equipped with MIDS terminals. Further details regarding the MIDS hardware architecture can be found in the appendix, which also provides manufacturing sources for the hardware components of the system.

The MIDS LVT software architecture is divided in two major parts, as shown in the right-hand figure of the chart. The first is the common software core, which supports basic functions such as message processing, signal processing, and Link 16 waveform generation. This part is employed in the basic functioning of all MIDS terminals on all MIDS platforms.

The second major part is the I/O software module, which contains I/O interfaces that are specific to each LVT platform. For example, the U.S. reference platform for the LVT is the U.S. Navy F/A-18. The LVT I/O software module contains all the necessary software interfaces for the LVT to reside on the F/A-18 avionics bus and exchange information with other relevant bus systems.

Perhaps the most complex part of the MIDS LVT software architecture is the I/O software module. This module has grown in size and complexity because it contains the I/O interfaces needed for all LVT platforms. By design and to ensure compatibility, each LVT terminal is loaded with the *same* I/O software module, although only a portion of the module is used on any specific LVT platform. Thus, as the number of LVT platforms increases, so does the size of the I/O module. Furthermore, as the size of the I/O module has increased, it has reportedly become more difficult to add new platform interfaces to it.[9] For example, when the F-16 was first added to the list of LVT platforms, the initial estimate for the software lines of code (LOCs) that would have to be added to the I/O module for the F-16 was 100 lines. However, after a more detailed analysis of data bus and data interoperability issues, it was determined that it would take 2,000 additional lines of code, largely because of data format differences between the variants of the "standard" 1553 avionics bus on different MIDS platforms (e.g., the F/A-18 and the F-16).

A key challenge for the MIDS program since 1990 has been the harmonization of terminal requirements for the LVT platforms of the participating member nations. Requirements definition has been difficult for both hardware and software. Hardware requirements have been difficult to define for the precise locations and

[9]Communications with James Lewis, Air Force Data Link Integration Office, Electronic Systems Center, Hanscom Air Force Base.

specifications of the physical interfaces of the LVT, such as air inlets, electrical connectors, and power cables. Difficult hardware issues included the power levels for the TACAN system and for the Link 16 radio itself. The original TACAN power-level requirement was 500 watts. However, the Link 16 power-level requirement was 200 watts. Eventually, a TACAN power level of 200 watts was agreed to by the member nations to reduce cost and terminal complexity. France also reportedly wanted the terminal radio to be capable of three power levels: 1, 40, and 200 watts. In addition, France wanted the radio to be able to operate in a receive-only mode for low-probability-of-intercept operations.[10]

Another difficult hardware issue was the electromagnetic interference/electromagnetic compatibility (EMI/EMC) and radiation-hardening requirements for the terminal. The EF-2000 program had unique and rigorous EMI/EMC and radiation-hardened electronics requirements. Eventually, a compromise was reached and these requirements were dropped from the core MIDS program. Instead, Germany, Italy, and Spain agreed to jointly develop a unique power supply for a radiation-hardened version of the LVT.

Perhaps the most difficult hardware requirement issue concerned the anti-jam performance of the LVT. The original anti-jam requirement was identical to that for the JTIDS Class 2 terminal: the so-called 8/8 requirement of eight receiver-synthesizers. However, it became apparent that the 8/8 requirement was a significant cost driver for the LVT because of the need to fit the terminal within a 0.6 cubic ft volume. The MIDS member nations agreed to reduce this to a 4/4 requirement of four receiver-synthesizers.[11] Agreement on the hardware configuration for the LVT took three years to complete and was not finalized until late 1993, just before the U.S. MIDS program Defense Acquisition Board review.[12]

Negotiations to finalize the software configuration of the LVT have taken even longer to complete. This software configuration defines LVT messages, message routing procedures, acceptable avionics bus

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[10]Norman S. Bull, *Multifunctional Information Distribution System-Low Volume Terminal (MIDS-LVT)*, Defense Systems Management College, Fort Belvoir, Virginia, November 1998.

[11]The receiver-synthesizers contain up/down converters, frequency synthesizers and detectors, modulators, and switching circuits. Some authors call this device the transmitter/receiver (for example, see *JTIDS Overview Description*, JTIDS Project Staff, MTR 8413R2, MITRE, Bedford MA, 1993).

[12]Ibid.

configurations, software programmable radio modes, and other software standards for the wide variety of platforms and national C2 centers involved. Each of the MIDS member nations will use the LVT to support national operations according to specific concepts of operations (CONOPS). Because of the large number of CONOPS and different C2 centers involved, many different messaging capabilities (for example, message relay capabilities and specific reply modes) have to be programmed into the LVT, which have increased the system software complexity.

Consequently, because of the many diverse hardware and software terminal requirements of the MIDS nations, the performance specification for the LVT has grown to more than 800 pages and the interface control document (ICD) is now more than 1500 pages long.[13]

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[13]Ibid.

MIDS Member Nation LVT (1&2) Platforms

FRANCE	RAFALE Navy and Army platforms Air Force ground C2
GERMANY	EF-2000/TYPHOON ACCS platforms Frigate 124
ITALY	TORNADO FBX/SEAD AMX Navy platforms Air Force and Army ground C2 EF-2000/TYPHOON
SPAIN	EF-2000/TYPHOON EF-18 ACCS platforms (Air Force)
U.S.	F/A-18, Army ground C2, Navy ships, F-16, Airborne Laser
UK	EF-2000/TYPHOON

Total of 14 platforms

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Before we turn to further details on the MIDS software architecture, it is instructive to consider the platforms that MIDS terminals will be carried on. As alluded to above, the MIDS FDL terminal will be integrated only into U.S. Air Force F-15 aircraft.

The types of platforms that MIDS member nations will equip with the LVT are shown above. These nations will equip NATO Air Command and Control System (ACCS) C2 centers, as well as national C2 centers and force elements, with LVT.[14] This list shows the required platforms that the MIDS LVT terminal must interface with and be integrated into.

Both the U.S. Air Force and Army entered or reentered the MIDS program after it began. In 1994, the U.S. Army decided to procure a version of the MIDS terminal called LVT (2) for ground vehicles to replace the JTIDS Class 2M terminal. In 1998, the Air Force decided to acquire MIDS LVT terminals for the F-16 and for the Airborne Laser (ABL). As we shall see below, the addition of each new platform to the program has increased the complexity of the MIDS software architecture and in some cases has introduced schedule delays.

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[14]The EF-2000/TYPHOON is the next-generation Eurofighter under development by the nations indicated. AMX is an Italian fighter aircraft.

Thus, at the time data collection for this research was completed in 1999, the LVT (1) (the original LVT terminal) and the LVT (2) were being designed to be compatible with 14 platforms.

MIDS LVT and FDL Common Cards

	LVT (LOC)*	FDL (LOC)*
Core software	97,000	97,000
I/O software	340,000	24,000

*LOC: Lines of code

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The sizes of core and I/O software modules of the LVT and FDL terminals are shown above. One can see that the core software modules for the two terminals are identical in size. However, there is a great difference in the size of the I/O software modules. The FDL terminal is designed specifically for one platform—the F-15—and so the I/O module can be tailored to this platform and is relatively small, on the order of 24,000 LOC. On the other hand, the LVT terminal is designed for integration into 14 platform types. Consequently, the I/O module for this terminal is much larger, on the order of 340,000 LOC.

This difference in software complexity illustrates one of the possible drawbacks of achieving interoperability in the way envisioned in the MIDS program—developing a common data communications terminal for the many distinct platforms of the MIDS program member nations. In this regard, it is interesting to note that the LVT I/O software module is approximately 14 times larger (in terms of the number of lines of software code) than that of the FDL terminal. This factor corresponds to the number of LVT platforms.

Furthermore, in the MIDS common terminal approach, terminal integration into additional combat aircraft or a ground C2 center potentially requires the development or adoption of multiple additional common hardware and software interface standards. In addition, the messages exchanged between the terminal and other systems on the aircraft avionics bus or in a ground C2 center must be convertible into multiple message formats so messages can be processed correctly by the full range of MIDS platforms. Because of the many platform and avionics bus standards involved, the maintenance of the MIDS I/O software module may be a continuing challenge. Changes in a particular interface standard or message format used by one of the MIDS platforms may require changes to the MIDS I/O software module. Furthermore, as avionics and ground-based local area network architectures advance with technology, these physical interface standards, message standards, and message converter routines in the MIDS software I/O module will have to be upgraded too.

Finally, it should be noted that in late 1999 efforts were under way in the Congress and elsewhere to procure Link 16 (MIDS LVT) terminals for Air Force B-1, B-2, and B-52 aircraft and Navy EP-3 and S-3 aircraft. The addition of these platforms to the MIDS program will most likely require the addition of further interface standards and message formats to the MIDS software I/O module.

Outline

- MIDS program goals and architecture
- History, schedule, and management structure
- MIDS and JTIDS Class 2R program costs
- Summary and concluding observations

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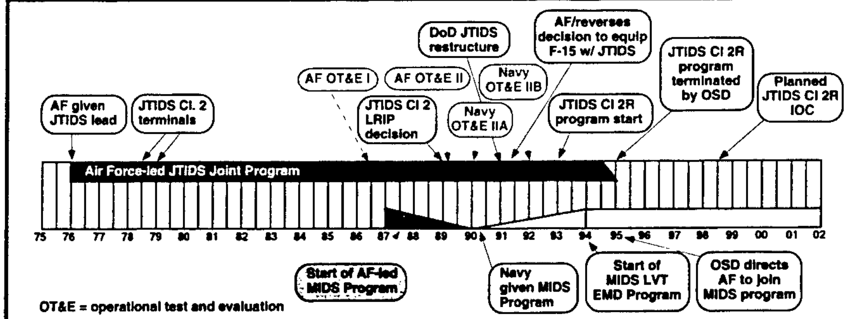
Next we turn to the history of the MIDS program and the projected schedules for LVT and FDL terminals. First, we briefly recount how the program originated.

Turbulent History of the JTIDS Class 2 Terminal and MIDS Programs



- **JTIDS Class 2 terminal program marked by testing problems and changing Service requirements**
- **JTIDS is operational on the F-15 (1 Sqdrn), AWACS, JSTARS, Rivet Joint, Airborne Battle Command and Control Center (ABCCC), E-2C, F-14, Army Forward Area Air Defense System (FAADS), Navy ships**

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HISTORY, SCHEDULE, AND MANAGEMENT STRUCTURE

The JTIDS and MIDS programs have had a long and turbulent history. JTIDS Air Force and Navy technology developments began in the late 1960s. The Air Force JTIDS system was based on a time-division multiple access (TDMA) architecture, while the Navy's competing JTIDS system was based on a distributed time-division multiple access (DTDMA) architecture. Early technical problems hampered both programs, but the problems encountered by the Navy were more severe (a working prototype DTDMA terminal was never demonstrated).

In 1974, Dr. William Perry, then director of DoD Defense Research and Engineering (DDR&E), directed that the Service JTIDS programs be combined into a single joint program. The JTIDS joint Program Office was created in 1976 and the Air Force was given the lead. The first operational application of JTIDS was the Air Force JTIDS Class 1 terminal for U.S. AWACS aircraft. JTIDS Class 1 terminals were large, taking up several cabinets' worth of space on AWACS. They could not fit onto smaller fighter aircraft. In the late 1970s, the Air Force initiated efforts to produce a JTIDS Class 2 terminal that could fit within the small confines of fighter aircraft.

In the 1980s and early 1990s, a series of operational tests were conducted by the Navy and Air Force to evaluate JTIDS Class 2 terminals. A series of problems was encountered in these operational tests, including high terminal failure rates, short lifetimes of key components, and software reliability problems. In short, the terminals were not reliable. Although the Air Force went ahead with a decision for low-rate initial production (LRIP) of the JTIDS Class 2 terminal in 1989, the JTIDS program was later restructured by DoD because of these problems. The Air Force grew increasingly concerned about the cost and reliability of JTIDS Class 2 terminals. Consequently, in 1991 the Air Force reversed its decision to equip the F-15 with JTIDS.

However, after the Gulf War the importance of data communications for situation awareness and for the rapid transfer of targeting and threat information became apparent. Also, in the early 1990s the Air Force conducted a series of successful operational tests of candidate JTIDS Class 2 terminals with an F-15 squadron at Mountain Home Air Force Base. As a consequence of these developments, in 1993 the Air Force started the JTIDS Class 2R program and in 1994 Air Combat Command published the Operational Requirements Document (ORD) for the Class 2R data link radio.

In parallel with U.S. national efforts to develop the JTIDS Class 2 terminal, the United States and NATO engaged in diplomatic and programmatic efforts to promote interoperability among NATO allies. In 1976, Dr. William Perry had offered JTIDS to NATO, where interest in JTIDS waxed and waned over the next decade. In 1987, NATO signed a Military Operational Requirement (MOR) document that stated the need for jam-resistant tactical communications. In that same year, the North Atlantic Council directed the NATO Conference of National Armaments Directors (CNAD) to complete the NATO standardization agreement (STANAG) on MIDS (STANAG 4175, *Characteristics of MIDS*). Also in 1987, phase one of the MIDS program was initiated by eight nations: the United States, Germany, Italy, Spain, France, Canada, Norway, and the United Kingdom. These nations signed a Statement of Intent to develop a Link 16 compatible data communications radio. At this time MIDS was viewed as a planned project product improvement (P3I) based upon the U.S. JTIDS program—NATO had acquired JTIDS Class 1 terminals for NATO AWACS in 1978.

Initial U.S. participation in the MIDS program was led by the Air Force because the Air Force led the JTIDS joint Program Office. In 1989, the Air Force became increasingly concerned about the reliability and cost of JTIDS Class 2 terminals. The Air Force Assistant Secretary for Acquisition wrote to OSD (A&T) expressing these concerns, and the Air Force withdrew the F-16 as the U.S. reference platform for the planned MIDS terminal. The U.S. Navy responded quickly by offering the F/A-18 as the new U.S. MIDS reference platform. The Navy proposal was accepted by OSD and the Navy assumed leadership of the MIDS program in early 1990. It should be noted, however, that the MIDS program under Navy leadership has never been a joint service program. From 1990 on the MIDS program has been an international program led by the U.S. Navy SPAWAR office PMW-101.

A MIDS Program Memorandum of Understanding (PMOU) that governs development of the MIDS terminal was signed by the participating member nations in 1991. This document restricts member nations from developing "competing systems" to the MIDS terminal. Shortly before the signing of the PMOU, three member nations withdrew from the program: Canada, Norway, and the United Kingdom.

PMOU Supplement 1 (S1) was also signed in 1991 and authorized pre-EMD negotiations among participants and national funding of risk-reduction activities by the national industries. Risk reduction and requirements-setting activities were carried out for a number of years while negotiations were under way defining cost shares and responsibilities for the MIDS EMD program. The U.S. Navy was not authorized to enter into EMD on MIDS until the program had successfully passed Defense Acquisition Board (DAB) review.

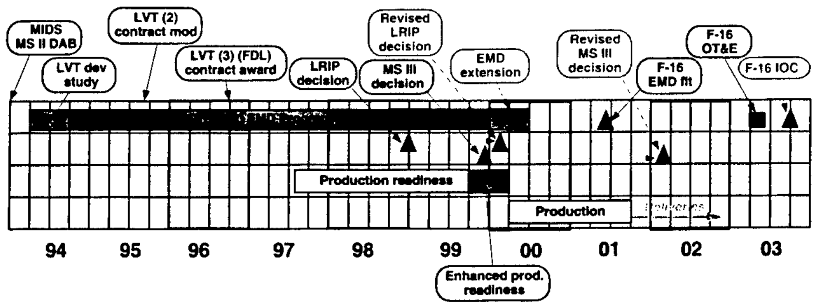
In 1993, under the leadership of Mr. Noel Longuemare, the Principal Deputy Under Secretary of Defense Acquisition and Technology, the MIDS program was restructured; an open architecture and the use of commercial parts became central features of the program. After restructuring, the MIDS program passed DAB review and shortly thereafter, in early 1994, the U.S. Navy was authorized to sign PMOU Supplement 2 (S2) and to award an EMD contract to MIDSCO, the consortium of international companies that were authorized to bid on the program. PMOU S2 defines the cost shares and management structure for the EMD program and gives the MIDS IPO the authority to contract directly with MIDSCO. It also establishes EMD exit criteria or criteria for the successful completion of this phase of the program.

Meanwhile, the Air Force and its industry partners were proceeding smoothly with the development of the JTIDS Class 2R terminal. The Air Force issued a cost target of $100,000 per terminal and planned an accelerated nondevelopmental item acquisition program for a terminal that would not be subject to traditional military acquisition standards. The Class 2R terminal was comparable in size and weight to the MIDS LVT, although it did not have all of its capabilities (e.g., no voice or TACAN capability, lower power). In 1993, the Air Force also determined that it had an urgent operational requirement for a Link 16 capability on its air superiority fighter, the F-15, by the end of 1998.

Within a short time, OSD became aware of the conflict between the MIDS LVT and the Air Force JTIDS Class 2R terminal programs. In 1995, OSD directed the Air Force to terminate the Class 2R program and effectively to join the MIDS program. A compromise was reached that satisfied the restrictions of the MIDS PMOU and that could apparently satisfy the Air Force's urgent need for Link 16 capability by the end of 1998. The Air Force could proceed with the acquisition of a Link 16 terminal for the F-15—the Fighter Data Link (FDL)—but the MIDS IPO would be responsible for the acquisition of these terminals (also called the LVT-3). Thus, the FDL program was authorized to enter directly to the production phase and to bypass the MIDS LVT EMD program, at least in terms of acquisition milestone decisions.

Despite the testing and acquisition problems associated with JTIDS terminals for fighter aircraft, JTIDS is operational on U.S. Air Force, UK, French, and NATO AWACS, on JSTARS, Rivet Joint, ABCCC, the E-2C, F-14, Army Patriot, and on Navy ships.

MIDS LVT Program History and Schedule



- **EMD and production phase issues**
  - 33 terminals constructed, but only 19 available for platform integration
  - F-16 or ABL LVT interfaces not incorporated into LVT I/O software
  - Parts availability from foreign suppliers
  - Contractor production readiness, IPO production plan

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The history for the MIDS LVT EMD program and the prognosis for a smooth transition to the production phase for the LVT terminal is discussed in this section. EMD started in 1994 with a six-month restructuring effort and development study to reduce program cost and schedule by implementing acquisition streamlining. At that time, an open architecture and the use of commercial parts were agreed to by the MIDS member nations. A one-year reduction in the original EMD program schedule was planned in this streamlining effort (in fact a year of schedule slips have been absorbed by the program). In the third quarter of 1995, an Army version of the LVT terminal was added, LVT (2). The Air Force FDL or LVT (3) contract was awarded in the third quarter of 1996.

The FDL program is subject to a production contract that is completely separate from the LVT EMD program, although there has been substantial sharing of technology and system design information between the two programs. From the program management standpoint, the relationship between the two programs has been informal, even though many contractors are developing and producing components for both of the terminal systems. Beginning in 1999, the MIDS IPO announced delays in the EMD program. Terminal LRIP was delayed one year to the first quarter of CY00. The Milestone III decision was delayed two years to the beginning of CY02. EMD was originally scheduled to end in CY99, but was extended six months to meet the program exit criteria. In addition, production readiness activities were extended by six months.

According to the MIDS IPO, there were two major reasons for the delays in the EMD program. The first was the lack of a sufficient number of EMD terminals for terminal platform-integration activities. In April 1999, there were supposed to be 33 EMD terminals available to the member nations, and the first production terminals were to be available in CY99. However, there were only 19 available at that time and terminal production was delayed until CY00.

A complicating factor was the late addition of the USAF F-16 to the LVT EMD program, which increased the EMD terminal requirement substantially beyond the initial 33 that were contracted for. However, the MIDS IPO did not have the financial resources to build the original number of EMD terminals, let alone additional ones needed for new "arrivals" to the program, because of program cost growth. As of April 1999, the F-16 program had access to only one EMD terminal out of the 14 required. The F-16 SPO will receive four additional EMD terminals in June 2000, but none thereafter. To provide additional terminals, the MIDS IPO originally suggested that the Air Force contract with MIDSCO—the EMD contractor—for additional EMD terminals at the conclusion of EMD. However, the cost of additional EMD terminals was estimated to be nearly $735,000 each, which was not acceptable. Instead, the Air Force will buy some of the first production LVT terminals for F-16 integration testing. If the production terminals can be produced for the EMD exit criteria cost of $250,000 per unit, this alternative will be much more cost-effective for the Air Force, but it will nevertheless cause the substantial schedule delays indicated above.

There appear to be two reasons for the EMD terminal shortage. The first is a shortage from foreign suppliers of key parts needed to complete the terminals. Second is the requirements growth that delayed the final terminal design. Details of terminal requirements growth or changes were not available to the authors. However, we are aware of reliability problems with the exciter/IPF (intermediate pulse frequency) card.

The second reason for the delay in the EMD program was the slow pace and incremental delivery of the Technical Data Package (TDP). A complete TDP is one of the deliverables of the EMD program, and is critical for ensuring competition and contractor readiness for the production phase of the program. The TDP will also be critical for ensuring competition for the U.S. production contract. The TDP will be owned by the MIDS member nations and not by MIDSCO, so the entire TDP or portions of it could be made available to U.S. contractors that are not members of MIDSCO. It will not provide a build-to-print blueprint of the EMD terminal. However, it should provide sufficient technical detail to produce many of the system components. The status of the TDP has caused concern in some circles regarding potential LVT contractor production readiness and with the MIDS IPO production plan.

From an Air Force perspective, the immediate effect of the delays described above has been to move the initial operational capability (IOC) for the first Link 16 capable F-16 squadron to the third quarter of CY03. This represents a delay of almost three years in fielding an operational datalink capability for the F-16. This delay is also likely to cause significant delays in fielding other avionics upgrades that will provide new operational capabilities because LVT integration into the aircraft will be done only when depot-level maintenance and other major avionics upgrades (aircraft avionics block changes) have taken place. Furthermore, rescheduling and delaying depot-level maintenance is not only significant operationally, it is also disruptive for program planners for a complex weapons system like the F-16. For example, in response to the delays in the MIDS LVT program, SAF/AQ and the F-16 SPO have had to engage in reprogramming actions and changes to adjust depot-level maintenance schedules and avionics upgrades for the F-16 fleet.[15]

In addition to the above program planning and operational concerns, the F-16 LVT interface, although approved by the MIDS IPO and MIDS steering committee, has yet to be implemented. There is concern within the Air Force that the necessary software for this interface will not be completed before the scheduled end of the EMD program. This could further delay the F-16 MIDS LVT IOC and therefore may require further delays in operational capability and reprogramming actions on the part of the F-16 SPO.[16]

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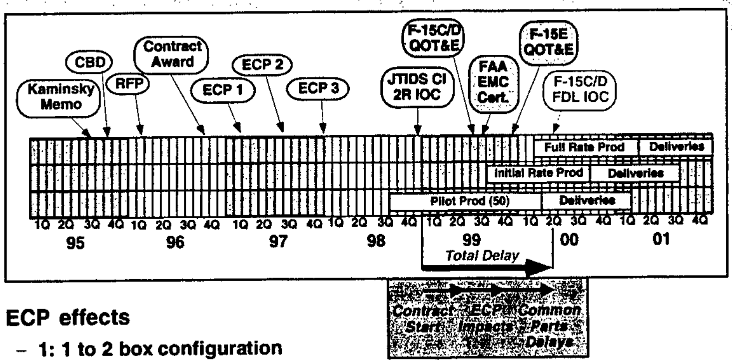
[15]Communications with Maj James Ashworth, SAF/AQI.

[16]Communications with Maj James Ashworth, SAF/AQI, and Mr. James Lewis, Air Force Data Link Integration Office, Hanscom Air Force Base.

MIDS FDL Program History and Schedule



- **ECP effects**
  - **1: 1 to 2 box configuration**
  - **2: FAA EMC certification changes**
  - **3: Addition of F-15E (common configuration terminal)**
- **Total delay approximately 22 months**
  - **Additional delays due to delays in production of parts common with the LVT program**

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When the FDL program began, the scheduled date for Initial Operational Capability (IOC) of the first F-15 squadron was at the end of 1998 (coinciding with the original requirement for the JTIDS Class 2R terminal IOC). However, the F-15 FDL IOC has been delayed for five main reasons:

1. An initial delay with contractor award (this appears to have been caused by congressional budget actions in FY95).
2. Engineering Change Proposal (ECP) 1. Hardware configuration was changed from "one box" to "two box," changing the FDL terminal design to closely resemble that of the LVT. From this point on, the FDL and LVT terminals were based on common software and hardware.
3. ECP 2. A number of changes were required for electromagnetic compatibility certification from the Federal Aviation Administration (FAA). These changes comprise ECP 2.
4. ECP 3. The F-15E was added to the program. Because the F-15E has a digital avionics bus that is entirely different from the analog avionics bus of the earlier versions of the F-15, new interface software was required for the LVT. This I/O software development made up ECP 3.

5. Common parts delays. After ECP 1, a number of parts became common to the LVT and FDL. Some of these parts have been in short supply because of contractor difficulties in producing reliable components, such as exciter/IPF cards, causing delays in the FDL program.

According to MIDS IPO projections, the FDL IOC will occur approximately 22 months later than planned for the JTIDS Class 2R terminal. If additional parts delays are encountered in the LVT program, there could be further delays in the FDL program. Just as with the F-16 upgrade program, major avionics block upgrades will be accomplished when FDL terminals are integrated into the F-15 fleet (both Air Force National Guard and active duty Air Force F-15s). Further delays in FDL terminal acquisition could further delay the entire set of F-15 fleet upgrade programs.[17]

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[17]Communications with Maj James Ashworth, SAF/AQI, and Mr. James Lewis, Air Force Data Link Integration Office, Hanscom Air Force Base.

MIDS IPO Management Structure

EMD phase

- **Navy program manager, French deputy program manager**
- **MIDS steering committee: international body**
  - **joint issues resolved within IPO**
- **Program executive council included 3 service PEOs**
- **OASDC3I (Mr. Bennet Hart) program sponsor**

Production phase

- **Program management structure and cost shares in negotiation**
- **Draft PMOU Supplement 3 and JMOA stipulate IPO central management of European and U.S. MIDS terminal production***

Issues: viable production plan, Air Force insight into program status, and Air Force SPO-IPO coordination

* Program Memorandum of Understanding (PMOU) Supplement 3 (S3) and the Joint Memorandum of Agreement (JMOA) respectively govern the international and U.S. tri-Service aspects of the MIDS program.

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During the EMD phase of the program, the IPO is directed by Navy O6-level program manager; the deputy program manager is a French O6-level officer.

The international board of directors for the MIDS program is called the MIDS Steering Committee. Each nation has one representative on the committee. The U.S. representative is the OSD program sponsor, Mr. Bennett Hart from OASDC3I. The Steering Committee is given substantial management authority for the EMD program as stipulated in PMOU S2.

The MIDS EMD program also has a U.S.-only management committee, the Program Executive Council (PEC). The U.S. Air Force representative to the PEC is Brig Gen McFarland (EST/CV). The PEC is chaired by the Navy Program Executive Officer (PEO). The role of the PEC is limited largely to financial issues, such as program cost sharing between the individual services. For example, how to share non-recurring start-up costs for production was actively debated in the PEC recently. In this regard, it is important to realize that MIDS is not a joint service program. It is a Navy-led international program. Therefore, according to the current MIDS program manager, detailed joint issues regarding costs and schedules are to be resolved within the MIDS IPO.

At the time this research was conducted, the senior Air Force officer within the MIDS IPO was an O6-level officer. However, this individual did not have written or agreed-upon responsibilities within the IPO. He was a kind of Air Force representative-at-large within the IPO. Therefore, it was not clear to the authors of this report whether the senior Air Force officer in the IPO had timely access to all program information necessary to manage the program efficiently from an Air Force perspective or to coordinate with other acquisition organizations in the Air Force, such as the fighter SPOs.

The management structure for the EMD program was established several years ago when PMOU S2 was negotiated and signed by the member nations. However, the management structure and cost shares among the international partners for the production phase are in negotiation and will be established in PMOU S3. Details of the draft PMOU S3 were not made available to the authors except for a few major features of the draft agreement. One of these stipulates that the IPO will remain the central management structure for the procurement of both European and U.S. MIDS terminals. European MIDS terminals will be acquired under a separate contract with a single European industry consortium. However, the U.S. contract for MIDS terminals destined for U.S. platforms will be competed. Many of the details of how these two contracts will be managed are likely to be laid out in PMOU S3.

A second agreement, the Joint Memorandum of Agreement (JMOA), establishes the contributions and roles of the individual U.S. military services in the MIDS program. A draft JMOA for the production phase of the MIDS program is also under negotiation. Because the EMD program is essentially a Navy program, the roles of the Air Force and Army are rather limited. An issue that should be addressed by the Air Force in the ongoing negotiations over the JMOA that will apply to the production phase is whether the Air Force should have a larger and more substantial role in the production phase. The following issues are also relevant to the Air Force:

1. Does the MIDS IPO have a viable production plan that will enable MIDS terminals to be delivered on schedule and on budget?

2. Does the Air Force have sufficient insight into the status of and changes in the program as they occur?

3. Does the current Air Force role in the MIDS IPO enable sufficient coordination between the IPO and relevant Air Force SPOs, such as the F-16 SPO?

Outline

- MIDS program goals and architecture
- History, schedule, and management structure
- ➡ MIDS and JTIDS Class 2R program costs
- Summary and concluding observations

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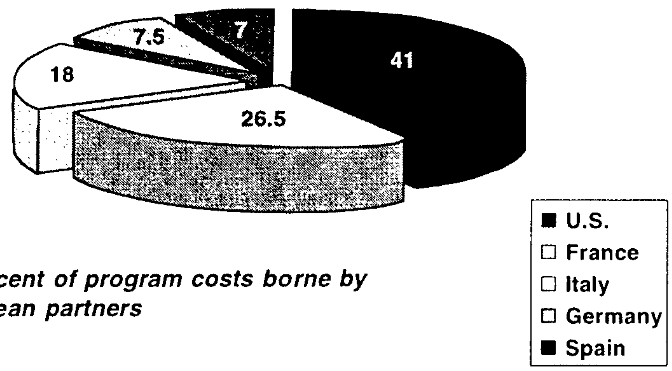
Next we consider the cost implications of achieving interoperability among NATO allies through the MIDS program. First, we briefly review the international cost structure of the current EMD program. We then consider how the costs of the FDL terminal might compare with those of the JTIDS Class 2R terminal if the latter program had not been canceled. This will provide insights into the cost penalty, if any, for achieving interoperability in a cooperative development program such as MIDS. We then examine how nonrecurring start-up costs have been shared between the U.S. military services in several past programs. We contrast these with the estimated nonrecurring start-up costs for the MIDS program. We conclude with some observations on the overall costs of the program.

Cost Shares for MIDS-EMD Program*



59 percent of program costs borne by European partners

*Percentage of EMD program costs for international partners defined in PMOU Supplement 2

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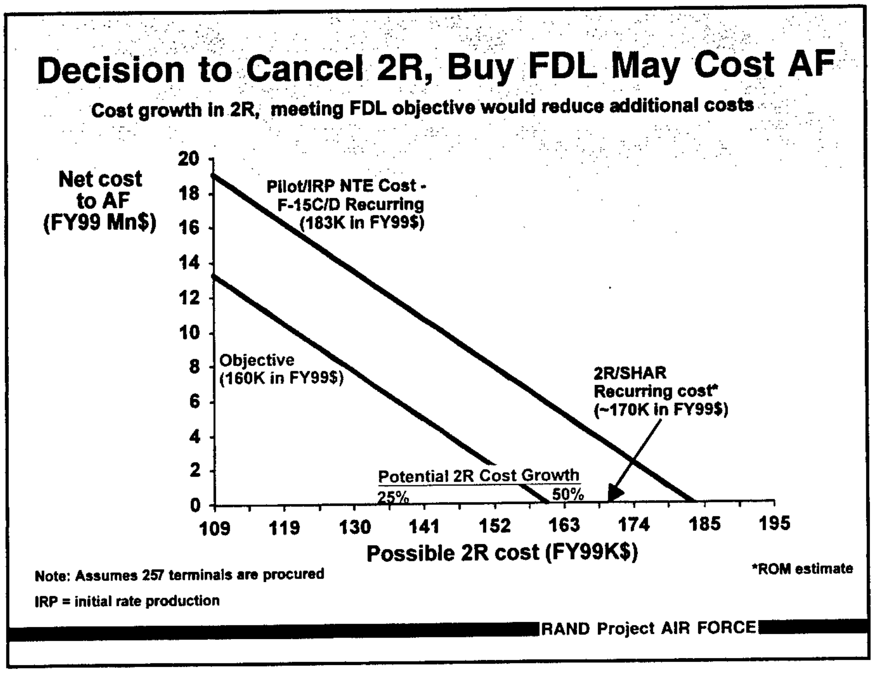
MIDS AND JTIDS CLASS 2R PROGRAM COSTS

The share of RDT&E spending funded by each partner country is defined in PMOU Supplement 2. The funding shares were determined roughly in accordance with their expected share of the total buy. The value of the EMD contracts given to contractors from participating MIDS program member nations were allocated on the basis of their EMD contribution. The largest share has been funded by the United States, at approximately $265 million, with France and Italy not far behind. Note that the majority of EMD program funding is provided by the European member nations.



In February 1995, the Air Force announced the need for a reduced function JTIDS Class 2 terminal (2R) for the F-15 to meet a critical need date of December 1998. It subsequently received a bid to provide Class 2R terminals at a unit cost of $109,000. In August of that year, the Undersecretary of Defense for Acquisition & Technology directed the Air Force to join the MIDS-LVT program and cancel the 2R.

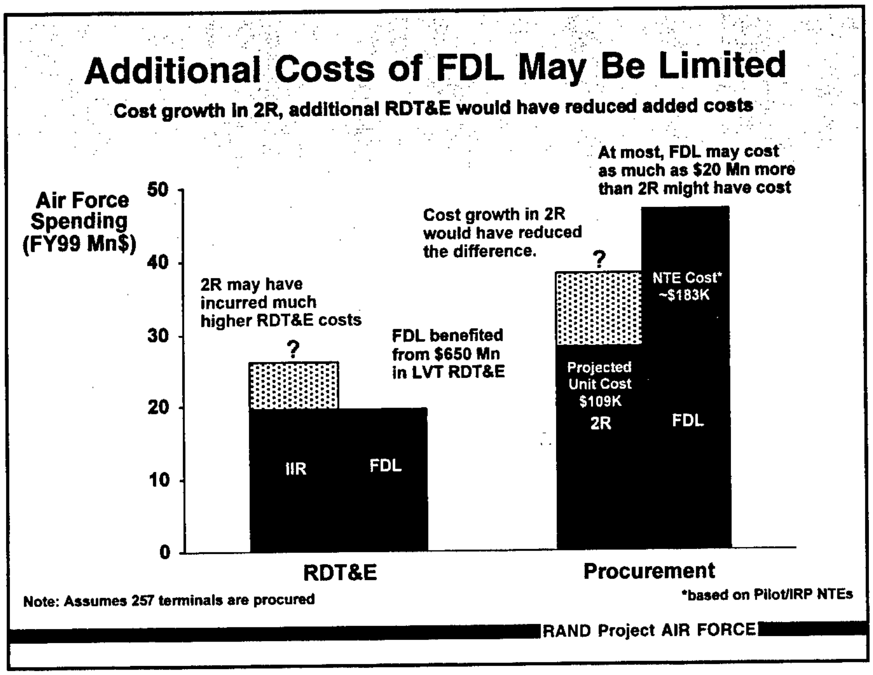
The cost implications of the decision to cancel 2R and join the MIDS program are uncertain. As of this writing, the not-to-exceed (NTE) cost for the pilot buy of 50 MIDS-FDL terminals is about $183,000. These are the only units currently under contract. The objective cost is approximately $160,000. Note that both the 2R target and FDL objective costs are approximate. The 2R terminal was never under contract, while the FDL costs for the remaining lot buys remain to be negotiated.

Had the Air Force been able to procure the 2R at the target price, the additional cost per terminal would have been $50–$75,000, or between $13 and $20 million for the current 257 terminal buy. This $13–20 million figure represents an upper bound on the net cost impact.

However, it's not clear that the 2R program would have come in at its target cost. The Rockwell-Collins Sea Harrier (SHAR) terminal is a derivative of the 2R terminal, and its specifications are similar to those of the original 2R. Thus, it provides an indication of what the

2R might have cost had it continued in development and gone into production. The SHAR cost is consistent with FDL costs, falling midway between the NTE pilot cost and the objective cost. Had the 2R come in at the SHAR cost, the net cost of the decision to terminate the 2R and buy FDL would have been negligible. Had the 2R cost increased by 25–50 percent, the net cost impact would have been on the order of a few to several million dollars.

Even in the worst case, the net cost of the decision to cancel the 2R and procure the FDL is small relative to Air Force spending on modifications for the F-15, which runs into the hundreds of millions of dollars each year. Had the 2R not achieved its cost objective, the net impact would have been even less.



Adding in RDT&E spending provides a more complete assessment of the possible cost impact of the decision to cancel the 2R terminal and procure FDL. As noted earlier, the Air Force may have incurred as much as $20 million in additional costs from that decision. Cost growth in the 2R program would have reduced the total.

However, procuring a MIDS terminal variant (FDL) for the F-15 allowed the Air Force to leverage off of the $650 million RDT&E investment made by the Navy and the allied partners involved in the program. This investment level dwarfs the relatively modest RDT&E effort associated with FDL. The high degree of commonality between the FDL and LVT terminals and software suggests that the FDL program has benefited from LVT RDT&E. Discussions with the program office confirm this finding.

Had the Air Force continued with the 2R program, it might have been forced to fund additional development efforts, thus offsetting some of the additional costs associated with procuring FDL. The 2R terminal did not continue in development, so it's impossible to determine what additional RDT&E costs might have been incurred. Still, any additional costs would have further reduced the net cost of the decision.

In FY99, the Air Force and the Navy disagreed about the allocation of nonrecurring costs in the MIDS-LVT program. The Air Force position had been that it is simply buying additional units and thus shouldn't have to fund its full share of nonrecurring costs. The

Navy view was that each of the services should pay for nonrecurring costs in proportion to the number of terminals they are buying.

A look at five current joint programs provides some perspective on the issue. In virtually every case, the share of the nonrecurring costs borne by the lead service is slightly to moderately in excess of the quantity procured. The lone exception is the Air Force-led JDAM program, where the Navy is paying four-fifths of the nonrecurring costs yet buying only a quarter of the total quantity.

If the MIDS LVT program is viewed in isolation, it follows the established pattern of the lead service disproportionately paying the nonrecurring costs. However, the Air Force share of those costs is substantially less than its share of the buy, thus lending some credence to the Navy position. The cost of bringing the Air Force into rough compliance with the practice in other joint programs would be on the order of $4–5 million, a relatively small amount in the context of the total program.

However, the high degree of linkage between the MIDS-LVT and FDL programs suggests that they should be viewed as one program rather than two individual programs. When viewed together, the assessment changes substantially. The Air Force is paying a share of the combined nonrecurring costs commensurate with its share of the total buy, and thus no additional Air Force funding for nonrecurring costs is warranted.

After this research was completed, the authors learned that OSD had directed the Navy to pay for the nonrecurring costs of the MIDS LVT program.

In some ways, the MIDS terminal program has been a dramatic success. Six nations have participated in the development, and all plan to procure the system. Each of the participants has a substantial incentive to continue with the program in that their domestic industries are rewarded as a function of the country's participation. The integration of MIDS on allied fighters should substantially increase situational awareness and subsequently increase force effectiveness. U.S. exercises have repeatedly shown that JTIDS-equipped aircraft perform much more effectively than equivalent aircraft that lack the system.

However, the success of the program has not come without cost. Had the United States and other nations chosen to procure an off-the-shelf JTIDS terminal such as SHAR, they might have avoided paying hundreds of millions of dollars in MIDS RDT&E costs. They might have saved on procurement as well, as SHAR's costs are substantially lower than those of MIDS.

Discussion of the MIDS and SHAR programs is complicated by the fact that they are not independent. SHAR is built by Rockwell-Collins, a major partner in Digital Link Solutions, the prime contractor for the FDL program. SHAR probably benefited from the substantial RDT&E investment made in the MIDS program. In the absence of MIDS, SHAR's development costs might have been much greater.

While it's possible that the United States could have procured JTIDS terminals at a lower cost than that of MIDS, such an arrangement probably would have involved only U.S. contractors. The NATO allies may not have been willing to simply procure a U.S. system. They might have pursued an independent program instead, and subsequently ended up with a system that might have been less compatible with JTIDS systems. Absent U.S. leadership, they might not have pursued a JTIDS capability at all and would subsequently not achieve the improvements in interoperability that they are likely to enjoy over the next few years.

Thus, the success of the program must be viewed in the context of the broader policy objectives. MIDS may be more expensive than some of the alternatives, but it has created incentives for allied participation and significantly enhanced the likelihood that aircraft participating in future coalition operations will have greater situational awareness and subsequently greater effectiveness than they do today.

Outline

- MIDS program goals and architecture
- History, schedule, and management structure
- MIDS and JTIDS Class 2R program costs
- ➡ Summary and concluding observations

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Summary of MIDS Program Issues

LVT

- **Increasing software complexity**
- **Schedule delay of at least one year**
  - Late addition of the USAF ABL and F-16 platforms
  - Parts availability from foreign suppliers
  - Contractor production readiness
- **Does the MIDS IPO have a viable production plan?**
  - Air Force insight into the program
- **Platform integration linked avionics upgrade programs**
  - MIDS delays have caused nearly a *three-year delay* in F-16 Link 16 operational capability

FDL

- **Schedule delay**
- **High degree of commonality with LVT**
  - Parts availability concerns

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SUMMARY AND CONCLUDING OBSERVATIONS

Shown above is a summary of the major MIDS program issues identified in this study. The major issues relating to the LVT program are: (1) increasing software complexity; (2) a one-year delay in the availability of LRIP terminals; (3) concerns regarding the MIDS IPO production plan; and (4) delays in integrating terminals into Air Force platforms.

We found that the increasing software complexity arises from requirements growth and the addition of more platforms to the program. Schedule delays resulted from the late addition of Air Force platforms to the program, parts shortages, and contractor production readiness concerns that led to a delay in completion of the EMD phase. The sources of schedule delay and the unanticipated announcement of the delay have in turn led to concerns about whether the MIDS IPO has a viable terminal production plan and whether the Air Force has sufficient insight into the inner workings of the program. Finally, the schedule delay has had an adverse effect on planned avionics upgrades for the Air Force F-16 program. Because MIDS terminals must be integrated into platforms during major avionics upgrade programs, a delay in the MIDS program can have a ripple effect and cause major disruption to these upgrades. Furthermore, as MIDS terminal integration is linked to these upgrade programs, a delay in the MIDS program can cause delays in the fielding of a range of operation capabilities that could take place with the upgrades.

The FDL portion of the MIDS program has also suffered delays because of changing requirements, parts availability concerns, and FAA certification. Finally, future delays or parts problems in the LVT program could cause similar delays or problems in the FDL program because of the high degree of commonality between the systems. For better or worse, the two portions of the program are now tightly linked.

Observations

- Decision to cancel 2R and join MIDS has had cost and schedule implications for the Air Force
  - Additional cost might reach $12-20M, but less is likely
  - F-15 JTIDS IOC may have been delayed 22 months (vs. 2R plan)
  - *Potentially significant additional cost and schedule impacts on fighter upgrade programs*
- MIDS program may not have survived without U.S. Air Force participation initially with FDL and later with LVT procurement
- AF participation in MIDS program should bring key interoperability and cost benefits
  - Will encourage continued allied participation, enabling interoperability
  - AF buys to drive down terminal costs (should realize substantial savings)
  - AF able to leverage $650M allied/USN investment
- MIDS, a complex international program, could be subject to future delays leading to a continuing management challenge
  - Current senior AF officer in IPO has no officially agreed-upon duties
- Air Force now intimately linked to MIDS program and its risks
  - Linkage between LVT and FDL programs
  - MIDS presents significant risks to F-16 and F-15E upgrade programs
- If procurement and integration programs are properly implemented, allied participation will enhance interoperability

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We conclude with the following observations. First, we found that the cancellation of the JTIDS Class 2R program and the decision to join the MIDS program have had cost and schedule implications for the Air Force. The additional cost for a MIDS Link 16 terminal system may be as much as $20 million, but the actual cost is probably much less. There is also a possibility that the Class 2R program would have encountered significant cost growth that could have reduced the cost advantage for the 2R terminal.[18]

More important to the Air Force has been the delay in acquiring a Link 16 capability for F-15 aircraft. We estimate this delay to be a minimum of almost two years, if we include only the delays associated with delivery of the terminals. There may be additional delays arising from possible difficulties in coordinating avionics upgrades, FDL integration, and depot-level maintenance for the USAF F-15 fleet. Furthermore, because the MIDS LVT EMD program has incurred a substantial delay as well, there will also be a minimum delay of nearly three years in the IOC of a Link 16 capability for USAF F-16s. As a consequence, the entire F-16 upgrade program has had to be reprogrammed to adjust for the LVT delay.

[18]For example, according to some OSD officials familiar with the OSD Cost Analysis Improvement Group (CAIG), the group concluded that the cost projections for the terminal were too optimistic. The quantitative cost estimates of this group were not made available to RAND for this study.

There have been benefits to the decision as well. Air Force participation in the program, early on with the FDL portion of the program and later in the LVT procurement, has helped to ensure the survival of the MIDS program. This is important to the U.S. and its European partners. Now that the Air Force is a major participant in the program, its survival should be assured as long as the program meets its cost and schedule targets.

Furthermore, continued Air Force participation in the MIDS program should bring key cost and interoperability benefits. By doing so, the Air Force will encourage continued allied participation in the program during the production phase, thereby enabling Link 16 interoperability of U.S. and NATO forces. The substantial Air Force LVT procurement should drive down terminal costs for the Navy and possibly for the other countries. The Air Force should be able to leverage the $650 million investment in technology and terminal design that has been made by the other MIDS member nations and the U.S. Navy. Economies of scale and this investment should reduce the costs of producing reliable Link 16 terminals.

Nevertheless, MIDS is a complex international program that could be subject to additional delays and cost growth. Effective execution of the MIDS program in the production phase will present numerous management challenges to the IPO, including acquisition management and apportionment of production units to several user platforms in three services, quality control, and configuration management. Under the existing EMD management arrangement, the current senior Air Force officer in the IPO has no officially agreed-upon or assigned duties; thus, Air Force insight into this complex program is difficult and challenging. To ensure its equities as the largest single buyer of MIDS terminals, the USAF should be directly involved in defining the management structure for the production phase of MIDS.

Despite the many problems encountered in the turbulent history of the JTIDS and MIDS programs, MIDS is now an important program for both the USAF and U.S. Navy because it will provide the first extensive deployment of a NATO interoperable Link 16 network to MIDS platforms. Furthermore, it appears that both services now have within their reach a Link 16 data communications terminal that can fit in fighter aircraft and still be affordable.

Finally, it should be noted that the LVT and FDL programs are now closely linked. Therefore, while MIDS holds significant promise for the Air Force, it also possesses programmatic risks for both the F-16 and F-15 upgrade programs because of the linkage to avionics upgrade programs. However, if the MIDS program can be managed effectively in the production phase and MIDS platform integration issues are addressed, Air Force, Navy, Army, and allied participation in the MIDS program will substantially enhance the interoperability of U.S. and NATO forces.

Suggested Actions

- Ensure LVT EMD program successfully completed
  - Complete technical document to allow production by multiple vendors,* meet exit cost criteria
- Strengthen production phase management structure to ensure viable production program and increased AF insight into program
  - 1. Maintain as a Navy-led program, establish clear set of responsibilities for senior AF officer in IPO in amended JMOA. Or,
  - 2. Convert to a joint program, without amending JMOA, with AF PM proposed by AF PEC representative. Or,
  - 3. Convert to a joint program by amending the JMOA governing the MIDS program.
- Ensure effective coordination of MIDS production phase with AF aircraft upgrade programs
  - Central Air Force (ESC/SIO) management of MIDS terminal acquisition
- Continue to coordinate Link 16 CONOPS development with allies through NATO working groups (AC2ISRC/C2PT)

*Document may also enable card-level interoperability, although feasibility is an issue.

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SUGGESTED ACTIONS

To ensure that the production phase for the LVT and FDL programs is successful, a number of actions should be taken by the Air Force. First, the Air Force should closely monitor the LVT EMD program and verify that it is successfully completed. The Technical Data Package must be completed with sufficient detail to ensure that the production of LVT terminals can be undertaken by multiple U.S. vendors. This action should foster sufficient competition in the production phase. It is also important to verify that the EMD program exit cost criteria are met.

Further, the management structure of the MIDS IPO should be modified in the production phase to provide the Air Force with sufficient visibility and commensurate responsibilities for adequate coordination of the MIDS production program with Air Force fighter and other platform upgrade programs. We believe there are three options for doing this.

The first option would have the least impact on the existing management structure. In this case, MIDS would continue to be a U.S. Navy-led program. However, the senior Air Force officer in the IPO would be given a clear set of management responsibilities that would be agreed upon by negotiation among U.S. services. These responsibilities would be recorded in the Joint Memorandum of Agreement (JMOA), now under negotiation for the production phase of the program.

A second option is to create a joint U.S. MIDS program within the IPO, without changing the international management structure of the program. This may be possible by having the Air Force representative on the MIDS Program Executive Council (PEC) nominate a senior O-6 Air Force officer to the position of Joint Program Director. It may be that the draft JMOA that is now under negotiation for the production phase program would not have to be amended, but it might require the approval of international partners in the IPO. Because we have been unable to gain access to PMOU S2, we do not know whether this option would be acceptable to the other MIDS member nations. Furthermore, because we do not have access to the draft JMOA, we do not know precisely what mechanisms it permits for the possible transition of MIDS to a joint program (as has been suggested by some knowledgeable parties).

The third option would be to convert the MIDS program into a true joint service program. One way to do this would be to amend the JMOA that is now under negotiation to explicitly call for the rotation of the program director position between the Air Force and the Navy. Again, because we have not seen the PMOU S2, we don't know if this option would be acceptable to the other U.S. services and MIDS member nations.

The factors that need to be considered before choosing a particular option include the total additional cost to the Air Force of taking a management leadership role in the MIDS program and the risks the Air Force would incur by not taking such leadership role. The overhead costs for managing a joint international program could be substantial, and additional costs may be incurred in moving or consolidating program offices to one central location. However, in the long run the costs and risks to the Air Force could be far higher if the Air Force does nothing to reduce the risks of MIDS terminal production and delivery delays. The avionics upgrade programs for Air Force fighter and bomber aircraft could be adversely affected, as alluded to earlier in this briefing.

Whether the MIDS IPO management structure is changed or not, coordination between the MIDS program and the Air Force fighter SPOs should be improved. Perhaps the most effective way of doing this is to ensure central Air Force management of MIDS terminal acquisition and integration. Currently, the Electronic Systems Center Systems Integration Office (ESC/SIO) nominally has this responsibility. However, funding reductions have limited the ability of ESC/SIO to carry out the added responsibility as the MIDS program proceeds into the production phase. This office, or another appropriate organization, should be provided with clear terms of reference and sufficient funding for effective central Air Force management of MIDS terminal acquisition for all Air Force platforms.

Finally, another important dimension to the effective operational employment of Link 16 and MIDS is the cooperative development and use of concepts of operation for this sophisticated data communications capability. In future coalition operations, U.S. aircraft and C2 nodes may communicate via Link 16 with aircraft or C2 nodes of other NATO nations, so it is imperative that all coalition partners have a common understanding and definition for the concepts of operation for Link 16. The Air Force JINTACCS office, AC2ISRC/C2PT, is charged with coordinating TADIL J message standardization efforts with NATO partners and in representing Air Force positions in U.S. joint and NATO working groups. The activities of this office are vital in ensuring that Link 16 and MIDS can be used effectively in future coalition operations.

Implications of Suggested Actions

- **Technical document, JMOA actions, *or conversion to a MIDS JPO,* should allow AF to**
  - **Minimize risk of further delays and cost increases in developing and producing terminals**
  - **Reduce risk of future complications in implementing upgrades after the system is fielded**
- **Central AF management actions, *or conversion to a MIDS JPO,* should allow AF to**
  - **Match acquisition schedule with depot mods cycle for each aircraft to minimize integration cost and aircraft downtime**
  - **Align MIDS procurement plans for different platforms to ensure efficient production and reduce cost**
  - **Ensure MIDS employment in NATO air operations**

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Completion of the technical document or data package, amendments to the JMOA to permit greater Air Force management participation in the program, or the conversion of the MIDS program to a Joint Program Office (JPO) should allow the Air Force to:

1. Minimize the risk of further delays in the MIDS program and possible cost increases for MIDS production terminals.
2. Reduce risk of complications in implementing upgrades to the MIDS architecture after the system is fielded.

Central management of Air Force MIDS terminal acquisitions, or conversion of the MIDS program to a JPO should allow the Air Force to:

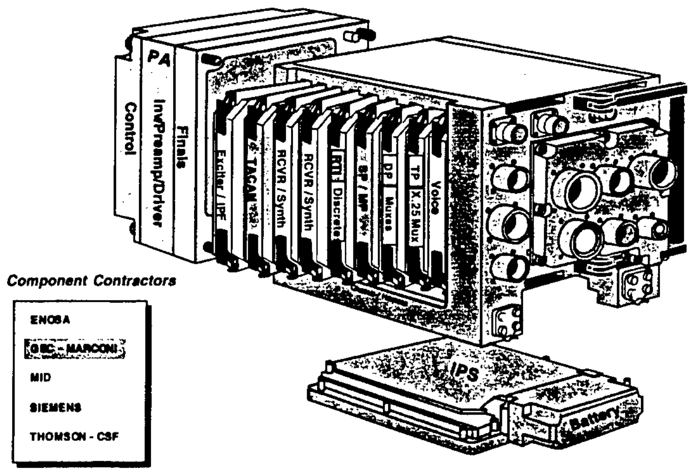
1. Better match the acquisition schedule for U.S. Air Force fighter and bomber aircraft with the depot modifications cycle for each aircraft to minimize terminal integration costs and aircraft downtime.
2. Better align plans for different Air Force platforms to ensure the efficient use of production terminals, to reduce overall integration costs, and to ensure that the Air Force fleet of aircraft is upgraded with MIDS terminals as soon as possible.
3. Ensure effective MIDS employment in future NATO air operations.

Appendix

MIDS SYSTEM COMPONENTS AND MANUFACTURING SOURCES

In this appendix, we consider the MIDS hardware architecture in more detail, giving the specific functionality and manufacturing sources for each MIDS SEM-E card. From this description, the truly international character of this program and the large European content of each MIDS terminal become apparent. The details of the MIDS LVT and FDL terminal hardware architectures also reveal the commonality between these terminals in their current design configuration and which MIDS SEM-E cards of the two systems will be common.

MIDS Low Volume Terminal (LVT) Configuration



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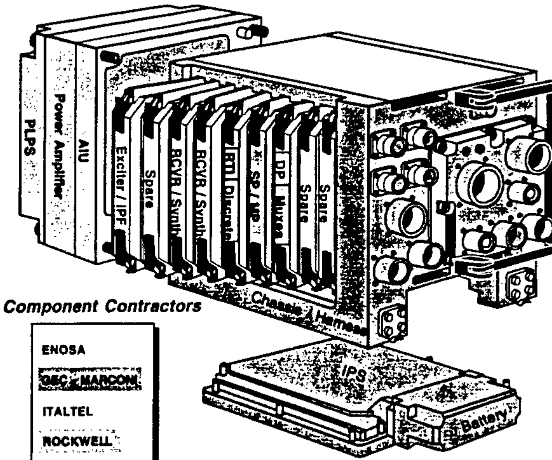
The MIDS LVT terminal will be manufactured by a U.S. and European industrial team. The shading of terminal components in the chart indicates which contractors of the international industrial team make specific components of the EMD version of the LVT terminal. The chassis, interim power supply (IPS), and battery are manufactured by GEC-Marconi, a U.S. contractor. The MIDS LVT TACAN, signal processing (SP), message processing (MP), and real-time interface (RTI) cards are also manufactured by GEC-Marconi. The power amplifier is manufactured by Siemens of Germany. The receiver-synthesizer cards are manufactured by Thompson-CSF of France. The voice card, tactical processor, and data processor are manufactured by the Italian company ENOSA. Finally, other components including the exciter/intermediate pulse frequency (IPF) are manufactured by a European consortium formed for the MIDS program called MID.[1]

The contractor team for the production phase and the design of components for the production version of the terminal may differ from that for the LVT EMD terminal. In particular, the contractor team for U.S. production phase terminals may differ considerably from the LVT EMD terminal contractor team because of efforts to generate competition for the U.S. LVT production buy.

[1]The exciter/IPF generates the JTIDS waveform at an intermediate frequency and is responsible for IFF and TACAN beacon signal interference control.

An important element of the modular open architecture adopted for the MIDS program is evident in the chart. The chassis is based on the commercial standard VME backplane or system bus. Processors and control units on individual cards communicate with one another through the VME backplane.

MIDS Fighter Data Link (FDL) Terminal Configuration



MIDS FDL / LVT Commonality

Item	100% Common	LVT Modified	New Variant Module
DP	X		
1553 MUX			X
SMP	X		
RTI	X		
Discrete			X
R/S (2)	X		
Exciter/IPF	X		
PA/AIU			X
IPS	X		
Chassis		X	
PCU			X
Core SW	X		
Tailored SW			X

* FDL Tailored elements are backward compatible to LVT

Component Contractors

ENOSA
GEC-MARCONI
ITALTEL
ROCKWELL
THOMSON - CSF

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In 1995, the Air Force joined the MIDS program with a new variant of the MIDS LVT terminal called the MIDS Fighter Data Link (FDL). The FDL terminal is designed specifically for the U.S. Air Force F-15. Its major components and cards are illustrated above. FDL has 80 percent hardware and software in common with the LVT. One can see that it shares the same modular open architecture of the LVT, although the FDL chassis is a slightly modified version of the LVT chassis. Also shown are the contractors that manufacture system components. Note that new variants of existing LVT components were necessary in some cases because of unique avionics standards or performance requirements related to the F-15 avionics environment. For example, the 1553 bus on the F-15 differs from the 1553 bus on the F-16 and on other NATO aircraft, so the 1553 multiplexer had to be modified for the F-15.

The FDL terminal design differs from the LVT. The FDL has no voice or TACAN capability (it has no requirement for this capability), and it has a lower maximum transmit power level of 50 watts (200 watts for the LVT). Thus, the FDL has a smaller anti-jam link margin than the LVT in the transmit mode and a shorter range of 200 nmi relative to the 300 nmi range of the LVT. Both the LVT and FDL have the same physical dimensions of 0.6 cubic ft.

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