TACTICAL DATA LINKS

There has long been a need for interoperable data communications for fighter aircraft. Today, most U.S. and NATO allies' fighters communicate using unsecure analog radios that provide only interactive voice communications. This severely limits the coalition partners' ability to reliably share a wide range of combat data in addition to voice over a secure, jam-resistant communications network.

Communications systems that include TADIL capabilities offer a near-term solution for exchanging digital data over a common network that is continuously and automatically updated. Precise quantitative information (data) can be sent faster and more reliably via direct digital (i.e., computer-to-computer) communications. In addition, text messages need only a small fraction of the communications resources that interactive voice messages require and can also be delivered much more reliably than voice in high-stress combat conditions.

Moreover, digital modulation[1] offers many advantages over analog modulation. Four of these are particularly important: the ability to send data; the ability to encrypt voice or data;[2] the use of error detection and correction coding, which increases the reliability and

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[1]Digital modulation means that information (voice or data) is transmitted as a sequence of discrete symbols, each of which represents a small number of bits. Voice must be converted to a digital stream, a process that is performed by a vocoder.

[2]Analog voice can be scrambled, but this is much less secure than encryption of digital voice and also tends to degrade intelligibility.

quality of transmissions over channels affected by noise, interference, or fading; and, depending on the digital modulation scheme used, a means to distribute energy in ways that can hide the signal to provide for low probability of detection or resistance to jamming.

TADIL J, JTIDS, AND LINK 16

Several communications systems have been developed over many years to support TADIL communications, or the near-real-time exchange of data among tactical data systems. Each such system is specified by hardware/software characteristics (e.g., waveform, modulation, data rates, transmission media, etc.) as well as by message and protocol standards. The most recent system is the JTIDS/TADIL J system, which is commonly referred to as Link 16 in the United States. Link 16 is an encrypted, 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.

Link 16 data communications standards and technology were developed in the U.S. JTIDS program, which began in 1975. The first JTIDS terminals or Class 1 terminals were large and were installed only on AWACS and at U.S., U.K., and NATO ground-control facilities. Smaller JTIDS terminals (Class 2) were also developed. However, because of their high cost, large size, and reliability issues, only a limited number of such terminals were procured to equip U.S. fighters specifically—U.S. Navy F-14Ds and a single squadron of U.S. Air Force F-15Cs.

The MIDS program was created to put small, lightweight Link 16 terminals on U.S. and participating allies' fighter aircraft. MIDS is a major international program led by the United States, specifically the U.S. Navy, and has a Navy captain as its program manager. By international agreement, the deputy program manager MIDS is a French military officer.[3] The countries funding the development of MIDS are the United States, France, Germany, Italy, and Spain.

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

With the Low Volume Terminal (LVT) and Fighter Data Link (FDL) terminals—the two terminals being developed and acquired under the MIDS program—Link 16 communications networks will encompass all critical airborne assets involved in air combat, including U.S. F-15, F-16, and F/A-18 aircraft and selected NATO-ally fighters. As indicated in Figure 9.1, MIDS will link fighters to airborne controllers, selected to ISR collection and exploitation centers, and to ground-based C2 nodes such as DCAOCs.

Link 16 can provide a range of combat information in near-real time to U.S. and NATO allies' combat aircraft and C2 centers. The displayed information includes an integrated air picture with both friendly and hostile aircraft locations, general situational awareness data, and amplifying data on air and ground targets, including air defense threats. This will contribute to the integrated control of fighters by either ground-based or airborne controllers and will greatly increase the fighters' situational awareness and ability either to engage targets designated by controllers or to avoid threats, thereby increasing mission effectiveness and reducing fratricide and attrition. An in-depth description of the U.S. Air Force concept of Link 16 employment (COLE) for counterair, interdiction, SEAD, and
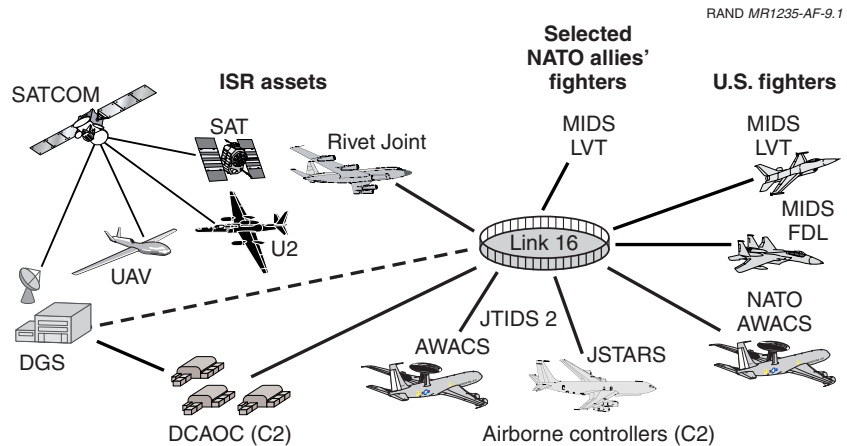
RAND *MR1235-AF-9.1*

Figure 9.1—MIDS in the Future Interoperable Tactical
Communications Architecture

CAS missions can be found in the COLE document prepared by the Link 16 System Integration Office.[4] This document describes the information that will be exchanged, how it will be used to support each mission, and the data link architecture that will be employed.

Table 9.1 provides a representative list of the various Link 16 terminals and the platforms (both U.S. and NATO allies) on which they are currently installed or planned for the near future (2010). In principle, if any of these platforms are within line of sight, they could establish tactical communications using Link 16.

LINK 16 TERMINOLOGY

Because Link 16 terminology is not standardized within the United States or within NATO, we list here the specific standards to clearly indicate how we are using the terms in this report. We also compare U.S. and NATO definitions and standards.

As discussed above, Link 16 uses JTIDS-compatible communication terminals that transmit and receive data messages in the TADIL J message catalog. Specifically, the terminal interface standards (hardware/software) are presented in the JTIDS System Segment Specification (SSS) (DCB79S4000C), and the procedural interface standards (message formats and protocols) are presented in the TADIL J Message Standard (MIL-STD-6016).

These definitions and standards can be illustrated by examining the process for information exchange for a particular mission. Figure 9.2 illustrates this process for the counterair mission. The AWACS surveillance sensor detects a threat. An AWACS crew member prepares the information that will be sent to the F-15C using the situation display console (SDC). The flight processor takes the information and formats it into TADIL J messages. The JTIDS Class 2H terminal encrypts the messages and transmits them to the JTIDS network. The F-15C's JTIDS Class 2 terminal receives the messages, decrypts them, and filters out nonrelevant messages. The flight pro-

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[4]See Electronic System sCenter (1997).

Table 9.1

Representative Installations of Link 16 Terminals

Terminal	Current	Planned (2010)
JTIDS Class 1	None	None
JTIDS Class 2	US: F-14D, E-2C, ABCCC, JSTARS, MCE/TAOM, Rivet Joint, F-15C,[a] submarines UK: ADGE, Tornado F3,[b] NIMROD MR	No additional systems
JTIDS Class 2H	US: AWACS, MCE/TAOM NATO: AWACS, NADGE UK/FR: AWACS	No additional systems
JTIDS Class 2H Shipboard	US: aircraft carriers, destroyers, cruisers	UK: carriers, destroyers
JTIDS Class 2M	US: FAAD, Patriot NL/GE: Patriot	No additional systems
JTIDS Class 2R (never developed)	None	None
SHAR (2R derivative)	None	UK: Sea Harrier
MIDS LVT(1)	None	US: F-16, ABL, F/A-18A/F, Navy ships, submarines FR: Rafale, AF ground C2, Navy platforms GE: EF-2000, ACCS platforms, Navy Frigate 124 IT: Tornado FBX/SEAD, AMX, EF 2000, Navy platforms SP: EF-2000, EF-18 UK: EF-2000, JSF
MIDS LVT(2)	None	US: FAAD, THAAD, other C2 FR: Army platforms IT: Ground C2 (AF & Army) SP: ACCS platforms (AF)

Table 9.1—continued

Terminal	Current	Planned (2010)
MIDS LVT(3)/FDL	None	US: F-15A/E
Specific terminal to be determined[c]		US: F-117, A-10, F-22, B-1, B-2, B-52, JSF
		UK: JSF

NOTES:

ABCCC = Airborne Battlefield Command and Control Center (USAF).

ACCS = Air Command and Control System (NATO).

ADGE = Air Defense Ground Environment (U.K.).

FAAD = forward area air defense (U.S. Army).

MCE/TAOM = modular control equipment/tactical air operator module (USAF, USMC).

NADGE = NATO Air Defense Ground Environment.

THAAD = Theater High-Altitude Area Defense (U.S. Army).

[a]Eighteen F-15Cs are equipped with Class 2 terminals.

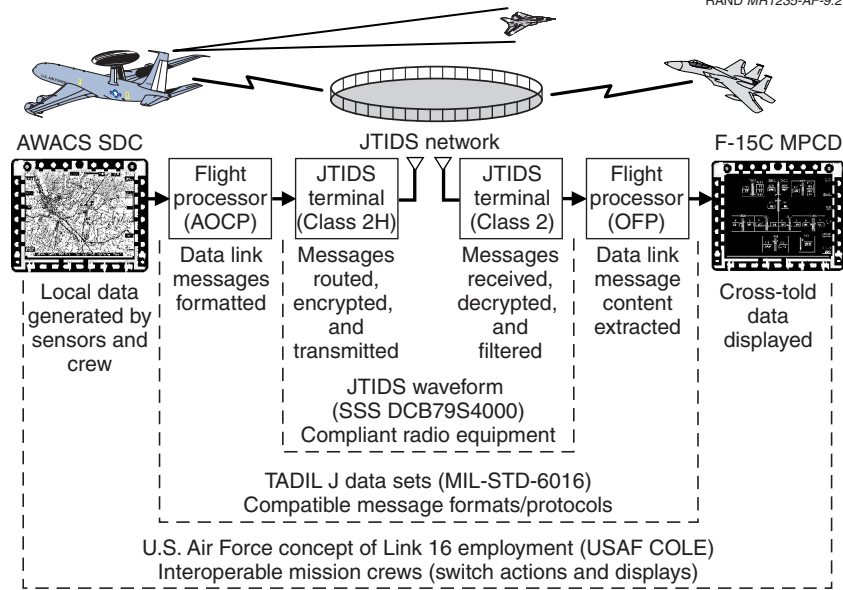[b]Three squadrons of Tornado F3s are equipped with Class 2 Link 16 terminals.

[c]At the end of 1999, Air Force data link plans envision incorporating Link 16 terminals on all fighters and bombers. Terminal selection has not been made.

cessor then extracts the content from the messages and displays the information on the F-15C's multipurpose color display (MPCD).

The JTIDS-compliant radio equipment and the TADIL J message formats and protocols are clearly illustrated. The definition of Link 16 provided above includes just these two components. A broader definition of Link 16 is depicted in Figure 9.2. This system-of-systems concept includes the systems used by the aircrews to perform the functions to move the information from one aircrew to another. Although this broader definition is not used in this report, it clearly depicts the aircrews' role in Link 16 and the need for interoperability at the aircrew level.

Within the United States, confusion arises when JTIDS and Link 16 are used interchangeably for the data link. JTIDS and JTIDS-compliant radio equipment (such as MIDS) are just the communications element. There is also confusion surrounding the use of TADIL J. Some want the term to apply to the link, and others want the term to apply only to the message formats and protocols (as

Figure 9.2—Counterair Example of Link 16 (JTIDS/TADIL J) Employment

defined by MIL-STD-6016). In this report, we use TADIL J only for the message formats and protocols.

NATO has a different view of this terminology. The TADIL J messages and protocols become "Link 16" (STANAG 5516), while the JTIDS communication element becomes "MIDS" (STANAG 4175). Thus, NATO uses Link 16 in a narrower sense than that used in the United States. There are also differences in standard operating procedures: The United States uses the Joint Multi-TADIL Operating Procedures (JMTOP) (Chairman Joint Chiefs of Staff Manual CJCSM 6120.01), and NATO uses Allied Data Publication-16 (ADAP-16). JMTOP has been recommended to NATO for adoption. The different specifications are listed in Table 9.2. It is probably not necessary to

Table 9.2

Link 16/TADIL J/JTIDS/MIDS Specifications[a]

Standard	U.S. Specifications	NATO Specifications
Terminal interface standards (hardware/software)	JTIDS SSS DCB79S4000C	MIDS STANAG 4175
Procedural interface standards (message formats/protocols)	TADIL J MIL-STD-6016	Link 16 STANAG 5516
Standard operating procedures	JMTOP CJCSM 6120.01	ADATP-16

SOURCE: Burnham (2000).

[a]There are other specifications. These are the principal ones.

resolve the differences between the United States and NATO on Link 16 terminology as long as both sides understand these differences.

SUMMARY OF MIDS CASE STUDY

The MIDS program, which is currently in the final phases of engineering and manufacturing development (EMD), is of high interest to the DoD, as evidenced by Secretary of Defense guidance to the U.S. Air Force to join the program. The international participating nations see it as a successful cooperative program that will provide a near-term solution to a long-standing need for interoperable data communications for fighters. Although the United Kingdom is not part of the MIDS program, it is acquiring another Link 16 terminal known as SHAR (for Sea Harrier) to install on some of its fighters. Thus, six major NATO nations will soon have interoperable, encrypted, jam-resistant communications on their newest fighters. Given the importance of the program for enhancing interoperability with selected NATO allies, MIDS was regarded as a good candidate for a case study.

The MIDS case study, however, is different from the other case studies in which potential solutions to interoperability problems are analyzed and discussed. In this case study, the near-term solution for an interoperable communication system has already been selected, and

it is MIDS.[5] Thus, this case study is really an acquisition case study that highlights the programmatic complexities of cooperative initiatives designed to enhance interoperability among coalition forces. The study assesses the advantages and disadvantages of achieving data link interoperability with coalition partners by means of the MIDS program, one of the few international system development programs that has enjoyed sustained international support for an extended period of time.

Below we describe the three major reasons for the MIDS program, summarize our observations of the case study, and present suggested actions the Air Force could take to ensure the success of the program. Because of the complexity of the MIDS program and because there is a separate report on the case study,[6] most of the details are presented in Appendix C. There we examine the goals of the program and the MIDS terminal architectures; discuss programmatic issues, including the history of the program over the last decade; review how MIDS grew out of the original U.S. Air Force–led JTIDS joint-service program; 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.

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[5]One of the drawbacks of MIDS, which is shared by other Link 16 terminals, is an aging system design that takes limited advantage of recent technology developments. This case study does not address the issue of whether this program—or, for that matter, JTIDS—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. This case study focuses on short-term solutions to urgent operational requirements. More capable and more technologically advanced data link systems such at the Joint Tactical Radio System (JTRS) are under development by the DoD and may meet the more stressing far-term needs of the services. However, JTRS will not be available in the near term. On the other hand, if the MIDS program can be transitioned into the production phase without major delays, the urgent data link requirements of the MIDS program member nations can be satisfied in the near term.

After this research was completed, additional information regarding enhancements to Link 16 became available. In particular, the U.S. military is investigating enhanced throughput (higher data rates) and dynamic network management for Link 16 (Simkol, 2000). These enhancements would mitigate some of the current shortfalls of Link 16.

[6]See Gonzales et al. (2000).

Why MIDS?

There are three major reasons for the MIDS program. The first is operational and has already been discussed: to provide interoperable data links between NATO allies' aircraft (fighters, bombers) and air-based, ground-based, and ship-based C2 centers. Because of the position location reporting and identification capabilities of Link 16 terminals, MIDS could provide aircraft IFF information, another desire of the NATO allies. Also, if data could be communicated quickly and accurately by means of a data communications network, it could help overcome language barriers between pilots of different nationalities and thus more effectively integrate the air forces of NATO member nations.

Second, the U.S. NATO allies share a desire for international cooperation and technology sharing with the United States, especially since the United States is viewed as the leader in many military technologies. According to senior DoD officials, the full participation of the U.S. Navy and the U.S. Air Force in the program helped ensure the continued active participation of the international partners in the program. European partners continue to be concerned that competing U.S. system developments will draw funding and resources from the MIDS program and potentially reduce DoD commitment to it. Thus, MIDS serves as a useful test case regarding the feasibility of a truly international system development designed to allow for interoperability among NATO nations.

Finally, although many NATO nations would like a Link 16 capability, they are reluctant to buy JTIDS terminals off the shelf from U.S. industry; European nations want to preserve their own defense development and production industrial base. 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 U.S. military technology led the program partners to favor an international acquisition program that would be a cooperative development effort between U.S. and European defense companies.

Observations

The cancellation of the JTIDS Class 2R program in 1995 and the decision to join the MIDS program have had cost and schedule implications for the Air Force. The additional cost of procuring the MIDS FDL for the F-15 may be as much as $20 million, but the actual cost is probably much less. There is a strong possibility that the Class 2R program would have encountered significant cost growth (for example, the OSD Cost Analysis Improvement Group (CAIG) concluded at the time that the cost projections for the terminal were too optimistic). Had that been the case, the cost advantage of the Class 2R terminal would have been significantly reduced.

More important for the Air Force has been the delay in acquiring a Link 16 capability for the F-15 aircraft. We estimate this delay to be a minimum of almost two years. This estimate includes only the delays associated with delivery of the terminals, but there may be additional delays caused by possible difficulties in coordinating FDL integration with other avionics upgrades and depot-level maintenance for the 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 Link 16 IOC for F-16s. As a consequence, the F-16 upgrade program has had to be reprogrammed to adjust for the LVT program delay. The delays in acquiring a Link 16 capability for the F-15 and F-16 aircraft are discussed in Appendix C.

There have been benefits to the decision as well. Air Force participation in the program, initially with the FDL and later with LVT, has helped ensure the continuation of the program. This is important to the United States and its European partners. Now that the Air Force is a major participant, continuation of the program should be assured as long as cost and schedule targets are met.

Furthermore, continued Air Force participation in the MIDS program should bring considerable cost and interoperability benefits. By continuing, the Air Force will encourage allied participation in the program during the production phase, thereby allowing for Link 16 interoperability between U.S. and selected NATO allies' combat aircraft and C2 nodes. The substantial Air Force LVT procurement should drive down terminal costs for the U.S. Navy and possibly for

the other countries as well. The Air Force should similarly benefit in that Navy and possible foreign buys should drive down MIDS terminal acquisition costs. In addition, the Air Force should be able to leverage the $650 million investment in technology and terminal design that the other MIDS member nations and the U.S. Navy have made.

Nevertheless, MIDS is a complex international program that could be subject to additional delays and future cost growth. Effective execution of the MIDS program in the production phase will present numerous management challenges to the MIDS International Program Office (IPO), including acquisition management and apportionment of production units to user platforms in three services, quality control, and configuration management. Under the existing EMD management arrangement (see Appendix C), the current senior Air Force officer in the IPO has no officially agreed-upon or assigned duties. Thus, maintaining Air Force insight into this complex program is difficult. To ensure its equities as the largest single buyer of MIDS terminals, the Air Force 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 (see Appendix C), MIDS is now an important program for both the U.S. Air Force and the U.S. Navy. 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 within 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 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 the avionics upgrade programs of these aircraft. However, if the MIDS program can be managed effectively in the production phase and if MIDS platform integration issues are addressed, U.S. Air Force, Navy, Army, and allied participation in the MIDS program will substantially enhance the interoperability of U.S. and participating NATO allies' forces.

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 Air Force must also verify that the EMD program exit cost criteria are met. The Technical Data Package (TDP)[7] 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 competition in the production phase of the U.S. portion of the program and help ensure that cost and performance objectives 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 into the program and commensurate responsibilities for adequate coordination of the MIDS production program with Air Force fighter and other platform upgrade programs. Three options for doing this should be considered.

The first option would have the smallest 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 on by negotiation among the 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. The Air Force representative on the MIDS Program Executive Council (PEC) could nominate a senior O-6 Air Force officer to the position of joint program director. This may be possible to

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[7]A complete TDP is a critical deliverable of the EMD program—it is essential for ensuring competition and contractor readiness for the U.S. portion of the production phase. The TDP will be owned by the MIDS member nations, so the entire TDP or portions of it could be made available to U.S. contractors. It will not provide a build-to-print blueprint of the EMD terminal. However, it should provide sufficient technical detail to facilitate design and production of system components by contractors not involved in the EMD portion of the program.

accomplish without amending the draft JMOA that is now under negotiation for the production phase program, but it might require the approval of international partners in the IPO. Because we have been unable to gain access to Program Memorandum of Understanding Supplement 2 (PMOU S2), which defines the cost shares and management structure for the EMD program and establishes EMD exit criteria, we do not know whether this option would be acceptable to the other MIDS member nations. Furthermore, we do not know precisely what mechanisms it permits for the possible transition of MIDS to a joint program (as has been suggested by knowledgeable parties).

The third option would be to convert the MIDS program into a true joint-service program. One way to do this is to amend the JMOA that is now under negotiation to explicitly call for rotation of the program director position between the Air Force and the Navy. Again, because we have been unable to gain access to PMOU S2, it is not known whether this option would be acceptable to the other U.S. services and MIDS program member nations.

The factors that need to be considered before choosing a particular option include the total additional cost the Air Force would incur by taking a management leadership role in the MIDS program and the risks the Air Force would incur by not doing so. 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 could be far higher if the Air Force does nothing to reduce the risks of MIDS terminal production and delivery delays.

Regardless of whether the MIDS IPO management structure is changed significantly, coordination between the MIDS program and 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 activities. Currently, the Systems Integration Office (SIO) at the ESC 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. Consideration should be given to provide this office, or another appropriate organization, with clear terms of reference and sufficient funding to help ensure

effective central Air Force management of MIDS terminal acquisition for all platforms in the Air Force.

Finally, another important dimension to the effective operational employment of Link 16 and MIDS lies in the cooperative development and use of concepts of operation. In future coalition operations, U.S. aircraft and C2 nodes may communicate via Link 16 with the aircraft or C2 nodes of other NATO nations, so it is imperative that all coalition partners have a common understanding of and definition for the concept of operations for Link 16, including adequate combined training and exercises.

The Air Force Joint Interoperability of Tactical Command and Control Systems (JINTACCS) office, AC2ISRC/C2PT, is charged with coordinating TADIL J message standardization efforts with NATO partners and with 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.