To the Graduate Council:

I am submitting herewith a thesis written by Matthew Shihadeh entitled "Lessons Learned from the Developmental Flight Testing of the Advanced Tactical Air Reconnaissance System." I have examined the final 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.

Ralph D. Kimberlin

Dr. Ralph D. Kimberlin, Major Professor

We have read this thesis
and recommend its acceptance:

Charles T. N. Paludan

Fred Stellar

Accepted for the Council:

[signature]

Associate Vice Chancellor and
Dean of The Graduate School

LESSONS LEARNED FROM THE DEVELOPMENTAL FLIGHT TESTING OF THE ADVANCED TACTICAL AIR RECONNAISSANCE SYSTEM

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

Matthew Shihadeh
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DISCLAIMER

The analyses, opinions, conclusions and recommendations expressed herein are those of the author and do not represent the official position of the Naval Air Warfare Center, the Naval Air Systems Command, the United States Marine Corps, or the United States Department of the Navy. The author's recommendations should not be considered attributable to any of the aforementioned authorities or for any purpose other than fulfillment of the thesis requirements.

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ABSTRACT

In 1984, the U.S. Navy and Marine Corps established an operational requirement for an F/A-18 Reconnaissance Capable aircraft. In 1985, the Navy and Marine Corps joined with the Air Force on the Advanced Tactical Air Reconnaissance System (ATARS) program. ATARS was the first reconnaissance system for manned tactical aircraft that was designed from inception to incorporate digital sensors instead of the wet-film based systems that were in use at the time.

In 1999, the developmental testing of ATARS was finally completed and an Early Operational Capability (EOC) flight clearance was granted to fleet F/A-18D Hornet aircraft. The EOC allowed a Marine F/A-18D squadron to deploy with two ATARS-equipped aircraft to Hungary in May 1999 to support the air war over Yugoslavia, even though the operational testing of ATARS had not yet been completed.

This thesis examines why it took 15 years to go from the establishment of an operational requirement to the completion of ATARS developmental testing. The primary causes were program management and technical delays. The program management delays were mostly the result of inadequate program funding and the large turnover of program personnel. The technical delays were caused by the technological challenges of producing a digital reconnaissance system with eight complex subsystems. The author's intent is to provide "lessons learned" that program managers, test engineers,

and test pilots can use to their benefit in future acquisition programs, especially those involving reconnaissance systems for manned tactical aircraft.

PREFACE

In 1991 while serving as a Weapon System Officer (WSO) for an F/A-18D squadron in the Fleet Marine Force, the author first heard about a new reconnaissance system called ATARS. Marines at higher headquarters predicted that ATARS would be available for fleet use in the F/A-18D by 1994. In 1996 when ATARS still had not shown up in fleet squadrons, no one seemed able to explain why, in terms understandable to fleet aircrew.

In June 1997 the author graduated from U.S. Naval Test Pilot School and reported to the Naval Strike Aircraft Test Squadron (NSATS). Soon after joining NSATS, he became the ATARS Project Officer and has maintained that assignment to the present. The author's duties at NSATS encompass several different test projects and other management functions, however ATARS has always been his primary test project. He has participated in 28 ATARS test flights, occupying the aft (WSO) crew station of the F/A-18D. The author will return to the Fleet Marine Force in January 2000 and looks forward to using ATARS operationally in an F/A-18D squadron.

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ACRONYMS AND ABBREVIATIONS

AEDO	Aerospace Engineering Duty Officer
AGL	Above Ground Level
AMA	Airborne Modem Assembly
ANSI	American National Standards Institute
ATARS	Advanced Tactical Air Reconnaissance System
BIT	Built-In-Test
BITPFA	Built-In-Test Percent False Alarm
CDL	Common Data Link
CEU	Control Electronics Unit
CG	Center of Gravity
Comm 1	Communications radio #1
COTS	Commercial-Off-The-Shelf
DDI	Digital Display Indicator
DOD	Department of Defense
DoN	Department of the Navy
DT	Developmental Testing
DT&E	Developmental Test and Evaluation
DTR	Digital Tape Recorder
E^3	Electromagnetic Environmental Effects
EO	Electro-Optical
EOC	Early Operational Capability
F-	Fighter aircraft
F/A-	Fighter/Attack aircraft
FOV	Field of View
ft	feet
FY	Fiscal Year
HUD	Head-Up Display
IBIT	Initiated Built-In-Test
IR	Infrared
IRLS	Infrared Line Scanner
LAEO	Low Altitude Electro-Optical
LAIU	Low Altitude Imaging Unit
lbs	pounds
LRIP	Low-Rate Initial Production
MAEO	Medium Altitude Electro-Optical
MAIU	Medium Altitude Imaging Unit

ACRONYMS AND ABBREVIATIONS (continued)

MDA	McDonnell Douglas Aerospace
MFHBFBI	Mean Flight Hours Between False Built-In-Test Indication
MIL-SPEC	Military Specification
MIL-STD	Military Standard
MOA	Memorandum of Agreement
MPCD	Multi-Purpose Color Display
MR-UAV	Medium Range Unmanned Aerial Vehicle
NATO	North Atlantic Treaty Organization
NAWS	Naval Air Weapons Station
NFOV	Narrow Field of View
NSATS	Naval Strike Aircraft Test Squadron
OT	Operational Testing
PBIT	Periodic Built-In-Test
R&D	Research & Development
R&M	Reliability & Maintainability
RC	Reconnaissance Capable
RF-	Reconnaissance Fighter aircraft
RFA	Radio Frequency Amplifier
RGE	Rate Gyro Electronics
RMS	Reconnaissance Management System
SAR	Synthetic Aperture Radar
SGS	Squadron Ground Station
SHARP	Shared Reconnaissance Pod
SMEU	Switchable Main Electronics Unit
Tac Recce	Tactical Reconnaissance
TARS	Theater Airborne Reconnaissance System
TRU	Transformer Rectifier Unit
UAV	Unmanned Aerial Vehicle
UFC	Up-Front Control
USAF	United States Air Force
VLSS	Visible Light Sensor Subsystem
VMFA(AW)-	Marine All-Weather Fighter Attack Squadron
WFOV	Wide Field of View
WRA	Weapon Replaceable Assembly
WSO	Weapon System Officer

TERMINOLOGY

DEPARTMENT OF THE NAVY

The U.S. Department of the Navy (DoN) includes two uniformed Services: the Navy and the Marine Corps. Throughout this thesis the author uses the term "DoN" when referring to them collectively, and uses "Navy" or "Marine Corps" when referring to them individually.

AIRCRAFT DESIGNATIONS

Military aircraft are normally designated by an abbreviation followed by a number and a common name. For instance, "F/A-18" designates a fighter/attack aircraft that is also known as the Hornet. A letter that indicates the variant of the aircraft can also follow the designation. For instance, "F/A-18A" designates the first variant of the F/A-18; "F/A-18B" designates the second variant, and so on.

CHAPTER 1

INTRODUCTION

THE NEED FOR ATARS

During peacetime, tactical reconnaissance capabilities are often overlooked by high-level decision-makers in the U.S. Armed Services and Congress. Their attention is focused on acquiring improved weapons and the platforms to deliver them. Because of this, Tactical Reconnaissance (Tac Recce) has historically been a popular peacetime target for budget cuts. Once the U.S becomes engaged in conflict, however, those same officials demand pre-strike and post-strike target pictures; and they don't want to wait for them or hear that current pictures aren't available due to cloud cover in the target area.

ATARS was developed to improve timeliness of intelligence data, increase operational capability, and reduce support costs for the existing Department of Defense (DOD) film-based Tac Recce platforms. It represented a decision to switch to completely digital systems with a data-link capability.[1] When fielded, ATARS was to give the theater commander an organic asset capable of providing near real-time, high resolution imagery intelligence on targets of interest within the theater of operation.[2] ATARS was needed to replace the aging Tac Recce systems (in aging aircraft) of the U.S. Air Force, Navy and Marine Corps.

Lessons from Operation Desert Storm (the Persian Gulf War) in 1991 included numerous references to the lack of accurate and up-to-date targeting information. Target photos provided to the aircrew were days, weeks, and many times months old. Without current aerial photos, it was extremely difficult for aircrew to find a pre-assigned point target, even in a low-threat environment.[3] This further highlighted the need for ATARS.

The fact that Unmanned Aerial Vehicles (UAVs) were employed with some success in Desert Storm led many military planners in the early 1990s to declare that a manned tactical reconnaissance capability was no longer needed. However, a study conducted by the DoN in 1996 concluded that manned Tac Recce and UAVs are complementary and that both capabilities are necessary. Manned Tac Recce provides commanders an armed, fast response, penetrating asset while UAVs provide advantages in endurance and ability to dwell without risking an aircrew. The study concluded that a force of only UAVs simply would not meet the tempo of operations required by the tactical commander. Manned Tac Recce provides the capability to immediately react to battlefield conditions and make critical, time sensitive decisions to implement the commander's intent.[4]

A BRIEF HISTORY OF THE ATARS PROGRAM

ATARS began as an Air Force-only program with a Statement of Need in 1979.[5] In 1984, the DoN issued an Operational Requirement for a tactical air reconnaissance system in the F/A-18.[6] In 1985, the U.S. Air Force (USAF) and the DoN signed a Memorandum of Agreement stating that the Air Force would take the lead in development of electro-optical imagery sensors and the DoN would be the lead service for concept definition of unmanned tactical reconnaissance vehicles.[7] This vague wording translated into the Air Force being the lead for ATARS and the DoN being the lead for integrating ATARS sensors into the Medium Range Unmanned Aerial Vehicle (MR-UAV).[1] ATARS was to be the first major upgrade to Air Force and Navy tactical reconnaissance fleets in more than 20 years.[8]

In 1988, the Air Force signed a firm fixed price contract with Control Data Corporation for ATARS full-scale development. At that time, Air Force officials estimated that the entire ATARS program could be worth as much as $3.5 billion, with 1,000-1,500 systems being purchased over 10-15 years. The Air Force planned to integrate ATARS into the nose bay of the RF-4C Phantom first and then into a podded system to be carried by F-16 Fighting Falcons. In a similar fashion, the DoN planned to integrate ATARS into the nose bay of the F/A-18D first and then into a podded system to replace the Tactical Air Reconnaissance Pod System carried by F-14D Tomcats.[9]

In August 1990, the Marine Corps' RF-4B Phantoms were retired due to the prohibitive cost of maintaining them. This left the Corps without a manned Tac Recce platform and increased the urgency to field ATARS. Coincidentally, the RF-4B retirement occurred within days of the Iraqi invasion of Kuwait that precipitated Operation Desert Storm and the reconnaissance lessons learned previously described in this thesis.[10]

In October 1990, Martin Marietta Corporation purchased the ATARS contract from Control Data. Martin Marietta offered transfers to some of Control Data's reconnaissance systems employees when the job functions were relocated to Orlando, Florida.[11] In February 1991, the Air Force signed an agreement formally acknowledging the transfer of the contract.[12]

The first flight with ATARS sensors occurred on 27 February 1991 in an Air Force RF-4C.[5] In August 1992, the ATARS Program Office and Martin Marietta reached an agreement to revise (referred to as rebaseline) the ATARS full-scale development contract to set reasonable delivery dates and return the contract to an enforceable basis, because the contract was currently neither enforceable nor executable.[12]

In June 1993, the Air Force cancelled the ATARS program and negotiated an early end to the contract with Martin Marietta. The Air Force cited program cost overruns, schedule slips, and technical problems in their decision to cancel ATARS.[13] Almost immediately, the DoN requested (and the Air Force agreed) that the contractor turn over three developmental ATARS systems to the Navy for testing.

In July 1993, the Office of the Chief of Naval Operations sent a letter directing the F/A-18 Program Manager to expeditiously conduct a limited technical demonstration of the ATARS sensor suite in the F/A-18D Reconnaissance Capable (RC). The purpose of the demonstration was to verify the F/A-18D(RC)'s capability to collect tactical reconnaissance imagery using ATARS sensors and to enable further decisions on development and procurement of ATARS.[14] Despite the formal wording in the letter, the tasking that trickled down to the F/A-18 ATARS test team was much simpler and direct, as can be seen from the quote posted by the ATARS Project Officer, Major Russ Jones (Figure 1).[15]

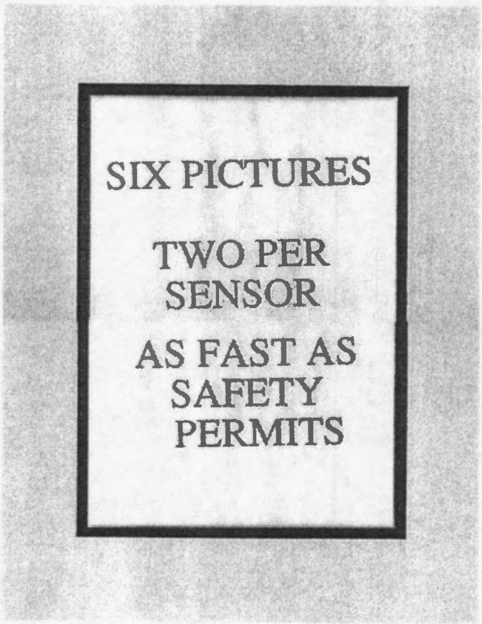

Figure 1. Plaque posted by the ATARS Project Officer (August 1993)

Provided by: L.A.M. Gallo, Naval Air Warfare Center Aircraft Division.

The DoN test team received the ATARS avionics on 13 August, and conducted five demonstration test flights by 3 September 1993. Based on the test results and the quality of the imagery, the DoN declared that ATARS had excellent potential to satisfy all requirements of the tactical reconnaissance mission.[16] Meanwhile, the Air Force continued to use the RF-4C as a test bed for ATARS until October 1993 when program responsibility was transferred to the DoN*.[1] At the same time, the MR-UAV program was terminated for affordability reasons.[17]

In January 1994 the Marine Corps assumed management of the ATARS program as lead service.[18] The Marine Corps and McDonnell Douglas Aerospace (MDA) established a basic ordering agreement in June 1994, contracting MDA to continue the development of ATARS.[13] MDA (now part of Boeing) has served as the prime contractor for ATARS since that time, with Lockheed Martin Fairchild Systems as the principal subcontractor. A listing of the current ATARS major contractors is contained in Table A-1.

By September 1999, Boeing had been granted approval from the DoN for three low-rate initial productions (LRIPs 1, 2, and 3) of ATARS, totaling 12 ATARS suites, 4 Data Link Pods, and 3 Squadron Ground Stations (SGSs).[15, 19] A full-rate production decision is expected in Fiscal Year (FY)-00.[20] Total expected procurement is 31 ATARS suites and Tac Recce conversion kits, 24 Data Link Pods, and 7 SGSs, to be delivered from FY99 through FY02.[21]

---

* In 1995, the Air Force reversed their decision to get out of the manned tactical reconnaissance business and began looking for a near-term replacement for its retiring RF-4Cs.[22] By 1999, the Theater Airborne Reconnaissance System (TARS) was being fielded on Air National Guard F-16s. Some of the TARS pods contained the same MAEO sensor used in ATARS.[23]

ATARS FLIGHT TEST HISTORY

ATARS flight tests have been conducted by the Air Force in the RF-4C and by the DoN in the F/A-18D. From February to October 1993, the Air Force conducted a limited Developmental Test and Evaluation (DT&E), accumulating 87 flight hours with ATARS at Eglin Air Force Base, Florida. The purpose of this evaluation was to determine ATARS performance, mission suitability, reliability, maintainability, system health monitoring, and man-machine interface.[1]

From December 1988 to July 1999, the DoN accumulated 726 flight hours during ATARS testing. The vast majority of these test flights originated from either Naval Air Station (NAS) Patuxent River, Maryland, or Naval Air Weapons Station (NAWS) China Lake, California. For the most part, hardware Developmental Testing (DT) took place at Patuxent River, while software DT and the Operational Testing (OT) took place at China Lake. DT accounted for 624 of these flight hours and two OT periods accounted for the remaining 102. The major tests conducted during DT and OT include the following: Flying qualities and structural integrity of the new nose configuration after an F/A-18D was converted to an F/A-18D(RC), sensor performance, digital tape recorder performance, data link, environmental control systems, recce software, reliability & maintainability, built-in-test, electromagnetic environmental effects, and aircraft carrier suitability. The ATARS flight testing conducted to date is summarized in Table A-2. An Operational Evaluation of ATARS is scheduled to be conducted from September through

November 1999, with Follow-On Test and Evaluation scheduled for March through May 2000.[19]

FIRST OPERATIONAL EMPLOYMENT OF ATARS

In April 1999 the ATARS program team was nearing the completion of DT and preparing for the Operational Evaluation. At the same time the North Atlantic Treaty Organization (NATO) was in the second month of its air campaign over Yugoslavia in defense of the Kosovo province. NATO's supreme allied commander (U.S. Army General Wesley Clark) had repeatedly requested a greater tactical reconnaissance capability against Serbia.[24] The 26th Marine Expeditionary Unit was preparing to go ashore in Kosovo and needed timely imagery of bridges, airfields and roads.[25]

In early May 1999, an Early Operational Capability was granted for ATARS so that a Marine F/A-18D squadron, VMFA(AW)-332*, could deploy with ATARS installed in 2 of their 12 aircraft.[26] The squadron deployed to Taszar Air Base, Hungary, and began combat flights with ATARS on 28 May (Figure 2).

* By chance (or perhaps by design) the Commanding Officer of VMFA(AW)-332 at this time was Lieutenant Colonel Russ Jones, who had been the DON's ATARS Project Officer in 1993 when the DON took over the program from the Air Force.

Figure 2. F/A-18D(RC) from VMFA(AW)-332 over Yugoslavia (May 1999)

Photograph taken by Captain Casey Travers, USMC
Source: "Marines Employ ATARS in Operation Allied Force," Marine Corps News, 10 June 1999.

By the bombing halt in mid June 1999, the squadron had logged more than 120 combat flight hours with ATARS.[27] In combat, ATARS was used for the following:

1. To get pre-strike and post-strike target assessments (accomplished by the same aircraft that attacked the targets).

2. To search for surface-to-air missile early warning and fire control radars.

3. To detect and classify targets real-time in the cockpit during forward air control missions.

4. To collect imagery of the next day's target sets to update target photos provided by other sources, that were 30-45 days old in most cases.[28]

The squadron aircrew, intelligence personnel, and higher headquarters (all the way up to the Combined Air Operations Center in Vicenza, Italy) were very impressed with the quality of the ATARS imagery provided.[27] In addition to its Electro-Optical (EO) and Infrared (IR) imagery, ATARS's Synthetic Aperture Radar (SAR) capability made it the only tactical all-weather imagery system available to NATO.[29]

CHAPTER 2

TEST AIRCRAFT AND ATARS SYSTEM DESCRIPTIONS

TEST AIRCRAFT DESCRIPTIONS

RF-4C Phantom

The McDonnell Douglas RF-4C Phantom II (Figure 3) was a two-seat, twin engine, unarmed, photographic reconnaissance version of the USAF F-4C fighter aircraft. The initial flight of the first production RF-4C was in 1964. The aircraft were first flown operationally in 1965 by a USAF squadron that deployed with it to Southeast Asia.[30]

Figure 3. RF-4C Phantom II from the 67th Tactical Reconnaissance Wing
Bergstrom Air Force Base, Texas

Source: FAS Intelligence Resource Program Internet site www.fas.org/irp/program/collect/re-4.htm.

The RF-4C was 62 feet (ft) long with a wingspan of 38 ft. It weighed approximately 28,000 pounds (lbs) empty and could take-off at gross weights up to 58,000 lbs.[31] The aircraft carried no offensive armament, although during the last few years of its service some were fitted with four Sidewinder air-to-air missiles for defense. The RF-4C was quite fast, with a maximum speed of 2.2 Mach. It was also capable of climbing to 59,000 ft.[30] The RF-4C was 4 ft longer than the F-4C to accommodate three camera stations. These stations were used to carry an assortment of vertical and oblique, high and low-altitude cameras. The RF-4C could carry a long-range camera in a large pod mounted on the aircraft centerline station. The aircraft also carried side-looking, mapping radar antennas on either side of the lower nose.

Just over 500 RF-4Cs were produced. In 1988 the Air Force decided to replace the aging RF-4C fleet with reconnaissance capable F-16s that were to carry an ATARS centerline pod. The last RF-4C was retired from the Air National Guard in 1994.[32] The F-16s never did incorporate ATARS but would eventually carry a pod called the Theater Airborne Reconnaissance System (TARS).

F/A-18D(RC) Hornet

The F/A-18A Hornet is a single-seat, twin engine strike fighter that first flew in 1978 and entered service with the U.S. Navy and Marine Corps in 1983. It was built by McDonnell Douglas Aircraft, which has since become part of The Boeing Company (hereafter referred to as Boeing). The F/A-18 was the first tactical aircraft designed from inception to carry out both air-to-air and air-to-ground missions. The aircraft has been updated regularly over the years and is now also in service with the air forces of Canada, Australia, Spain, Kuwait, Finland, Switzerland, and Malaysia.[33] The most current versions of F/A-18s delivered to date are the C-model (single seat) and the D-model (two seat). The F/A-18E/F Super Hornet is currently undergoing flight test.

The F/A-18D has been in service with the Marine Corps since 1990, and saw its first combat during Desert Storm in 1991. The Marine Corps has six operational F/A-18D squadrons, each containing 12 aircraft. The aircraft is 56 ft long with a wingspan of 38 ft. It weighs approximately 25,000 lbs empty and can be loaded with fuel and ordnance up to a maximum take-off weight of 51,900 lbs. The F/A-18 can carry Sidewinder and Sparrow missiles, and Advanced Medium Range Air-to-Air Missiles for use in air-to-air combat. For the air-to-ground combat mission, the Hornet can carry a variety of freefall bombs, mines, rockets, cluster bombs and smart weapons. The Hornet's maximum speed and ceiling are approximately 1.8 Mach and 50,000 ft, respectively.[34] Figure 4 shows NSATS's primary Tac Recce test aircraft. The F/A-18D(RC) aircraft's recce nose and centerline ATARS Data Link Pod are clearly visible.

The pilot mans the front cockpit of the F/A-18D, which contains the flight control stick and throttles. The aft cockpit is equipped with two hand controllers and is manned by the WSO*.

---

* The aft cockpit of the F/A-18D can be equipped with a flight control stick and throttles and used for pilot training, however this is usually only done in training squadrons, not in the operational squadrons.

Figure 4. F/A-18D(RC) Hornet from the Naval Strike Aircraft Test Squadron
Naval Air Station Patuxent River, Maryland (1998)

Photograph taken by Mike McCabe

Both aircrew get most of their information from computer-controlled cathode-ray tube displays. Each cockpit is equipped with left and right Digital Display Indicators (DDIs) and a Multi-Purpose Color Display (MPCD). In addition, the front cockpit has a Head-Up Display (HUD) that serves as the pilot's primary flight instrument. The MPCD in each cockpit is generally used to display a full color moving-map, and the DDIs are used to display any of the many tactical and support formats to the aircrew. The DDIs and MPCDs are each surrounded by 20 push-tiles that the aircrew use to interface with the aircraft and weapon systems. Each cockpit also has an Up-Front Control (UFC). The UFC provides controls for the aircraft's radios, transponder, autopilot, and other frequently used communications, navigation, and identification functions.[35]

F/A-18D TACTICAL RECONNAISSANCE SYSTEM DESCRIPTION

Reference 35, the F/A-18C/D 13C-software manual, was the source document for the following F/A-18D Tac Recce system description. ATARS was installed in the RF-4C in a manner similar to its installation in the F/A-18D.

During production, all Lot Number 14 and higher F/A-18Ds were modified to support the installation of the Recce Kit. When an aircraft is made Reconnaissance Capable (RC) by the incorporation of the Recce Kit, it is designated an F/A-18D(RC)*. The conversion to RC involves installing the ATARS sensor suite into the nose bay of the aircraft in place of the 20-millimeter gun and adding a new sensor access door containing one optical window and one infrared window. In addition, the APG-73 Radar can be used as a recce sensor by adding two Shop Replaceable Assemblies and one Weapon Replaceable Assembly (WRA) to the existing APG-73 suite. When timely data transfer to a ground station is critical for mission success, the aircraft can carry an ATARS Data Link Pod and data link imagery during the return leg of a mission.

The F/A-18D provides high-resolution long-range standoff and overflight recce capabilities, for day or night, all-weather or under-the-weather missions. As with other missions, reconnaissance missions are first developed at the Tactical Aircraft Mission Planning System workstation where a recce data file is generated and placed onto a

* For brevity, "F/A-18D" will be used to mean F/A-18D(RC) throughout this thesis, except in cases where it is necessary to distinguish between the two aircraft configurations.

Memory Unit cartridge. The aircrew carry this cartridge to the aircraft and the data file is automatically downloaded into the aircraft mission computers at power up.

The F/A-18D(RC) employs electro-optical (EO), infrared (IR), and synthetic aperture radar (SAR) sensors to gather imagery data. The aircraft carries all of these sensors on every recce flight; there is no need to upload or download sensors between flights as is required with some other recce platforms. The two onboard ATARS Digital Tape Recorders (DTRs) each record the imagery data onto a mission tape. Each mission tape can store up to 45 minutes of EO/IR imagery or 29 minutes of SAR imagery. The system allows for the recording of 12 pre-briefed targets and 20 targets-of-opportunity.

The end products of the F/A-18D reconnaissance mission are the handoff of EO, IR, and SAR imagery data to a ground based imagery processing station for subsequent exploitation and dissemination. The handoff of these data can be from two interfaces; a physical handoff of mission tapes post-flight or by data linking the imagery data while the aircraft is still in-flight. The receiving ground station for these imagery data can be an SGS, a Tactical Exploitation Group, a Joint Service Imagery Processing System-Navy, or other imagery processing systems that conform to the Common Imagery Ground/Surface System architecture. All of these ground stations except the SGS can receive imagery via data link. Figure B-1 is an example of a Medium Altitude Electro-Optical image printed at a ground station after it had been data linked from an F/A-18D during flight test. Figure 5 shows the interfaces between an F/A-18D and the ground stations.

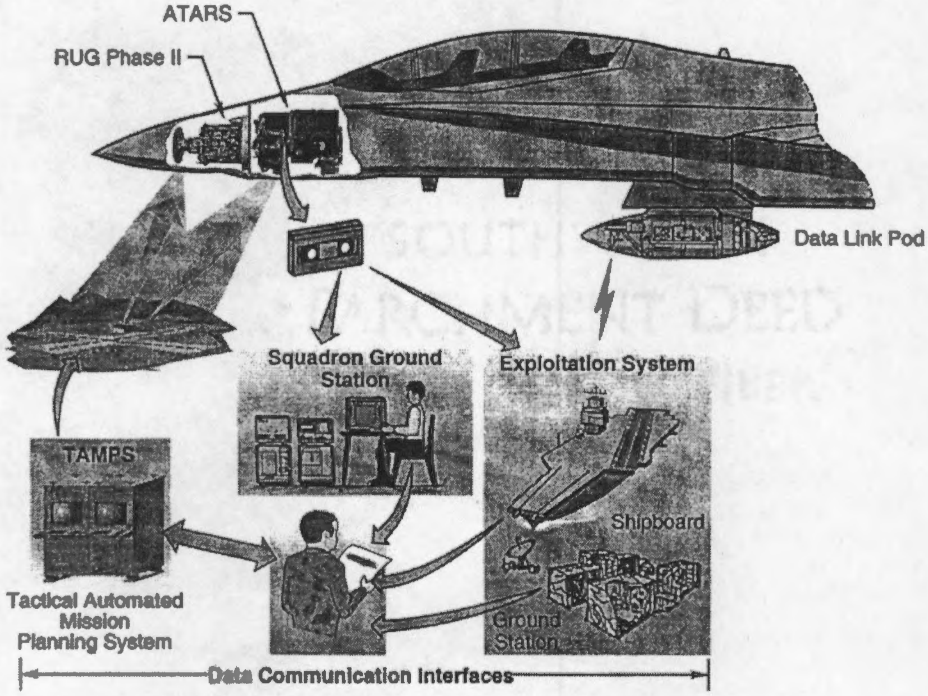

Figure 5. ATARS System Interfaces

Source: "F/A-18 Multi-Spectral Tactical Reconnaissance," briefing to SPIE Conference July 1997.

The aircrew access the reconnaissance functions through the cockpit displays, the HUD, the UFC, the stick and throttle switches in the front cockpit, and the ATARS power control and hand controller switches in the aft cockpit. The EO/IR sensors are "push-broom" sensors that scan one line of imagery at a time across the aircraft's flight path and build the complete image as the aircraft moves over the ground. Imagery from the EO and IR sensors is available for cockpit viewing on the displays during data capture, during image review, and during image down-link. The EO/IR imagery scrolls from the top of the selected DDI in a waterfall-type format as the images are being scanned.

The aircrew cannot view SAR imagery in the cockpit. This is because the SAR imagery data are raw video phase history data that have to be processed post-flight at a ground station to produce an image. Figure B-2 illustrates the two SAR acquisition modes of the F/A-18D. The first is a very-high-resolution Spotlight map mode that is used to collect a patch of data about a specific point target. The second is a high-resolution Strip map mode that is used to conduct target area searches. Figure B-3 is an example of SAR imagery recorded during flight test in an F/A-18D. SAR imagery collection differs from EO/IR imagery collection in two important ways. First, SAR imagery can be recorded through clouds (i.e., it is "all-weather"), whereas EO/IR imagery requires a clear line-of-sight to the target. Secondly, while collecting SAR imagery the aircraft is offset a large distance from the target, making the aircraft more survivable. To collect EO/IR imagery, the aircraft is usually flown almost directly over the target.

ATARS AVIONICS OVERVIEW

ATARS was the first recce system for manned tactical aircraft that was designed from inception to incorporate digital sensors instead of using wet-film. Digital systems offer a dramatic reduction in the support requirements, hazardous chemicals, and processing delays associated with wet-film based systems. Digital systems also offer improvements in image exploitation and speed of dissemination, thereby getting the imagery quickly into the hands of the warfighters and other users of tactical reconnaissance. The avionics are mounted on the ATARS pallet as shown in Figure 6.

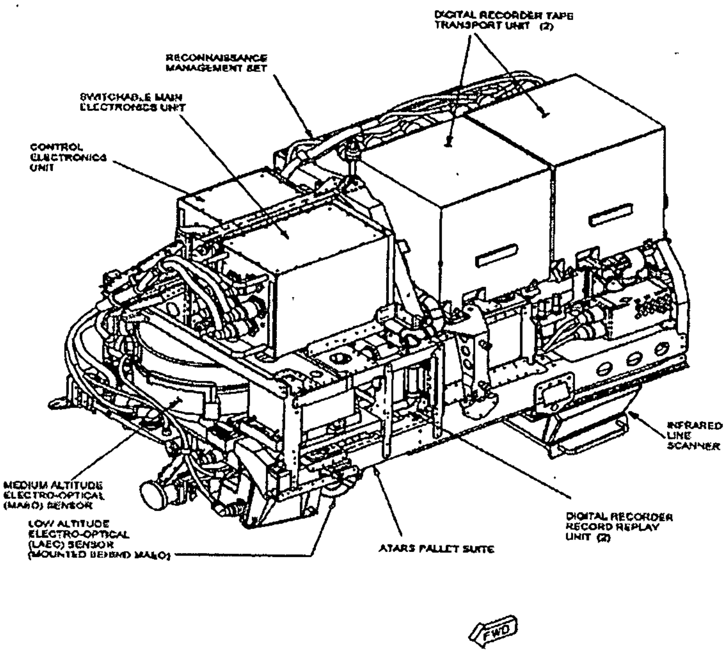

Figure 6. ATARS Components

Source: Ferrucci, D., "F/A-18D(RC) ATARS System Qualification Review," May 1999.

This pallet is subsequently hoisted into the nose bay of the aircraft in place of the 20-millimeter gun. The ATARS avionics suite consists of the following:

Reconnaissance Management System (RMS)

The RMS is the "brains" of the system and provides management and control functions in support of the recce mission. Besides the ATARS subsystem, the RMS interfaces with the F/A-18D mission computers, APG-73 radar set, and recce data link subsystem.

Visible Light Sensor Subsystem (VLSS)

The VLSS provides visual near infrared waveband imaging from the selected low or medium altitude imaging unit (LAIU or MAIU). The Switchable Main Electronics

Unit (SMEU) performs video post processing and control functions. The combination of SMEU and LAIU is referred to as the Low Altitude Electro-Optical (LAEO) sensor. The Control Electronics Unit (CEU) provides stabilization control for the MAIU. The Rate Gyro Electronics (RGE), along with the rate gyro sensors on the MAIU, provide MAIU body attitude-rate data to the CEU and the MAIU. The combination of SMEU, MAIU, CEU, RGE, and rate gyro sensors is referred to as the Medium Altitude Electro-Optical (MAEO) sensor. The LAEO and MAEO cannot provide imagery at the same time, as they share the SMEU.

Low Altitude Electro-Optical Sensor

The LAEO is sensitive to 0.55 to 0.95-micrometer wavelength radiation. As depicted in Figure B-4, the LAEO has a 140° Field of View (FOV) and was designed to image from 200 and 3,000 ft Above Ground Level (AGL). It has two selectable line-of-sight pointing positions, Vertical (92° below the horizon) and Forward Oblique (42° below the horizon). Figure B-5 is an example of a LAEO image recorded during flight test in an F/A-18D.

Medium Altitude Electro-Optical Sensor

The MAEO is also sensitive to 0.55 to 0.95-micrometer wavelength radiation. As depicted in Figure B-6, the MAEO has a 22° FOV that the aircrew can point laterally from wingtip (horizon) to wingtip. The MAEO was designed to image from 3,000 to 25,000 ft AGL, but has recorded usable imagery from 35,000 ft AGL and slant ranges out to 20 nautical miles. Figure B-7 is an example of a MAEO image recorded during flight test in an F/A-18D.

Infrared Line Scanner (IRLS)

The IRLS provides thermal imaging in the long wave infrared, 8-12 micrometer wavelength radiation. The Sensor Electronics Unit performs the signal processing. As depicted in Figures B-8 and B-9, the IRLS has a Wide FOV (WFOV) and a Narrow FOV (NFOV). The 140° WFOV was designed to gather imagery from 200 to 3,000 ft AGL, the same FOV and altitude range as the LAEO. The 70° NFOV was designed to gather imagery from 3,000 to 25,000 ft AGL, the same altitude range as the MAEO. NFOV has three side pointing angles selectable by the aircrew: Vertical, Left and Right. Figure B-10 is an example of an IRLS image recorded during flight test in an F/A-18D.

Digital Tape Recorders

The DTRs record and playback EO and IR imagery data and record SAR signal data. Each DTR is capable of recording data at rates up to 240 megabits/second and consists of a Tape Transport Unit and a Record/Replay Unit. The imagery and signal data are recorded onto two cassettes that house 19-millimeter wide magnetic tape. Each mission tape must be configured to record either EO/IR or SAR imagery. The two types of data are recorded using different formats and cannot be mixed on the same tape because ground stations process the two formats differently. The aircrew can choose to configure one tape for EO/IR imagery and one tape for SAR imagery, or to configure both tapes for the same type of imagery.

Vertical Reference Gyroscope

The Vertical Reference Gyroscope provides aircraft roll axis orientation to the VLSS and IRLS.

Pallet Subsystem

The Pallet Subsystem consists of the mounting structure for ATARS, the Transformer Rectifier Unit (TRU) and the associated cabling. The TRU performs the power rectification of the 115-Volt Alternating Current three-phase primary aircraft power input to yield a 28-Volt Direct Current output that is used by all of the WRAs of the ATARS system.

Data Link Pod Subsystem

The ATARS Data Link Pod (Figure 7) can be carried on the centerline station of the F/A-18D. To be data linked, reconnaissance imagery must first be recorded to the mission tapes*. It takes 1.5 minutes to data link each minute of recorded EO/IR imagery data and 2.3 minutes to data link each minute of recorded SAR imagery data.

* The ATARS imagery cannot be data linked at the same time it is being recorded. The imagery data are recorded at one rate and must be data linked at a much slower rate. Because of this requirement and the lack of a suitable temporary data storage medium within the Reconnaissance Management System, the imagery data must first be stored on the mission tapes before it can be data linked.

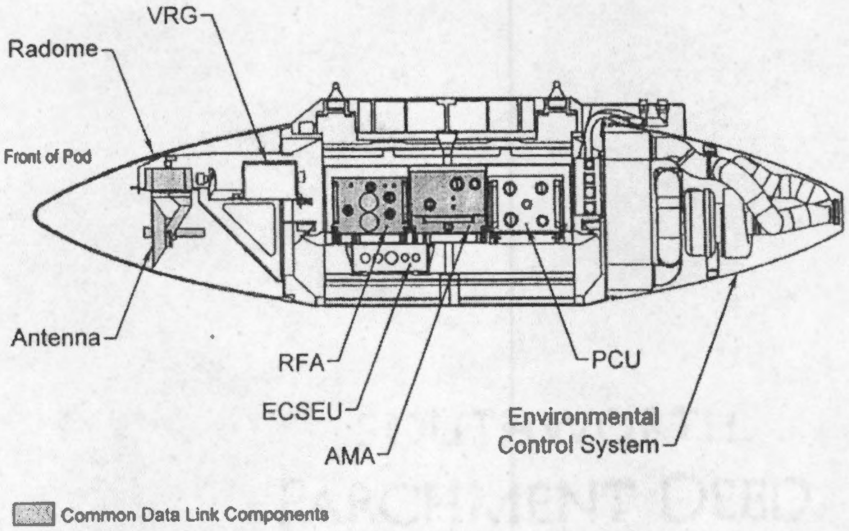

Figure 7. ATARS Data Link Pod Components

Source: "F/A-18 Multi-Spectral Tactical Reconnaissance," briefing to SPIE Conference July 1997.

CHAPTER 3

PROGRAM MANAGEMENT LESSONS LEARNED

This chapter contains an examination of ATARS program management to identify lessons learned. The following topics are discussed:

- Program Funding Shortfalls
- Turnover of Program Personnel
- Joint Staffing of the ATARS Program Office
- Common Data Link Component Break Out

PROGRAM FUNDING SHORTFALLS

Observation

Insufficient funding has plagued the acquisition of ATARS.

Discussion

As stated in Chapter 1, high-level government decision-makers tend to ignore the need for recce systems during peacetime. They focus more on acquiring “sexy” new weapon systems and the platforms to deliver them. Therefore, to “sell” a recce system the contractor must make it appear affordable, and there is a tendency for the contractor to underestimate life-cycle costs. On the government side of the acquisition process, program managers have been under extreme pressure to cut costs since the post-Cold War budget cutting frenzy of the early 1990s.

In 1991, a Defense Acquisition Executive Summary Report on ATARS was published. The report stated that the prime contractor was minimizing its current investment in the ATARS contract and was not committing the necessary resources to complete the contract in a timely manner. The major impacts of this problem were late hardware deliveries and delayed testing.[5] In a 1992 memorandum, the Director of the ATARS Program Office stated that the F-16 reconnaissance program was not adequately funded due to poor technical definition and understated government and contractor cost estimates.[12]

In 1993, the ATARS program came under intense Pentagon scrutiny because it was severely under-funded. Due to technical problems and decreasing orders, the cost of each ATARS produced for engineering and manufacturing development had pushed well above the $3-million mark, even though the system had originally been envisioned to cost $800,000 per production copy. According to a Pentagon analysis, the escalating costs had resulted in under-funding of ATARS research and development by $200 million and production by $1.5 billion.[36]

An audit report by the DOD Office of the Inspector General in 1993 found that the ATARS Program Office had not developed a complete life-cycle cost estimate at the time of the full-scale development decision in FY 1987. In 1993, the Program Office had still not developed such an estimate for the ATARS Program. As a result, program decisions were made without full knowledge of the total program cost. The reasons for the inadequate cost estimates included the following:

1. The ATARS Program Office was reluctant to report costs that it did not budget or fund. The Program Office only reported the projected costs for the ATARS to be used in Air Force F-16s and omitted the nearly $1 billion in acquisition costs for the 550 ATARS to be used in DoN MR-UAVs and F/A-18Ds. The DoN ATARS costs were contained in DoN estimates for the MR-UAV and F/A-18D, but were not separately identified for ATARS.

2. The cost estimates were based on the assumption that ATARS was considered "off-the-shelf technology." However, technical complexities contributed to cost overruns and schedule delays for the program.

3. The estimates omitted approximately $82 million of the DoN's unique maintenance costs. Specifically, the cost of the intermediate-level maintenance program planned for the DoN was not included.

4. An independent cost estimate was not prepared. Such an estimate is required for a major defense acquisition program like ATARS to test the reasonableness of the Program Office estimate.

Without complete cost estimates, decision-makers were not aware of the ATARS program total cost, and the program was faced with funding shortages.[12]

Under-funding of the ATARS program did not end when the Air Force cancelled its participation and turned the program over to the DoN in 1993. If anything, the adverse effects of under-funding became even more pronounced. Lack of program funding drove many technical decisions to utilize a less than optimum approach and forced the DoN test teams to minimize personnel. In turn, personnel shortages resulted in insufficient analyses of ATARS anomalies and inadequate documentation of fixes incorporated by the test teams, government and contractor. Unanticipated cost growth was largely responsible for the program becoming under-funded, and was especially apparent in areas such as testing and logistics support.[37]

Something that is easily overlooked during the initial budgeting process for developmental testing is the requirement to have adequate numbers of spare components and parts. The program funding provided for a very limited number of ATARS suites. This forced the test teams at Patuxent River and China Lake to share them with each other and with the contractors. Having a few more ATARS suites would have enabled the government and the contractors to work simultaneously, saving time and ultimately saving program dollars. On numerous occasions over the years, testing came to a halt while ATARS components were fixed or replaced.[38]

Another factor that has affected ATARS program funding within the last few years is that ATARS is now intended for only one armed service, the U.S. Marine Corps, with a total planned procurement of only 31 systems. In 1993 before the Air Force left the program, ATARS included three armed services (Air Force, Navy and Marines) and carried the very real possibility of foreign military sales. In December 1996, the Navy committed to a podded follow-on reconnaissance system (which eventually became known as the Shared Reconnaissance Pod), thereby removing the possibility of ATARS going into Navy aircraft.[13] With the recent DOD emphasis on saving money by making acquisition programs "joint" (to include more than one armed service), a single-service program like ATARS is continually fighting for survival and having to thoroughly justify any request for additional funding.

Lessons Learned

Budget constraints will be a dominant factor for the defense acquisition process in the foreseeable future. No longer will program managers have the luxury, as many of them did during the Cold War, of focusing on system performance without much regard to cost. Personnel involved in the acquisition of recce systems must be especially wary of the tendency for contractors and government officials to underestimate life-cycle costs. In addition, program managers must demand that cost estimates include all facets of system development and production, and plan for the inevitable technical challenges that become cost growth in every developmental test program. Program managers need to ensure that adequate spare components and parts are available throughout testing. Where feasible, acquisition programs should be joint in composition to maximize standardization between the armed services and to take advantage of the cost savings made possible by using common weapon systems.

TURNOVER OF PROGRAM PERSONNEL

Observation

The large turnover of ATARS program personnel (industry and government) has caused significant delays in getting ATARS successfully through developmental testing.

Discussion

ATARS program support by industry has included three different prime contractors between 1988 and 1999: Control Data, Martin Marietta, and Boeing (formerly McDonnell Douglas). There has also been a multitude of subcontractors. Table A-1 lists the current major contractors but does not even begin to show all of the subcontractors that have worked on, or are currently working on ATARS components. In the highly competitive aerospace industry, there is little or no incentive for a contractor to provide its successor with a thorough turnover of equipment or documentation. There is even less incentive to encourage skilled personnel to transfer to another contractor; as a result, less than 5 prime contractor personnel remained with ATARS during the transition from Control Data to Martin Marietta to McDonnell Douglas.[39] Thus each new contractor began work on ATARS without the benefit of much corporate knowledge or documentation. This inevitably led to delays as each new contractor duplicated a lot of the work performed by the previous contractor.

The turnover of prime contractor also involved a lengthy contract negotiation process (between the government and the contractors) to set new, reasonable delivery dates and return the contract to an enforceable basis. This "rebaselining" process in both cases involved establishing new milestone dates and significantly sliding the program schedule into the future. In the first turnover, Control Data sold the ATARS contract to Martin Marietta in October 1990. However, it was not until August 1992 that the Air Force reached an agreement with Martin Marietta on the contract rebaseline.[12] In the second "turnover", the Air Force cancelled the ATARS program and negotiated a settlement with Martin Marietta in June 1993. It was not until June 1994, however, that the Marine Corps and McDonnell Douglas established a basic ordering agreement to continue the development of ATARS.[13]

On the government side of the ATARS program, there have been two different lead services (Air Force and Marine Corps) and numerous different key program personnel. Program delays were encountered whenever there was a turnover between personnel as each new program manager, project officer or project engineer, would out of necessity spend several months learning the new job and learning about ATARS. From 1988-1999 there were 11 different military officers assigned as ATARS program managers for the DoN and 8 different ATARS project officers in the DoN test squadrons*. The main reason for this high personnel turnover rate was the practice of moving military officers to new assignments every 2-3 years. The assignment of civil service personnel to the ATARS program was only slightly more stable.[15]

In the DoN, the majority of ATARS program managers and project officers have been Marines, especially since 1994 when the Marine Corps became the lead service for ATARS. Unfortunately, Marine officers generally do not spend more than one tour of duty (2-3 years in duration) in the acquisition field during their careers. In contrast, once Air Force and Navy officers enter the acquisition field, there is much more emphasis placed on keeping them in acquisition. In the Air Force, after completing test pilot school, officers remain in the acquisition field for the remainder of their careers. Likewise in the Navy, officers can remain in the acquisition field for the remainder of their careers by applying and being selected for designation as Aerospace Engineering Duty Officers (AEDOs).

* At times, 2 people were assigned simultaneously as ATARS program managers or as project officers to staff two geographic locations or two functional divisions within the program.

Another result of the large personnel turnover was that program officials tended to take a short-term outlook of the ATARS program. It is only natural to focus on upcoming milestones and budgetary decision points that will be reached during a short tenure (1-3 years), rather than on what is best for the program in the long-term. Over the years many newcomers to the ATARS program complained about the short-sightedness of their predecessors, claiming that the current personnel should not be held accountable for the expedient decisions made by the previous personnel.[40]

In 1997, the ATARS Program Office moved with the rest of the Naval Air Systems Command from Arlington, Virginia to NAS Patuxent River, Maryland. As can be expected with almost every move (whether it is to the office space of a new program manager or to a totally new geographic location), documentation that was considered outdated or no longer needed was destroyed or discarded*.

Lessons Learned

Among those in the defense acquisition field, it is generally agreed that minimizing personnel turnover during developmental testing is very conducive to program success. The three most negative results of a large personnel turnover rate are program delays, short-term mindsets, and lost documentation.

High-level decision-makers on future acquisition programs would do well to select the "right" prime contractor the first time around. While that is easier said than

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* This fact was made painfully obvious to the author of this thesis in his attempts to locate documentation that was more than a few years old.

done, there are certain qualities that one should look for in a defense contractor. Rather than selecting the lowest bidder, acquisition personnel will usually be better off by choosing a contractor with a proven record and the financial stability to see the program through to completion.

While the process of moving military officers to new assignments every 2-3 years works well in an operational environment, the acquisition process would be better served by longer tours of duty, possibly 4-5 years. The Marine Corps leadership should consider implementing a career path, similar to the Navy's AEDO program, which allows officers to remain in the acquisition field for an extended period of time.

JOINT STAFFING OF THE ATARS PROGRAM OFFICE

Observation

There were no DoN personnel assigned full-time to the ATARS Program Office from 1985 to 1993.

Discussion

In 1985, the Air Force and the Navy signed a Memorandum of Agreement (MOA) to coordinate tactical reconnaissance development efforts. The MOA directed that the Air Force take the lead for development of electro-optical imagery sensors and the Navy be the lead for concept definition of unmanned tactical recce vehicles. The MOA also stated that each program's lead service would establish a program office that was augmented by personnel from the other service to make it a "joint" office.

A 1993 audit report by the DOD Office of the Inspector General found that the ATARS Program Office was staffed with only Air Force personnel and had no DoN representatives. This was due to a failure by both services to implement the MOA requirement for joint staffing. The report stated that the lack of a Navy representative contributed to coordination problems relating to specifications, contracting, testing, and cost reporting. One example of this was that in 1989 the Air Force and Navy determined that the ATARS payload wound not fit into the MR-UAV. This resulted from the Air Force's failure to coordinate adequately with the MR-UAV Program Office and to control the size of the ATARS payload being developed by its contractor. The fit problem was eventually resolved by redesigning the MR-UAV and including the redesign in a contract modification.[12] As described earlier in this thesis, however, the MR-UAV was subsequently terminated in October 1993 for affordability reasons.[17]

Lessons Learned

As stated earlier, shrinking U.S. defense budgets in the 1990s have resulted in an increasing percentage of acquisition programs being joint programs to minimize costs among the armed services. In addition, the frequent requirement for U.S. armed services to operate with their sister services and as part of multinational coalitions necessitates "joint-ness" in acquisition programs to ensure new systems are interoperable. In a joint acquisition program, each service should be represented in the program office. For example, if the Army is the lead service acquiring a new howitzer with the Marine Corps, an experienced Marine artillery officer should be assigned to the program office. Such an individual would be motivated to ensure that the Marines' requirements for the howitzer are met, and he would know what demands Marines will put on it in the field. E-mail, phone calls, and video-conferencing will never adequately substitute for having a person assigned full-time to a program office.

COMMON DATA LINK COMPONENT BREAK OUT

Observation

The government did not initially take advantage of cost savings that could have been achieved by buying the common data link directly from the manufacturer.

Discussion

The common data link is a subsystem of ATARS and consists of hardware and software modules that also support many DOD weapon system programs in various intelligence-gathering operations. The common data link is used to transmit imagery and associated support data to compatible ground stations. In 1988, Congress directed the establishment of the Common Data Link (CDL) program. In 1991, the Assistant Secretary of Defense for Command, Control, Communications and Intelligence directed that the CDL system specifications be used in all Service and Defense Agency imagery and signals intelligence collection systems unless a written exception was granted by that office. The Assistant Secretary stated that common interfaces among these systems are essential for interoperability and provide the opportunity for significant cost-savings in development procurement and support of airborne and ground systems.[12]

Component "break out" is the process whereby the government purchases components directly from the manufacturer or supplier and furnishes the components to the end-item prime contractor as government-furnished equipment. It is DOD policy to break out components whenever it is expected that prime contracts will be awarded without adequate price competition; substantial net cost savings can be achieved; and the component break out decision does not jeopardize the quality, reliability, performance, or timely delivery of the system.[12]

A 1993 audit report of ATARS acquisition (reference 12) recommended that the CDL be purchased directly by the government based on the following considerations:

1 The government had procured the CDL directly from the manufacturer, Paramax, Inc., for other DOD programs dating back to 1990.

2 The CDL was considered a very reliable system that had experienced few failures.

3 The CDL design was stable.

4 The ATARS prime contractor did not add any further design or engineering effort to the CDL.

5 A substantial cost savings could be achieved by avoiding the price markups (estimated at 20-46%) that the prime contractor would apply to the manufacturer's price.[12]

After this audit report was published, the government did in fact break out the CDL contract. The CDL contained in the ATARS Data Link Pod is purchased directly from the present manufacturer, L-3 Communications.[15] The CDL components were shown in Figure 7, and consist of the antenna, the Radio Frequency Amplifier (RFA), and the Airborne Modem Assembly (AMA).[35]

Lessons Learned

When the government is able to break out an expensive component and buy it directly from the manufacturer (rather than through the prime contractor), the potential exists for a significant cost savings. In such a case, the government has "eliminated the middle man" and an associated price markup. When a component is common to several different acquisition programs, break out allows the government further cost savings by buying large quantities. The government must be judicious in the use of component break out, reserving this procedure for components that have reached design stability and proven their reliability. Also, when the government breaks out a component, it greatly reduces the influence that the prime contractor has over the component manufacturer. If late delivery of that component causes delays for the overall system delivery, the prime contractor might then be able to make a monetary claim against the government.

CHAPTER 4

TECHNICAL LESSONS LEARNED

This chapter contains an examination of ATARS technical lessons learned. The following topics are discussed:

- Reliability of Digital Tape Recorders
- Use of Commercial-Off-The-Shelf DTRs
- The Challenges of Sensor Stabilization
- The Importance of E^3 Testing
- Evaluating Built-In-Test False Alarms

RELIABILITY OF DIGITAL TAPE RECORDERS

Observation

Improving DTR reliability has been one of the biggest technical challenges throughout the ATARS program.

Discussion

The two DTRs are crucial to the success of any ATARS reconnaissance mission. Without properly operating DTRs, the aircrew cannot record imagery for in-flight data linking or post-flight handoff to an imagery processing station. If the DTRs are not reliable in the demanding environment of a tactical reconnaissance jet, commanders will be reluctant to risk aircrew and aircraft by sending them into a threat area to get imagery.

In 1994 the Air Force published a report on ATARS Development Test and Evaluation to cover the results of flight testing conducted the previous year. One of the results reported was that the DTRs experienced four times as many critical failures as any other subsystem and required almost continuous maintenance by an on-site contractor technician. A recommendation of the report was to improve the performance, reliability, cross-play capability, and response time of the DTRs, especially during tactical maneuvering. During tactical maneuvering that involved moderate to high-g loading of the aircraft, there were numerous data dropouts caused by DTR/tape miss-track problems. The LAEO image in Figure 8 plainly shows the effects of data dropouts during aircraft maneuvering.[1]

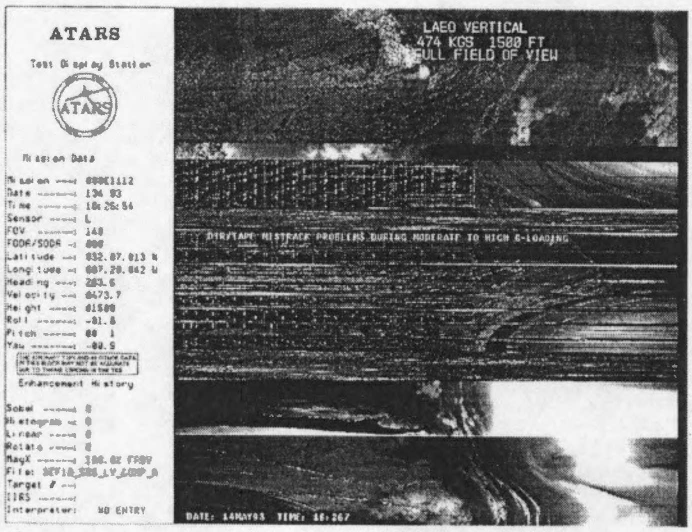

Figure 8. Example of Recorded Data Dropouts during maneuvering

Source: Minor, J.L., *ATARS Development Test and Evaluation*, AFDTC Technical Report, June 1994.

It was generally agreed, and acknowledged by the DTR supplier (Data Tape, Inc.) that at the end of the Air Force ATARS program, the DTR design was not yet mature, reliable, producible, or affordable. Notable problems experienced with the DTRs included the following:

1. The error rate never met the specified requirement and resulted in the loss of significant portions of imagery.

2. Experience in flight testing indicated that the DTR performance and reliability were unsatisfactory for the tactical aircraft environment.

3. The design contained mechanical problems that resulted in the DTRs occasionally damaging a tape and destroying the ability to retrieve data from it.

4. There were many occurrences of the cassette-carriage bending or distorting, preventing the insertion or removal of tapes from the DTR.

When the Air Force cancelled the ATARS program in 1993, the DoN conducted five demonstration test flights (described in Chapter 1) with ATARS installed in an F/A-18D. The report that followed these flights stated that the frequency of data dropouts on the imagery tapes increased with each flight, indicating a reliability problem with the DTRs. The report recommended that alternatives to the Data Tape DTR be aggressively pursued for incorporation into the production ATARS.[16] The Naval Air Warfare Center and Lockheed Martin Fairchild Systems independently launched investigations into the commercial availability of candidate DTRs. From a list of four potential suppliers, Schlumberger Industries was selected to produce the new ATARS DTR.[41]

The DoN conducted a 10-flight developmental test of the Schlumberger DTRs in November 1996. The report of test results concluded that the integration of the Schlumberger DTRs into the F/A-18D showed excellent potential and would be satisfactory upon correction of the deficiencies found. These deficiencies included the fact that ATARS failed to record imagery onto tape for 30 (14%) of the 221 attempted record sessions over the course of four of the flights. During three of the ten flights a DTR stopped functioning, requiring the aircrew to cycle ATARS power (via the cockpit power switch) to regain control of the DTR. An enhancing characteristic of the Schlumberger DTRs was that they successfully recorded imagery during aircraft maneuvers up to the test limit load factor of 7.6g's.[42]

An ATARS Reliability & Maintainability (R&M) flight evaluation was conducted in November 1997 and consisted of 17 test sorties. ATARS had 4 operational mission failures during this evaluation, all of which were directly attributed to the DTRs.[43] In fact, the DTRs have been the primary contributor to ATARS mission failures throughout testing to date, accounting for more than 60% of flight failures.[44]

Lessons Learned

The technical challenges of recording Tac Recce imagery to a magnetic cassette tape have had an enormous impact on the reliability of the entire ATARS system. Efforts to improve the reliability of the DTRs have had an adverse effect on the cost and schedule of the ATARS program. It appears that inadequate attention and resources were committed early in the ATARS program to ensure that the DTRs were well designed and integrated into the F/A-18D. In the future, officials involved in acquiring Tac Recce systems should realize the limitations of current magnetic tape recorders and consider the use of alternate methods of digital recording.

Disk recorders and solid state recorders are two options that have been discussed for use in ATARS as well as follow-on Tac Recce systems. The funding constraints of the ATARS program coupled with the design immaturity of disk/solid state recorders makes it unlikely that they will ever be incorporated into ATARS. However, disk/solid state recorders are being considered for the DoN's follow-on Tac Recce system, which is called the Shared Reconnaissance Pod (SHARP). SHARP is currently planned to be carried by the F/A-18E/F Super Hornet as well as a variety of other aircraft in all of the U.S. armed services (hence the title "Shared").

In simplistic terms, the difference between magnetic tape and disk/solid state recorders is comparable to the difference between an eight-track tape music recording (1960s technology) and a compact disc music recording (1980s technology)[15]. Since they have few moving parts, disk/solid state recorders offer the potential for better reliability than magnetic tape recorders. They also offer the capability to immediately access data, whereas magnetic tape recorders require a time-consuming rewind/fast forward process to find specific data. The disadvantages of disk/solid state recorders are their potential high cost and the fact that their current designs do not meet Tac Recce requirements.[45]

USE OF COMMERCIAL-OFF-THE-SHELF COMPONENTS

Observation

The incorporation of Commercial-Off-The-Shelf (COTS) components into ATARS has posed some technical challenges to the program.

Discussion

Prior to acquisition reform, the DOD relied heavily on the use of military specifications (MIL-SPECs) and military standards (MIL-STDs), which accounted for more than 35,000 documents at the height of their popularity. It was "safe" for a program manager to rely on MIL-SPECs and MIL-STDs. If he advocated a performance-based specification or used a commercial standard, and something went wrong, then his decision was subjected to intense scrutiny. He literally would put his career on the line for taking such a risk to save the government money.[46]

The collapse of the Berlin Wall (1989) and the demise of the Soviet Union (1991) resulted in a dramatic reduction of the U.S. defense budgets. Affordability became the driving force behind acquisition reform of the 1990s. U.S. Secretary of Defense William Perry sent out a Policy Memo entitled "Specification and Standards -- A new Way of Doing Business" in June 1994. This memo centered on reducing the reliance on MIL-SPECs and MIL-STDs and was followed by the Federal Acquisition Streamlining Act that became law in October 1994. The effect of this law was to allow the commercial sector to lead Research & Development (R&D) investment and demand for products. This meant that military acquisition programs could no longer afford to support a separate infrastructure for a military industrial base, but would need to integrate where feasible to a common military-commercial industrial base. In 1965, the commercial sector's investment in R&D surpassed that of the DOD and the disparity has continued to grow in the 34 years since. This has established the commercial sector as the driving force behind the pace of technological innovation in the U.S.[46] The incorporation of COTS products into military systems has become increasingly popular throughout the 1990s. The basic premise is to save money and time by allowing the commercial sector to design, develop, and test new products that are then purchased by the military.

Early on, the ATARS program dispensed with many of the rigid military design specification and standards to give contractors greater latitude in designing the system.[8] The ATARS Statement of Work dictated that the DTR manufacturer "shall analyze available commercial off-the-shelf DTRs that may be modified, with low risk, to meet these requirements." When Schlumberger was selected to manufacture the DTRs, its proposal was derived from a COTS baseline product that was compliant to the American National Standards Institute (ANSI) ID-1 digital cassette tape format.[41] The ANSI standard was distinct from a specification in that it delineated a minimum of restrictions consistent with compatibility in media interchange transactions.[47] It is important to note that ID-1 cassette tapes and their associated recorders were originally designed to operate in broadcast studios, not in the nose of a tactical jet aircraft.[48]

To make their COTS recorder work as an ATARS DTR, Schlumberger was forced to implement major modifications. Schlumberger split some of the functions of the baseline DTR, and repackaged them to be able to fit onto the ATARS pallet and to be compatible with the existing cabling. Hermetic air-to-air heat exchangers were incorporated in the re-packaging to meet the F/A-18 cooling requirements. The cassette loading mechanism was redesigned to allow for the aircrew to load both mission tapes into the DTRs through the existing access door on the side of the F/A-18 nose.[41] Figure 9 shows the basic repackaging that was required of the manufacturer to make their existing recorder (on the left in the figure) into one compatible with the F/A-18.

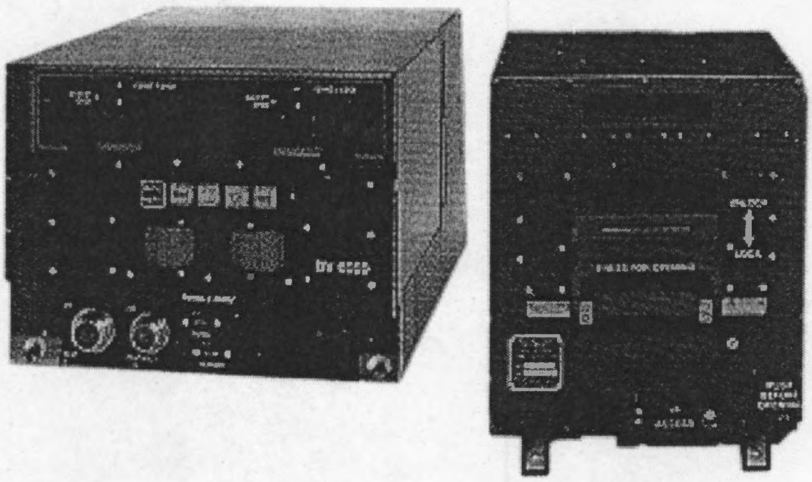

Figure 9. Repackaging of the existing recorder (left) into an F/A-18 DTR (right)

Source: Enertec industry brochure

In 1995, when Schlumberger was selected to produce the DTRs, ID-1 cassette tapes were available at low-cost from three different sources.[41] At the completion of

ATARS DT in 1999, however, the number of suppliers of ID-1 cassettes suitable for use in ATARS had dwindled to only one, Sony Corporation.

At the present time, the ATARS program utilizes Sony's ID-1 tape, called the SD-1. In 1998 Sony ceased manufacturing the SD-1 tape and replaced it with a new version called the SD-1A. At that time, the ATARS test team purchased all of the remaining SD-1 tapes available in the U.S., roughly 300. By producing the SD-1A, Sony was responding to their largest customer base, the commercial sector. Because the number of SD-1 tapes remaining is limited, the ATARS program will eventually need to transition to a different ID-1 tape. Whichever tape is chosen will undoubtedly have different magnetic and physical characteristics than the SD-1; even the SD-1A does. Schlumberger will then be required to test the new tape (at government expense) in the DTR.[45]

As indicated previously in this thesis, improving the DTRs' reliability has been one of the biggest technical challenges throughout the ATARS program. It is the author's belief that a contributing factor to DTR unreliability has been the repackaging of the COTS recorder to make it compatible with the ATARS installation in an F/A-18.

Lessons Learned

The nose of a tactical jet is a very hostile environment for electromechanical systems. Using COTS components and being free from MIL-SPECs / MIL-STDs can be attractive, especially from a cost standpoint. However, this is not always appropriate for military applications. If COTS components must undergo major modifications or repackaging to make them usable in a military environment, program managers and test engineers should expect problems. In addition, modifying and repackaging can defeat the purpose of buying "off-the-shelf" components in the first place. When the decision is made to purchase COTS components, government officials must be aware that they will probably not have much long-term influence over the manufacturer. The manufacturer will be free to modify their COTS components to please their biggest customers in the commercial sector, without consulting or even informing the government.

THE CHALLENGES OF SENSOR STABILIZATION

Observation

Stabilizing the ATARS sensors, especially the MAEO, posed a difficult challenge for the ATARS test team (government and industry), requiring several fly-fix-fly test periods to achieve adequate performance.

Discussion

The MAEO stabilization system inside the RF-4C (and later in the F/A-18D) consisted of passive isolators and an active three-axis servo system. The MAEO was mounted on vibration dampening shock mounts (the passive isolators). In conjunction, a complex electro-mechanical stabilization system (the active servo system) was used to compensate for aircraft motion and vibration not damped by the shock mounts.

During the 1993 Air Force flight testing of ATARS in RF-4Cs, the MAEO was plagued by stabilization problems. The MAEO image in Figure 10 was taken in April 1993 before the contractor implemented corrective actions to mitigate the vibration problems. Both low and high frequency effects of vibration on the image integrity are evident along the edges of the highway and the truck.

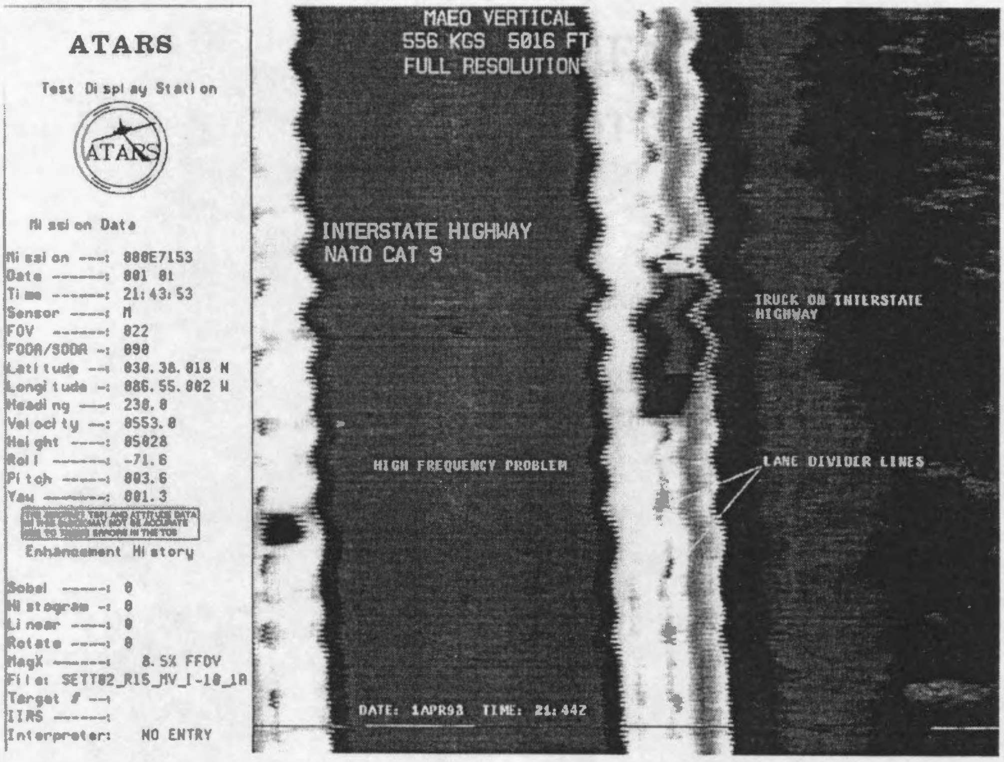

Figure 10. MAEO image of a truck on a highway (prior to MAEO modification)

Source: *ATARS Development Test and Evaluation*, AFDTC Technical Report 94-06, June 1994

The contractor implemented several modifications to the MAEO to correct the stabilization deficiencies. These changes included a lighter, larger diameter prism with new shaft bearings. Flight tests conducted with the modified MAEO indicated that while significant improvement had been made in the stabilization system, both low (25-40 hertz) and high (200-300 hertz) frequency effects were still present in the imagery.

The amplitude of the vibration increased as aircraft speed increased. The image shown in Figure 11 was taken with the modified MAEO in August 1993. Although the amplitude of the vibrations is significantly less than those in Figure 10, both low and high frequency artifacts are still present in the image, essentially destroying the integrity of the image for intelligence purposes.[1]

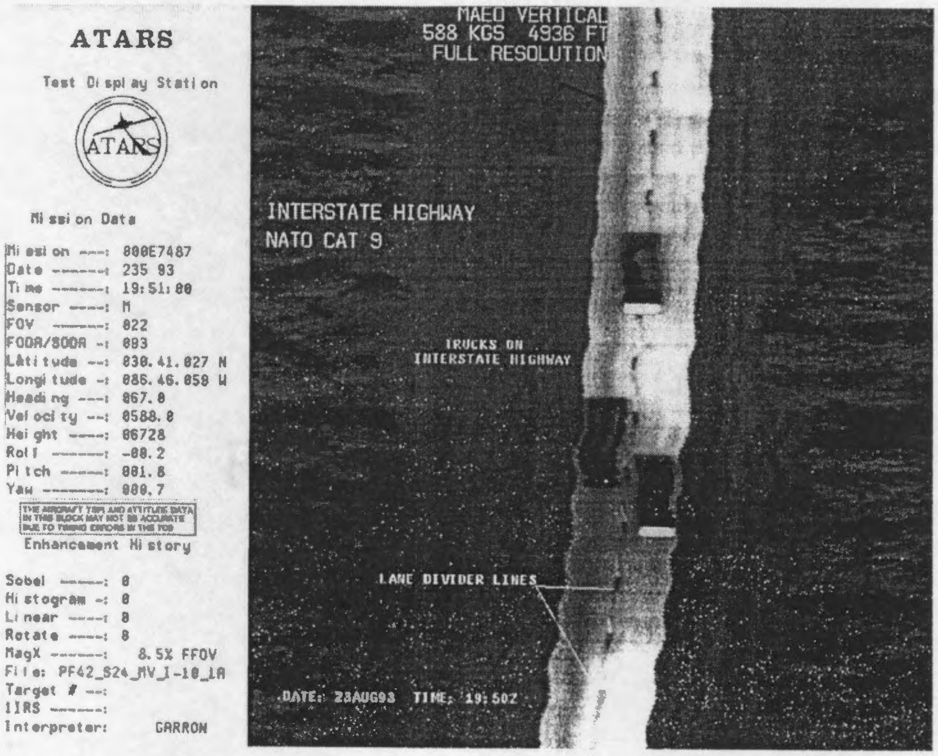

Figure 11. MAEO image of trucks on a highway (after MAEO modification)

Source: *ATARS Development Test and Evaluation*, AFDTC Technical Report 94-06, June 1994

During flight testing the next year, the DoN test team found the same anomalies with the MAEO sensor. In February 1994, the test team reported that the MAEO's stabilization system was not optimized to isolate the MAEO from the vibrational environment of the F/A-18D. Image anomalies induced by vibration ranged from scalloped edges on roads and buildings (best case) to duplications of targets (worst case).[49] A Report of Test Results in October 1994 described image anomalies characterized by oscillation of the MAEO FOV that caused alternating bands of compressed and expanded imagery. The anomalies appeared sporadically, leaving some portions of the imagery unaffected. The authors of that report postulated that the vibration problem was due to the fact that the stabilization system was designed to operate inside the nose of a RF-4C, not an F/A-18D.[50]

The ATARS principal subcontractor implemented several modifications to the MAEO installation in the F/A-18D. The MAEO mounting was changed to align the center of gravity (CG) of the MAIU with the rotational center of the isolation system; prior to this, the CG was offset approximately an inch in all three axes (vertical, longitudinal and lateral). The orientation of the isolation mounts was changed from horizontal to vertical. The servo electronics were remounted onto the fixed structure of the ATARS pallet, independently from the MAIU.[51] The gear-drive pointing prism in the MAIU was replaced with a simpler direct-drive mirror system to decrease vibration, improve pointing response to servo inputs, and reduce mechanical complexity and weight.[52] These and other modifications to the MAEO eventually resulted in high resolution, vibration-free imagery, such as that shown in Figures B-1 and B-7.

During March 1997, the upgraded MAEO was flight tested by the DoN. The message report that followed testing stated that the MAEO resolution performance allowed the aircrew to collect high quality tactical imagery while maintaining stand-off from the target area, and was an enhancing characteristic that should be incorporated in future designs.[52]

Lessons Learned

Stabilizing a reconnaissance sensor inside the nose of a high-speed tactical aircraft is very difficult. Those involved in the acquisition of future Tac Recce systems need to be aware of this technical challenge and prepared to undergo several iterations of the fly-fix-fly process during flight test. A recce sensor <u>outside</u> the skin of an aircraft (e.g., a podded system) will be directly subjected to air loads, another potential source of vibrations and imagery anomalies. This should be kept in mind during the development testing of the DoN's follow-on Tac Recce system, the Shared Reconnaissance Pod.

THE IMPORTANCE OF E^3 TESTING

Observation

Electromagnetic Environmental Effects (E^3) testing revealed a major incompatibility between ATARS and the existing F/A-18D avionics systems.

Discussion

In accordance with a military standard (MIL-STD 464), all new avionics systems must undergo E^3 testing during the developmental testing phase.[53] The purpose of E^3 testing is to ensure that the new avionics functions as designed in its predicted operational electromagnetic environment (land-based, shipboard, and airborne) and does not interfere with the proper functioning of existing avionics. E^3 testing verifies that new avionics do not compromise security or aircraft survivability through unintentional radiated emissions. It also verifies that the new avionics are not affected by the dissipation of static electrical charges that may build up on the external surface of the aircraft.[54]

From 1 February through 18 March 1999, an E^3 technical evaluation was performed on an F/A-18D aircraft with ATARS installed. The testing was conducted using the E^3 ground-test facilities at NAS Patuxent River. As part of this evaluation, intrasystem electromagnetic compatibility tests were conducted to determine the degree of compatibility between ATARS and the existing F/A-18D avionics systems. With the aircraft landing gear up & locked, electromagnetic interference occurred when transmitting on a specific frequency band of the aircraft's Communications radio #1 (Comm 1) through the Comm 1 Lower Antenna.

Figure 12 shows the mold-line of the nose of an F/A-18D after it has been converted to an F/A-18D(RC). The dashed line in the figure represents the mold-line of an F/A-18D before conversion. When the conversion takes place, the Comm 1 Lower Antenna is moved approximately eight feet towards the rear of the aircraft (to the position shown in Figure 12, labeled "UHF/IFF/VHF COMM ANTENNA") and attached to the nose landing gear door. This movement aft is necessary because the aircraft panel that the antenna was attached to in the F/A-18D configuration is replaced by the sensor access door (shown in Figure 12 with two sensor windows) in the F/A-18D(RC) configuration.

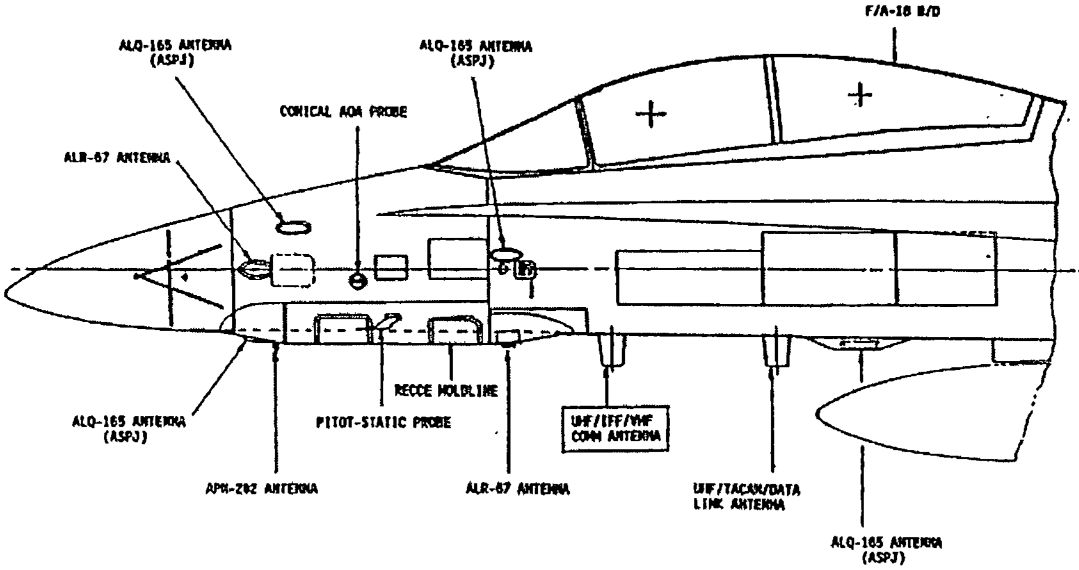

Figure 12. Mold-line of the F/A-18D(RC) Nose Section

Source: Beck, E., "F/A-18D Reconnaissance Flying Qualities," technical report, May 1992.

The nose landing gear door is closed after the landing gear are raised in flight, placing the Comm 1 Lower Antenna within inches of the nose landing gear up-lock proximity switch ("up-lock switch") which is located inside the aircraft's nose wheel well. The up-lock switch indicates when the nose landing gear is up & locked. During E^3 testing, the aircraft was hoisted off the ground and the landing gear was raised to simulate an in-flight condition. Because of the new location of the Comm 1 Lower Antenna, radio-frequency energy transmitted from it (in a specific frequency band) was found to interfere with the proper functioning of the nose landing gear up-lock switch. This interference caused the switch to change state and erroneously indicate that the nose landing gear was <u>not</u> up & locked while radio transmissions were in progress. This would in turn cause false cockpit warnings to the test personnel in the cockpit (visual and audio) that the nose gear was not up & locked. These same indications prevented simulated launches of air-to-air and air-to-ground weapons, since having the landing gear up & locked is a prerequisite to releasing ordnance from the F/A-18. This deficiency was duplicated in flight on two occasions with another F/A-18D aircraft, but was not repeated with any regularity.[54]

Over a period of several weeks, the test team investigated several potential fixes to the problem before discovering a feasible solution. It was found that the nose gear up-lock switches, in the F/A-18Ds that had experienced this deficiency, were an older version of the switch. The manufacturer of that switch had stopped producing them, and another manufacturer was contracted to supply the switch. The new manufacturer redesigned the switch to improve its electrical efficiency (reduce the power requirements). A by-product of this redesign was that the new switch had better shielding to prevent electromagnetic interference.[55] The nose gear up-lock switches had been replaced with this new switch in some but not all of the F/A-18s. Once the new switch was installed in the test aircraft, the interference problems described above were no longer experienced. The test team's proposed solution to the Comm 1 Lower Antenna deficiency was to require that the new nose gear up-lock switch be installed in all F/A-18D aircraft that are converted to F/A-18D(RC) in the future.[54]

Lessons Learned

Many individuals involved in the test and evaluation of new weapon systems do not fully understand or appreciate the requirement to conduct E^3 testing. Until this recent experience with ATARS testing, the author was among those who questioned the large investment in time and money that E^3 testing requires. In this particular case, E^3 testing revealed a deficiency that might not have been discovered until after ATARS was deployed operationally in combat. If that were the case, this deficiency could have prevented F/A-18D aircrew from launching weapons (offensively or defensively), resulting in a mission-abort or even possibly the loss of aircraft and aircrew.

Design and test engineers should be especially vigilant for electromagnetic interference whenever existing avionics components (such as the Comm 1 Lower Antenna) are moved to allow the incorporation of new systems. When feasible, E^3 testing should be conducted as soon as the system-under-test has reached sufficient maturity. This will allow the government/contractor test team to investigate and implement fixes early in the test & evaluation cycle.

EVALUATING BUILT-IN-TEST FALSE ALARMS

Observation

The ATARS Program used two different methods to evaluate ATARS Built-In-Test (BIT) false alarms: BIT Percent False Alarm (BITPFA) and Mean Flight Hours Between False BIT Indication (MFHBFBI). MFHBFBI proved to be a much more meaningful and operationally significant indication of ATARS R&M.

Discussion

The F/A-18 status monitoring subsystem was designed to improve aircraft maintainability, and was mechanized in such a way as to provide the F/A-18 aircrew with simple displays of weapon system status without interfering with their primary mission essential functions. This subsystem was also designed to provide maintenance technicians with clear diagnostic information. The information presented to aircrew and maintainers is derived from BIT mechanization resident within each avionics equipment set. In most instances, two types of BITs are mechanized, periodic and initiated. A Periodic BIT (PBIT) automatically begins functioning upon equipment power application. An Initiated BIT (IBIT) is run only after an operator (aircrew or maintainer) commands it. IBIT is more thorough than PBIT; however, IBIT takes more time to complete than PBIT and usually interferes with the normal operation of the equipment being tested while IBIT is running.[35] Both PBIT and IBIT results are used in determining system BIT false alarms. False failure indications (BIT false alarms), not only degrade maintainer confidence in BIT, they also degrade the aircrew's confidence in determining the aircraft's readiness to accomplish the assigned mission[56].

The Operational Requirements Document for the Reconnaissance Capable F/A-18 contains several requirements for ATARS R&M. Two of these requirements directly pertain to ATARS BIT false alarms:

1. BITPFA must be less than 35%, and
2. MFHBFBI must be greater than or equal to 5.4 hours.[6]

By the end of Developmental Testing, ATARS was meeting the requirement for MFHBFBI (test result -- 6.4 hours) but was not meeting the requirement for BITPFA (test result -- 77.6%).[19]

After discussing the measurement of BIT false alarms with other members of the flight test community and reviewing the available literature on the subject, it became apparent to the author of this thesis that MFHBFBI is a much better measure of ATARS R&M than BITPFA. BITPFA is a ratio of BIT false alarms to total BIT indications, but it does not quantify the <u>frequency</u> of false alarms like MFHBFBI does. Also, there is an inherent deficiency associated with the BITPFA metric in that equipment is actually penalized for high reliability. For example, if System A has 5 BIT false alarms and 5 BIT-relevant actual failures in 10 flight hours, then the BITPFA is 50%. If System B has 5 BIT false alarms and no actual failures in 1000 flight hours, the BITPFA is 100%. From the BITPFA metric it appears that System A is performing twice as well (from an R&M standpoint) as System B, though it is obvious upon further inspection of the data that System B is much more reliable. Using the same example, the MFHBFBI for System A is 2 hours and the MFHBFBI for System B is 200 hours, clearly showing the higher reliability of System B. A BIT false alarm metric in terms of flight hours per false alarms (like MFHBFBI) provides a measurement that is operationally significant, since mission and resource allocation planning are typically calculated in terms of flights or flight hours.[56]

In September 1999 the office of the Chief of Naval Operations released a naval message stating that the BITPFA metric would not be evaluated during the ATARS Operational Evaluation. The message also stated that omitting this metric from the evaluation would not have an impact of the fleet use of ATARS, since the MFHBFBI metric had met the requirements of the Operational Requirements Document during Developmental Testing and would be further evaluated during the Operational Evaluation.[57]

Lessons Learned

Personnel that set the requirements for future avionics programs should carefully choose their metrics for determining R&M based on BIT results. A BIT false alarm metric like BITPFA can yield misleading results by actually penalizing a system for being reliable. A metric based on flight hours will be much more meaningful to test aircrew and engineers as well as to high-level decision-makers in the acquisition process. Such a metric will also be more relevant and easy to understand for the final customer, fleet aircrew and maintainers. For these reasons, MFHBFBI should be used instead of BITPFA as the metric for determining R&M based on BIT results.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The ATARS program has been in existence (at least on paper) for the past 20 years. During that time there have been many changes in the defense acquisition process. In the same year (1991) that flight testing began with ATARS sensors, the Soviet Union was disbanded and U.S. defense budgets were soon undergoing massive cuts. This in turn led to "acquisition reform" in which affordability became the driving force. Most of the nine lessons learned, previously described in this thesis and summarized below, can be directly or indirectly linked to a lack of program funding.

Program Funding Shortfalls

Budget constraints will be a dominant factor for the defense acquisition process in the foreseeable future. Personnel involved in the acquisition of recce systems must be especially wary of the tendency for contractors and government officials to underestimate life-cycle costs in order to make the program more attractive. This leads to program budgets that are too small to hire enough people (government and industry), to meet technical challenges, to have adequate spare parts available, and so on. Where feasible, acquisition programs should be joint programs to take advantage of the cost savings made possible by using common weapon systems among different armed services.

Turnover of Program Personnel

Minimizing industry and government personnel turnover during developmental testing is conducive to program success. The three most negative results of a large personnel turnover rate are program delays, short-term mindsets, and lost documentation. Government officials should go to great efforts to select the "right" prime contractor at the start of an acquisition program, one that can see the program through to completion and not have to turn it over to another contractor. In the acquisition field, military officers should serve longer tours of duty to minimize the turnover of program managers and project officers.

Joint Staffing of the ATARS Program Office

For good reasons, many of the future acquisition programs will be joint programs. This is a more cost-effective way of doing business and helps ensure that the armed services can operate together and as part of multinational coalitions. In a joint acquisition program, each service must be represented in the program office. That is the first, crucial step to ensure that the unique requirements of each armed service will be met.

Common Data Link Component Break Out

When the government is able to "break out" an expensive component and buy it directly from the manufacturer (rather than through the prime contractor), the potential exists for a significant cost savings. When that component is common to several different acquisition programs, break out allows the government further cost savings by buying in quantity.

Reliability of Digital Tape Recorders

The technical challenges of recording Tac Recce imagery to a magnetic cassette tape have had an enormous impact on the reliability of the entire ATARS system. Efforts to improve the reliability of the DTRs have had an adverse effect on the cost and schedule of the ATARS program. In the future, officials involved in acquiring Tac Recce systems should realize the limitation of current magnetic tape recorders and consider the use of alternate methods of digital recording. Disk recorders and solid state recorders offer the potential for better reliability as well as the capability to access data quickly.

Use of Commercial-Off-The-Shelf Components

Using COTS components can be attractive, especially from a cost standpoint. However, COTS components are not always appropriate for military environments, such as inside the nose of a tactical jet, which can be very hostile to electromechanical systems. If COTS components must undergo major modifications to make them usable in a military environment, program managers and test engineers should expect problems. With COTS, government officials have very little long-term influence over the manufacturer; the manufacturer is free to modify their components to please their biggest customers in the commercial sector, without consulting or even informing the government.

The Challenges of Sensor Stabilization

Stabilizing a recce sensor inside the nose of a high-speed tactical aircraft is very difficult. Personnel involved in developing future Tac Recce systems should anticipate needing several iterations of the fly-fix-fly process during flight test. Podded systems (like SHARP) will be directly subjected to air loads, another potential source of vibrations and image anomalies.

The Importance of E^3 Testing

Electromagnetic Environmental Effects testing is well worth the time and money required to conduct it. In the case of ATARS, E^3 testing revealed a major deficiency that might not have been discovered until after ATARS was deployed operationally. Design and test engineers should be especially vigilant for electromagnetic interference whenever existing avionics components are moved to allow the incorporation of new systems.

Evaluating Built-In-Test False Alarms

Personnel that set the requirements for future avionics programs should carefully choose their metrics for determining R&M based on BIT results. A BIT false alarm metric like BITPFA can yield misleading results by actually penalizing a system for being reliable. A metric based on flight hours, like MFHBFBI, will be much more meaningful to high-level decision-makers, test aircrew and engineers, and to the final customer, fleet aircrew and maintainers.

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52 *F/A-18D(RC) ATARS Data Link Integration and MAEO Sensor Performance Test Results*, Naval Message R 301331Z APR 97, from Naval Strike Aircraft Test Squadron, 30 April 1997.

53 *MIL-STD 464, Interface Standard, Electromagnetic Environmental Effects Requirements For Systems*, 18 March 1997.

54 Finley, J.R. and Clelland, M.R., *F/A-18D(RC) ATARS and Tactical Aircraft Moving Map Capability E^3 Evaluation*, Report of Test Results NAWCADPAX—99-141-RTR, 1 July 1999.

55 Clelland, M.R., Electromagnetic Environmental Effects test engineer, Naval Air Warfare Center Aircraft Division, interviewed by the author 29 July 1999.

56 *Built-In-Test Process White Paper*, prepared by the Naval Air Warfare Center Aircraft Division Reliability & Maintainability competency team, 17 September 1997.

57 *FA-18D Advanced Tactical Air Reconnaissance System Certification of Readiness for OT-IIB, OpEval, CNO Project 0201-01*, Naval Message R 011601Z SEP 99, from DoN Program Executive Officer for Tactical Aircraft Programs, 1 September 1999.

APPENDICES

APPENDIX A (TABLES)

Table A-1. Current ATARS Major Contractors (as of August 1999)

Sources: Contractor Internet web sites, industry brochures, ATARS Program Office briefings and personal interviews with ATARS program officials.

Company Name	Location	ATARS Components Made	Remarks
Boeing	St. Louis, MO	Recce Conversion Kit for the F/A-18D	Prime Contractor through Low-Rate Initial Production (LRIP). Responsible for overall program management and integration. Formerly McDonnell Douglas Aerospace.
Lockheed Martin Fairchild Systems	Syosset, NY	MAEO and LAEO sensors RMS software	Principal Subcontractor for LRIP. Prime Contractor for full-rate production. Formerly Loral Fairchild Systems.
Lockheed Martin IR Imaging Systems	Lexington, MA	IRLS sensor	Formerly Loral Infrared Imaging Systems
Red Wing Products	Kellyville, OK	ATARS pallet structure	
Computing Devices Limited	St Leonards-on-the-Sea, England	RMS hardware and firmware	Formerly Control Data Corporation, Hastings Division.
Enertec	Clamart, France	Digital Tape Recorders	Formerly Schlumberger.
Sony	Sendai, Japan	Data Tapes	
Sargent Fletcher	El Monte, CA	Pod enclosure, ducting and wire harnesses for the ATARS Data Link pod	
L-3 Communication Systems – West	Salt Lake City, UT	Common High Bandwidth Datalink for the ATARS Data Link pod	Formerly Paramax. Formerly Lockheed Martin Wideband Systems.
Raytheon Systems	El Segundo, CA	AN/APG-73 radar and Radar-Upgrade Phase II	Formerly Hughes Aircraft
Raytheon Systems	Garland, TX	Squadron Ground Station	

Table A-2. Summary of ATARS Flight Testing (through August 1999).

Sources: *ATARS Development Test and Evaluation*, AFDTC Technical Report 94-06, June 1994 and *F/A-18D Tactical Reconnaissance System DT/OT Transition Report*, August 1999.

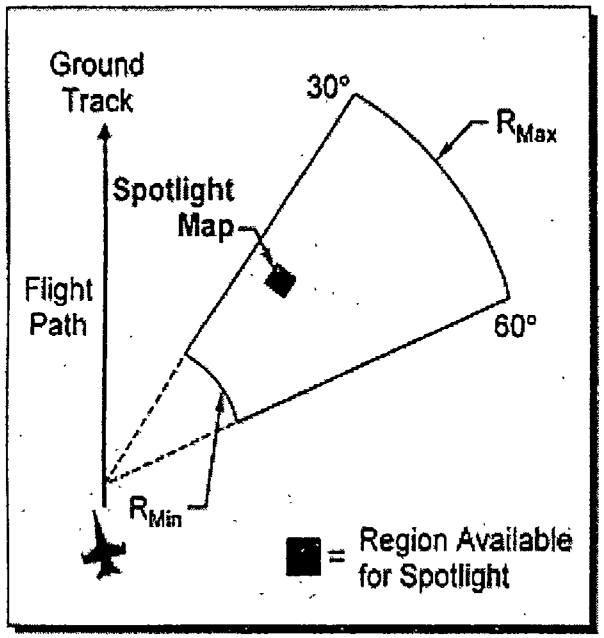
Test Phase	Description	Dates	Flight Hours	Organization
Limited DT&E	USAF assessment of ATARS in the RF-4C (see Note)	Feb – Oct '93	87.1	46th Electronic Combat Test Squadron, Eglin AFB, FL
Engineering Change Proposal (ECP)-206	Air Data Computer/Source Error Correction and Flight Control Computer tests	Dec '88 – May '92	81.1	Naval Air Warfare Center Aircraft Division (NAWCAD), NAS Patuxent River, MD
DT-IIA	ECP-206/ATARS Mass Model tests	Jun – Nov '92	44.9	NAWCAD
DT-IIA1	Quick Look Assessment and ECP-206 Integration	Aug '93 – Sep '94	118.4	NAWCAD
DT-IIB1	Contractor tests	Nov '94 – July '95	45.8	MDA and LMFS at Patuxent River
DT-IIB2	Pre-production Sensor Characterization and Resolution Performance	Sep – Oct '95	36.7	NAWCAD
OT-IIA	Early Operational Assessment	Feb – Mar '96	45.1	Operational Test and Evaluation Force (VX-9), NAWS China Lake, CA
DT-IIC1	DTR and Data Link Integration	Oct '96 – Mar '97	40.6	NAWCAD
DT-IIC2	Full-scale development Data Link compatibility and Data Link ECS performance	Feb – May '98	37.7	NAWCAD
DT-IIC3	Tac Recce Software Design & Development and Validation & Verification	Dec '96 – Jul '99	193.6	Naval Air Warfare Center Weapons Division, NAWS China Lake, CA
OT-IIA	Operational Assessment of ATARS Reliability & Maintainability	Aug – Nov '97	56.6	VX-9
DT-IIC4	Production Verification	Dec '98 – Apr '99	25.1	NAWCAD

Note: The limited DT&E conducted by the Air Force was the only flight testing of ATARS conducted in the RF-4C; all other testing shown in this table was conducted in the F/A-18.

APPENDIX B (FIGURES)

Figure B-1. MAEO image printed at a ground station after being data linked from an F/A-18D.

Spotlight Map



Strip Map

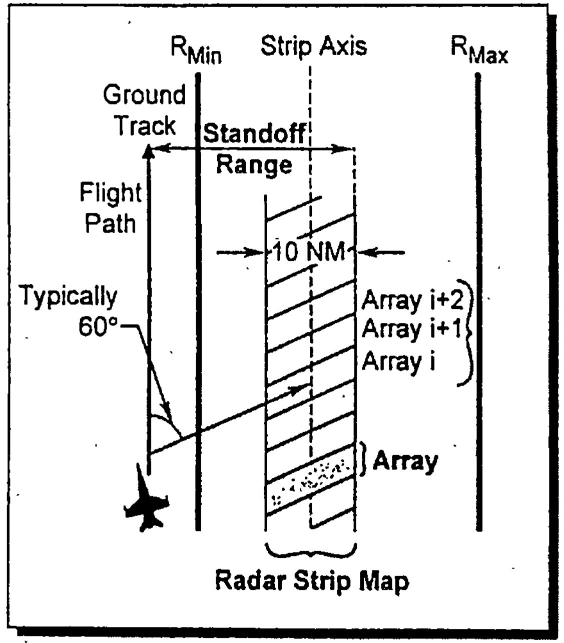


Figure B-2. F/A-18D Synthetic Aperture Radar Acquisition Modes

Source: Shihadeh, M., *ATARS Brief to AIE/SCS Surveillance & Reconnaissance Conference*, 03Jun99.

Figure B-3. SAR image recorded during flight test in an F/A-18D.

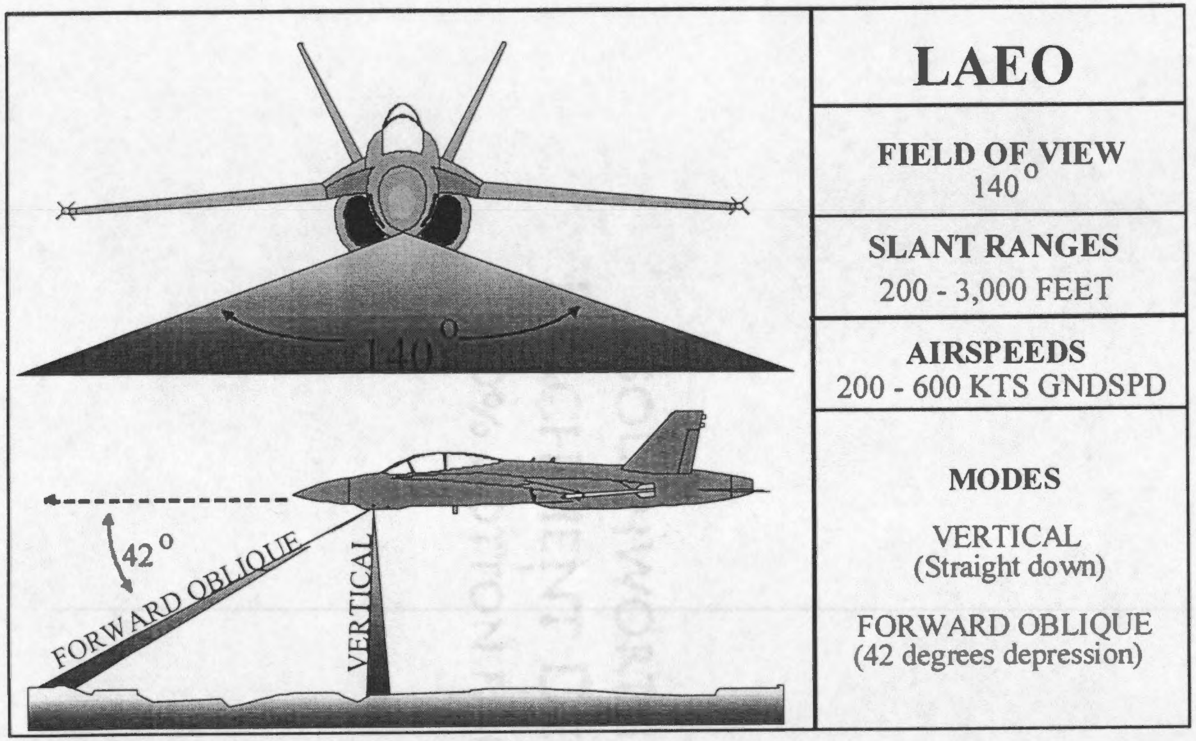


Figure B-4. F/A-18D Low Altitude Electro-Optical Sensor

Source: Shihadeh, M., *ATARS Brief to AIE/SCS Surveillance & Reconnaissance Conference*, 03Jun99.

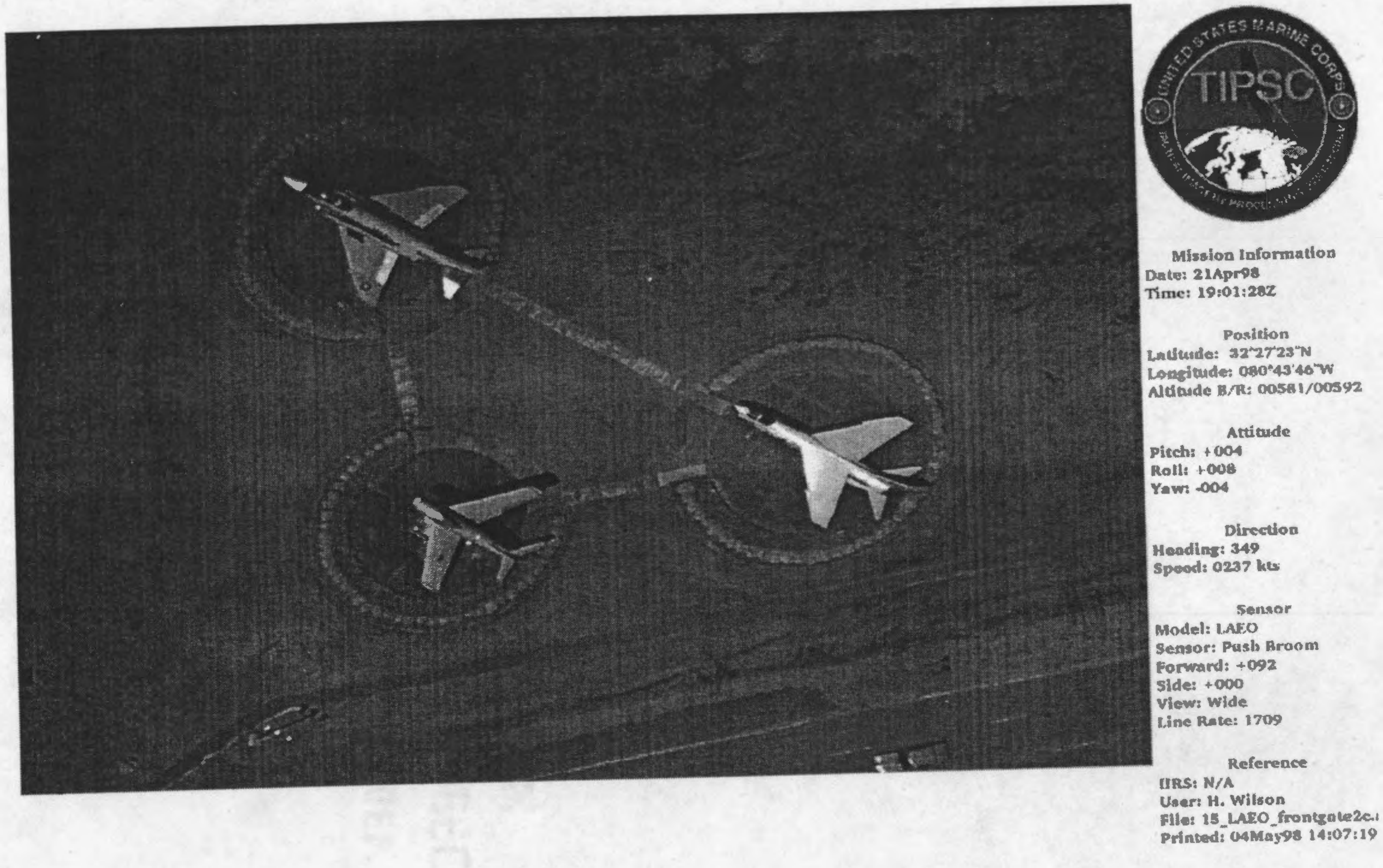


Figure B-5. LAEO image recorded during flight test in an F/A-18D (21 April 1998).

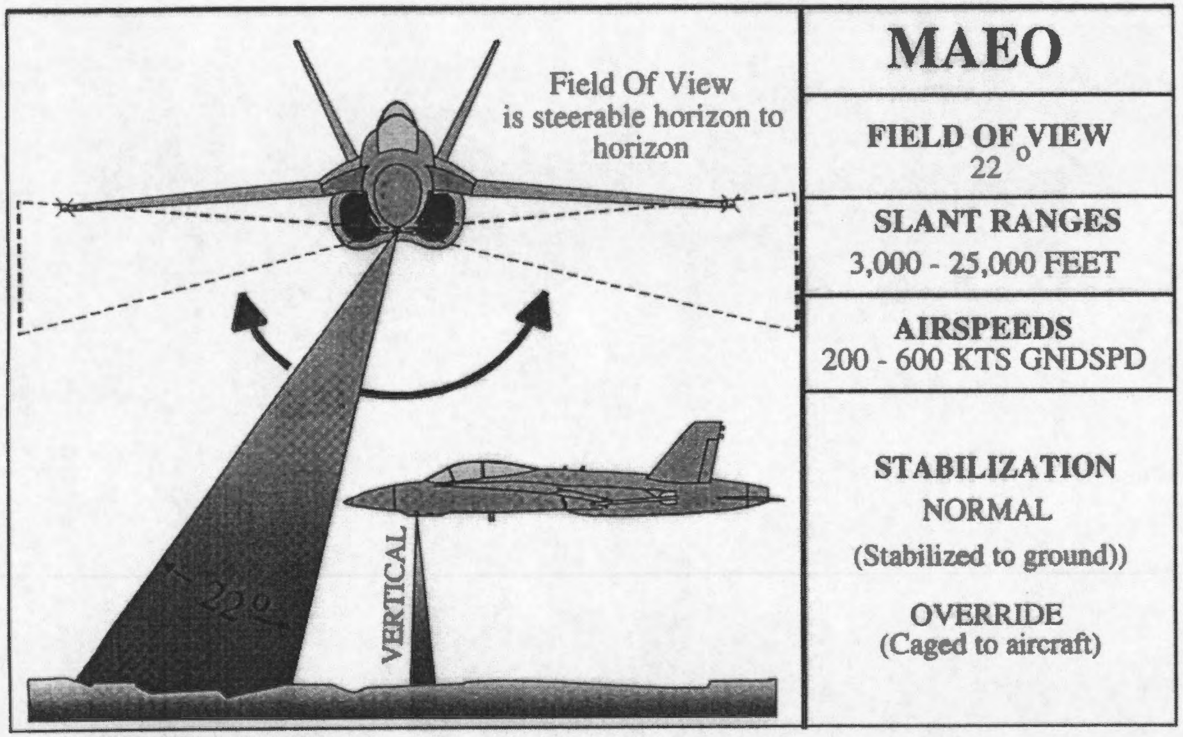


Figure B-6. F/A-18D Medium Altitude Electro-Optical Sensor

Source: Shihadeh, M., *ATARS Brief to AIE/SCS Surveillance & Reconnaissance Conference*, 03Jun99.

Figure B-7. MAEO image recorded during flight test in an F/A-18D.

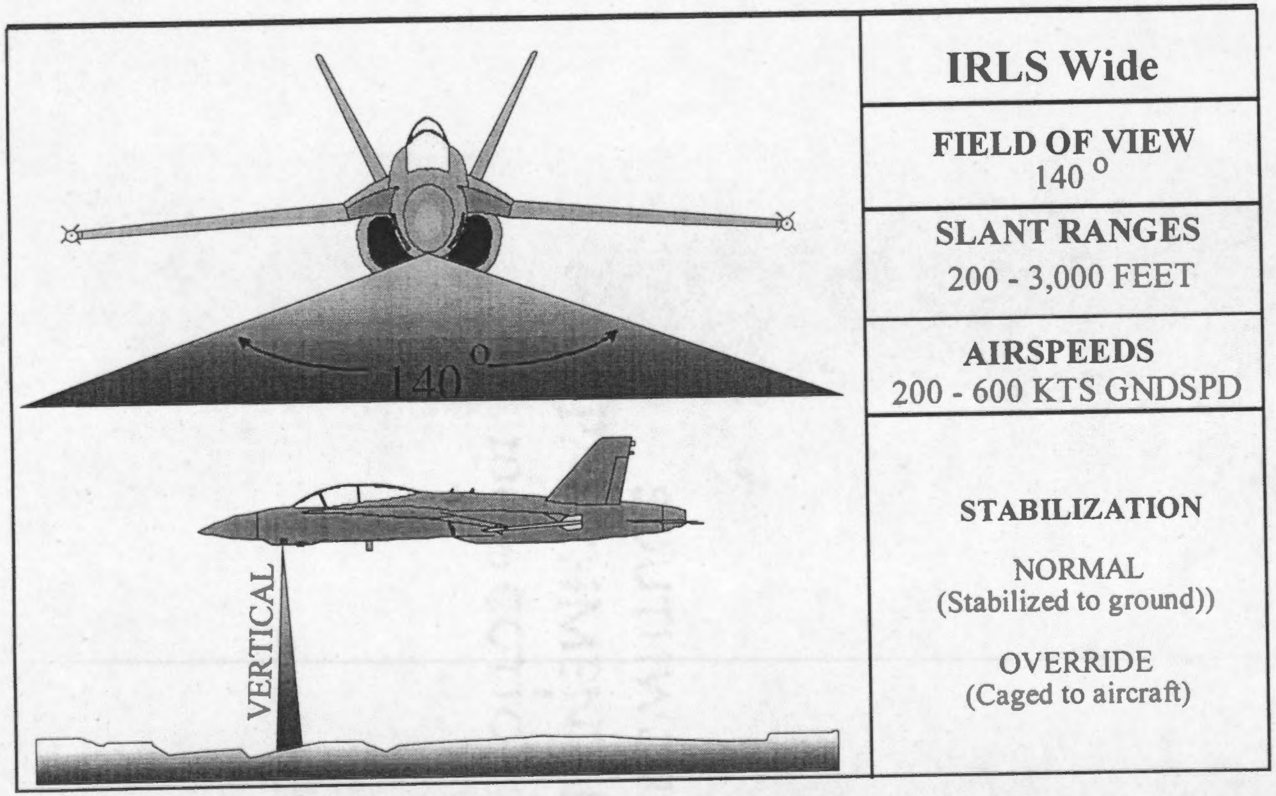


Figure B-8. F/A-18D Infrared Line Scanner Sensor (Wide Field-of-View)

Source: Shihadeh, M., *ATARS Brief to AIE/SCS Surveillance & Reconnaissance Conference*, 03Jun99.

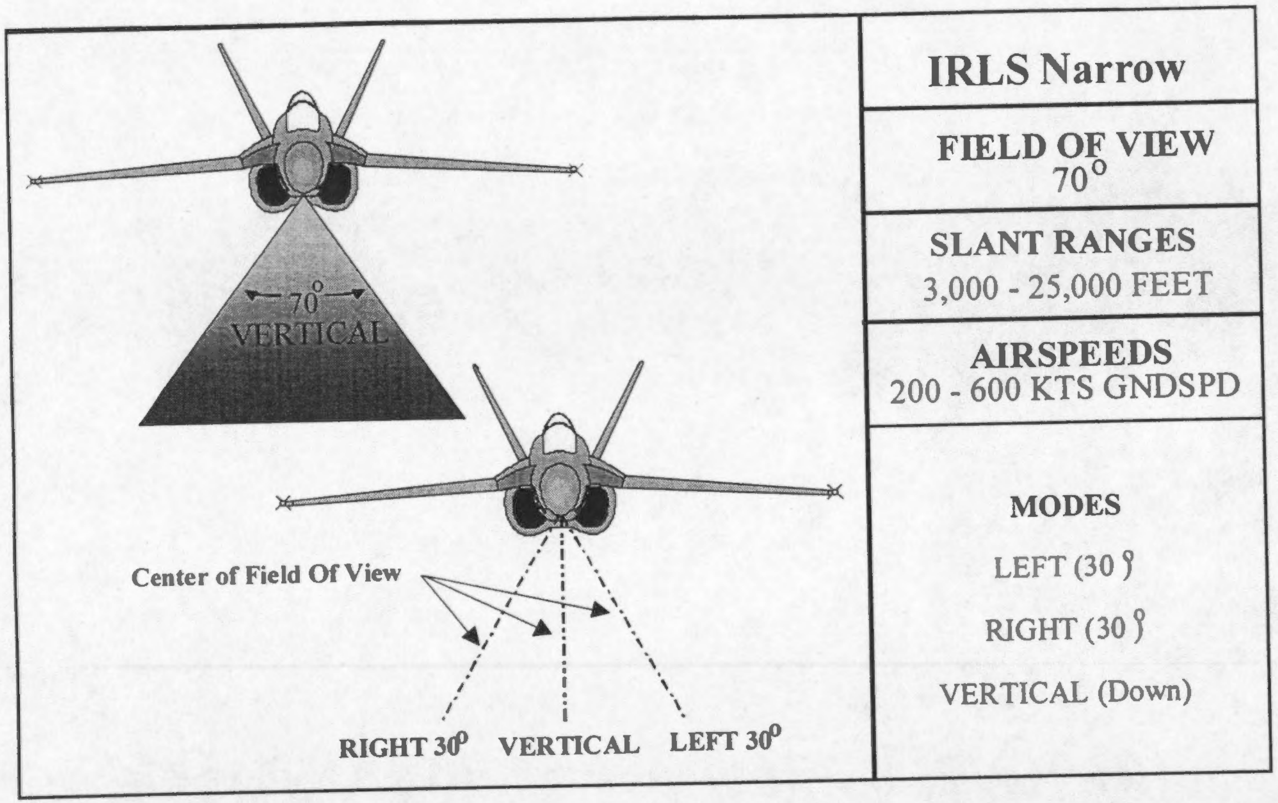


Figure B-9. F/A-18D Infrared Line Scanner Sensor (Narrow Field-of-View)

Source: Shihadeh, M., *ATARS Brief to AIE/SCS Surveillance & Reconnaissance Conference*, 03Jun99.

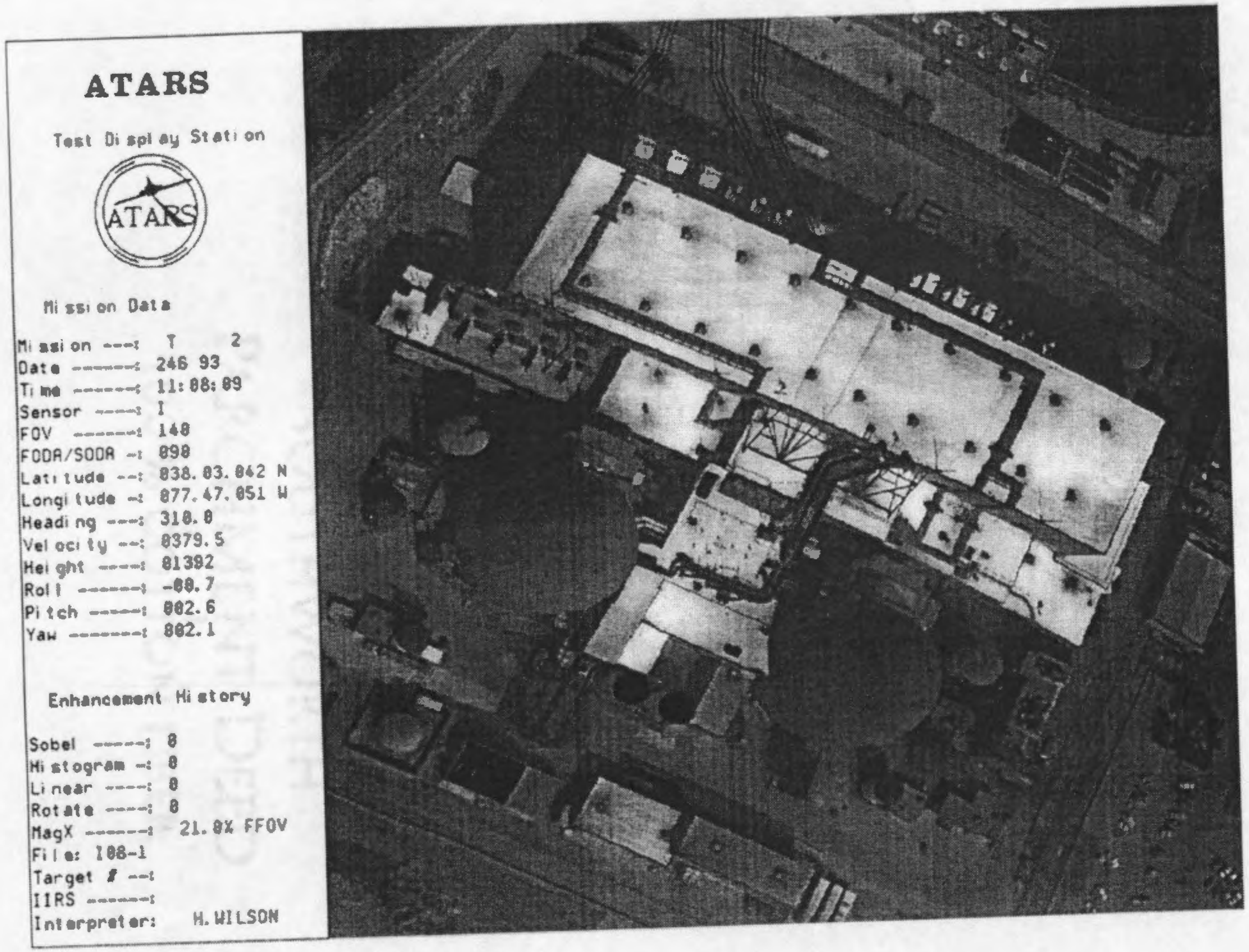


Figure B-10. IRLS image recorded during flight test in an F/A-18D.

VITA

Matthew Shihadeh was born October 2, 1962 in Bryn Mawr, Pennsylvania. In 1975, he moved with his family to Satellite Beach, Florida. He graduated from Satellite High School in 1981 and reported to the U.S. Naval Academy in Annapolis, Maryland. Matthew graduated from the Naval Academy in 1985 with a Bachelor of Science in Physics, and was commissioned a Second Lieutenant in the United States Marine Corps. He began U.S. Navy flight training in 1986 and earned Naval Flight Officer wings in 1987. In 1988, he was assigned to the Fleet Marine Force at Marine Corps Air Station El Toro, California, as a Bombardier/Navigator in the A-6E Intruder. In 1991, he transitioned to the F/A-18 Hornet and has served as a Weapon System Officer in that aircraft ever since. His only time out of the cockpit so far was for 10 months in 1992 when he served as the Air Officer for 1st Battalion, 9th Marines at Camp Pendleton, California. With his Marine squadrons, Matthew made three six-month-long overseas deployments to the Western Pacific region before being selected to attend the U.S. Naval Test Pilot School at Naval Air Station Patuxent River, Maryland. Upon completion of test pilot school he joined the Naval Strike Aircraft Test Squadron in Patuxent River as an F/A-18 Project Officer. He currently serves as the squadron's F/A-18(A-D) Department Head. In January 2000, Matthew will be joining a fleet F/A-18D squadron at Marine Corps Air Station Miramar, California.