5-2004

The Need for Accelerated Integration of the Multifunctional Information Distribution System in the FA-18C Hornet

William S. Koyama
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by William S. Koyama entitled "The Need for Accelerated Integration of the Multifunctional Information Distribution System in the FA-18C Hornet." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

R. B. Richards, Major Professor

We have read this thesis and recommend its acceptance:

C. Ted N. Paludan, U. Peter Solies

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

Anne Mayhew

Vice Chancellor and Dean of Graduate Studies

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The Need for Accelerated Integration of the Multifunctional Information Distribution System in the FA-18C Hornet

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

William S. Koyama

May, 2004

DEDICATION

This thesis is dedicated to
My family and my friends who
Have always supported me.
And to the one at the end of the tunnel.

"I am still learning"
-Michelangelo

ACKNOWLEDGMENTS

My Sincere appreciation goes out to the team of engineers and test pilots at Patuxent River and in China Lake who work continuously to provide a better product to the fleet. Special thanks goes to Peter Davies of STASYS, a U.K. company, for his generous help in suppplying the Data Links Training CD for use in the creation of this work.

Thanks also to Captain David Prater for his insight and direction, and to Lieutenant Commander Lance Floyd for his help in updating my MIDS information to more recent standards.

The instructors at the United States Naval Test Pilot School and at the University of Tennessee Space Institute have been indispensible and I could not have completed this effort without their talents and their flexibility.

Lastly, but most importantly, the men and women of Strike Fighter Squadron One Nine Two and Carrier Air Wing Five are to be acknowledged, for their efforts and faith illustrated what could be done better and what could never be improved upon.

ABSTRACT

The FA-18 Hornet is a fourth-generation, supersonic, multi-role aircraft designed and built by the Boeing Aircraft Company, primarily for use as a single-seat US Navy and Marine Corps carrier-based strike/fighter. The Hornet has also been successful in the dual seat variant as both a trainer, and as a land-based aircraft for the Marines. All A through D variants have been marketed internationally as well. While the newer "E" and "F" variants are significantly different from the A through D variants in size and range and endurance capabilities, the avionics suites and capabilities are nearly identical. Except where noted, discussions of operations and aircraft/aircrew workload refer to single seat operation, as that is the majority of the combat operation of the FA-18s currently in the inventory. The purpose of this study was to examine the need (from specific operational experience) in the single seat FA-18 for a jam resistant, long range, high bandwidth datalink for the Strike mission, and how the Multifunctional Information Distribution System (MIDS) and its integration into the Hornet can fill that need. The author's operational analysis was done primarily on personal notes and observations during combat operations in Afghanistan October through December of 2001 and combat

operations in Operation Iraqi Freedom from February through April of 2003. The capabilities and limitations of the current LINK-4 system in the FA-18, the newer Digital Communication System's Variable Message Format and finally the MIDS/LINK-16 systems were considered, along with difficulties of MIDS integration into the current FA-18. This analysis was done partially on data and experience obtained as the Project Officer assigned to the MIDS program, however all conclusions and recommendations are independent of the test program.

PREFACE

A portion of the information contained within this thesis was obtained during the developmental phase of the MIDS program at Naval Air Systems Command, Strike Test Squadron (now VX-23) between June of 1996 and December of 1997. Other data was obtained through operational activities between October 2001 and April 2003, while deployed with Strike Fighter Squadron One Nine Two and Carrier Air Wing Five. The research, results and conclusions and recommendations presented are the opinion of the author and should not be construed as an official position of the United States Department of Defense, the United States Navy, the Naval Air Systems Command, Boeing Aircraft Company, or MIDSCO.

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LIST OF ABBREVIATIONS

ACI	Amplifier Control, Intercommunication
ACLS	Automatic Carrier Landing System
AEW	Airborne Early Warning
ATO	Air Tasking Order
AWACS	Airborne Warning And Control System
BHA	Bomb Hit Assessment
CAP	Combat Air Patrol
CAS	Close Air Support
CIA	Central Intelligence Agency
C^2 or C2	Command and Control
CLC	Command Launch Computer
DDI	Data Display Indicator
DME	Distance Measuring Equipment
DMPI	Desired Mean Impact Point
DOD	Department Of Defense
ECS	Environmental Control System
ECM	Electronic Counter Measures
EMD	Engineering and Manufacturing Development
EW	Electronic Warfare
FAA	Federal Aviation Administration
FLIR	Forward Looking Infra-Red
GPS	Global Positioning System
HARM	High speed Anti Radiation Missile
HOTAS	Hands On Throttle And Stick
HUD	Heads Up Display
IBU	Interference Blanking Unit
IFF	Identification Friendly or Foe
ILS	Instrument Landing System
INS	Inertial Navigation System
IOC	Initial Operational Capability

IPF	Interference Protection Feature
IJMS	Interim JTIDS Message Specification
ITO	Integrated Tasking Order
JDAM	Joint Direct Attack Munition
JSOW	Joint Stand Off Weapon
JTIDS	Joint Tactical Information Distribution System
JU	JTIDS User
LOB	Line Of Bearing
LRU	Line Replaceable Unit
LVT	Low Volume Terminal
MIDS	Multifunctional Information Distribition System
MPCD	Multi Purpose Color Display
NATO	North Atlantic Treaty Organization
NVG / NVD	Night Vision Goggles / Night Vision Device
NPG	Network Participation Group
OEF	Operation Enduring Freedom
OFP	Operational Flight Program
OIF	Operation Iraqi Freedom
PATRIOT	Phased Array TRacking to Intercept Of Target
PIM	Projected Intended Movement
PPLI	Precise Participant Location Information
RASP	Recognized Air and Surface Picture
RELNAV	Relative Navigation
RPS	Remote Power Supply
RWR	Radar Warning Receiver
SA	Situational Awareness
SAM	Surface to Air Missile
STADIL-J	Satellite Tactical Data Information Link – J (Link-16)
STANAG	STANdardization AGreement (NATO)
TACAN	TACtical Air Navigation
TADIL-J	Tactical Data Information Link –J (Link 16)
TDMA	Time Division Multiple Access

TUMA	Target Under Missile Attack
UFC	Up Front Control
UHF	Ultra High Frequency

CHAPTER I: INTRODUCTION

The FA-18 Hornet is a fourth generation, supersonic, multi mission carrier based aircraft. Originally designed primarily as a single seat replacement for the aging A-4, A-7, and F-4 aircraft, it evolved into the leader in the concept of "Strike Fighter" and a true multiple mission capable aircraft. Since inception, the two seat training version (FA-18B) has evolved into operational FA-18D aircraft used by the US Marine Corps, and by several foreign military sales customers. Still, only the single seat version of the original FA-18 (now the FA-18C model) is utilized on board aircraft carriers due to fuel constraints and ability to bring back any ordnance for carrier landings. The newer FA-18 E and F models are significantly larger aircraft with much greater bring back capability, and both models are being introduced to the carrier environment. With the elimination of the A-6 Intruder attack aircraft, and the nearly complete phasing out of the F-14 fighter aircraft, the FA-18 has become the mainstay of the US Navy's Strike Fighter aircraft capability. This was illustrated most recently in Afghanistan and Iraq during Operation Enduring Freedom and Operation Iraqi Freedom. All Hornet sorties flown from Aircraft Carriers in both of these operations were single seat. The advances in avionics, aircraft reliability, and computer systems have enabled a single pilot to accomplish multiple missions, often in a single sortie, but in many cases with a higher workload than is found in multiple crew tactical aircraft. As mission tasking has been added, very little has been deleted from the responsibilities of the single seat pilot. At the same time, the nature of strike warfare (including the concept of “network centric warfare”) the proliferation of immediate and detailed meida coverage of combat action results, and the evolving political environment has increased every aircrew’s workload by *decreasing* almost every margin for error in combat. This, coupled with the popular mantra of “more for less” and the very real cutbacks in combat resources has highlighted combat efficiency as perhaps *the* primary metric in any conflict. Efficient and timely distribution of relevant information decreases workload and increases efficiency and accuracy in almost any endeavour. The effect is multiplied in combat.

The FA-18 has always included a data link capability in its avionics suite. The current Link-4 capable data link system, however, is extremely limited, and is primarily used to perform Automatic Carrier Landing System (ACLS) approaches in the FA-18. Although Link-4 can be and is used in training and in conjunction with the E-2C Airborne Early Warning aircraft as well as several air warefare capable battle group ships, it is not secure, it has no resistance to electronic countermeasures (jamming) and can only cater to eight participants at a time. It is still important to mention because of its role in ACLS approaches and the continuing need for that function.

The purpose of this thesis is to delineate the need for and benefits of a robust, jam resistant, and jointly interoperable secure data link in the FA-18, and how the Multifunctional Information Distribution System (MIDS) integration into FA-18 can fill that need. In order to acomplish this clearly, a basic understanding of tactical data links, specifically utilizing the Link-16 message standard and the hardware/software suites used to support that message standard is useful. This thesis will cover an introduction to MIDS/Link-16, and its already established capabilities, then go into some depth involving the single seat carrier based Strike fighter mission (with emphasis on the Strike mission and recent conflicts). Finally, the integration of MIDS-Low Volume Terminal (MIDS-LVT) into the FA-18 and current issues will be covered, and conclusions and recommendadtions made. The appendices cover MIDS FA-18 installation, the FA-18 Air-to-Air mission with MIDS, and J-Series messages in more detail, including a some FA-18 MIDS-driven displays.

Background

Because of the existence of the F-14, when the FA-18 was being developed it was never intended to be the air defense fighter for the carrier battle group. The culture that wrote specifications for the FA-18 was one from which there had always been fighter aircraft and attack aircraft, and because the missions were seen as completely different, the aircraft produced for those missions were completely different and equipped differently. In fact, the original designation of the FA-18 was the A-18.[1] The concept of a "Strike Fighter" was new and many believed it would never be possible for a single aircraft to accomplish both missions, certainly not a single aircraft crewed with only a single pilot, and to say nothing of additional missions on top of those. The A-4 and A-7 aircraft, while in the business of attack or "strike" as it is more commonly known now, were both single seat aircraft, but they belonged to the "Light Attack" community, which set them apart from the A-6 Intruder which could carry more bombs and was designed to fly in instrument conditions at low level, requiring a more complex (and expensive) radar system and a bombardier/navagator to accomplish the mission. Since the FA-18 was to replace the A-4 and A-7 fleet initially, it did not warrant the terrain following ability of the A-6 nor the Fighter communications or data link capabilities of the F-14. Joint Tactical Information Distribution System (JTIDS) was being developed for aircraft, and would eventually be fitted to the F-14 aircraft, which at that time still had a service life that would extend well into the forseeable future. F-14 upgrade programs were already in plans to make the platform viable well beyond 2005. Because of the rapid advances in computer technology, and the fact that the FA-18 was truly a software-based fighter from the begining, it rapidly overtook the A-6 in precision bombing, and made the integration of newer and smarter weapons orders of magnitude easier.

Concurrently the A-6 fleet was experiencing wing problems, and the plan for the A-12 attack aircraft probably also led to a lack of enthusiasm for pouring money into upgrading or fixing the current A-6 fleet, resulting in an acceleration of the retirement of the A-6.

The FA-18 quickly put to rest any doubts about the ability of a single pilot to perform either the Strike or the Fighter mission. It was more accurate than the A-6, it was more maneuverable than the F-14, and did not suffer from engine problems which plagued the F-14 with the TF-30 engines. It was also the most maintainable tactical aircraft on the carrier. The FA-18 continued to get strong support in part because the leaders of the community, in an effort to prove its worth, continually told higher authority that the FA-

18 could take on additional tasking. The advances in cockpit and system design which were integrated into the FA-18 included a highly accurate and reliable Inertial Navigation System (INS) and a color moving map display, alleviating the need for a separate navigator. Control of the weapons systems was greatly simplified in both the Air-to-Air and Air-to-Ground arena, however, the pilot still needed to be familiar with delivery parameters. And now, the pilot needed to be familiar with virtually every weapon in the inventory. This now included mines, as that mission was accepted, several Air-to-Air missiles, dumb bombs, laser guided munitions, cluster munitions, and the newest Joint Direct Attack Munition (JDAM) and Joint Stand-Off Weapon (JSOW). The Division (four aircraft) still being the basic standard fighting unit of preference, the single seat Hornet Division leader has three other aircraft to shepherd, maintain awareness of fuel states, weapons remaining, and in tactical scenarios, which target (Air-to-Air especially, but also applicable to aim points in Air-to-Ground operations) each flight member is attacking. During night operations, the Night Vision Goggles (NVGs) greatly aid in some tasks of aircraft formation keeping and target area detection or recognition, but there are limitations and ambiguities. By the mid 1990s it was apparent that the F-14 would be retiring much earlier than expected, and that the FA-18 would be (and in some cases already had been) taking on the role of the air defense fighter for the carrrier battle group. While the APG-73 radar installed on the latest FA-18s is much better mechanized and suited for single pilot operations, the total power output is much less than the larger radar on the F-14, and simple detection ranges remain significantly less than those of the F-14.

These developments made it clear that a tactical data link would be necessary on any viable strike fighter into the forseeable future, and the MIDS program for the FA-18 was born. Hanging the urgency to integrate MIDS onto the FA-18 solely on its role in the air warfare picture, however, would be a mistake. Based on the number of Air-to-Air engagements the US has been involved in since the close of the Vietnam war, that might lead one to believe that MIDS integration could be delayed or even cancelled as a technology that is no longer needed for the current threat(s). It certainly could be argued that the F-14 was designed as a Mach 2+ capable aircraft because the threat had that capability, and the FA-18, with a much lower maximum speed fills the F-14's role in that respect because the majority of the threat no longer exists. The reality is that MIDS integration is desperately needed and long overdue for its usefulness in Strike warfare, force multiplying, battle efficiency, and saving lives and assets in friendly fire, or "blue-on-blue" avoidance. Like every avionics integration program, MIDS for the FA-18 has had technical problems. And like any other program, the technical problems either lead to progam delays or higher cost, or (usually) both. In the case of fixed or nearly fixed budgets, the solution is usually to delay or stretch out the program, unless it is shown that the need is critical, and then the funds may be reallocated.

CHAPTER II: JTIDS/MIDS, and LINK-16

Background

Joint Tactical Information Display System (JTIDS) was developed by the United States based on 1970s technology, and integrated the capability to include jam resistance, relatively high data rates, secure transmissions, and much greater flexibility for multiple users. It was conceived as an aid to the complex problems encountered in Vietnam while trying to command and control joint and single service operations.[2] Historically, command and control as well as surveillance and other information all had been passed over voice radio transmissions. Although the voice UHF radio transmissions now have some ECM jam resistance (Have Quick frequency agility) and secure capability (utilizing KY-58 encrypted transmission), it still is impossible to convey large amounts of information accurately to many users simultaneously using voice circuits alone. Tactical Data Links were developed as a means of distributing information efficiently and accurately, and in many instances distributing information that may be impossible to send over a voice circuit (such as video). JTIDS is a system architecture, and several physical sets of hardware have been designed and produced based on this archtecture. MIDS is the name given to a system designed to fulfill the NATO operational requirement for a flexible, secure, ECM-resistant, high capacity system also capable of supporting a wide range of functions. The requirements for MIDS were derived from the requirements for

JTIDS and JTIDS is a MIDS compliant implementation.[3] Different terminal types now in use and soon to be in use are sometimes referred to as JTIDS Class 2, or MIDS, or MIDS LVT. While they vary greatly in physical size, interface requirements, and additional capabilities they all conform to the Link-16 message standard. Interim JTIDS Message Specification (IJMS) was a temporary message specification to be utilized on JTIDS hardware due to the fact that the JTIDS hardware became available before the United States Tactical Digital Information Link –J (TADIL J) message standard was complete. Link-16 is a message standard based on TADIL J, but the two terms are somtimes used interchangeably. While it should be noted that all of the current data link standards, including Link-16 were developed before or during the cold war, and as a result were focused on providing air control and related information, not necessarily strike information. Because of the flexible nature of Link-16, however it is able to serve multiple functional areas, including Surveillace, Air control, Fighter-to-Fighter, and others. Appendix 3 describes the Link-16 J-Messages in greater detail.

JTIDS Architecture Technical Description

Data is conveyed on JTIDS/MIDS on UHF frequencies in the so called, “Lx band” the band from 969 to 1206 MHz. Transmissions are pseudo-randomly hopped among 51 frequencies spaced 3MHz apart, according to a crypto-variable driven pattern. This accomplishes both security (data is also encrypted on other levels before transmission) and jam resistance, as the transmissions are spread over an entire band at different

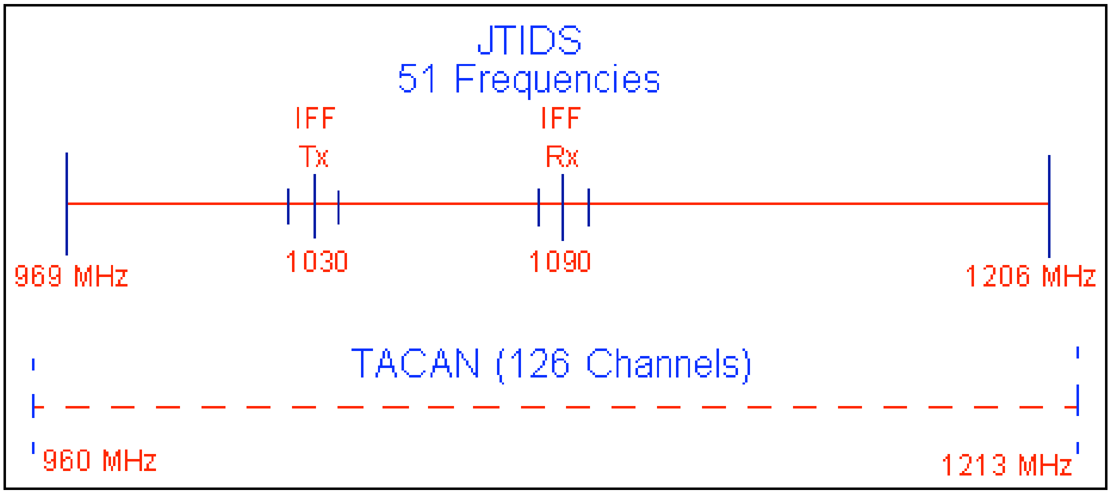

Figure 1 - JTIDS, TACAN, and IFF Frequency Band. [2]

times.[3] Figure 1 shows the working frequency band for JTIDS with TACAN and IFF bands annotated.

It should be noted that some TACAN and civilian IFF frequencies fall within the JTIDS working band, and this has created problems in training and use of JTIDS networks in peacetime, for safety reasons. In order to alleviate some of these issues, MIDS implements training modes which do not utilize full frequency hopping. As the normal combat mode of operation would be for MIDS to hop frequencies randomly, it could not be assured which frequencies would be utilized at any given moment. Three major modes are incorporated, as a result, to control the communication mode utilized. These are:

MODE 1 –Normal mode of operation using frequency hopping, full message security and full transmission security features (crypto encoding, etc.)

MODE 2 – No frequency hopping. All pulses are transmitted on a single frequency and peacetime constraints on slot usage are eliminated.

MODE 4 – No frequency hopping and some communications security processing is eliminated .

The limiting of frequency hopping was not sufficient to satisfy all international Air Traffic Control concerns over TACAN and/or IFF interference when utilizing JTIDS/MIDS in peacetime for training, therefore an Interference Protection Feature (IPF) was also developed. This feature monitors all transmissions from the terminal. IPF monitors the transmitter output for out-of-band transmissions, transmissions in the IFF notches, improper frequency hopping distribution, incorrect pulse lengths, and several other terminal parameters. The IPF has the ability to disable the terminal's transmissions if limits are exceeded in any area. In MODE 1 operations with the MIDS/JTIDS terminal, the IPF may be set to one of three conditions, NORMAL, EXERCISE OVERRIDE, and COMBAT OVERRIDE. As the names suggest, NORMAL mode allows the IPF to place all the peacetime restrictions and monitoring on the JTIDS terminal. EXERCISE OVERRIDE provides a partial interference protection, most importantly allowing the terminals to transmit more power and have more flexible use of their transmission time slots in terms of duty factor. COMBAT OVERRIDE effectively takes the IPF out of the loop and no interference monitoring or protection is provided. Both the EXERCISE and COMBAT OVERRIDE settings must be authorized by the Battle Group Commander (or Joint service equivalent).[3] Also, it was conceived that, since the MIDS frequencies were already in the TACAN spectrum, the implementation for the FA-18 would include a TACAN capability in the Low Volume Termianal, thus simplifying some on-board frequency interference issues.

JTIDS uses a Time Division Multiple Access (TDMA) data transmission scheme. It divides time as shown in Figure 2.

In short, this means that many users can be accommodated (like in some cell phone systems) but each user will be assigned a unique "time slot", and can only transmit during that dedicated time slot. Each user, however, can listen during all other time slots. This system may be visualized as a repeating cycle of a collection of timeslots, as illustrated in Figure 3.

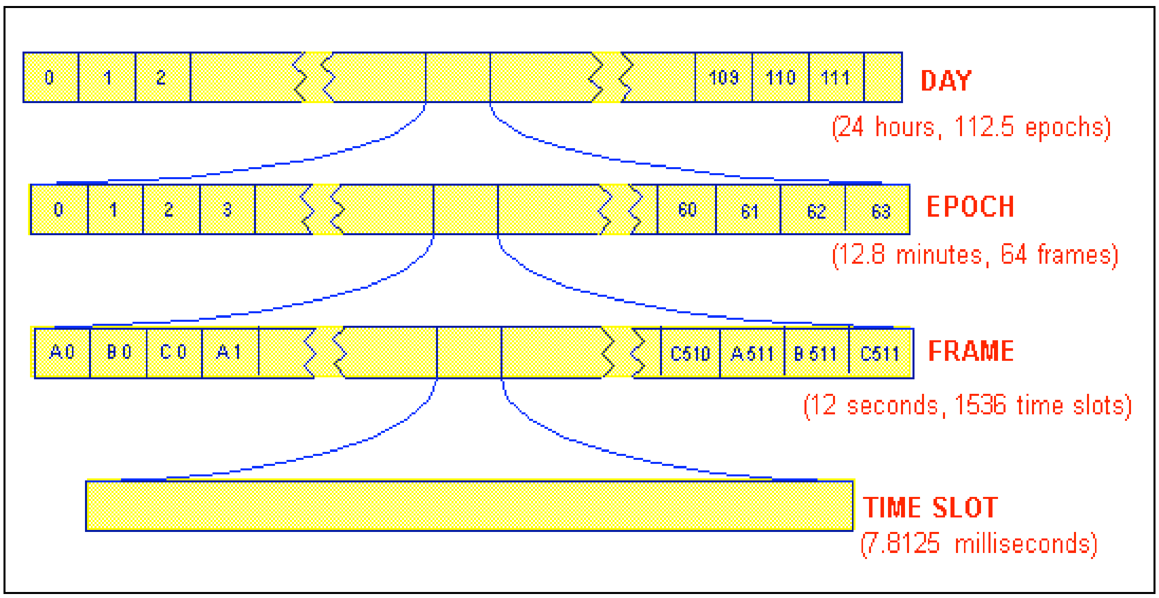

Figure 2 - JTIDS TDMA Time Slot Architecture. [2]

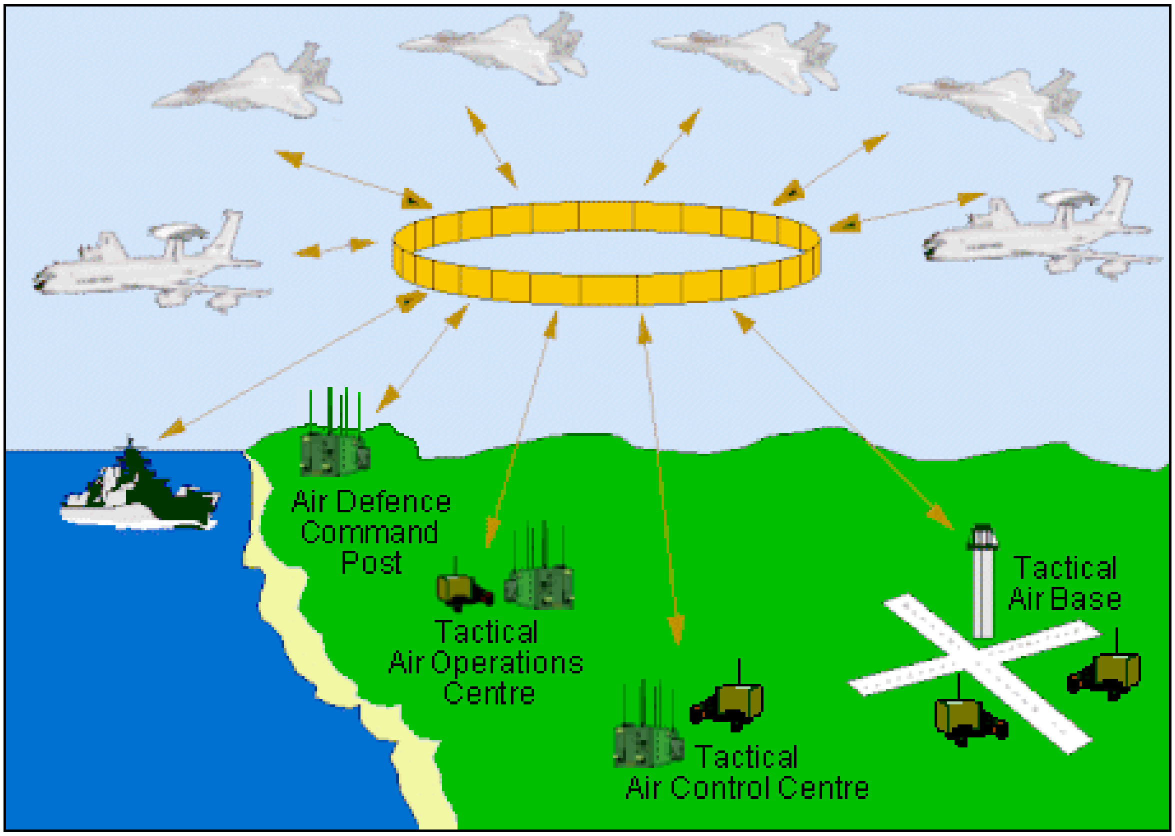

Figure 3 - Visualization of TDMA Network Participants. [2]

As implied by Figure 3, the users can vary from tactical aircraft to command posts to PATRIOT batteries or ships at sea. Also important to note is that this architecture is "non nodal", meaning any one participant could fall out and the network will continue to function. Because of both the frequency hopping and the nature of TDMA architecture, it is critical that all participants are time synchronized. It does not actually matter what time standard they are synchronized to, it just matters that all users on a net are synchronized to the same standard. This is accomplished through course and fine synchronizing processes, but only the network designers need be concerned with the details of the process. It is fairly transparent to the end user.

The UHF frequency band was chosen for its higher available data rates, but that constrained the system to line-of-sight communications. However, through the use of relays, JTIDS becomes a beyond-line-of-sight system. Implementation of Satellite Tactical Data Information Link J (S-TADIL J) could make a given JTIDS network globally accessible as well.

Although some manufacturers will claim data rates as high as 230,000 bits per second, there is overhead for data packing and error correction which brings the practical transmitted data rate to around 57,600 bits per second. Still, this compares well to the 3,800 bits per second available with the Link-4 architecture.[2]

Networks

The “wheel of data” illustrated in Figure 3 is a representation of a single “network” on the JTIDS system, using Link-16 message standards. Remember that the JTIDS/MIDS systems are pseudo-randomly hopping frequencies in a relatively wide band, only transmitting on one of 51 frequencies (3MHz wide) at a time for a given net. It is possible for other nets to exist simultaneously, as long as they are hopping to different frequencies at any one given instant in time. This is at the core of multiple network design. The diagram below illustrates how more than one net can exist at the same time. Note that because the hopping is pseudo-random, it is possible for data collisions or “pulse clashes” to occur. For this reason, all data is sent using error correction

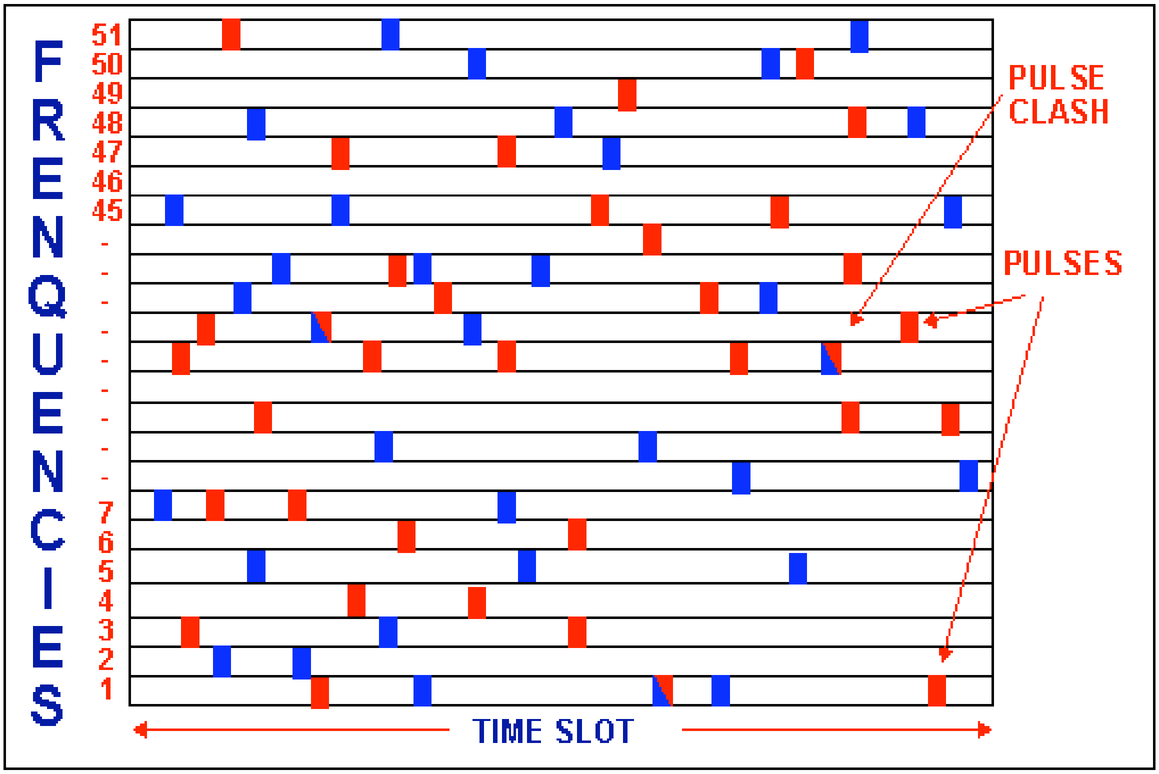

Figure 4 - Multiple Network Frequency Hopping. [2]

techniques, and to minimize pulse clashes, the network number (0-128) is one of the seed variables in the pseudo-random hopping scheme. Figure 4 illustrates two nets operating (one with "blue" data pulses and one with "red" data pulses).[2]

The Information

Appendix 3 goes into greater detail on what messages are implemented in the Link 16 J-Series standard. In summary, some key information transmitted through these messages on a given network include the following functions:

Precise Participant Location and Identification (PPLI)

This function, as the name implies, provides a trackfile to the user for each participant in the current network. This includes an unambiguous identification of the participant, its geographic position, and can also include weapons loadout and fuel states, and platform status.[3]

Wide Area Surveillance

Wide Area Surveillance is a general term which covers data about the tactical picture. This air tracks (of unknown or known hostile aircraft) which may include sensor information from several different sources, fused into a single track containing all the information. Surface and ground tracks, again of unknown or hostile combatants, can be displayed. Points or "waypoints" which have significance can be sent over the net, rather than via voice. This may include re-routing information, or rendezvous point information. Areas can be displayed as well, which may include no-fly zones or international borders. Areas may be transmitted to show missile engagement zones or other tactical boundaries as well. In real time, Surface-to-Air Missile (SAM) location may be transmitted over the net (these areas, if known, may also be pre-programmed into MIDS for display in the FA-18). Finally, Electronic Warfare information may be displayed, showing emitters that anyone on the net is detecting.[3]

Air Control

In the air control arena, which is probably the greater part of what the link was originally envisioned as supporting, commands can be sent to individual fighters or flights of fighters. Command and control correlations can be made using the net as well. If an enemy or unknown trackfile is not yet created, but there are some sources of electronic intelligence or other means of target detection, vectors may be sent on the net to a fighter or flight of fighters to a cap station or to investigate and continue to search using their own ship radars. Appendix 2 covers a summary of possible Air-to-Air utilization of MIDS with the FA-18.[3]

Fighter-to-Fighter

Within a flight, especially in the Air-to-Air arena, once an intercept has commenced, there is a wealth of information which is specific to the intercept but may not be relevant to other units not dirctly involed in that action. Fighter-to-Fighter data link is supported to give detailed information in real time to a flight prosecuting an attack/intercept. This information can include targeting data, so that the flight leader and other flight member can be assured that they are targeting the correct groups of enemy in a flight of multiple enemy aircraft, and/or to let the leader know at a glance if there are enemy groups going untargeted.

Within a group, the data link can show which specific contact has been sorted for attack by which fighter. "3D" information is available, in that geographic position as well as altitude of trackfiles is displayed. Also, the display of information is not constrained to the radar gimbal limits. Trackfiles may be abeam or behind the fighters, and on an egress, as long as the AWACS or perhaps AEGIS cruiser is still tracking the contact, situational awareness will not be lost when the contact falls outside of the fighter's radar field of view. [3]

Relative Navigation

The PPLI messages described above are sent by each network participating unit. Thus it is actually the participating unit that is broadcasting its position (as well as a host of other information) to all others on the net. All users are time synchronized, as noted earlier, and the time of transmission for a given user (his time slot) is a known quantity. Any user, then can take a received PPLI message from another user, and calculate the difference in time between own clock and when the other user transmitted his PPLI message. This time is the travel time between the users at the speed of light. Using this time, the distance between users is calculated. Thus, the original user knows he is somewhere on a circle that distance from the PPLI sending user. By completing this process for at least three unit's PPLI messages in rapid succession, a receiving unit can calculate his own position. Keep in mind that the accuracy of the calculated Relative Navigation (RELNAV) solution depends on synchronization accuracy, and the accuracy of the location reported in the PPLI messages utilized for that RELNAV calculation.[3]

Other Information

Engagement status may be sent from the fighter(s) back through the net for command and control or higher authority to monitor. In addition to pure data and messages, MIDS includes two channels of secure digital voice transmission which do not utilize the aircraft's UHF radios. Because the voice is embedded in the data stream, if relay is used, this equates to beyond-line-of-sight voice communications without satellites. If STADIL-J is implemented this can equate to global secure voice communication capability.[2]

The possibilities extend well beyond aircraft, ships, and missile batteries. This has already been illustrated in the Afghanistan theater of operations. The following is taken from an article in Jane's Defence Weekly of 21 December 2001:

> "The US successfully linked the RQ-1 Predator unmanned air vehicle (UAV), RC-135V/W Rivet Joint signals intelligence aircraft, U-2 high-altitude reconnaissance aircraft, E-8 Joint Surveillance Target Attack Radar System (Joint STARS) aircraft, and RQ-4A Global Hawk long-endurance UAV using Link 16 and other datalink technology, US Air Force (USAF) officials said."

"Predator images can now be sent directly to the cockpits of aircraft such as the AC-130U Spectre gunships" USAF Gen J Jumper, USAF Chief of Staff.[4]

With the proper mission computer software in the user aircraft, these images could also be sent to and utilized by any other net participant.

CHAPTER III: The Need For A Tactical Data Link in the Current Single Seat Tactical Strike Environment

Introduction

As noted earlier, today's single seat FA-18 pilot in a combat environment is tasked with multiple missions during a single sortie. It is useful to delineate mission phases and their demands in order to illustrate how MIDS integration can be useful in this environment. Drawing from notes and logbook entries from recent conflicts in Afghanistan and Iraq, the author will first outline a typical combat mission, then examine that mission in functional areas in order to illustrate where MIDS/Link-16 will play a part in each area.

A Typical Combat Sortie in Operation Iraqi Freedom

The Air Tasking Order (ATO), or Integrated Tasking Order (ITO), delineates targets and missions for each operational unit in theater. It includes in flight refueling plans, time-on-target, aircraft type and number, and weapon type desired or required, and of course it includes the target, hopefully with detailed aimpoint information, for each sortie or flight (sometimes it is left to the mission commander to delineate who in a flight is responsible for which target aimpoint). It is important to note that the ATO or ITO is the end result of, traditionally, a 72 hour cycle of planning. Targets are moved up or down in priority depending on the situation and the success of each previous day's ATO execution. The battlefield picture, however, is obviously not tied to a 72 hour cycle, and in fact, can change rapidly during the length of a single sortie. However, for planning purposes, the aircrew and the ship and Air Wing team must have a working document to plan for sortie numbers, launch and recovery times, and loads. The ATO is received the evening prior to the day it pertains to, and the planning cycle starts on board the ship. On the night schedule, the ATO may task a flight of four FA-18s to carry two one thousand pound JDAMs, and self escort to a target area where three Desired Mean Impact Points (DMPIs) have been identified. The flight leader or planning team then works to acquire imagery, to verify exact DMPI coordinates, and to plan for in-flight refueling and timing versus distance to make the sortie fit into the ship's cycle times (when the ship is actually launching and recovering aircraft). Operations from the individual squadron tasked will identify the flight leader and wingmen. Prior to the flight, the actual aircrew might have only an hour or two (possibly less time) to study imagery, review any weapon peculiarities, and to study what threats are currently predicted for the flight (usually surface-to-air) and how to defend against or avoid them.

The flight launches into the darkness, perhaps one minute or more apart, and possibly not in sequence (i.e. other aircraft may be launched in between members of this particular flight). The aircrew don NVGs and proceed to make mandatory voice calls to check in airborne with various agencies, first the ship, then external controlling or coordinating agencies. Aircraft systems are re-checked airborne, especially Mode 4 Friendly/Foe (IFF), as the lack of working and properly crypto-keyed IFF will preclude entry into hostile territory. Once joined, the flight prceeds toward the scheduled or “fragged” tanker for front-side refueling. After refueling, the flight departs the tanker and switches back to a coordinating tactical control agency, where updates to any changes in the overall tactical situation may be relayed, and where the mission number of the flight can be checked against for "re-role" or reassignment for a different mission. If the situation has changed on the ground, often the original targets will be changed, and any pre-flight target study is now irrelevant. The flight is then told to contact a different agency, on an encripted UHF radio for further tasking. The flight leader changes frequencies and radio modes to go secure, and attempts to contact the new agency, on a color coded frequency (i.e. frequency numbers are not given in the clear, but the pilot carries a list of color coded frequencies in the aircraft). If no contact is made, or if the agency is coordinating a different flight, the flight leader either waits for a clear moment, or returns to the last agency for another frequency or agency. The wingmen generally must follow the lead through all frequency changes. Meanwhile, the flight may have to hold if transit has been completed, prior to entering a hostile target environment. Depending on the distances involved from the tanker track, there may be only minutes of actual holding time available before the flight must return to the tanker, and then either return to the ship with unexpended ordnance (if it is a recoverable load) to make the cycle time, or request an extension which entails identifying additional airborne fuel for the flight, and can also affect following missions from the ship. If a final agency is contacted successfully, they may pass new target coordinates, which must be read back and then manually entered into the aircraft system for weapon delivery. The coordinates are then usually checked one final time between at least two flight members to ensure their accuracy and record the voice transmission of the coordinates on tape. The controlling agency may still have not given an order to execute the delivery, and the flight leader will wait for that, fuel permitting, while trying to convey an accurate available time on station estimate to the agency. This estimate may have changed drastically if the original destination and the new target destination are widely separated. After an execute order is received, the flight proceeds to the target area, and possibly separates into two formations of two aircraft for ease of formation keeping. Meanwhile, fuel states are checked on the radio to ensure the lowest state aircraft still has adequate fuel to continue. This low state aircraft is usually the most junior member, coincidentally, as he/she often uses the most fuel to stay in formation. As the flight has switched to a tactical control frequency, there is likely no traffic avoidance being given, and the flight clears its path using its own radars. All the while, PATRIOT batteries have been scanning the skies for a possible SCUD launch, periodically locking one of the aircraft to check speed and direction. Possible pop-up Surface-to-Air threats are passed on UHF, if the cognizant agency is currently being received. The flight reaches the target area and delivers ordnance, attempting to train any available on-board sensor, such as the Forward Looking InfraRed (FLIR) on the target area, and recording any impact on video for later analysis as to Bomb Hit Assessment (BHA) which is critical to feed back to the ATO process for further planning. The flight rejoins as expeditiously as possible and proceeds to the fragged "backside" tanker to receive fuel necessary for the return to the ship and recovery. Each agency contacted along the way needs a status report as to mission success and ordnance expended, requiring additional radio calls. If ordnance was unexpended, the ship must be notified, especially if the resulting load is un-recoverable, so that a safe jettison area can be identified and coordinated prior to recovery.

Air Traffic Management and Awareness

The first obvious use for MIDS/Link-16 is in air traffic management and awareness. Examining the phases of a mission where this is important, one first comes to the basic task of rendezvous and flight integrity. The timeline is tight, so perhaps one turn enroute is allowed to attempt to join the four separate aircraft as a flight. The leader can use Air-to-Air TACAN and three other aircraft can attain range to the leader, but the leader does not know which wingman is ranging from him. Once joined, the NVGs help maintain situational awareness on the other aircraft in the flight. Prior to close formation, however, the sky appears completely filled with lights which look identical and give no perception or range to the viewer. The NVGs are monochromatic as well, so it is not possible to tell whether a light is red or white or bright, or if it is green or blue or dim. Aircraft have joined on the wrong aircraft, and attempted to join on stars or ships. Use of the FA-18 radar helps to find and track aircraft in the forward hemisphere, as it provides altitude and speed of the target aircraft, filling in the picture of who and where the correct aircraft is to be joined upon. In the end, while checking in and accomplishing other administrative tasks with a coordinating agency, the second UHF radio is utilized for inter-flight communication in order to expedite the joinup. With MIDS, each member of the flight and indeed any aircraft which is participating in the net can be displayed in the cockpit on the Multi Purpose Color Display (MPCD). Using Relative Navigation (RelNav) these tracks are highly accurate in position, and can clearly identify not only aircraft type but aircraft identification–something probably not possible using NVGs unless in a tight parade formation. Confusion over whether one is joining on his lead or on another wingman is eliminated, and no voice transmission is necessary, freeing the flight lead to focus on coordinating the check-in or next tanking phase of the flight.

The assigned tanker may be in a stack of tankers spaced two thousand feet apart vertically, but in the same geographic area, therefore indistinguishable with the NVGs until an altitude can be confirmed. The tanker will usually utilize an Air-to-Air TACAN as well, so the flight lead is forced to switch his Air-to-Air TACAN off the interflight channel if ranging to the tanker is desired. The tanker is usually found utilizing radar and correlating geographic position with expected altitude and Air-to-Air TACAN ranging , although at range, the altitude which the radar resolves can easily read the wrong thousand-foot level, and it is also possible that the tankers, on their own coordination frequency, have consolidated and/or simply changed the altitude that they are operating at, possibly for convenience, or possibly for weather considerations. The UHF radio is again utilized to sort out the position and confirm the tanking plan. With MIDS/Link-16, the tanker would be joined on the net, and again, the track displayed on the MPCD, enabling a voice communication-free rendezvous. Further, if there are other flights just approaching or just leaving the tanker, and they are on the net, they will be displayed, not only in the forward hemisphere, but behind the aircraft on the moving map. Using Link-16 for tanker position awareness also frees the radar to remain exclusively in search in case there is a non "linked" aircraft in the vicinity or in the flight path ahead. The Link picture is constant and automatic, so more time can be devoted to visual lookout and effecting a safe and expeditous rendezvous.

In the target area the same holds true for traffic avoidance and management. There is no need to radar lock a contact (setting off its radar warning gear) that already correlates to a friendly track. While there may be contacts that are friendly and not on the net, due to equipment malfunction or to lack of a JTIDS/MIDS system installed, anyone who *is* on the net is by default a friendly. This greatly clarifies the Air-to-Air picture.

There is another advantage of position-keeping utilizing MIDS vice current methods. Besides the reduction in confusion and UHF transmissions, the Air-to-Air TACAN can become a thing of the past. MIDS utilizes a frequency hopping scheme, which has a lower probability of detection and certainly lower probability of tracking than an Air-to-Air TACAN system, which is continually radiating on the same frequency for the exact purpose of ranging to another aircraft. Abandoning the TACAN in a tactical environment by no means ensures stealth or low observability, but it decreases transmissions, lowering observability, and moves at least in the right direction.

Inter-flight Tactical Information

MIDS incorporates the ability to have Fighter-to-Fighter data Link, which is designed for use within, say a flight of four aircraft. Fighter-to-Fighter data link includes information that is pertinent to that flight and flight leader, but not necessarily to everyone else on the net. Tactical calls on UHF radio can be reduced or eliminated between the flight members, as that data will be passed from the mission computer through MIDS to the other flight members. Also available is weapon status and inventory, and further, what target is being attacked in an Air-to-Air engagement, eliminating redundant targeting and errors in sorting. These information exchanges should in no way be discounted, and are very important, especially if the scenario should ever involve a complicated air threat, however, in the recent conflicts, there was little or no need for targeting data, as the air threat was minimal or non-existent. Still, in the day to day defense of the Carrier Battle Group, many transmissions could be eliminated during an intercept, which decreases emissions which may be exploited by the enemy, even during peacetime. When unknown contacts are detected and the alert aircraft launched to intercept and identify, there are almost always follow-on launches if the target remains unknown, continues to close on the battle group, or is identified as a "bandit". In these cases, the fighters are not initially in the same area, and the last fighter launched has much less situational awareness than the first. Fighter-to-Fighter data link enables the joining fighter to gather information of the current situation, including the lead fighter's position, and target(s) he may be tracking, without making lengthy calls to both the air warfare commander and the lead fighter. This instantly improved mutual support and frees the lead fighter to concentrate on detecting, tracking, identifying, and/or intercepting and escorting the target, rather than trying to talk the joining fighter into the current situation. Handoff for escorts, given differing fuel states of the fighters can be made more logically and more efficiently.

Target Data/ Go and No-go Sortie Efficiency

As was mentioned, in the majority of combat sorties recently in Afghanistan and in Iraq no fixed target was known and assigned prior to launch of the sortie, or the target changed in flight. In each case, there are several bits of information that the aircrew need to accomplish the mission. In the case of a GPS guided munition, the only information needed is the precise target coordinate, and clearance to actually deliver the weapon. In the case of LGBs or other munitions, the aircrew might need at least a description of the target, along with target coordinates at least precise enough to be able to point the sensor of choice such that the field of view covers the target, and again, clearance to drop on the target. In a more dynamic Close Air Support (CAS) environment, this may then involve multiple exchanges of data, target descriptions, confirmations, and positions of friendly forces. We will limit this discussion to the non "traditional CAS" environment. While traditional CAS is still a very important and viable tactic, a complete discussion would be beyond the scope of this thesis. In addition, CAS and modern techniques for information exchange in the CAS environment are covered well in discussion of the Digital Communication System radio installation in the FA-18.[5]

For conventional tagets, including targets of opportunity, time is always of the essence. Friendly forces may or may not be in the immediate vicinity of the targets, and the friendly presence may not be conventional, i.e. the entire friendly force may consist of a single CIA operative moving in an enemy area, and identifying target locations. In all cases, the information to be passed includes target position (hopefully precise coordinates) and whether it is safe/clear to deliver the weapon. Until the Strike aircrew has this information, he is merely burning precious airborne fuel.

In Afghanistan in 2001 and in Iraq in 2003, up to 50% of a given FA-18 strike aircrew's combat sorties did not expend ordnance. In the author's experience and in interviews with fellow aircrew, until the last week of "hot war" the number one reason for unexpended ordnance was the inability to receive target coordinates and clearance within the time allowed by fuel on board. The targets were there, and were eventually serviced by aircraft in another wave, but the frequencies may not have been workable for UHF (including Have Quick) voice communicaton, or a single controller was overloaded by UHF communication, attempting to hand targets off to several strike flights simultaneously, but only able to handle a single flight at a time. In some cases a target or target area would be passed to aircrew late in the vulnerability time (Vul time) only to realize that the distance could not be covered with the time remaining, but it *could have* been covered if the coordinates had been known ten or fifteen minutes earlier. Airborne fuel equals airborne loiter time.

At first glance, it may seem that simply increasing the amount of tanker fuel airborne would eliminate this problem. While no FA-18 pilot would vote for less fuel airborne, the reality is that tanker fuel can be a hugely limiting factor on an overall campaign. In fact, the number of strike sorties available in both OEF and OIF was limited by the amount of fuel which could be made available in the air. In OIF, the limiting factor may have been the availablility of fuel itself, rather than the number of tankers, in OEF, the great distances the tankers had to cover contributed to the difficulty of getting each pound of fuel into an airborne fighter in theater.[6] In either case, each additional pound of fuel airborne brings with it overhead for transporting that fuel. As the airborne fuel picture became clearer, early in OIF, the USS Kitty Hawk and Carrier Air Wing Five (CVW-5) devised an "all organic" tanking plan which involved an in-flight top-off from S-3 aircraft off the ship in the same cycle, and then a small in-flight refueling prior to recovery on the "backside". In cases where the target coordinates and clearance to drop were received in the transit into country, a mission into the Baghdad area dropping two 1,000 pound JDAMs could be accomplished with only the frontside tanking, using the backside fuel airborne for fuel emergencies or unforseen recovery problems. On the other hand, if no target coordinates/clearance was received in a timely manner, the strike aircraft had to carry their ordnance twice the distance, using more fuel and forcing a recovery with 2,000 pounds less fuel available for additional approaches. In essence, since each launch and recovery can be considered a hazardous activity, each and every sortie flown from the aircraft carrier, puts these resources at risk. This is of course a fact of war, the aircraft must be launched with ordnance. However, if successful delivery of ordnance is a measure of success, than the efficiency of all the operations from the beginning of the conflict up until a cease fire or a virtual cease fire might only be 60%. This would imply that perhaps 40% of those combat sorties did not need to be launched, or, perhaps more importantly, that if the efficiency was increased, up to 40% more sorties would have been successful resulting in the necessary targets being destroyed much more rapidly, which could lead to a much more rapid cessation of hostilities. The “Shock and Awe” term so commonly used in OIF would have had a new meaning if 40% more ordnance had fallen in the first two weeks of the conflict.

The use of MIDS in the FA-18 to pass precise target data and operational orders to deliver to the targets can directly and immediately increase the efficiency of the combat sorties flown. Since the network is always available, there is no contention for a clear UHF frequency for a single flight. Also, a given controller on the ground, linked with JTIDS, can input multiple targets for servicing simultaneously. The importance of accurate coordinate transfer cannot be over emphasized in the area of collateral damage. While never desireable, collateral damage has become politically unacceptable and perhaps a factor that can hinder the overall progress of a campaign by creating negative opinion and the slowing of resources to execute and finish the conflict quickly. Using MIDS for the transfer of this data, the accuracy of the coordinates can be checked on the ground, or at a command center, instead of in a cockpit whilst flying. While not currently implemented, precision coordinates, formatted for weapon entry, could easily be sent over MIDS and transferred directly into the FA-18 mission computer, and thence to a

GPS aided munition, taking input or transcription error in the cockpit out of the loop. The coordinates can still be checked by the pilot, and a sensor from the aircraft may still be trained on the desired target, but the responsibility for accuracy will be shifted to the entity inputting the coordinates into the net, which in many instances may be the individual closest to the target anyway, perhaps especially in the case of time sensitive targets. A significant gain in efficiency will be realized by simply receiving information on the target area, thereby enabling "smart" routing of the flight from the tanker to the combat zone.

While the ending of the conflict and the winding down period will inevitably include a very high percentage of sorties with unexpended ordnance, this is to be expected, to maintain a credible combat presence, and to be on call for any flare-up of activity. But even in the waning stages of a conflict, the ability to quickly and accurately receive target data will make the firepower airborne more efficient and more responsive. On the command and control side, the planners and commanders will have an immediate picture of what ordnance is available airborne, and what loiter time is available for any given aircraft.

Blue on Blue Deconfliction

Perhaps the most important aspect of MIDS integration on any platform which is in a hostile fire zone is its inherent friendly identification capability. As covered previously, the JTIDS network is a frequency hopping, TDMA architecture, and the frequency hopping scheme is dependent upon cryptovariables. In addition, all of the data transmitted is encoded utilizing cryptovariables. Any track which is transmitting an ID on the network is by default a friendly track. This is reflected in the track type and the information about each individual track.

Every combat aircraft in Operation Iraqi Freedom was required to have Mode IV IFF capability prior to entering the combat area. But Mode IV IFF return is no more geographically precise than a Mode 3C IFF return used in civilian air traffic control. The IFF return on a given radar scope must be correlated to a “skin paint”, or a raw radar return from the radar system in use. Sometimes, depending on refresh rate, and characteristics of the radar system in use, the Mode IV return is not exactly correlated to a radar return, and the slower the refresh rate and the faster the contact is moving, the worse this correlation may become, or the single aircraft appears to be two separate contacts, one with a Mode IV friendly squawk, and one with no Mode IV and a radar skin paint only. Of course, the weapons systems lock on to radar skin paints, not Mode IV returns, so the target could be engaged with the belief that it is simply in the vicinity of friendly aircraft. The Mode IV return does indicate that a friendly aircraft (properly crypto-keyed) is in “that piece of sky”, but it does not contain information such as aircraft type, callsign, etc. And due to the correlation errors, it is entirely possible to have multiple raw returns and IFF Mode IV returns from the same aircraft, appearing to be completely separate contacts.

A properly formatted JTIDS link trackfile not only contains unabiguous identification, but also indicates speed, altitude, and other information which leaves no doubt as to not only the friendly nature of the contact, but the type of vehicle and its current operating information. The JTIDS trackfile information will by default contain information that matches what the radar return is doing.

Blue on blue incidents, otherwise known as “fratricide” or “friendly fire” have always been a problem, really since the beginning of warfare. Modern systems are designed to alleviate ambiguity to the maximum extent so that operators of weapon systems have a clear task in making a decision to fire or not to fire. But no system has ever been perfect. Air-to-Air systems have improved dramatically in the avoidance of blue on blue likelihood, but there are other reasons outside of pure systems for the improvements in Air-to-Air accuracy. One reason is that in most instances, there are multiple operators evaluating the available information and making decisions. That is to say, in a typical intercept Air-to-Air, the first entity to detect the contact may be the AWACS aircraft with a powerful radar and perhaps other methods of identification. Then a fighter is vectored to intercept, and will eventually take a lock with his own radar with its own identification capabilities. Beyond that, both parties evaluate the geographical position, and flight characteristics of a given contact before commiting weapons. Rules of engagement, are, of course implemented at every one of these steps, and in the end, determine actions as well. But even in the modern Air-to-Air environment, fighter aircraft are prone to take radar locks and identify whatever contact they detect which has no trackfile. Assuming this is a friendly aircraft, if it is a fighter, it has now had its radar warning receiver set off and likely saturated by being locked by a friendly aircraft. This not only adds a nuisance alarm, noise and confusion to the locked aircraft, it renders the radar warning receiver useless in the detection and valid alarm notification due to enemy surface to air threats which may be currently locking the friendly aircraft. With JTIDS/MIDS on both combat aircraft platforms, there is no need to take a radar lock of a friendly trackfile, and at the same time, much more information is available for all parties involved.

Surface-to-Air combat operations can be another situation, however. This was illustrated clearly in the most recent conflicts. There were zero friendly aircraft downed by enemy aircraft. But there were friendly aircraft downed by friendly fire. Two highly publicized incidents included the downing of a British Tornado aircraft, and that of a United States Navy FA-18C. All aircrew were lost during these blue on blue incidents, and both of these incidents were attributed to friendly PATRIOT Missile batteries.

JTIDS terminals are already integrated in many PATRIOT missile batteries, and are continuing to be fitted. But without MIDS integration on the air platforms, the picture for blue on blue deconfliction will look the same to the PATRIOT operator. However, with MIDS integrated, and with the combat aircraft operating on the network, all of the information mentioned above will be available to the PATRIOT operator.

This is not to say that utilizing JTIDS in all of these platforms can guarantee zero blue on blue incidents, because ultimately each operator must be disciplined enough to *utilize* the available information when making combat decisions. However, the task can be made much easier by making more, relevant, and unambiguous information available to each operator tasked with the responsibility of weapons release.

It cannot be stated with 100% certainty that JTIDS/MIDS integration would have averted the PATRIOT shoot-downs of blue forces during OIF, but it is clear that more information would have been available to the operators, and the overall picture would have been clearer. The saving of a single FA-18C aircraft would have paid for all of the terminals needed for the FA-18s in an air wing. Indeed, since the FA-18C production line is closed, there is no way to replace that lost asset. The political, and media implications of the blue on blue incidents cannot be quantitatively evaluated, but certainly support for any campaign is strained by the loss of friendly forces. It goes without saying that no price can be put on the saving of the life of a fellow combat aviator.

CHAPTER IV: MIDS INTEGRATION IN THE FA-18

Background

As early as the late 1980s, the requirement was identified for a JTIDS terminal which would be significantly smaller and have lower power requirements than the existing terminals at that time. Class 1 JTIDS terminals had been in use in large scale airborne and surface command and control systems, and the Class 2 terminal was already developed for airborne and mobile use, although the size and power requirements were still fairly large, given the advances in technology and miniturization available. The Class 2 LVT, also known as MIDS was designed for use in space constrained platforms, ideal for fighter applications. Because of rapid technology advances, it was possible to include all the features of the basic Class 2 JTIDS terminal and at the same time add additional functionality.[3] Table 1 summarizes some basic specifications of the various classes of JTIDS terminals, including transmit power, volume and mass. Figure 5 adds a visual comparison of the various JTIDS Class 2 terminals.

MIDS was designed from the start to fill not only a US need, but for a NATO requirement for a small JTIDS terminal. Because of this, the actual hardware specification for MIDS was developed by a consortium of companies from five nations, France, Germany, Italy, Spain, and the United States. The development program has taken so

Table 1 – Comparison of JTIDS Terminal Specifications. [7]

	Class 2 AIR	Class 2H AIR	Class 2H Ship	Class 2M	MIDS
Volume (ft^3)	1.56	3.25	BIG	1.25	0.58
Weight (lbs)	125	220	HEAVY	90	62.8
Tx Pwr (watts)	200 (TACAN 500)	1000	1000	200	200

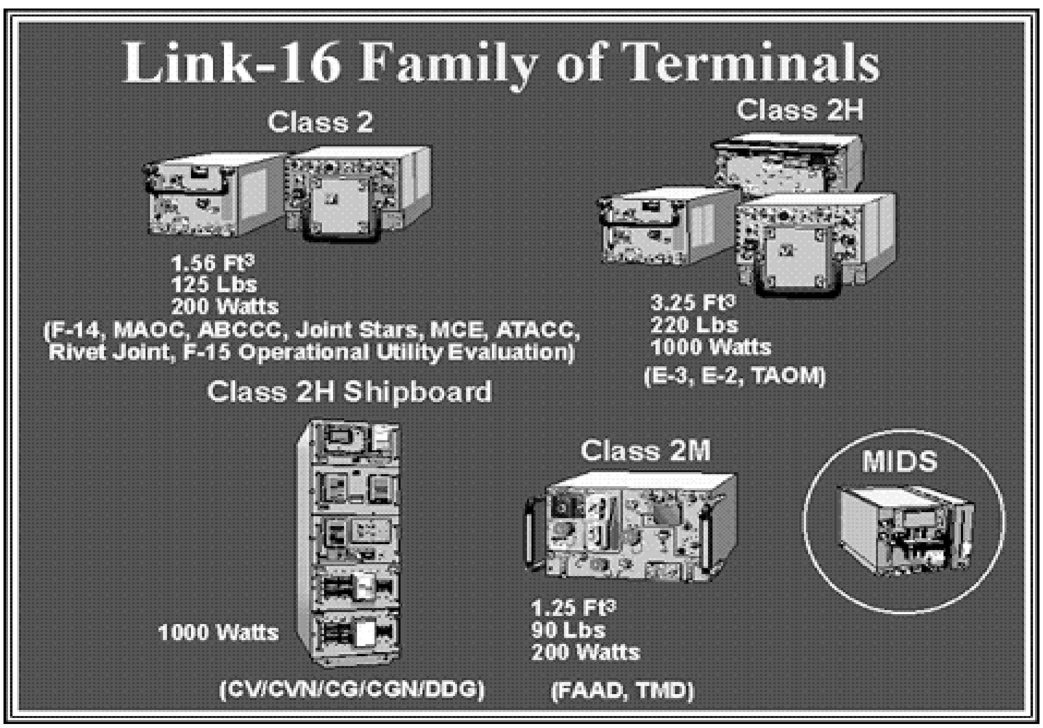

Figure 5 - Visual Comparison of JTIDS Terminals.[7]

long that some of the original companies have changed names, but the consortium was dubbed “MIDSCO”. The demonstration and validation phase was completed in 1990, and engineering and manufacturing development (EMD) was begun in 1994 [8], but due to some technical problems and, arguably, the nature of a five nation development program, the first working terminal was not delivered until much later, and the first EMD test flight in an FA-18 occurred in January of 1999.

MIDS FA-18 Integration

The MIDS LVT provides secure jam resistant communication, navigation, and identification functions, interoperable with the JTIDS Class 2 terminals. In addition, since the frequencies used encompass some TACAN frequencies, the MIDS terminal incorporates TACAN functions. This was desireable because frequency deconfliction between JTIDS functions and TACAN functions could be handled within the MIDS terminal. But more critically, in the FA-18, there would be no space for the MIDS terminal unless the existing TACAN hardware could be removed. Installation of MIDS into the existing FA-18 fleet requires removal of the ARN-118 TACAN, and it requires the downsized High Speed Anti-Radiation Missile (HARM) Command Launch Computer (CLC, now CLCP). The downsized CLCP has previously been incorporated into many later model FA-18s. The software capability to interface with the MIDS terminal was to be phased in to the Mission Computer Operational Flight Program (OFP) loads with OFP 15C Fleet load having Initial Operational Capability (IOC)[7], however, due to procurement rates and modification issues, 15C was introduced to the fleet in 2002/2003[9] with MIDS capabilities disabled. A MIDS FA-18 also requires AYK-14 XN-8 Mission Computers, and a Sixth Mux Bus, a new Amplifier Control Intercommunication (ACI) system panel and Interference Blanker Unit (IBU). Besides electronics and software, modifications are necessary to Bay 3R in the host FA-18 in the form of a Shelf Structural Redesign, Environmental Cooling System (ECS) Modification, and a power wiring modification.

Technical Challenges of Integration

Early in the integration phase of MIDS, it was realized through analysis that there would be cooling issues in Bay 3R. The MIDS hardware would require an ECS modification to allow adequate cooling airflow to the bay with MIDS installed. In part, this was a reason given for not pursuing a higher TACAN power output capability. MIDS with incorporated TACAN provides up to 200 watts transmit power for TACAN ranging functions. The Class 2 terminal used in the F-14 allows for 500 watts of TACAN power. The original TACAN installation in the FA-18, however, utilizing the ARN-118 has 1200 watts of TACAN transmit power available. This was intuitively flagged even before flight testing, while writing the test plan, as a possible problem. At the time, however, the manufacturers' and designers' assurance was that much smarter processing was utilized in the MIDS TACAN implementation, and thus the actual range degradation could not be determined from power output alone. Well before 2000, it was envisioned that GPS would be integrated on all military aircraft, and that the TACAN system in the United States would be phased out. However, GPS integration and FAA certification has not proceeded as planned, and the TACAN system is still widely used, and is the only certified backup air traffic control method of navigating with the FA-18. Additionally, the Navy FA-18 does not have a civilian Instrument Landing System (ILS). Its ILS is specifically for shipboard operations. Therefore, TACAN approaches are the only type of self-contained (non ground controlled) instrument approaches certified in the FA-18. Finally, and most importantly, the aircraft carrier still and for the forseeable future will continue to use TACAN as the primary means of air traffic management, for departures, marshalling prior to commencing an approach, and for instrument approaches if ILS or ACLS is not functioning. Even with ILS functioning, the TACAN distance measuring equipment (DME) is cross checked for safety. For these reasons, TACAN is still seen as a critical capability in the FA-18. Unfortunately, in operational evaluations which concluded in 2003, TACAN performance and reliability was identified as being a problem area. This and certain wiring problems in the depot-level modifications to incorporate MIDS have further slowed the integration.

It is worth noting that MIDS has been successfully fielded in the FA-18E and F. As some modifications were made during manufacture /design, this integration was much easier than the process of modifying already fielded fleet aircraft which may or may not have already had the necessary number of multiplex busses and level of mission computer. In the Fall of 2002, VFA-41 and VFA-14 installed MIDS into their aircraft, and subsequently completed work-ups and a successful deployment with MIDS integrated. Unfortunately, the aircraft that needs MIDS the most, in particular the FA-18C with lower fuel fraction on board and a single pilot, has yet to recieve MIDS for a deployment.

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

The author's main analysis was conducted using data and experiences obtained while serving as MIDS Project Officer at VX-23 and while serving as a combat FA-18C pilot in Afghanistan and Iraq in VFA-192 and CVW-5. The conclusions and recommendations, however, are the author's own, and are independent of those aforementioned organizations. Single piloted high performance combat jet aircraft operations have been made much more manageable through the automation of multiple functions such as navigation, radar processing, systems monitoring, and weapons management. But the workload has increased as a result of additional tasking, multiple simultaneous missions, and the greater emphasis now placed on zero tolerance for weapon delivery inaccuracies and errors. Manned combat air vehicles are still a viable delivery method of choice, as the final delivery decision still rests with a human. The information necessary to carry out the modern combat strike mission is available but sometimes in multiple locations, requiring tedious and error prone methods to retrieve that information. The difficulty in retreiving and integrating these multiple types and sources of information results in lower combat efficiency and higher risk of combat errors, including midair or near midair collisions, collateral damage, failure to provide air support in a timely manner, or blue on blue combat losses. The integration of MIDS into the FA-18 will simultaneously increase the combat efficiency and the combat safety during the execution of the Strike mission.

These benefits spill over into all other missions the FA-18 is tasked with, as well as the training environment. Though there have been some technological setbacks, use of MIDS in the FA-18 has already proven to be incredibly effective in the training environment, and the integration of MIDS into the FA-18 needs to become one of the highest priorities for the FA-18 community.

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8. http://www.defenselink.mil/news/Mar1998/b03111998_bt104-98.html

9. *Operation of the F/A-18 Avionic Subsystem for Aircraft with the 15C System Configuration Set*, MDC B1984-15C, dated 1 June 1999.

10. “Multifunctional Information Distribution System (MIDS) F/A-18 Mechanization Overview”, Powerpoint Presentation from Boeing/Navair Systems, dated 25 May 2000.

11. *F/A-18 NATOPS Flight Manual*, NAVAIR A1-F18AC-NFM-000, Interim change No. 78, dated 15 July 2001.

APPENDICES

APPENDIX 1: MIDS INSTALLATION IN THE FA-18C

MIDS Low Volume Terminal Description

Multi Functional Information Distribution System (MIDS) was born from a North Atlantic Treaty Organization (NATO) need for a common set of hardware/software with which to bear the Link 16 message standard. Joint Tactical Information Distribution System (JTIDS) had been in service, but a smaller hardware set, incorporating some additional features made possible through technology advances was envisioned for MIDS. The MIDS Low Volume Terminal, or MIDS LVT was created by a multi-national consortium of companies and was originally chartered by the United States Department of Defence (DOD). MIDS is unique in that it is actually DOD's first successful cooperative development of an electronic systems program. Although it is by definition a "Joint" program, the largest first user of MIDS was to be the US Navy FA-18 Hornet. Many capabilities of MIDS were required by the FA-18 installation, but compromises were also made for the other platforms MIDS had to acommodate.

The MIDS LVT is a tactical, secure, jam resistant voice and data communications system which is compliant to the LINK-16 message standard and previous JTIDS systems. MIDS LVT is smaller, occupying only 0.58 cubic feet of space and weighing 62.8 pounds. It has a capability for up to 200 watts (1 watt, 30 watts, or 200 watts) of transmit power in either data transmissions or in the TACAN utilization, but it includes a terminal capability to be connected to a high power amplifier JTIDS terminal. The MIDS LVT has about one quarter of the components and connections as the similar JTIDS class

2 terminal, resulting in more than a doubling of reliability. The MIDS LVT hardware configuration is one containing several shop replaceable cards, some of which can simply be removed or never supplied if certain functionality is not required (TACAN, for instance) and the MIDS LVT will recognize installed cards upon startup.

Included in the MIDS installation in the FA-18 is a remote power supply dedicated to the MIDS LVT. The remote power supply is shown beneath the main unit in Figure 6. This Line replaceable unit (LRU) converts platform primary power to Direct Current (DC) that the terminal requires. For instance, the FA-18 primary power is 115 volts Alternating Current (AC), three phase, 400 Hz and the LVT would not be capable of using this. Figure 7 shows a MIDS LVT with Power supply.

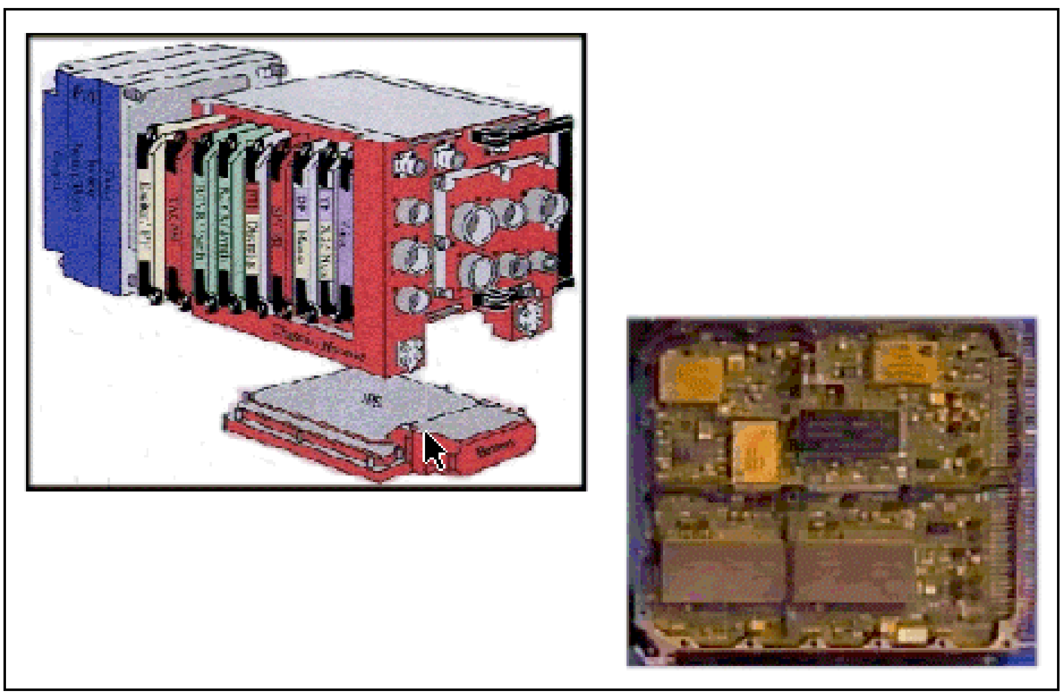


Figure 6 - MIDS LVT Exploded View and Shop Replaceable Card.[7]

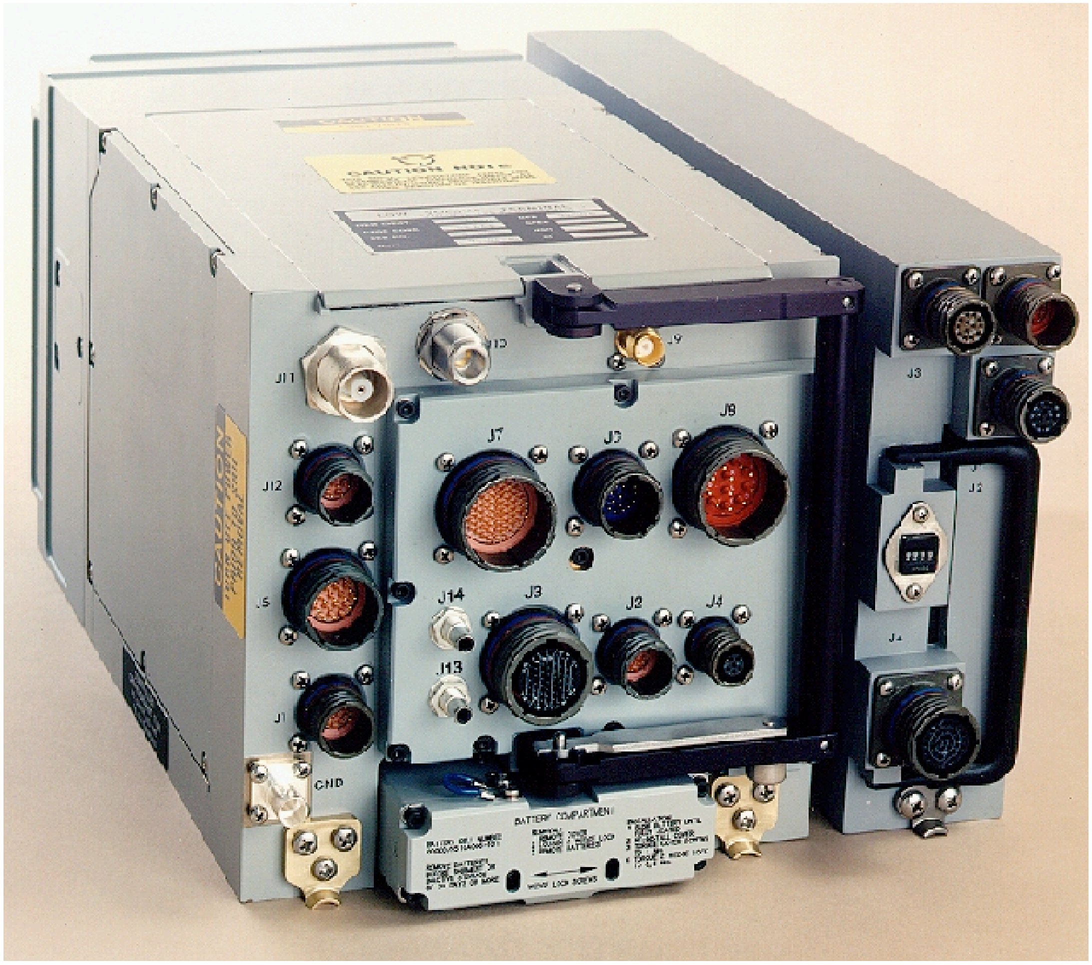


Figure 7 - MIDS LVT with Power Supply Installed.[10]

FA-18 Physical Installation

The MIDS LVT and remote power supply replaces the existing TACAN LRU in Bay 3 Right (Bay 3R) avionics compartment in the forward right fuselage. Figure 8 shows a line drawing of the FA-18 and the approximate location of Bay 3R. Figure 9 is a drawing of the details of the Bay 3R installation with MIDS on board. Installation of MIDS not only requires the removal of the existing TACAN equipment, but also that the smaller sized High Speed Anti-Radiation Missile (HARM) Command Launch Computer (CLC) be previously installed in that particular aircraft. The shelf that the MIDS LVT actually attaches to requires minor redesign as well, to accommodate the different shape of the MIDS LVT hardware.

Not shown are modifications necessary to the Environmental Control System, in order to increase the cooling airflow to Bay 3R as a result of the increased heat dissipation of the MIDS LVT over that of the old TACAN electronics.

MIDS LVT requires that the host FA-18 already have six 1553 Multiplex busses (MUX busses) which newer lot aircraft already have, but many existing fleet aircraft do not have. This also requires installation of the AYK-14 XN-8 Mission computers (or later model computers). MIDS LVT utilizes the existing TACAN antennas for both TACAN and communication functions, as the same radio frequency band is utilized for both. Figure 10 Illustrates a block diagram of MIDS electrical installation in the FA-18C. Note that this differs from the installation in the FA-18 E and F.

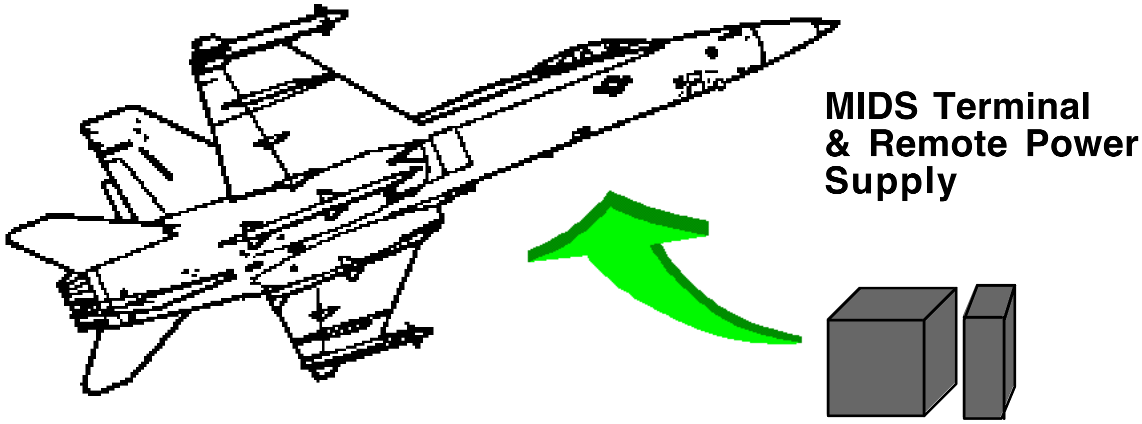


Figure 8 - Big Picture View of MIDS Location in the FA-18.[7]

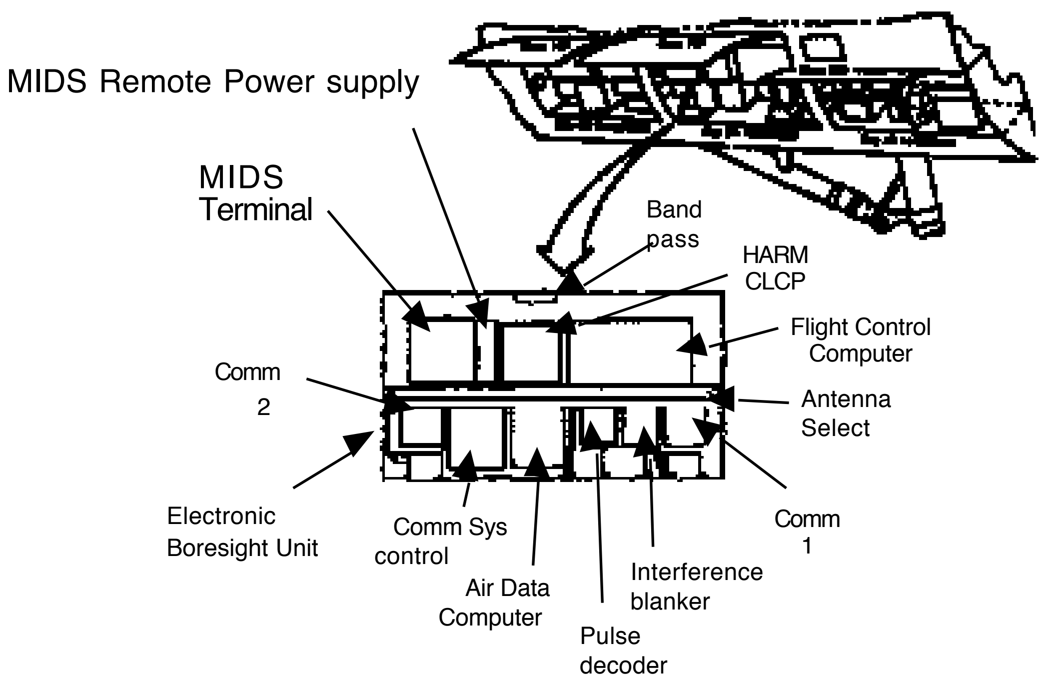


Figure 9 - Bay 3R Close up with MIDS Installed.[7]

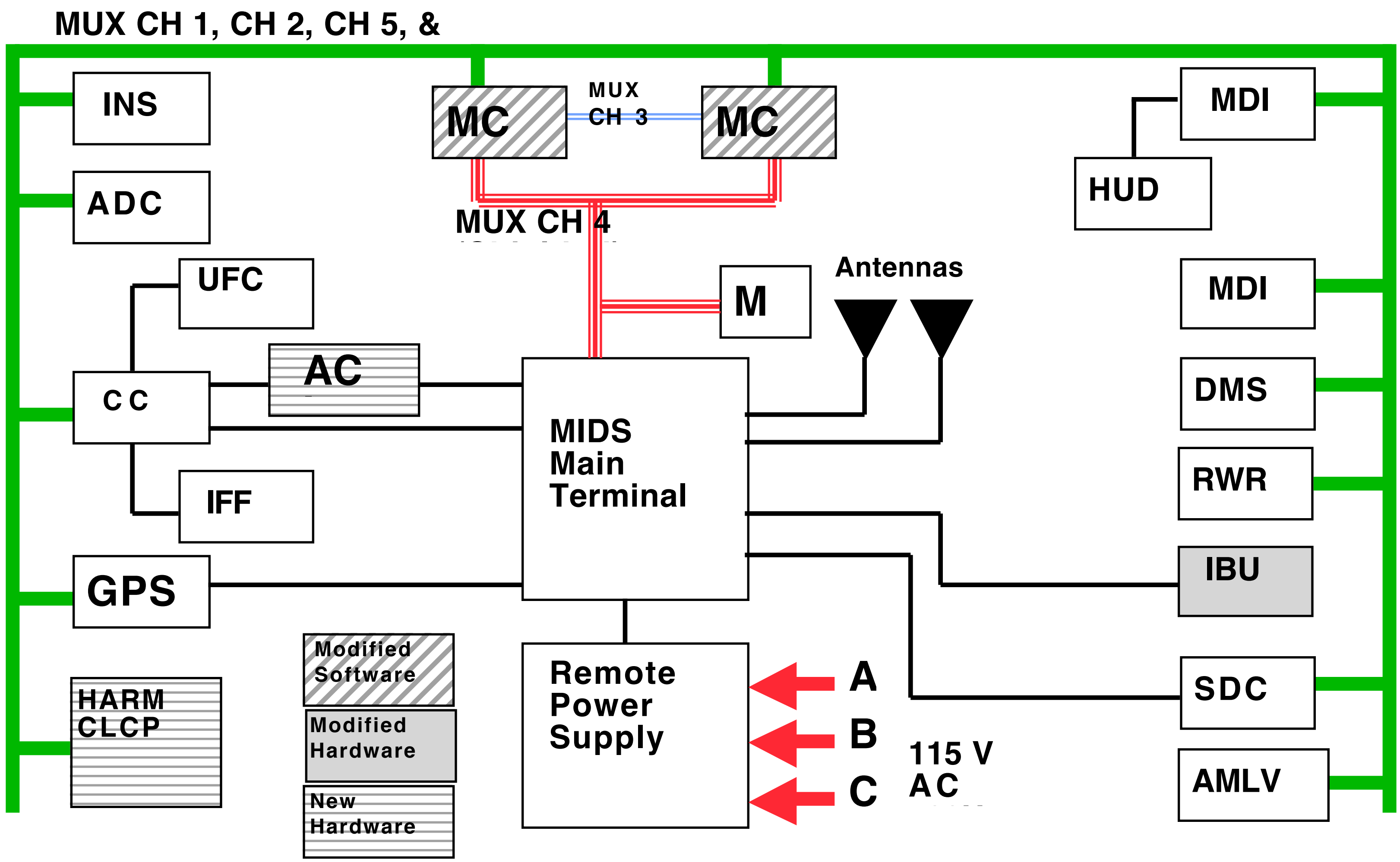


Figure 10 - Block Diagram of MIDS Integration[7].

Because of the additional voice channels, MIDS installation requires a new throttle grip communication switch. The existing switch has two momentary positions of up or down, spring loaded to the center position. The up position is for transmitting on radio 1, and the down position for transmitting on radio 2. In the original installation, the volume knobs on the up-front-control panel are used to set the volume of radio 1 and 2, but transmissions on either radio will overlap if they occur simultaneously. Since MIDS adds two more (secure) voice channels, the COMM switch is replaced with a six position switch. Up and down retain their functionality for COMM 1 and COMM 2, and the neutral position retains it's functionality of listening to all channels. However, the switch now also functions forward (MIDS Voice channel A transmit) and aft (MIDS Voice channel B transmit). An additional position of momentary center depression was added which functions as a "Quick isolate" to isolate a single channel, muting the other three possible sources of voice chatter. Figure 11 shows the additional communication switch positions on the right throttle grip for MIDS. The volume controls for the MIDS voice channels are included on a new Amplifier Control Interface (ACI) Volume panel. Figure 12 shows the MIDS ACI Volume panel. Besides the throttle switch and the ACI panel, the cockpit controls and physical displays for MIDS are unchanged from the non-MIDS FA-18.

Data can be entered via the Data Display Indicator (DDI) pushtiles, the Up-Front Control (UFC) keypad, or via Hands On Throttle and Stick (HOTAS) controls depending

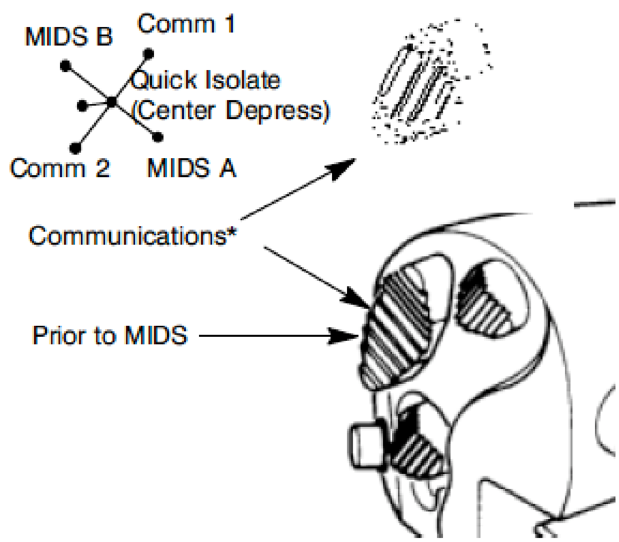


Figure 11 - Throttle Communications Switch with MIDS.[9]

Figure 12 - ACI Volume Panel with MIDS.[10]

on the type of data to be entered. Information is displayed to the pilot mainly on the Multi Purpose Color Display (MPCD) however, data is also displayed on the DDIs, the UFC scratchpad, and the Heads Up Display (HUD), dependent upon the type of data and mission phase. Figure 13 shows the general layout of the cockpit controls and displays for the FA-18C. Figures 17 through 19 (Appendix 4) illustrate representations of individual cockpit displays with MIDS data being displayed.

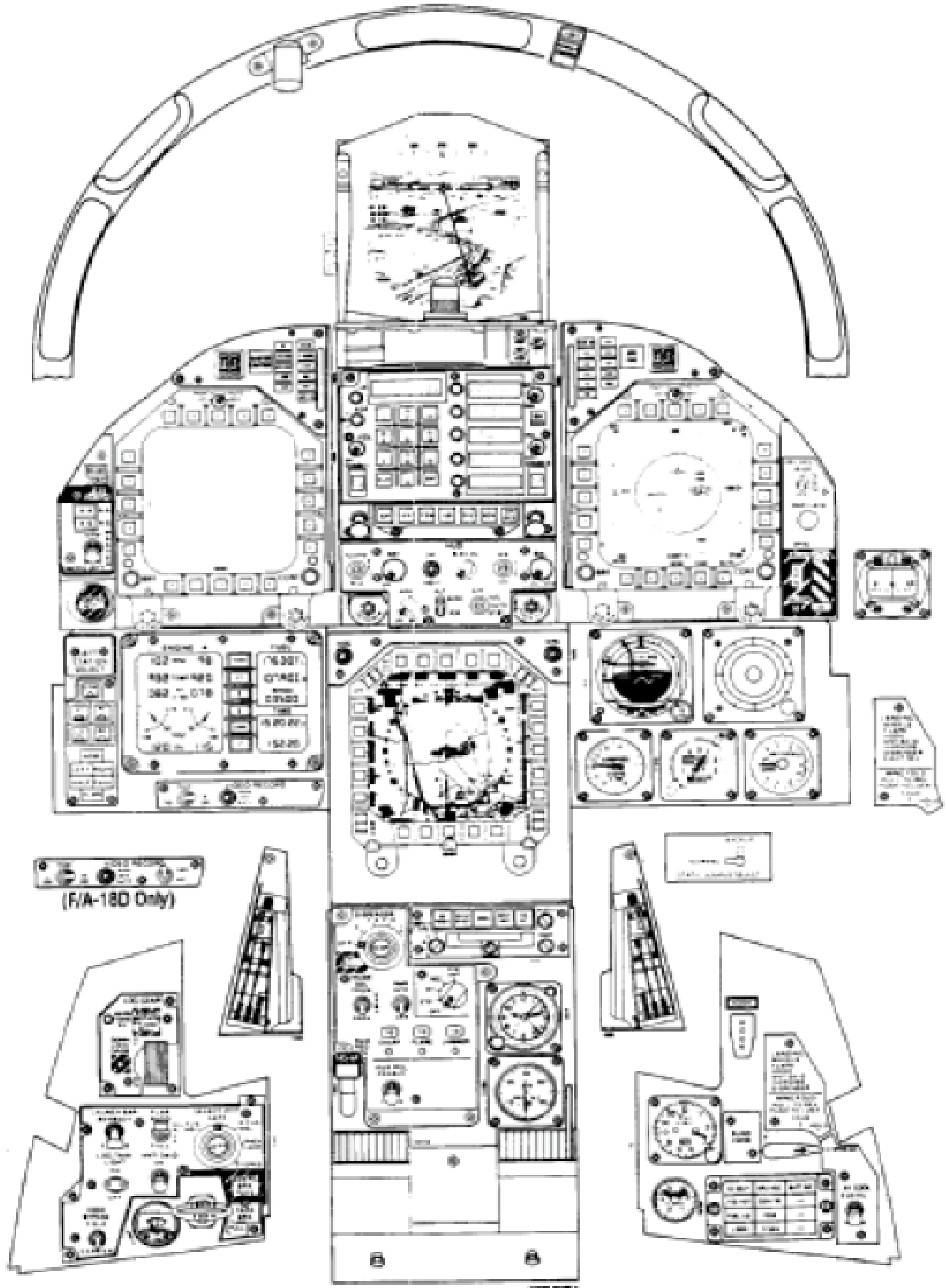


Figure 13 - Cockpit Displays in the FA-18C.[11]

APPENDIX 2: MIDS AIR-TO-AIR FUNCTIONAL SUMMARY IN THE FA-18 IMPLEMENTATION

Anti-Air Warfare Information

As previously covered, MIDS provides several ares of information to the tactical aircrew in the FA-18. This information can be used to greatly increase the combat efficiency and safety of the single seat pilot conducting the Strike mission. Much of the original impetus for the design of the Link-16 message standard and the JTIDS architecture was born from a larger Air-to-Air threat than has been seen in recent conflicts. Even though there was virtually no Air-to-Air war in either OEF or OIF, there remains an Air-to-Air requirement for protection of the battle group, for possible theaters where there would exist a large and credible airborne threat, and from perhaps yet unimagined Air-to-Air scenarios in unconventional warfare (e.g., intecepting and escorting or intercepting and downing a highjacked aircraft). The use of MIDS in the FA-18 can therefore become a key player in Air-to-Air missions as well as Strike missions.

PPLI

As in all cases when a JU is on a given network, it must report a PPLI message. Relevant to the Air-to-Air mission, the PPLI message from an airborne fighter will not only contain friendly identifaction (friendly by default because it is reporting), but geographic position will also be sent. In addition, the current loadout of weapons including number and type of Air-to-Air missiles will be included in the PPLI message, along with current fuel state of that fighter. Platform Status (referrring to the platform's network status, not aircraft status-that is reported in a separate message) is also reported. This information is available to the C^2 unit in control of the fighters on the net, and aids greatly in making vectoring and force placement decisions. Fighters receive information on the position of other fighters, helping to increase situational awareness and especially to decrease chances of fratricide.

Wide Area Surveillance

In the surveillance picture, the JTIDS network perhaps plays its greatest Air-to-Air role. Each JU can report on tracks, which may be hostile, unknown, or even friendly but not on the network, The C^2 unit on that given network may also have sensor or other information which can add to a given track, or contribute new tracks to the overall picture. The C^2 unit and other methods work together to ensure that each physical entity is represented by only a single track on the network, and that each entity that any JU has information on is at least represented by one track. This is something like a MACRO version of what the FA-18 has integrated for years, Multi-Sensor Integration (MSI). With MSI, the FA-18 may detect a target on the radar from long range, then the onboard Forward Looking Infrared (FLIR) may be slewed to that target. If Link 4 datalink was available from the E-2C, and the E-2C was tracking this contact, its datalinked trackfile may be displayed in the FA-18 as well, and still other sensors may be receiving information on this particular contact. MSI utilizes the mission computer in the FA-18 to correlate these inputs from different sensors into a single trackfile if possible, creating one track that has a greater amount of known information available. With Link 4, however, often the datalinked file and the aircraft detected file would be a mile or more apart in space, and correlation was not possible. The JTIDS network using the C^2 unit, correlates with much higher accuracy, ensuring greatly decreased ambiguity, and using sensors from multiple systems on mutiple air or surface vehicles, thus creating an extremely accurate and complete picture of the combat environment. Including the surface information, this is known as the Recognized Air and Surface Picture (RASP). Also included in the RASP are Surface to Air Missiles (SAMs) Surface and ground tracks, and electronic warfare information. Wide Area Surveillance will also distribute information such as points and areas of tactical significance. Figure 14 provides a graphic of Wide Area Surveillance in action using MIDS.

Air Control

Through decades of learning how cluttered the radio can become as soon as an intercept has been initiated (and even prior to that point) Top Gun and other weapons schools have written volumes on the single subject of Communications Brevity. This comm brevity changes rather frequently, and takes memorization and repetition to learn properly and to use effectively in the air. Still, in the heat of battle or the heat of training, calls become non-standard and commands are missed or mis-interpreted and correlations are made in error. The JTIDS network solves much of this through the use of Air Control messages. These messages may include commands such as “intercept” or “intercept and escort” or “destroy”. They can be in the form of vectors to contacts which the fighter has

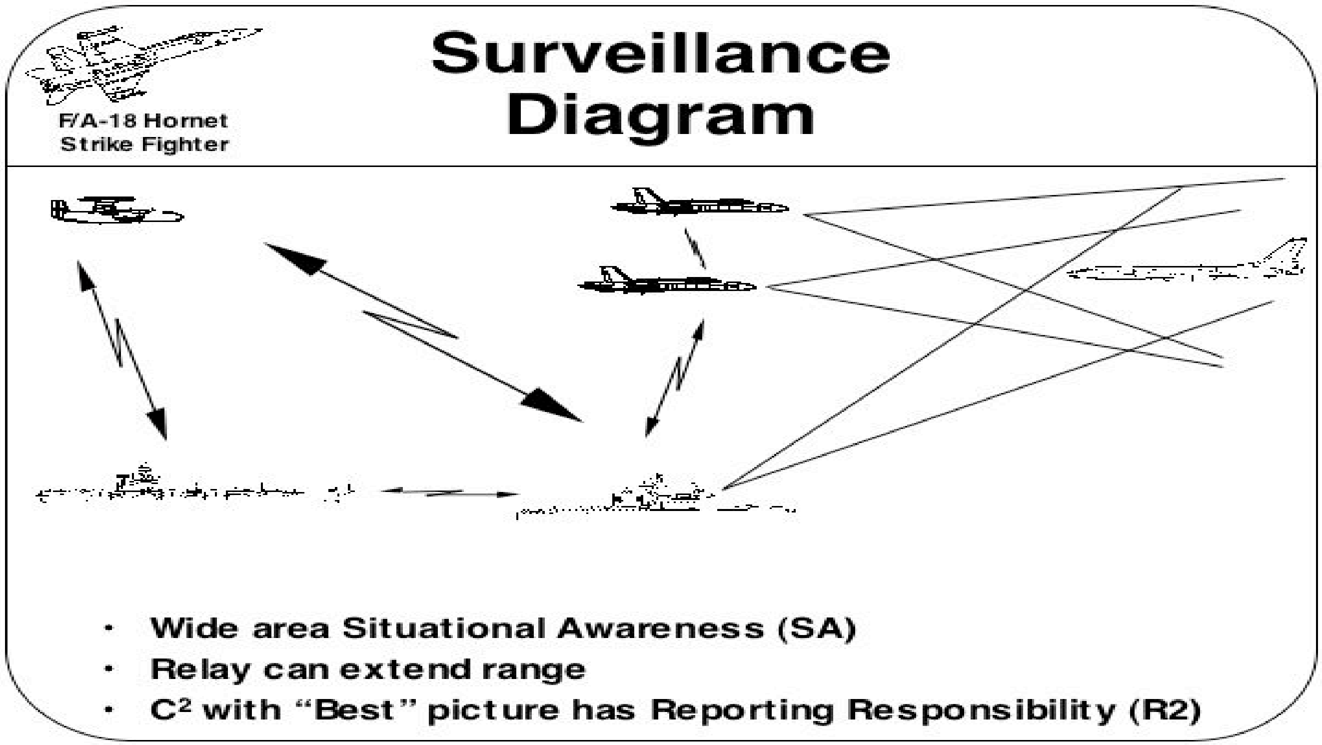


Figure 14 - Wide Area Surveillance Diagram.[7]

no on-board sensor information on, or vectors in a general direction in the case of no sensor information on the network at all. As discussed the C^2 correlations play a major role in clarifying the air picture for the fighters and all agencies on the network.

Fighter-to-Fighter

The Fighter-to-Fighter datalink function is simply a Network Participation Group (NPG) that is specifically designed for non C^2 units (NPG 19). It is provided for the exchange of radar sensor target information and and status, and each fighter "group" is assigned dedicated time slots on one of possibly several "stacked nets". The important point to note is that it is for the exchange of detailed data, it is a non C^2 Network, and it is designed for 2, 4, or 8 fighters per net, but not more. The radar data exchanged is detailed enough to provide three-dimensional information on contacts(s), and targeting data as well as sorting data withing the flight is also exchanged on this net.

Other Information

Several other areas of information exchange are supported in the Air-to-Air arena by JTIDS/MIDS. Worth mentioning in addition to the above are the Engagement status message which tells "the world" what a fighter's engagement status is with respect to particular targets. This eliminates some ambiguity possible when more than one fighter group is vectored possibly onto more than one enemy group. The MIDS Link-16 voice channels also warrant a mention. They are by definition secure without requiring any additional keying action or crypto selection by the pilot, and depending on the data rate they can be clearer and more intelligible than a weak UHF analog voice channel. In addition, using relays, the MIDS voice channels are able to have a much longer range, in fact, beyond line of sight, for communication with distant agencies. Fortunately or unfortunately, the ship can always call you back.

Typical Air-to-Air Scenario Using MIDS

Figure 15 Illustrates an Air Warfare Scenario utilizing MIDS for information distribution. To illustrate the usefulness of MIDS in the Air-to-Air arena, the six phases of an air intercept may be briefly explained and examined.

Phase One – Search

While on CAP with radars in search mode, the fighters receive Wide Area Surveillance data, enhancing their situational awareness. The most fuel conserving altitudes and orbits can be utilized, as information is received whether tracks are in the forward or rear quarter, and initial contacts will be longer range. When a contact is made, perhaps by the C^2 agency, the fighters are assigned the mission and given an initial vector. This vector may not even be necessary if a track is already created for the contact. Target location is passed when the track is passed on the net. It is possible for the fighters to silence their radars to avoid detection until the last second, thereby consummating a passive intercept.

Phase Two – Sample/Targeting

This phase in a traditional non-data link intercept is all but skipped with MIDS. Since the quality trackfile already exists, no sample locks need to be taken, and geometry can be

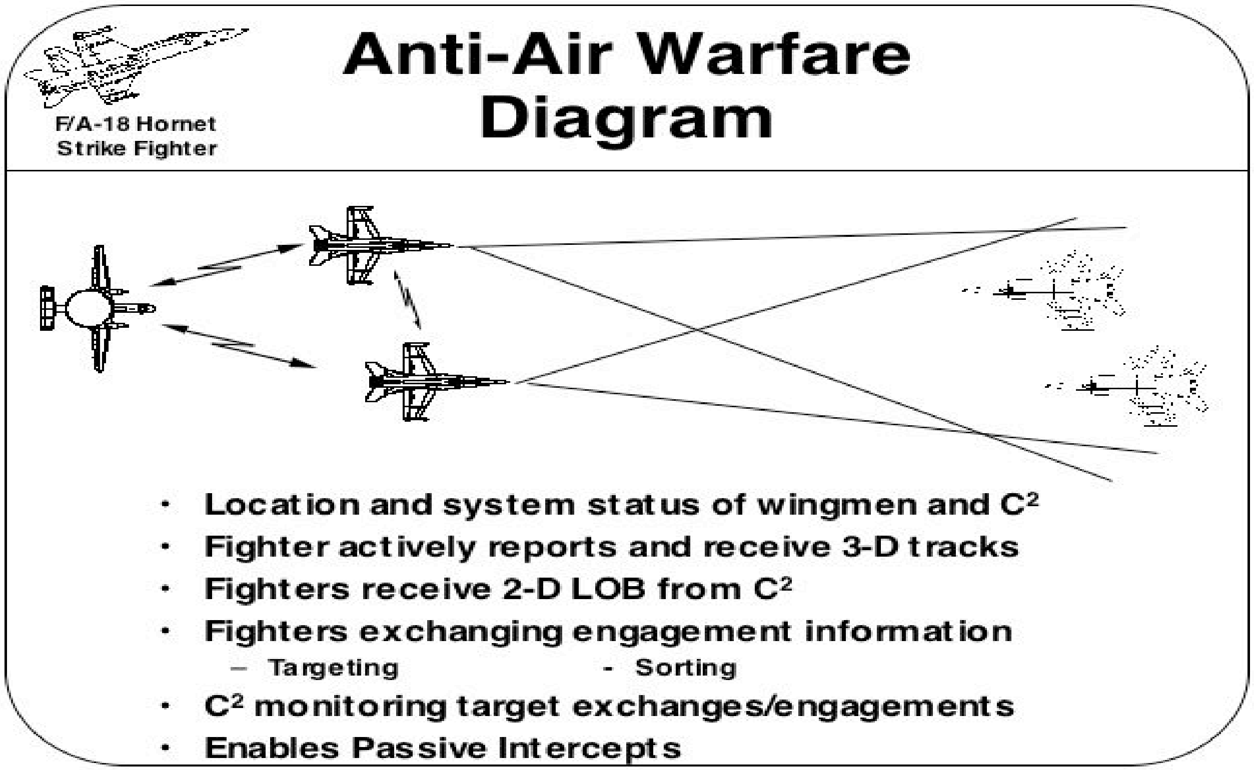


Figure 15 – Anti-Air Warfare Diagram.[7]

set based on the track shown on the net.

Phase Three – Sanitize

The fighters, again, do not need to sample lock therefore, they continue to remain in search or even silent, sanitizing for a pop-up contact, and using additional network information. Search will continue fro additional bogeys and situational awareness can be contributed with accuracy and precision from any wingman through datalink,

Phase Four – Sort

Within an enemy flight there may be one or more individual targets. Sorting is the process of assigning a specific target to a specific fighter. This can be done on the radio, usually prebriefed from geometry, or through pure datalink. If geometry changes during the intercept due to maneuvering, as the fighters take radar locks in preparation for weapons firing, radar lock lines appear on the MPCD, showing exactly which trackfile each fighter is locked on. Cross locks or redundant locks and any untargeted aircraft can easily be identified, and the situation corrected prior to first shot range.

Phase Five – Shoot

Again, radar lock lines are shown via MIDS, and they become commit lines, and then Target Under Missile Attack (TUMA) lines once a shot has been taken. If the shot is dropped that will be reflected in the datalink.

Phase Six – Short Range Options

Traditionally a "heads out of the cockpit" phase of an intercept, information on hostile missile launches can actually be passed, if the information is detected by some means, over MIDS. Missile defense may then be necessary, or it may be prebriefed to conduct a missile defense regardless of indications, or based on radar warning indications. Once inside the visual arena, the nearest threat is easily identified because even if radar situational awareness is lost, the high quaity trackfile remains on the datalink. If visual is lost, MIDS can be quickly referenced for the enemy position, as well as other fighter's positions, to prevent fratricide in a visual environment. Post merge, the area or safe direction can be passed from the controlling C^2 unit via MIDS and can be referenced without making a single radio call. If the fighters are to prosecute a trailing group, situational awareness to that next group is instantaneous, regardless of the lack of fighter radar data at that moment. With exact range data, tactical errors in the decision to continue the prosecution or to bugout can be drastically reduced or eliminated.

APPENDIX 3: LINK 16 Message Standard/J-Series Messages

Link-16 Message Types

While the details of message preparation and actual bit-by-bit transmission of data on a Link 16 network is important, it should be transparent to the user and is designed into the architecture of the JTIDS system. It does warrant describing the actual messages sent over the network, as these messages define the types of data which can be conveyed on the tactical data link. There are only four types of messages defined in the Link-16 message standard. These are: Fixed Format, Variable Format, Free Text, and Round-Trip timing. The standard messages utilized by the US Navy and many NATO users are the “J-Series” messages, and these are Fixed Format messages. The US Navy does not use Variable Format messages, although some services may, for instance, the Army uses Variable Format messages to send their Army Tactical Data Link messages over a Link-16 network. Variable Format messages being sent on a given network are simply ignored by a user that does not recognize them. Free Text Messages are used to send Link-16 voice, and they have no set format, therefore can utilize all data bits for digitized voice (with desired error correction). Round-Trip timing messages are unique in two ways. First, they are used by all users on a network in order to achieve and maintain time synchronization, and second, they are the only message that can be sent and received during the same time slot (with all other message types a given user may send or receive during a single time slot, but not do both).

J-Series Messages

Within the Link-16 specification, which is defined in the NATO Standardization Agreement, or STANAG 5516, there exist J-Series messages. There are 256 possible J-series messages, although not all 256 are currently defined. Changes and additions to STANAG 5516 are constantly in the process of being introduced and approved or rejected. Each J-series message, being a fixed format message, consists of one or more words, up to a maximum of eight. Each word consists of 75 data bits, of which 70 are data, 4 used for parity checks, and one is reserved as a spare.[3] All tactical and command information, aside from voice communication, is exchanged using these fixed format messages. There are three types of words in the fixed format world, Initial, Extension, and Continuation. Each message consists of at least an Initial word, one or more Extension words, and one or more Continuation words. As mentioned, parity checking is built into each word, using 4 bits, but each message is also encoded for error detection and correction using a Reed-Solomon (R-S) encoding. This adds 16 bits of error detection and correction for every 15 bits of data transmitted, so the encoding algorithm is sometimes referred to as (31/15) encoding (the 15 bits of data are taking 31 total bits to transmit). Each J-series message, then requires at least 155 bits and up to 1240 bits to transmit in encoded form. A relatively small subset of J-Series messages warrants further explanation, as they are used so frequently. Figure 16 illustrates some of the current J-Series messages as defined by the STANAG-5516. “J” identifies the message as J-series, the digits to the left of the decimal point define the category of message, and the digits to

TADIL-J Message Catalog

Network Management
J0.0 Initial Entry
J0.1 Test
J0.2 Network Time Update
J0.3 Time Slot Assignment
J0.4 Radio Relay Control
J0.5 Repromulgation Relay
J0.6 Communication Control
J0.7 Time Slot Reallocation
J1.0 Connectivity Interrogation
J1.1 Connectivity Status
J1.2 Route Establishment
J1.3 Acknowledgement
J1.4 Communicant Status
J1.5 Net Control Initialization
J1.6 Needline Participation Group Assignment

Precise Participant Location and Identification
J2.0 Indirect Interface Unit PPLI
J2.2 Air PPLI
J2.3 Surface PPLI
J2.4 Subsurface PPLI
J2.5 Land Point PPLI
J2.6 Land Track PPLI

Surveillance
J3.0 Reference Point
J3.1 Emergency Point
J3.2 Air Track
J3.3 Surface Track
J3.4 Subsurface Track
J3.5 Land Point or Track
J3.7 Electronic Warfare Product Information

Antisubmarine Warfare
J5.4 Acoustic Bearing and Range

Intelligence
J6.0 Intelligence Information

Information Management
J7.0 Track Management
J7.1 Data Update Request
J7.2 Correlation
J7.3 Pointer
J7.4 Track Identifier
J7.5 IFF/SIF Management
J7.6 Filter Management
J7.7 Association
J8.0 Unit Designator
J8.1 Mission Correlator Change

Weapons Coordination and Management
J9.0 Command
J10.2 Engagement Status
J10.3 Handover
J10.5 Controlling Unit Report
J10.6 Pairing

Control
J12.0 Mission Assignment
J12.1 Vector
J12.2 Precision Aircraft Direction
J12.3 Flight Path
J12.4 Controlling Unit Change
J12.5 Target/Track Correlation
J12.6 Target Sorting
J12.7 Target Bearing

Platform and System Status
J13.0 Airfield Status Message
J13.2 Air Platform and System Status
J13.3 Surface Platform and System Status
J13.4 Subsurface Platform and System Status
J13.5 Land Platform and System Status

Electronic Warfare
J14.0 Parametric Information
J14.2 Electronic Warfare Control/Coordination

Threat Warning
J15.0 Threat Warning

National Use
J28.0 U.S. National 1 (Army)
J28.1 U.S. National 2 (Navy)
J28.2 U.S. National 3 (Air Force)
J28.3 U.S. National 4 (Marine Corps)
J29 National Use (reserved)
J30 National Use (reserved)

Miscellaneous
J31.0 Over-the-air Rekeying Management
J31.1 Over-the-air Rekeying
J31.7 No Statement

Figure 16 - Abbreviated List of J-Series Messages. [3]

the right of the decimal place define the exact message title. "J2.2", therefore is a J-series PPLI message for an Airborne PPLI.[3]

PPLI

Each network participant, whether actually utiilizing a JTIDS Class 2 terminal or a MIDS terminal, is known as a JTIDS USER (JU). Every JU must transmit a PPLI message (for fighter aircraft, a J2.2 message) at least every 12 seconds. However fighter aircraft may transmit more frequently (perhaps every 3 seconds for an F-15 or every 2 seconds for an F-14) as this lends to greater situational awareness given the higher speeds of these vehicles compared to ships or land based units. The PPLI message contains the following data for the transmitting user:

- Position of the user. This includes both the geodetic and relative grid positions with their respective position qualities.
- The Platform Type (e.g. Fighter, Bomber, AEW, etc) and Platform Activity (e.g. Intercepting, CAP, RTB) of the user. The Specific Type, e.g. FA-18, is transmitted in the platform's status message.
- The network status of the user, including such parameters as Time Quality, Relay Status, Network Participation Status, Control Net used for Control NPG transmissions.
- IFF Codes. The Mode 1, 2 and 3 codes being transmitted by the user's Transponder (where applicable) may be included in PPLI messages to aid correlation between a

received PPLI message and another user's sensor data.

- Emergency Indicator. A JU can declare in its PPLI that it currently has an on-board emergency.
- Bailout Indicator. If the crew of an airborne JU ejects from the aircraft this indicator can be automatically set in its PPLI messages.
- Command & Control and Flight Leader Indicators. A JU can declare that it is a C^2 JU or a non-C^2 JU (set at initialization), and an aircraft JU may also declare itself as a Flight Leader.
- Strength. A JU can operate with a number of non-JUs (or JUs which are radio silent) and state in its PPLI message that it is reporting on behalf of a number of other units.
- Airborne Indicator. Air JUs can transmit PPLIs on the ground or in the air; this indicator is used to indicate which is the case.
- Force Tell Indicator
- Mission Correlators
- Voice call sign.[2]

Surveillance

Tracks are reported from any JU which has appropriate sensor capability using the J3.x messages. The exact message number depends on the type of track (i.e. air, surface, subsurface, land point, etc). Specific methods exist to ensure that all tracks are reported, and that each track is reported uniquely (i.e. two fighters reporting the same contact do not create two separate tracks for the network) the details of that method are beyond the scope of this discussion.

Engagement

Appropriate to a fighter JU, engagement status is reported on the net using the J12.6 message. This message is a "Target Sorting" message, but for a non Command and Control (C^2) unit, such as a fighter, it reports it's own engagement status via this message, but only on the Network Participation group for control. To disseminate engagement status to a wider community, the appropriate C^2 unit would report a J10.2 Engagement Status Message to all users. The fighter reporting it's engagement status would indicate the track being engaged, helping to eliminate redundant targeting.

Reference Points

Reference points can actually be points, lines, or areas in space, and they may or may not be stationary. Normally, reference points will be transmitted by a C^2 JU using the J3.0 Message. This message can contain extremely useful tactical data, which would otherwise be quite cumbersome to transmit via voice in real time. Reference point messages are not limited to, but may include:

-Hazard information (impact points, ground zero, missile launch point, engagement point, mine, oil rig, ecm decoy, etc.)

-General Reference Point (marshal point, corridor, search area, formation center, ship's projected intended movement (PIM) or submarine PIM)

-Station Air (Combat Air Patrol (CAP) point, Strike initial point, TACAN, Tanker, orbit racetrack or orbit point).

Threat Warning

C^2 JUs may transmit Threat Warning data to a particular JU or to all JUs on the network, via the J15.0 Threat Warning message. This message is given highest priority for transmission, and may contain data about high priority threat(s) against a particular JU, including missile or aircraft threats, including the threat posture. They are transmitted twice for each threat.[3]

APPENDIX 4: FIGURES/FA-18 SCREEN EXAMPLES

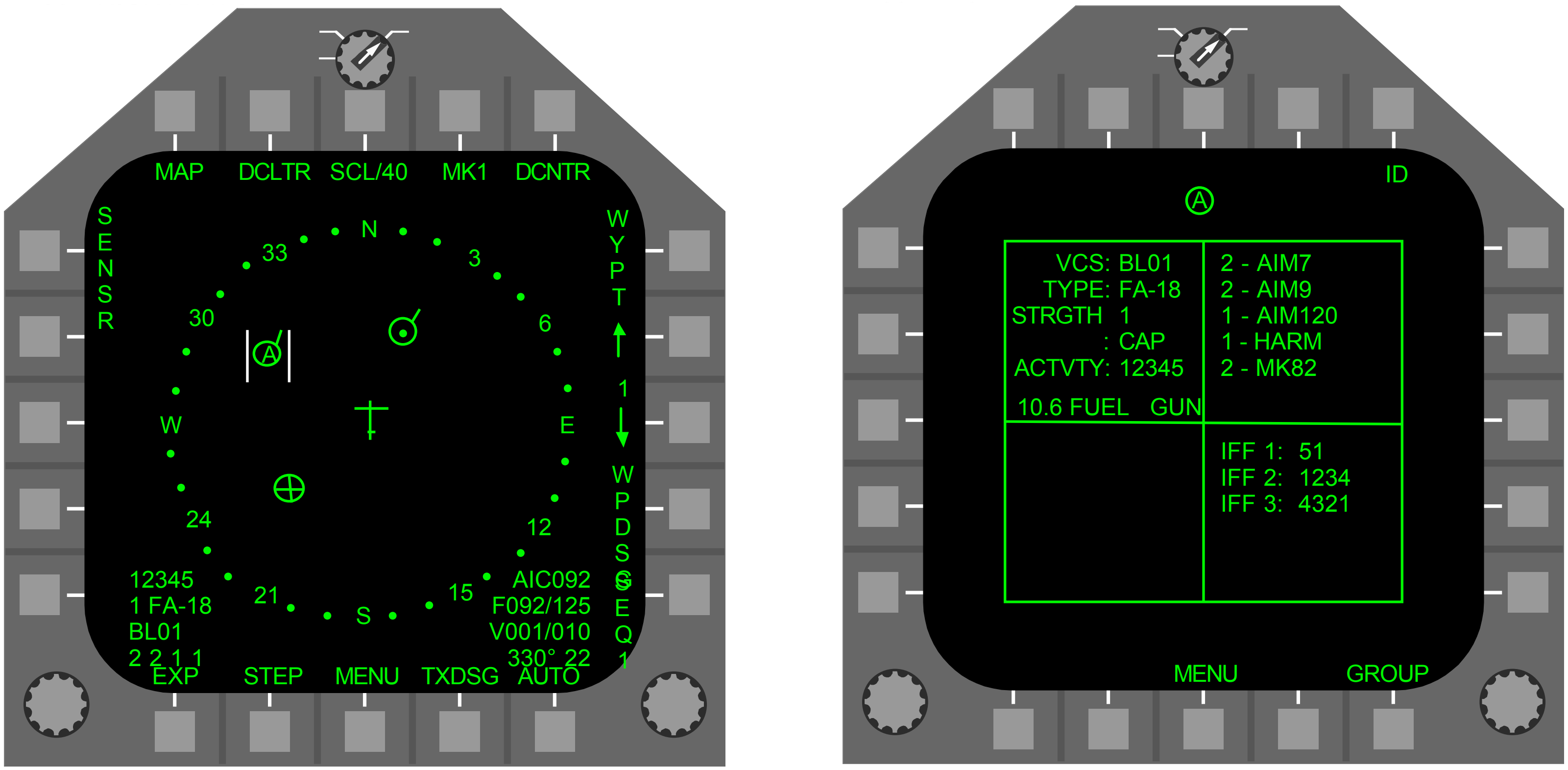


Figure 17 - FA-18 Data Display with MIDS PPLI Information. Friendly tracks on the network are shown from a God's eye view (40NM scale) as green circles. Placing the cursor over a particular PPLI track reveals more information about that JU as shown on the right display.[10]

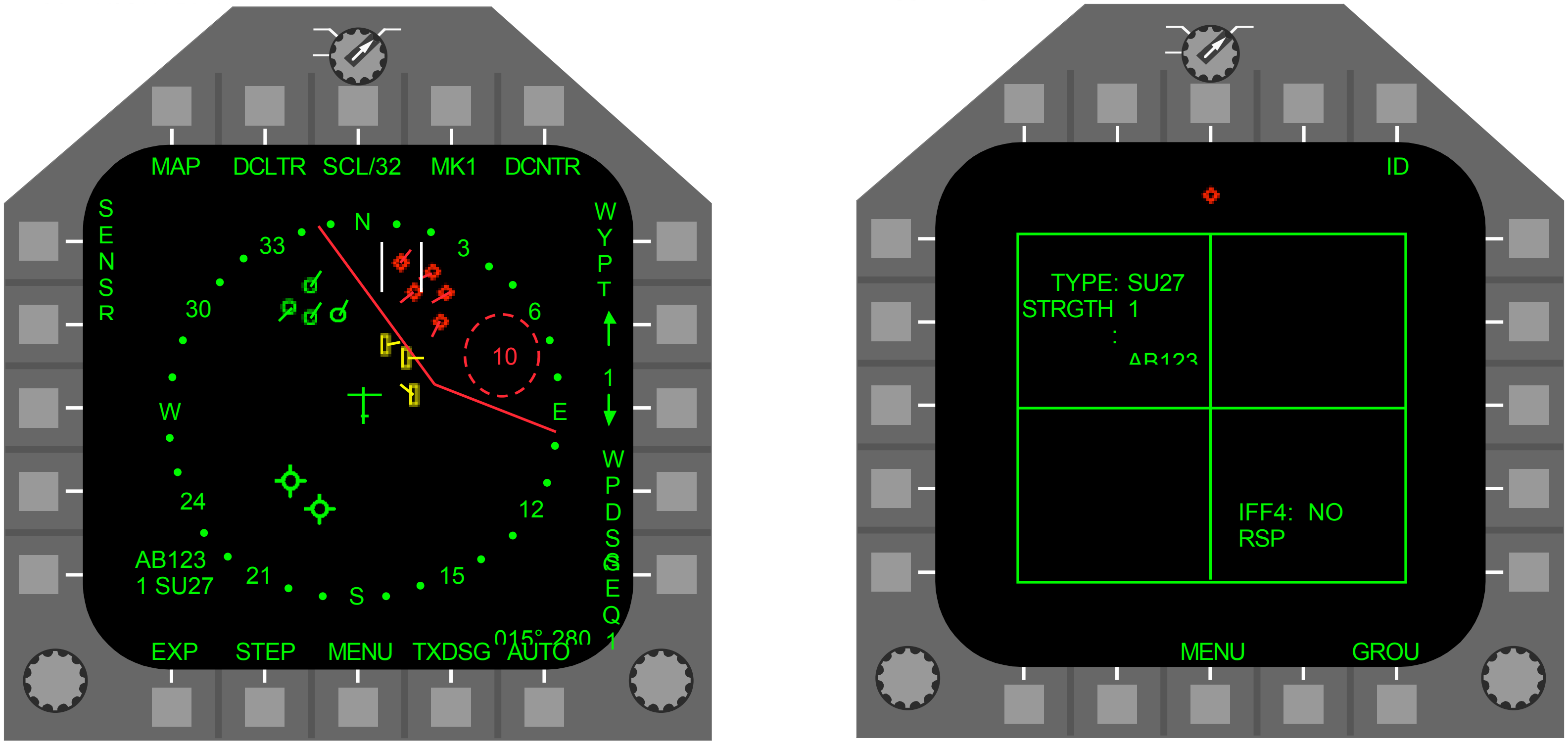
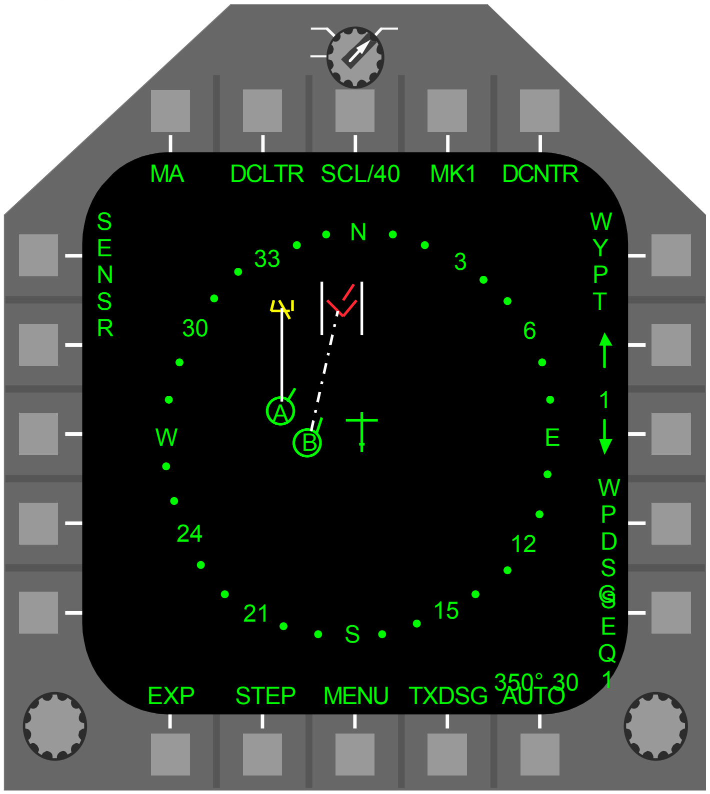


Figure 18 - FA-18 Data Display with MIDS Surveillance Data. Lines for political or tactical boundaries are shown in solid red. Possible SA-10 site with threat ring is shown in dashed red. Unknown tracks are yellow, hostile tracks are red. In this case, placing cursors over a desired hostile track of interest reveals more track data on the right display.[10]



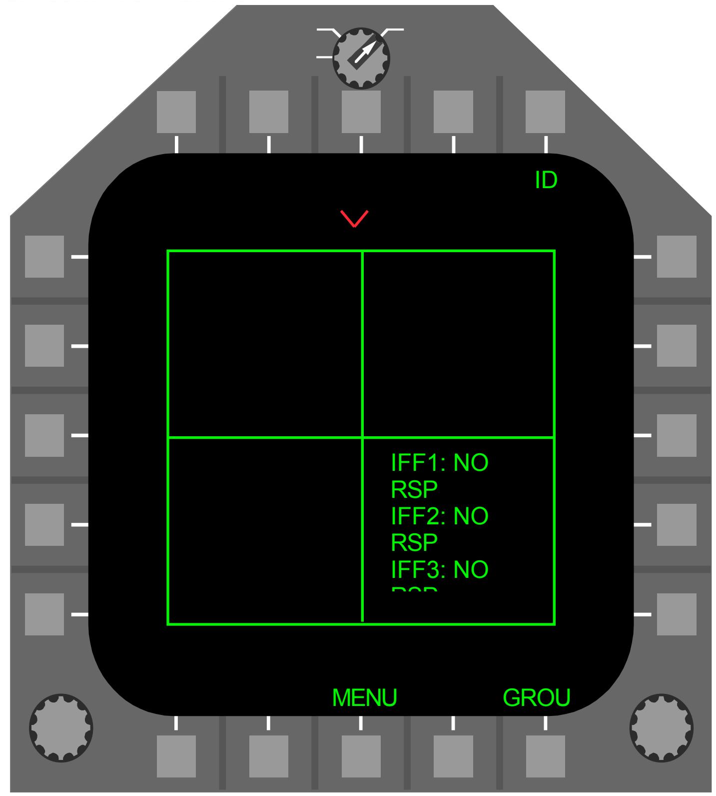


Figure 19 - FA-18 Data Display with MIDS Fighter-To-Fighter Information. Left display shows the God's eye view with two friendly fighters to the left, one unknown contact forward and left, and one hostile track ahead. NO IFF response is being received from the hostile trackfile.[10]

VITA

William Koyama was born on November 8th, 1964 in St. Cloud Minnesota. He grew up in Tigard Oregon, and graduated from Tigard High School in June of 1982. During his last two years of college he worked as an intern for the personal computer division of International Business Machines in Boca Raton Florida, designing and debugging hardware and software for personal computer diagnostics and hard drive controllers. He graduated from Rensselaer Polytechnic Institute in Troy, New York in December of 1986 with a Bachelor of Science degree in Electrical Engineering. Immediately after graduation, he was hired by NASA's Jet Propulsion Laboratory in Pasadena, California to work on the Galileo interplanetary spacecraft as a Member of the Technical Staff, Spacecraft Systems Engineering section. In November of 1988 he was accepted into the United States Navy Aviation Officer's Candidate School in Pensacola Florida. Upon graduation from AOCS, he was comissioned an Ensign in the United States Navy and reported to primary flight training in Corpus Christi, Texas in the T-34C Mentor. In August of 1989 he reported to Beeville, Texas for Intermediate Jet flight training in the T-2C Buckeye, and Advanced Jet training in the TA-4J Skyhawk. He received his Naval Aviator wings in December of 1990, and was selected for FA-18 training in Lemoore, California. As there was a backlog of FRS trainees at the time, he volunteered to serve aboard the USS Ranger, then on a combat cruise in the Persian Gulf, for nine months, as the Air Transfer Officer.

Completing this duty and transferring to Lemoore, he completed Fleet replacement training in the FA-18C in November of 1992, and reported to Strike Fighter Squadron One One Three for his initial operational tour on board USS Carl Vinson. He was selected for U. S. Navy Test Pilot School in 1995 and graduated in USNTPS Class 109 in June of 1996. Assigned to the FA-18 Project Office of VX-23, he was the Project Officer for several developmental projects for the FA-18 Production and Systems Development Team, including work for the Foreign Military Sales. He returned to USNTPS in November of 1997, serving as a Fixed Wing and Systems Flight Instructor until February of 1999 when he received orders to Commander, Carrier Group One in San Diego, California, where he served as Air Strike Operations Officer. From September 2000 until August 2003 he was assigned to Strike Fighter Squadron One Nine Two, Carrier Air Wing Five, homeported in Atsugi Japan and on board the USS Kitty Hawk, where he completed six deployments, including two combat deployments. He received the Air Medal and the Navy Commendation Medal with Combat "V" for missions flown during Operation Enduring Freedom in Afghanistan from October to December of 2001, and three further Air Medals, one specific action with Combat "V" for missions flown during Operation Iraqi Freedom from February to April of 2003. In October of 2003, he assumed the position of Fixed Wing Tutor at the British Empire Test Pilot's School, in Boscombe Down, England. He has accumulated over 3500 flight hours and has flown 45 different types of aircraft.