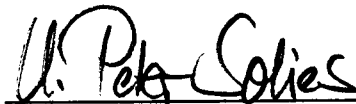


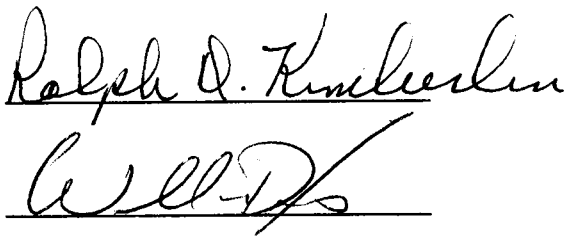
To the Graduate Council:

I am submitting herewith a dissertation written by Martin Gerard Rollinger entitled "An Evaluation of the Man-Machine Interface with the Advanced Tactical Airborne Reconnaissance System Installed in the F/A-18D Aircraft". I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science in Aviation Systems

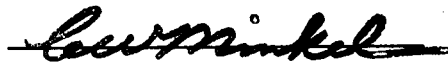


Peter Solies, Major Professor

We have read this dissertation
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Accepted for the Council:



Associate Vice Chancellor and
Dean of The Graduate School

**AN EVALUATION OF THE MAN-MACHINE INTERFACE
WITH THE
ADVANCED TACTICAL AIRBORNE
RECONNAISSANCE SYSTEM
INSTALLED IN THE F/A-18D AIRCRAFT.**

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

Martin Gerard Rollinger
December 1998

DISCLAIMER

The technical data contained in this thesis are the result of actual laboratory, flight simulator, and flight evaluations of the F/A-18D(RC) Hornet aircraft. All deficiencies and enhancements attributed to the aircraft and its systems are the opinion of the author and may or may not represent the official position of the Naval Air Weapons Center, the Naval Air Systems Command, the United States Marine Corps, or the United States Navy. The recommended corrections to the deficiencies documented by the author should not be considered attributable to any aforementioned authorities or for any purpose other than fulfillment of the thesis requirements.

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ABSTRACT

This paper describes and evaluates the man-machine interface between the F/A-18D crewmembers and the Advanced Tactical Airborne Reconnaissance System (ATARS) installed in the F/A-18D aircraft. ATARS is being purchased for use by the United States Marine Corps as a replacement for RF-4B Phantom photo reconnaissance aircraft that were decommissioned in August 1990. The new reconnaissance system is being integrated into the F/A-18 weapon system and is scheduled to reach initial operational capability by approximately June 1999.

The ATARS man-machine interface is evaluated for intuitiveness of use and consistency with F/A-18 man-machine interface conventions. The specific areas evaluated include the reconnaissance control panel, aircraft display formats, mission loading, and hands on throttle and stick controls.

The ATARS man-machine interface on the F/A-18D is **satisfactory**. ATARS is sufficiently compatible with existing Hornet interfaces to allow fleet operators to quickly learn the new system and react promptly when operating the reconnaissance system in a tactical environment. However, numerous human factors deficiencies exist. Recommendations are made to address the human factors deficiencies and to further enhance F/A-18D(RC) capabilities

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LIST OF ABBREVIATIONS

ANGL. Angle. The aircraft-to-target geometry is incorrect to collect data.

A/P. Auto Pilot

ATARS. Advanced Tactical Airborne Reconnaissance System

ATRS. Advanced Tactical Airborne Reconnaissance System

ATO. Air Tasking Order

AUTO. Automatic

BCN. Aircraft Beacon

BIT. Built In Test

BLK. Black. Display hot images as black on the display.

CLP. Center-Line Pod

CLR. Clear. Abbreviation on up front controller

CMD. Command Link Frequency

CMPRS. Compress

COMM1. Communications Radio number One

DC. Direct Current

DEGD. Degrade

DEL. Delete

DL. Data Link

D/L. Data Link

DLPCU. Data Link Power Control Unit

DSG. Designate

DTR. Digital Tape Recorder

ELEV. Elevation

EMCON. Emissions Control

ENT. Enter. Abbreviation on up front controller

EO/IR. Electro-Optical/Infrared. Referring to the non radar sensors

EXP. Expand

FLIR. Forward Looking Infrared

FOR. Field of Regard

FOV. Field of View
FREQ. Frequency
FRZ. Freeze. Stop the motion on the display.
FT. Feet
FWD. Forward Oblique, Low Altitude Electro-Optical Field of View
GEN. Generator
GMBL. Gimbals. Radar gimbal limits are preventing radar data collection.
HOTAS. Hands On Throttle and Stick
HSD. Horizontal Situation Display. Synonymous with HSI
HSI. Horizontal Situation Indicator. Synonymous with HSD
HUD. Head Up Display
HYD. Hydraulic System
IBIT. Initiated Built In Test
ICS. Intercom System
IFF. Identification Friend or Foe
ILS. Instrument Landing System
INS. Inertial Navigation System
IRLS. Infrared Line Scanner
JSIPS. Joint Service Imagery Processing System
KGS. Nautical miles per hour (Knots) Ground Speed
LAEO. Low Altitude Electro-Optical
LIUS. Low altitude Imaging Unit Subsystem
LKD. Locked
LNAR. Left Narrow, Infrared Line Scanner Field of View
MAEO. Medium Altitude Electro-Optical
MAINT. Maintenance
MAN. Manual
MC. Mission Computer
MDI. Multipurpose Display Indicator
MI. Maintenance Inspection
MIDL. Miniaturized Interoperable Data Link

MPCD. Multipurpose Color Display
MSN. Mission
MSS. Motion Sensing Subsystem
MU. Memory Unit
MUMI. Memory Unit Mission Initialization
NM. Nautical Miles
OPR. Operate
ORT. Operational Readiness Test
OVRD. Override
OVRHT. Overheat
PB. Pre-briefed
PBIT. Periodic Built In Test
POS. Position
PRI. Primary, referring to primary tape recorder
PRIM. Primary, referring to primary tape recorder
PROG. Program or Programming
P/S. Primary and Secondary
RAR. Recorder Activation Range
RC. Recce or Reconnaissance
RCPT. Reconnaissance Point
RCRD. Record
RDR. Radar
RECCE. Reconnaissance
REJ. Reject
RF. Radio Frequency
RMS. Reconnaissance Management System
RNAR. Right Narrow, Infrared Line Scanner Field of View
RNG. Range. The radar cannot collect data because it is range limited.
RTN. Return Link Frequency
RUG. Radar Up-Grade
SA. Situation Awareness

SAR. Synthetic Aperture Radar

SCND. Secondary, referring to secondary tape recorder

SEC. Secondary, referring to secondary tape recorder

SEG. Segment or segments

SENS. Sensor

SF TEST. Self Test

SHTDN. Shutdown

SIL. Silent. Terminate radar transmissions.

STAB. Stabilization

STBY. Standby

TAC. Tactical

TACAN. Tactical Air Navigation

TAMPS. Tactical Aircraft Mission Planning System

TCN. Abbreviation for TACAN on the up front controller

TCR. Target Configuration Range

TD. Target Designator

TDC. Target Designator Controller

TERM. Terminate

TOO. Target Of Opportunity

TTG. Time-to-go

UFC. Up-Front Control

VERT. Vertical, Low Altitude Electro-Optical Field of View

VNAR. Vertical Narrow, Infrared Line Scanner Field of View

WHT. White, as in display hot images bright green

WRA. Weapon Replaceable Assembly

WSO. Weapons System Officer. The second crewmen in the F/A-18D

XMIT. Transmit

Z. Zulu. Abbreviation for international standard time at the prime meridian

1. INTRODUCTION

BACKGROUND

The F/A-18D aircraft when fitted with the Advanced Tactical Airborne Reconnaissance System (ATARS) equipment is designated F/A-18D(RC). The RC suffix means that the aircraft is reconnaissance capable [1]. ATARS provides collection, storage, and near real-time data link of high-resolution digital imagery during day, night, under-the-weather, and all-weather conditions in over-flight and long range standoff situations [2]. This manned reconnaissance capability has been absent in the United States Marine Corps since the retirement of the RF-4B aircraft in August 1990 [3,4].

The author has been involved in ATARS testing from December 1996 to the present. The author participated in laboratory testing and flight simulator evaluations conducted at the avionics integration facilities located within the F/A-18 Advanced Weapons Laboratory at Naval Air Warfare Center, China Lake, California. The author conducted nineteen test flights of the ATARS pallet installed in F/A-18D number 164738 for a total of 33.2 flight hours. Aircraft number 164738 was specially configured with flight test instrumentation for the purpose of recording avionics multiplex bus traffic. Additionally, the author flew fourteen flights (26.0 flight hours) testing the ATARS radar by itself. The ATARS radar testing was done in various F/A-18C and F/A-18D aircraft modified to record the synthetic aperture radar imagery

data for processing at a ground station. At present, developmental testing is ongoing with emphasis on data link pod integration and production ATARS pallet verification.

PURPOSE

This thesis evaluates ATARS man-machine interface on the F/A-18 aircraft. The F/A-18 has been in operational use for the better part of the past two decades [5]. ATARS is a complex new system that must be integrated on the F/A-18 within the existing aircraft structure. For ATARS integration to be successful the reconnaissance system must be compatible with the existing F/A-18 man-machine interface conventions. Compatibility will enable the operators to learn the new system quicker, have faster reaction times and make fewer errors when operating the reconnaissance system [6]. The author will evaluate ATARS only from this man-machine interface perspective. The operators of the new reconnaissance system interface with ATARS through the reconnaissance control panel, eight new display formats on the multipurpose display indicators (MDIs), and through existing multifunction controls. Each of these interfaces is evaluated for adherence to F/A-18 convention. In cases where ATARS man-machine interface deviates from existing F/A-18 man-machine interface convention the mechanization is explored in greater detail. The exploration determines whether the departure from convention adds to, or detracts from, the overall effectiveness of the system. The author makes no attempt to evaluate the performance

of the ATARS sensors or the reliability and maintainability of the reconnaissance system.

DESCRIPTION OF THE F/A-18D HORNET

All F/A-18 Hornet aircraft are multi-mission, twin engine, fighter/attack aircraft [7]. They are built by the Boeing Aircraft Corporation, formerly the McDonnell Douglas Aircraft Company, in St. Louis, Missouri [5]. The F/A-18D is a tactical two seat aircraft with the crew stations arranged in tandem in the forward section of the aircraft fuselage. The F/A-18D is fifty-six feet long and has a wingspan of approximately forty feet. The aircraft weighs roughly 25,000 pounds empty and can be loaded with fuel and ordnance to a maximum gross weight of 51,900 pounds [7].

The F/A-18D pilot occupies the forward crew station where he controls the aircraft motion and has the ability to operate all the weapon systems. The F/A-18D Weapons System Officer (WSO) occupies the aft crew station where he has the ability to operate all the aircraft weapon systems. Figures A-1 through A-3 in Appendix A show the crew station arrangement.

The F/A-18 first flew in November 1978. The aircraft began operational service in January 1983 [5]. The F/A-18 has become the workhorse of United States Naval and Marine Corps aviation, occupying the decks of all operational American aircraft carriers. The F/A-18 has also been exported to several foreign air forces [5].

The United States Marine Corps operates six F/A-18D squadrons each containing twelve aircraft. These six F/A-18D squadrons have replaced the A-6E Intruder, OV-10 Bronco and RF-4B Phantom aircraft in the United States Marine Corps. The Advanced Tactical Airborne Reconnaissance System is being purchased for operational use in the F/A-18D aircraft of these six squadrons [8].

Avionics System

The avionics are highly advanced in the F/A-18D aircraft. The aircraft employs many integrated sensors designed to provide the crew useful information about airborne and ground targets and threats. The primary sensors are the multi-mode radar, Forward Looking Infrared (FLIR) targeting pod, and radar warning receivers [1, 9]. Many weapons carried by the F/A-18 contain sensors that are integrated with the Hornet avionics. Examples of these weapons are the Infrared Maverick missile and the High Speed Anti-Radiation Missile. Information from off-board sensors is integrated with onboard sensor information via tactical data link [1, 9].

The aircraft has two mission computers that control avionics functions. Mission computer number one performs primarily navigation functions. Mission computer number two performs tactical functions and has limited capability to back-up mission computer number one [1, 7]. The computers communicate with the sensors and other onboard computer processors via avionics multiplex buses [9].

Information is displayed to the F/A-18 crew via many instruments. The primary display surfaces are three cathode ray tube displays at each crew station. The center display surface is referred to as the multipurpose color display (MPCD) and features full color display capability [7]. The MPCD displays color 'moving maps' with a tactical information overlay, allowing the F/A-18 crew to navigate precisely while reducing workload. To each side of the MPCD are multipurpose display indicators (MDIs) capable of displaying three colors: red, green and yellow [1]. The MPCD and MDIs are each surrounded by twenty push-tiles. The push-tiles are numbered from one to twenty starting with the bottom push-tile on the left side of the display and proceeding clockwise around the display [1]. Figure 1-1 is provided to show the push-tile numbering. The push-tiles are used by the crew to interface with and control the aircraft and weapon systems. The legends, and thus the functions, assigned to push-tiles vary according to the display format selected [10].

In addition to the three multipurpose displays, the forward crew station has a head up display (HUD). The HUD is the primary attitude reference for the F/A-18 pilot [7]. Flight critical information (altitude, airspeed, and attitude) is projected onto the HUD combiner glass allowing the pilot to assimilate this information and view the external environment simultaneously [10]. The HUD also displays target and threat information depending on aircraft master mode and pilot selected reject levels [1]. The WSO does not have a dedicated HUD but may view a HUD format on any of his three multipurpose displays by selecting the HUD legend from the tactical menu format [1].

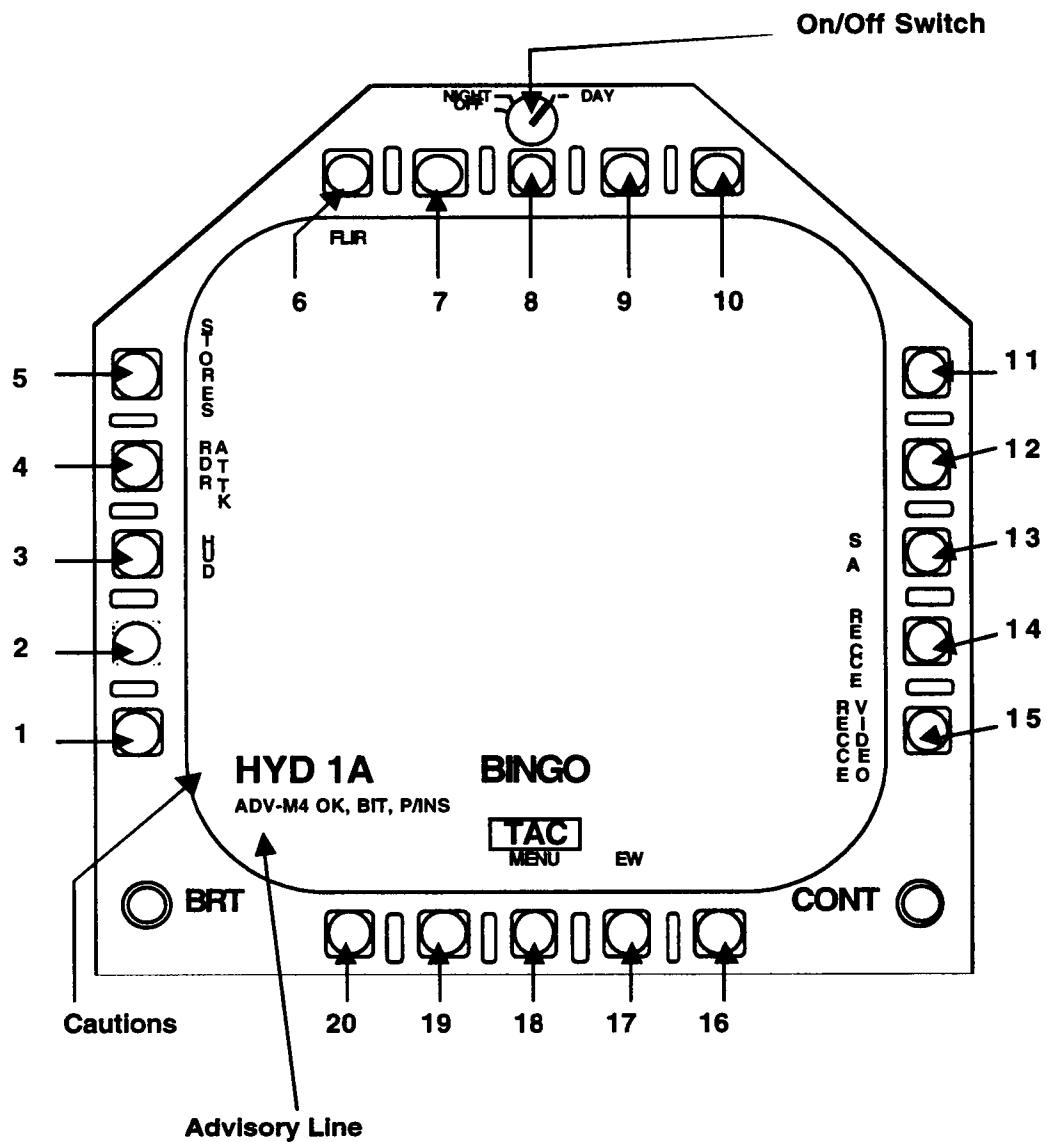


Figure 1-1. Multipurpose Display Push-tile Numbering

The pilot can also use one of his MDIs to display HUD information for the rare occasion when his HUD fails.

Warnings, Cautions, and Advisories

The F/A-18D aircraft has a multifaceted warning, caution, and advisory system. Warning lights are dedicated lights on the instrument panel that are reserved for instances when immediate action is required by the pilot and WSO. If warning light information is ignored, the results would likely be catastrophic [7]. An example of a warning light is the engine fire light. The engine fire light is red in color and positioned at the top of the instrument panel, within the pilot's zone primary cone of vision [10].

Cautions are used to describe conditions that if ignored may result in serious damage to equipment [7]. An example of a caution is HYD 1A. This caution means that hydraulic circuit one alpha is not functioning. The HYD 1A caution will be displayed on the left MDI in both crew stations. The caution display overwrites a portion of whatever tactical information is currently displayed on the left MDI. The actual caution may be up to 10 characters long and is in large font, capitalized letters [1]. Examples of cautions are provided in Figure 1-1.

Advisories are used to describe conditions that do not require immediate action. The advisory line will always appear below caution lines on the left MDI and are limited to five small font characters each [1]. Figure 1-1 shows example advisories. The P/INS legend tells the crew that global positioning system navigation is currently

not blended with inertial navigation system (INS) information. In this example the aircraft is tracking its present position (P) with the INS only [7]. Crew action is not immediately required although they may have to alter their tactics based on the inferior position keeping accuracy of the INS.

Mission Planning

The F/A-18 crewmembers plan their missions on a desktop computer system called the Tactical Aircraft Mission Planning System (TAMPS). The mission data is loaded onto a hard drive in a memory unit (MU). The memory unit plugs into the aircraft at the aft left bulkhead in the front cockpit. Mission data is automatically loaded into the aircraft at power up. The crew can edit most mission data, once downloaded, should this become necessary due to a change in tasking or assigned routing [1].

Up Front Control

The Up Front Control (UFC) is an advanced avionics device that allows the crew to interface with a variety of other avionics systems without having to look down onto a console to find individual switches. Depressing appropriately labeled push-tiles along the bottom of the UFC accesses these systems. The UFC is shown in Figure 1-2. In the front cockpit the UFC is mounted just below the head up display. In the aft cockpit, the UFC is mounted beneath the MPCD [7].

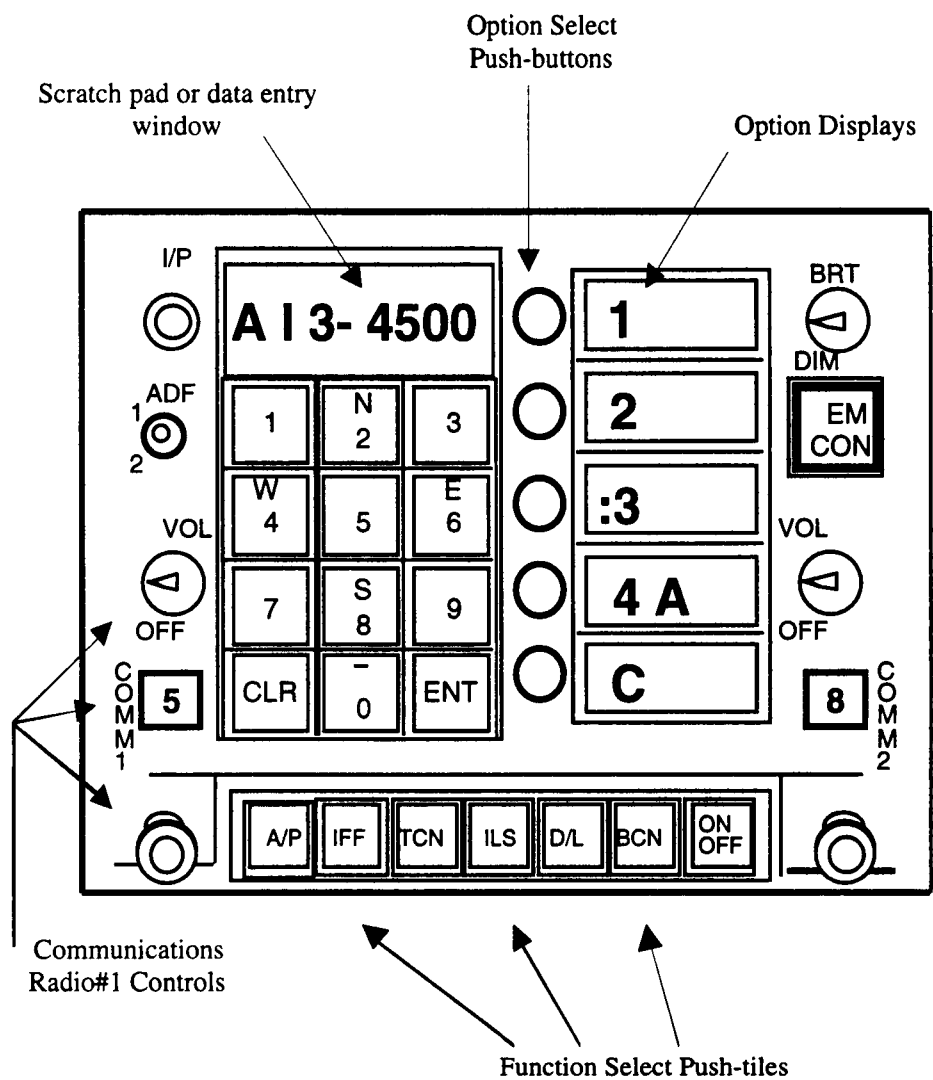


Figure 1-2. Up Front Control (UFC) Display

The UFC is a control and data input device for two radios, the Tactical Air Navigation System, the Identification Friend or Foe (IFF) System, auto-pilot, tactical data link, instrument landing system, and aircraft beacon. The UFC has a numerical keypad with a display window that allows the crew to enter numerical data into the aircraft mission and stores management computers [1]. The UFC design is very effective from a man-machine interface perspective because the pilot and WSO do not have to look down into the cockpit to turn on and control the aforementioned systems. This allows the crew to maintain their primary focus on critical flight and weapon system information.

Forward Crew Station - HOTAS

The F/A-18 has a large number of weapon system controls positioned on the pilot's flight control stick and throttles. These hands on throttle and stick (HOTAS) controls enable weapon system operation without removing hands from the control stick and throttles. The flight control stick and throttle controls are shown in Appendix A, Figure A-4. On the flight control stick the pilot has seven control switches. These switches are actuated with the fingers and thumb of the pilot's right hand while he controls the aircraft motion with the flight control stick [1,7].

The pilot has two throttle levers that he normally keeps matched at the same position. On the two throttles the pilot has a total of nine control switches. These

switches are actuated with the fingers and thumb of the pilot's left hand while he controls the aircraft velocity and acceleration with the throttles.

The Throttle Designator/Controller (TDC) is a two axis isometric positioning device on the right throttle lever [1]. The TDC is a mouse-like control that is used for positioning objects on the F/A-18 displays. The TDC also has a momentary depressed position. Cursor positioning can be performed with the TDC in the up position, called 'no action slew', or in the depressed position, called 'action slew'. The TDC is assigned to a particular display (left or right MDI, HUD, and MPCD) with the sensor control switch [1].

Aft Crew Station - Hand Controllers

The aft crew station of the tactical F/A-18D does not have a flight control stick or throttles. The aft crew station has two fixed hand controllers that have eight control switches each. These switches are used by the WSO for control of the aircraft sensors and weapon systems [1,7]. The designator/controller on each of the hand controllers performs identical functions as the TDC at the forward crew station. The aft crew station hand controllers are shown in Appendix A, Figure A-5.

2. ADVANCED TACTICAL AIRBORNE RECONNAISSANCE SYSTEM

BACKGROUND

The following sections describe the Advanced Tactical Airborne Reconnaissance System (ATARS). ATARS is a digital system that replaces wet-film based reconnaissance systems employed in the RF-4B. Digital systems offer a drastic reduction in the support requirements, hazardous chemicals, and processing delays associated with wet-film systems [11]. ATARS provides the means by which high resolution, long range standoff and over-flight reconnaissance images can be gathered, stored digitally, and transmitted to ground stations. This imagery can be collected day or night and in all weather conditions [2].

ATARS is a palletized grouping of electronic boxes fitted into the nose of the F/A-18D aircraft and replaces the aircraft's twenty millimeter cannon. The ATARS pallet is populated with components of the reconnaissance system. Figure B-2, in Appendix B, is provided to show the relationship of components on the pallet. The pallet contains the three electro-optical and infrared (EO/IR) sensors, the reconnaissance management system (RMS), and two digital tape recorders. The EO/IR sensors are the infrared line scanner (IRLS), low altitude electro-optic (LAEO) sensor, and the medium altitude electro-optic (MAEO) sensor. With the installation of the ATARS pallet the F/A-18D is re-designated F/A-18D(RC). The radar sensor and data link pod are

optional ATARS equipment that enhance the mission effectiveness of the reconnaissance system [1].

The EO/IR sensors are 'push-broom' sensors that view their targets through two windows on the underside of the nose of the aircraft. Push-broom sensors generate a one-pixel wide, lateral array of imagery under the aircraft that is digitally joined with subsequent arrays as the aircraft flies in a forward direction. The lateral arrays of imagery, when combined, form the two-dimensional image picture [12].

The reconnaissance system was designed to accept synthetic aperture radar (SAR) data from the multi-mode radar in the nose of the F/A-18. The radar is modified to collect reconnaissance data and maintains all existing radar capabilities. The radar modifications include new modules in the radar receiver and radar data processor as well as the addition of motion sensing hardware [1].

There is very little difference between crew stations of the F/A-18D and the F/A-18D(RC). The forward crew station has an additional button on the flight control stick called the reconnaissance event mark button. The aft crew station of the F/A-18D(RC) has the reconnaissance control panel mounted on the left console. This console has only two switches for ATARS power control. There are eight new MDI formats through which the crew controls the reconnaissance system.

Imagery gathered from the EO/IR sensors is available for viewing in the cockpit. Imagery viewing can be performed while the imagery is being gathered, while imagery is being down-linked to a cooperative ground station, and during a specific image review

mode [1]. The high-resolution radar imagery is not available for viewing in the cockpit because it exists only as raw video phase history on the aircraft and must be processed by a ground station prior to viewing.

DESCRIPTION OF THE IMAGING SENSORS

Infrared Line Scanner

The infrared line scanner (IRLS) provides thermal imaging in the long (8-12 micron) wavelength infrared wave band [1]. The IRLS does not need visible light to image a target; it provides useful imagery day or night. The crew can select from four field of view (FOV) options. Wide FOV is 140 degrees laterally, directly under the aircraft. The narrow FOV has a seventy-degree instantaneous field of view that is perpendicular to the longitudinal axis of the F/A-18 aircraft. The narrow FOV can be positioned vertically downward, or to the left (or right) with the center of the FOV thirty degrees left (or right) of vertical. The IRLS can be used from two hundred feet above ground level to the operational ceiling of the F/A-18 [1].

Low Altitude Electro-Optics

The low altitude electro-optical sensor (LAEO) is a combination of optics and electronics that enable the ATARS operator to image ground targets from low altitudes. The LAEO is designed to display and record images from as low as two hundred feet above the ground level to as high as three thousand feet above ground level. The LAEO

requires visible light to image the target [1]. The LAEO optics allow imagery to be recorded from either directly below the aircraft, called the vertical position, or looking forward approximately fifty degrees from the vertical, called the forward oblique position. The lateral field of view of the optics is 138 degrees in the vertical position and 120 degrees in the forward oblique position [1]. The LAEO does not have optical stabilization. If the aircraft changes its attitude the camera angle will change also, resulting in image distortion while the attitude change is in progress.

Medium Altitude Electro-Optics

The medium altitude electro-optical sensor (MAEO) is a combination of optics and electronics that enable the ATARS operator to image ground targets from medium to high altitudes. The MAEO is designed to display and record images from as low as two thousand feet above the ground level to the operational ceiling of the F/A-18 [1]. The MAEO requires visible light to image the target and has a twenty-two degree instantaneous field of view that is perpendicular to the longitudinal axis of the F/A-18 aircraft [1]. The instantaneous field of view may be positioned laterally from the right wingtip to left wingtip or any intermediate position. This positioning can be done automatically by the reconnaissance management system or manually by the operator, depending on the mode of the system. The MAEO and LAEO share a main electronics unit which imposes the limit that only one of these sensors can perform imaging at a given time [1].

Radar

The radar sensor provides ATARS with all-weather reconnaissance capability and significant standoff range. The standard AN/APG-73 radar is modified with the incorporation of three new components that enable the radar to collect high-resolution synthetic aperture radar (SAR) imagery [1]. SAR configured radar takes advantage of the aircraft's forward motion to "synthesize" a large antenna array, resulting in very high resolution ground images compared to those provided by conventional radar [13].

The ATARS radar maintains all of the AN/APG-73's existing air-to-air and air-to-ground search, detection, and track functions, but the ATARS radar functions cannot be done in parallel with the other functions. When the radar is being used for imagery collection that is all it is capable of doing [1].

The high resolution SAR imagery gathered by the AN/APG-73 cannot be viewed in the cockpit by the pilot or WSO. In fact, the imagery does not really ever exist within the F/A-18 aircraft. Raw radar data stored on the tapes must be processed before it can be converted into a visual image. The current F/A-18 hardware and software configurations do not support this processing [1].

The ATARS radar allows for two different types of radar imagery collection. Strip mapping involves continuous mapping of the ground beginning at some point laterally offset from the F/A-18 and continuing along a line roughly parallel to the ground track of the aircraft. The desired strip map may be defined with a start and stop point within a pre-briefed reconnaissance target data set or it may be commenced in the

target of opportunity (TOO) mode from a radar designation and continued on a line parallel to the aircraft ground track [1].

A spot map is a very high-resolution radar map of a small patch of ground [1]. The resolution is ten times better than that of the strip maps. No image resolution or standoff range performance data may be given in this document as they remain classified. The desired spot map may be defined as a pre-briefed reconnaissance point set or it may be made in the TOO mode from a radar designation.

RECONNAISSANCE MANAGEMENT SYSTEM

The reconnaissance management system (RMS) is the brain of the ATARS equipment. The RMS provides management and control functions in support of the ATARS mission [1]. The RMS interfaces with all the other ATARS equipment via the ATARS multiplex bus. The RMS provides the central interface with the aircraft mission computers and contains the operational flight program, which provides automatic management of sensors and imagery collection [1]. Commands from operators are relayed by aircraft mission computers to the RMS. The RMS then communicates the commanded tasks to the appropriate sensors and recorders within ATARS.

DATA LINK POD

The data link pod is an optional piece of reconnaissance equipment that is carried externally on the F/A-18D(RC). The pod is also referred to as the miniaturized

interoperable data link (MIDL) pod or the centerline pod (CLP). The data link pod is carried on the F/A-18D(RC) centerline weapons station, station number five [1]. The pod displaces other equipment that could be carried in its place, such as a fuel tank or bombs, and adds 550 pounds to the gross weight of the F/A-18D(RC). The data link pod allows the crew of the F/A-18D(RC) to send imagery to a ground station at 'near real time'. The term 'near real time' means that the imagery is first collected on the digital tape recorders and then the tapes are replayed with the data link transmitter on. Data link transmissions are not allowed while imagery is being collected to the tapes.

DIGITAL TAPE RECORDERS

The reconnaissance system has two digital tape recorders that are labeled primary and secondary. The tapes are commercial nineteen-millimeter cassettes that are installed into the recorders prior to flight. The tapes each store forty-two giga-bytes of information [1]. Imagery from the IRLS, MAEO, and LAEO is stored on the tapes in a similar fashion. Data from the radar is received and stored at a higher rate making it incompatible with the EO/IR imagery [1]. Therefore ATARS has the limitation that once a tape is configured for radar data it will not accept EO/IR imagery. The reverse is also true: If a tape has received imagery from an EO/IR source then it will not accept radar data. If all four sensors are to be utilized on a particular flight then all radar data will be recorded to one tape and the other three sensors will share the remaining tape.

3. SYSTEM EVALUATION AND RECOMMENDATIONS

RECONNAISSANCE CONTROL PANEL

The reconnaissance control panel is located on the left console in the aft cockpit of the F/A-18D(RC) aircraft, immediately forward of the volume control panel [1]. This relationship is depicted in Figure 3-1. The panel is conveniently located within the reach of the WSO. The WSO's left hand normally rests just above and forward of the reconnaissance control panel on the left hand controller.

Contrary to all other F/A-18 systems, ATARS power is controlled by the WSO occupying the aft crew station. Every other system on the F/A-18 has the ON/OFF control switches in the front cockpit where only the pilot has access to them. Although the reconnaissance system is inconsistent with previous systems the author does not find this objectionable for two reasons. First, both crewmembers maintain adequate control of all systems once they are powered regardless of which crewmember turned the system on. Second, operation of the reconnaissance system is primarily the responsibility of the WSO. If it becomes necessary to troubleshoot the reconnaissance system by cycling power the WSO is the ideal crewmen to do it. If a decision is made in the future to install ATARS on the single seat F/A-18C aircraft the reconnaissance control panel could easily be installed in the pilot's cockpit.

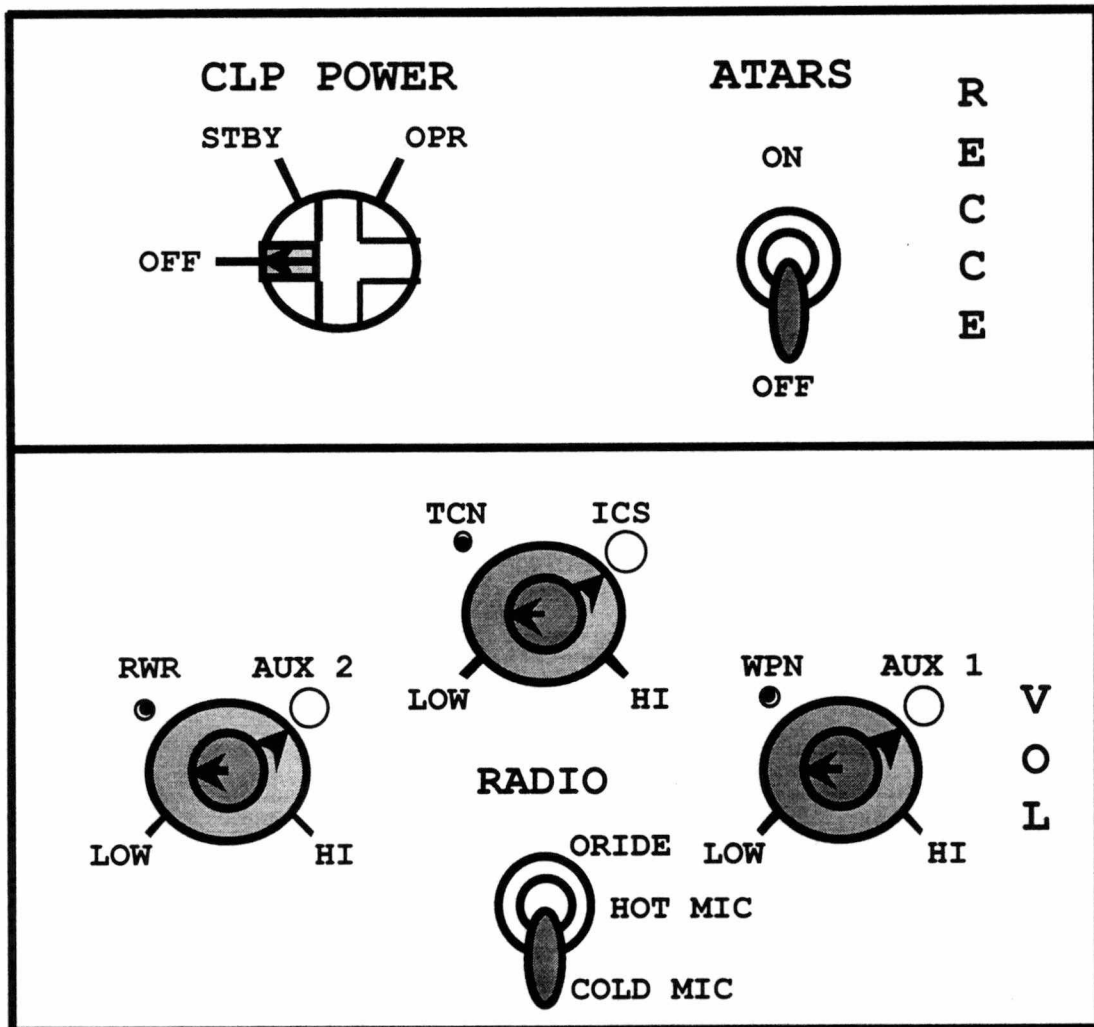


Figure 3-1. Reconnaissance Control Panel

The reconnaissance control panel was evaluated for visibility, legibility, arrangement, and overall utility. The panel is clearly visible on the left console, easily accessible, and features clear, concise labeling. The arrangement of the reconnaissance control panel with respect to the volume control panel degrades the overall utility of the reconnaissance control panel as explained in the following sections.

ATARS Power Switch

The reconnaissance system is turned on and off with the ATARS power switch on the reconnaissance control panel. The ATARS power switch is a two-position toggle switch that controls power to the ATARS pallet only. The radar and reconnaissance data link power are controlled separately [1]. The ATARS power switch conforms to the F/A-18 convention that the forward switch position is ON and the aft switch position is OFF. This is an excellent man-machine interface feature because the population of F/A-18 crewmembers have developed the expectation that forward motion should result in system activation. This mechanization reduces the potential for errors and confusion in the cockpit.

The author discovered a major problem with the ATARS power switch design. The location and arrangement of other switches on the left console cause the problem. The ATARS power switch is very similar to the intercom (ICS) switch on the aft cockpit volume control panel. The WSO will change the ICS switch position from HOT MIC to COLD MIC and back again many times during the course of a normal flight.

The WSO usually activates the ICS switch by feel. If the WSO erroneously grabs the ATARS power switch and turns it OFF, instead of activating the ICS switch from HOT MIC to COLD MIC, the reconnaissance system will be shut down. The results of his error could be as serious as total loss of the mission. The distance between these two switches is only three inches. The fact that there are other rotary switches between the ATARS power switch and the ICS switch mitigates the problem to some extent. The use of the ICS switch is time critical; the WSO should not have to feel around for it or remove his eyes from a tactical display to look down and find the switch.

There are several possible solutions to the switch similarity problem. ATARS is the new system being integrated into the existing F/A-18 system and therefore the ATARS power switch should be redesigned so that it is easily distinguishable from the existing ICS switch. The new ATARS power switch could be 'guarded' such that the WSO could not turn it off without a second action. The guarded switch could be a lever lock switch that requires the operator to lift against spring pressure before the switch can be pulled back to the OFF position.

The simplest and cheapest solution involves modifying the ICS switch with a short (approximately two inch) switch extender that would allow the WSO to throw the ICS switch without actually finding the particular switch. The WSO could run his hand across the console in an aft motion until he felt the ICS switch move to the aft position. This cockpit modification is in limited and unofficial use within F/A-18 training squadrons and tactical F/A-18D squadrons.

Voice activated intercom is offered as another solution to this man-machine interface problem. Incorporation of a voice activated ICS in the F/A-18D(RC) would eliminate the confusion between the ICS switch and ATARS power switch because the ICS switch could be removed altogether. A voice activated ICS system is planned for installation on all F/A-18D aircraft in approximately four years as part of a new tactical data link called the multi-function information distribution system.

The author recommends the combination solution of a lever locked ATARS power switch and an ICS switch extender, with the eventual upgrade to voice activated ICS.

Data Link Pod Power Control Knob

The data link pod power control knob is a three position rotary knob labeled CLP POWER. The data link pod power knob is a stepped knob; it turns with distinct clicks [6]. The three positions are OFF, STBY (standby), and OPR (operate). The data link pod power control knob is shape coded differently than the three other rotary knobs that are in the same vicinity. This is depicted in Figure 3-1 on page 20. The other knobs are only 1.75 inches, 2.5 inches, and 3.5 inches away from the data link power control knob. These three knobs are used to adjust the volume of different audio inputs to the WSO's helmet [1]. The volume switches are stacked, continuously rotating, rheostat switches with no discrete clicks or detents. The shape coding of the

data link power control knob is a good man-machine feature that should reduce confusion and errors in the cockpit.

The OFF position of the data link power control switch removes most, but not all, electrical power from the pod. It does not remove twenty-eight volt DC power, which is used by the data link pod environmental control system. The author found this mechanization unusual and unconventional. The twenty-eight volt DC power is always routed to the pod environmental control system to keep the pod electronics from getting cold soaked at high altitude, preventing an excessive warm-up time prior to transmission [14].

The author has two concerns with a switch that is labeled OFF when the system is still receiving electrical power. First, if the electrical power were to cause a fire in the pod the operator might be forced to jettison the pod to avoid endangering the aircraft. Secondly, if the aircraft experienced a significant power outage while airborne the crew of the F/A-18D(RC) would be unable to stop the pod from draining a portion of their DC electrical power. None of the eight circuit breakers in the cockpit of F/A-18 aircraft are associated with the data link pod. **The author recommends that the reconnaissance data link power control knob be modified to allow the WSO the ability to cut all electrical power to the data link pod.** This would make data link power control consistent with power control for all other F/A-18 systems.

The STBY position allows the pod to be powered to a level that will support multiplex bus communication. Full power data link transmissions are not allowed with

the switch in the STBY position. The ON position provides the pod with power and is one of the prerequisites that allow the pod to radiate data link at full power [1]. The STBY and ON mechanization is compatible with F/A-18 conventions.

NON-RECONNAISSANCE DISPLAYS

The tactical menu, or TAC menu, format has been altered to enable the crew to access the reconnaissance display formats and the reconnaissance video display formats. Two new push-tiles have been activated on the tactical menu. An example tactical menu is provided in Appendix C, Figure C-1. The push-tiles labeled RECCE and RECCE VIDEO when depressed cause the reconnaissance format and reconnaissance video format to be displayed. This functionality is intuitive and entirely compatible with the existing F/A-18 menu format convention.

The stores display incorporates minor changes to accommodate the reconnaissance system. There is no GUN legend and no gun rounds count because the twenty millimeter cannon has been removed. If the aircraft is loaded with a reconnaissance data link pod then the legend CLP appears at the centerline weapon station, weapon station number five. An example stores display is provided in Appendix C, Figure C-2.

Built In Test (BIT) Display Formats

The built in test (BIT), BIT sensors, and BIT configuration display formats have not changed as a result of ATARS integration. The reconnaissance system is treated as

any other sensor on these three displays. Examples are provided in Appendix C, Figures C-3 through C-5. The BIT display formats remain intuitive and are compatible with the existing F/A-18 BIT formats convention.

ATARS Maintenance Sublevel

The ATARS maintenance sublevel is accessed by depressing push-tile number nineteen, labeled ATARS MAINT, on the BIT sensors sublevel. The ATARS maintenance sublevel shows the health of the subsystems that comprise the reconnaissance system. If any one of the subsystems is in a condition other than GO, that subsystem status becomes the overall status of ATARS on the BIT displays discussed in the previous paragraphs [1]. This page was useful during the ATARS evaluation when the author became aware that he had a degraded reconnaissance system. The ATARS maintenance sublevel helped determine which particular subsystem was causing the overall degrade. An example ATARS maintenance sublevel is provided in Figure 3-2. In the center of the display is the status of the ATARS subsystems. Note in the example that the status of ATARS is overall DEGD because the subsystems LAEO and D/L (data link) are degraded. The degrades are further defined for maintenance personnel in the WRA FAILS section of the display.

The ATARS maintenance sublevel is superior to, but inconsistent with, existing F/A-18 radar and FLIR systems that also have maintenance sublevels. The radar and FLIR maintenance sublevels are not as useful as the new ATARS maintenance sublevel.

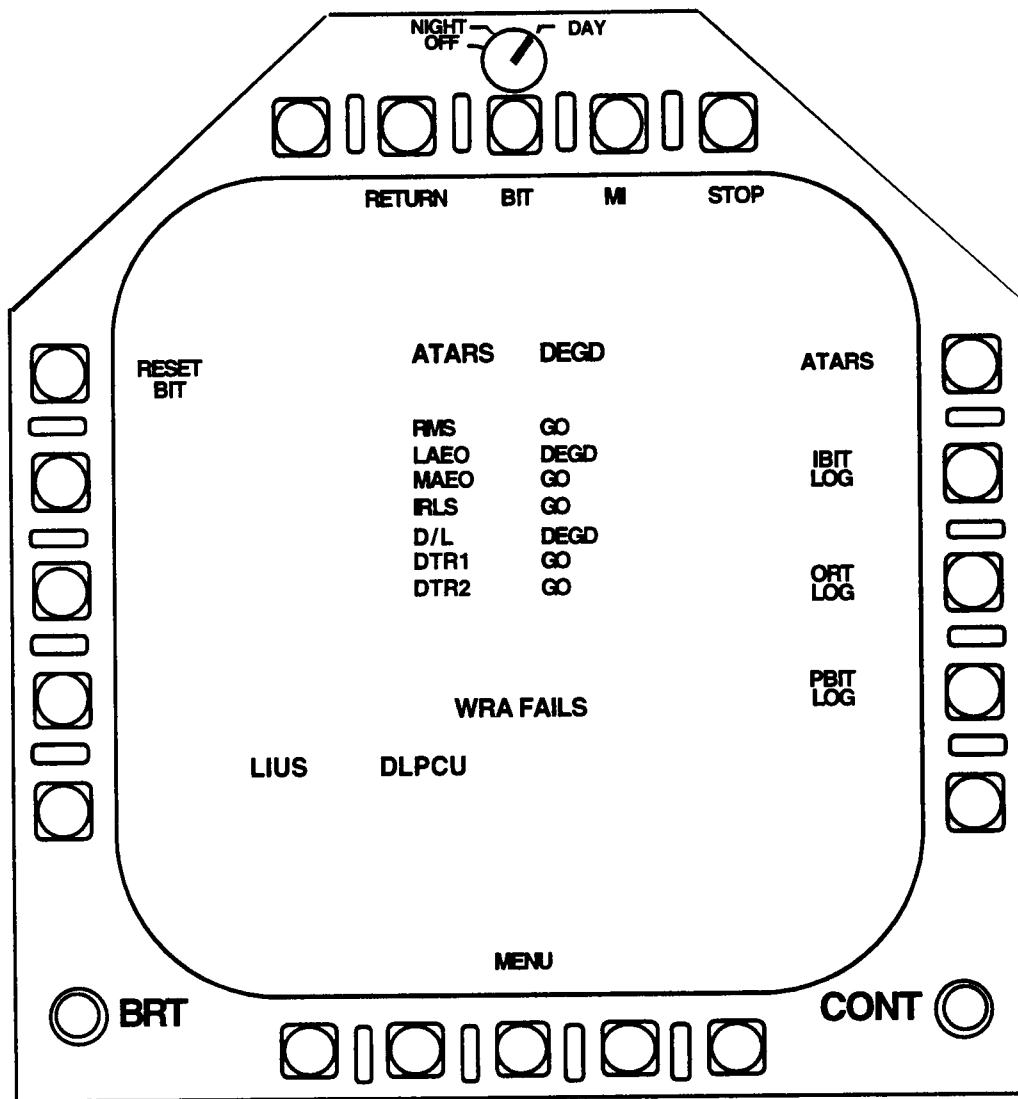


Figure 3-2. BIT Display, ATARS Maintenance Sublevel

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

The radar maintenance sublevel gives a series of three digit numbers that describe failure states. These numbers, however, are not available airborne. Access to the FLIR maintenance sublevel is denied while airborne [1]. The ability to access the ATARS maintenance sublevel while airborne, and the plain language display, is a man-machine interface feature that will help aircrew make time critical decisions should their reconnaissance system develop problems.

The push-tile labeled RETURN will return the operator to the sensors BIT sublevel. The push-tile labeled BIT will return the operator to the top-level BIT display. This functionality is the same as existing F/A-18 BIT formats. The push-tiles labeled RESET BIT, MI, IBIT LOG, ORT LOG, and PBIT LOG were designed to help a maintenance crew troubleshoot and repair the reconnaissance system and were not evaluated [1].

ATARS Initiated BIT

Built in test of the reconnaissance system is initiated by any one of four separate actions. This is consistent with most other systems on the F/A-18 and allows the crew a great deal of flexibility.

The author has two man-machine interface issues with ATARS IBIT integration on the F/A-18. First, the IBIT takes 4.5 to 7.0 minutes to complete [1]. This is an excessive amount of time for the crew to have to wait for the system test to complete. The reconnaissance crew will have to adjust their preflight time lines appropriately if

they desire to do an ATARS IBIT before flight. Second, while ATARS is in IBIT there are time periods during which the IBIT cannot be halted. If the IBIT 'stop' command is sent via the aircraft mission computers and the reconnaissance system does not respond then the crew is shown the SF TEST legend for ATARS status on the BIT display.

This legend appropriately tells the crew that ATARS is now in self-test. **It is recommended that the time required for ATARS IBIT be decreased to less than three minutes and that the stop test command be honored at all times.**

Although the ATARS BIT displays are consistent with F/A-18 BIT format convention, the author would like to see the use of color for degraded conditions on the BIT displays. The original F/A-18 displays were not capable of displaying colors; therefore the monochrome display of information became the convention. All F/A-18 aircraft delivered since 1990 have color MDIs. Yellow colored words and legends should be used for degraded conditions, those conditions that would still allow some portion of the mission to be accomplished. Red words and symbols should be used for failure conditions that would prevent mission accomplishment. For example, one digital tape recorder failure should be indicated with yellow. If the reconnaissance management set fails, its failure legend should be written in red. **The author recommends the use of color on the BIT format to highlight degraded and failure conditions.** Other systems on the F/A-18 would benefit, as the expanded use of color became the new, evolved convention.

Head Up Display

The pilot will glean much of his awareness of the reconnaissance mission status from information presented to him on the head up display (HUD) and the horizontal situation displays.

Record Cue

The record cue in the HUD will inform the pilot that recording is in progress and he should not maneuver the aircraft abruptly. The record cue is shortened to the abbreviation RCRD in HUD window number five. The RCRD cue will be followed by an abbreviation for which recorder is currently recording, a 'P' for the primary recorder, an 'S' for the secondary recorder, or a 'P S' for both recorders. The RCRD cue is clearly visible to the pilot and judged very useful. An example HUD is provided in Figure 3-3.

The author noted that RCRD cue remained in the HUD for up to twelve seconds after ATARS was commanded to stop recording. This was confusing during flight test until it was learned that ATARS requires up to twelve seconds to completely exit the record mode from the time at which it was commanded. The HUD RCRD cue is accurately displaying the status of the recorders. Even though the recorders are commanded off they are not off, reset, and ready to accept the next record command for up to twelve seconds. During these twelve seconds the pilot should not be constrained from maneuvering the aircraft to avoid threats or to reposition for the next

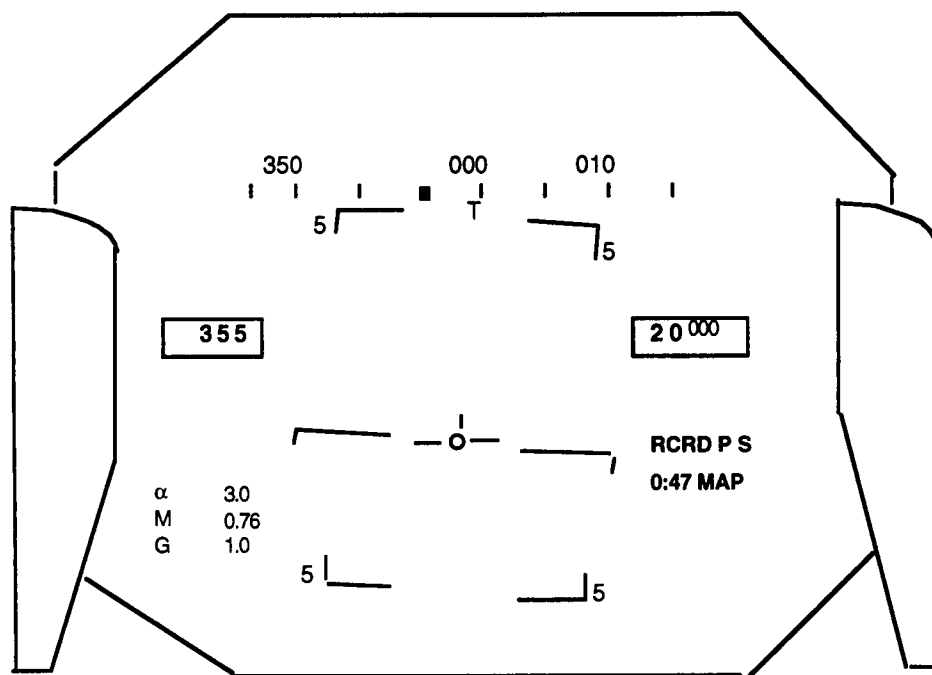


Figure 3-3. Head Up Display (HUD)

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

reconnaissance target. Twelve seconds is a tactically significant period of time. In the twelve seconds that it takes for the RCRD cue in the HUD to be blanked, the aircraft will have traveled an unnecessary two miles further downrange. In that same twelve seconds the aircraft could have been turned greater than ninety degrees. **The author recommends the use of another legend that informs the pilot that the imagery collection has ceased; yet the recorders are not ready to accept the next record command because they are in transition. The author recommends use of the legend TSN P S for the transition period.**

The author has a concern when the F/A-18D(RC) is operated in an environment where tactical data link commands are being sent to the aircraft. The tactical data link commands will be displayed in HUD window number five and have priority over the ATARS RCRD cue. The author was not able to adequately evaluate the integration of ATARS with existing and future data link systems. **It is recommended that ATARS integration testing be conducted in an environment where tactical data link is utilized.**

Radar Data Collection Cues

When radar imagery is being gathered, the pilot is given additional information in the HUD. In HUD window number six, below the recorder status window, there is a numeric time-to-go indication. When this number is followed by TTG (time-to-go), it indicates the remaining time until radar imagery collection begins, assuming the pilot

keeps the aircraft on the present course. Once radar data collection commences the counter starts a countdown for the amount of time until radar imagery collection is complete [1]. This is indicated to the pilot with the suffix MAP. There is a tendency to confuse the meaning of the two countdown timers in the HUD.

If aircraft-to-target geometry is outside allowable limits for radar data collection, the pilot is cued with one of three legends in the center of the HUD. The three cues are SAR RNG (SAR range), SAR GMBL (SAR gimbal), and SAR ANGL (SAR angle). If the pilot sees the SAR RNG cue the aircraft is either too far away or too close to the target to gather radar imagery [1]. To further understand the situation the pilot should first look at the countdown timer. If the countdown timer has a number that is decreasing followed by TTG then his current flight path will eventually get him within allowable range for recording. An example HUD for this situation is provided in Figure 3-4. On the other hand, if the countdown timer says 9:59 TTG and it is not counting down, then the pilot will need to reference the horizontal situation display to determine whether he is too close to the target or if he is too far away. The fixed 9:59 TTG legend implies that the current aircraft flight path will not put the aircraft within allowable distance of the target within the next nine minutes and fifty-nine seconds [1].

SAR GMBL indicates that the radar is, or will be soon, physically limited from looking any further to the side due to its mechanical gimbals [1]. The SAR GMBL cue indicates to the pilot that he should turn towards the target a few degrees so that the

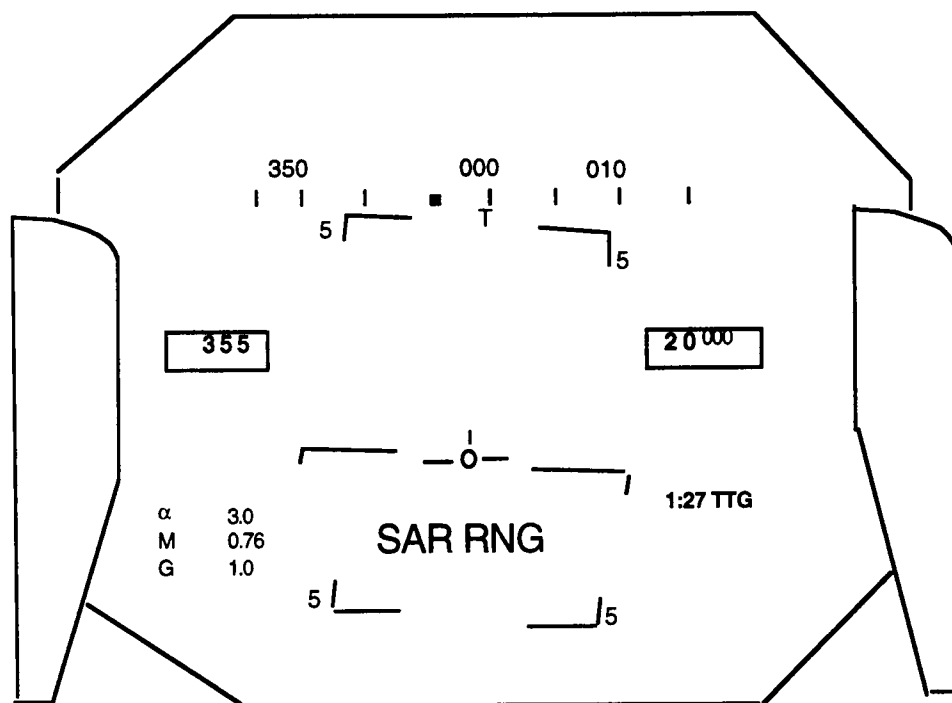


Figure 3-4. HUD, with SAR Range Cueing

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

mechanical gimbals do not interrupt radar imagery gathering. The author found that the SAR GMBL cue was the easiest of the three SAR cues to understand.

SAR ANGL indicates to the crew that on the current heading the aircraft-to-target geometry is not correct to collect SAR data [1]. If the countdown timer reads 9:59 TTG (the maximum allowed) then the aircraft should be maneuvered to a heading that presents a more favorable geometry. If the time-to-go timer is reading a few seconds and counting down then the aircraft-to-target geometry is acceptable and radar imagery collection will commence in the number of seconds displayed [1].

The SAR cues are in large font and directly in the pilot's central vision when he looks through the HUD. Their placement is excellent for the purpose of getting his attention. The cues themselves typically require the pilot to look inside the aircraft at his horizontal situation display to determine what type of maneuver is required to solve the aircraft-to-target geometry and begin recording. The SAR ANGL cue was found to be particularly confusing. A recommendation is made in the Horizontal Situation Display Format section to minimize this problem and enhance radar imagery collection.

Reconnaissance Data Link Transmission Cue

The reconnaissance data link transmission cue is displayed in HUD window number five whenever the reconnaissance pod is transmitting. The transmission cue is abbreviated XMIT. The XMIT cue is displayed in the same window as the recorder status cue [1]. This is good use of display space as the reconnaissance system cannot

be recording and transmitting at the same time. The XMIT cue is clearly visible to the pilot and will increase mission effectiveness by reminding the pilot to keep the aircraft pointed so that the ground receiving station is forward of the aircraft wing-line in order to maintain data link communication. Since the data link transmission cue uses the same window as the recorder status cue, the author has the same concerns and makes the same recommendation, that ATARS and tactical data link integration be further tested, as expressed in the earlier section.

Radar/Attack Display Format

One of the finest features of ATARS man-machine interface is that all normal radar/attack display functions are available when ATARS is gathering imagery via the EO/IR sensors [1]. The pilot can be searching for enemy airborne targets with the air search modes of the radar while the WSO supervises the collection of the EO/IR imagery. This integration feature increases the survivability of the F/A-18D(RC) in a combat environment.

When radar imagery collection is commanded the normal air-to-air and air-to-ground functions of the radar cease. If the crew is operating the aircraft in either the navigation or air-to-ground master mode, the radar attack format changes to reflect that it is in the reconnaissance mode [1]. This is good feedback to the crew that radar imagery collection has been commanded. The pilot is made aware that air-to-air target search has

terminated and that he should maintain present course and attitude while imagery is collected.

Upon completion of SAR strip or spot map data collection, the radar is commanded back to its previous mode [1]. This is excellent functionality and integration. The pilot is presented with vivid feedback that recording has finished and that he may once again maneuver the aircraft. Air-to-air search is immediately resumed, if that was the radar mode prior to SAR data collection, again enhancing the mission effectiveness and survivability of the F/A-18D(RC) [15].

The SAR reconnaissance radar display is essentially a blank format with the exception of a few reconnaissance cues [1]. Example reconnaissance radar displays are provided in Figures 3-5 and 3-6. If record is commanded and the aircraft is not at the proper geometry with respect to the target to initiate data collection, the radar will remain in an idle state until active data collection can be initiated. While in the idle state, the appropriate time-to-go and SAR geometry cues are presented on the radar/attack display format and repeated on the HUD [1]. This mechanization was described and evaluated in the HUD section of this document. Repeating mission information on more than one display is a good man-machine interface feature because the information has a greater chance of being assimilated by the crew when it is displayed at more than one location.

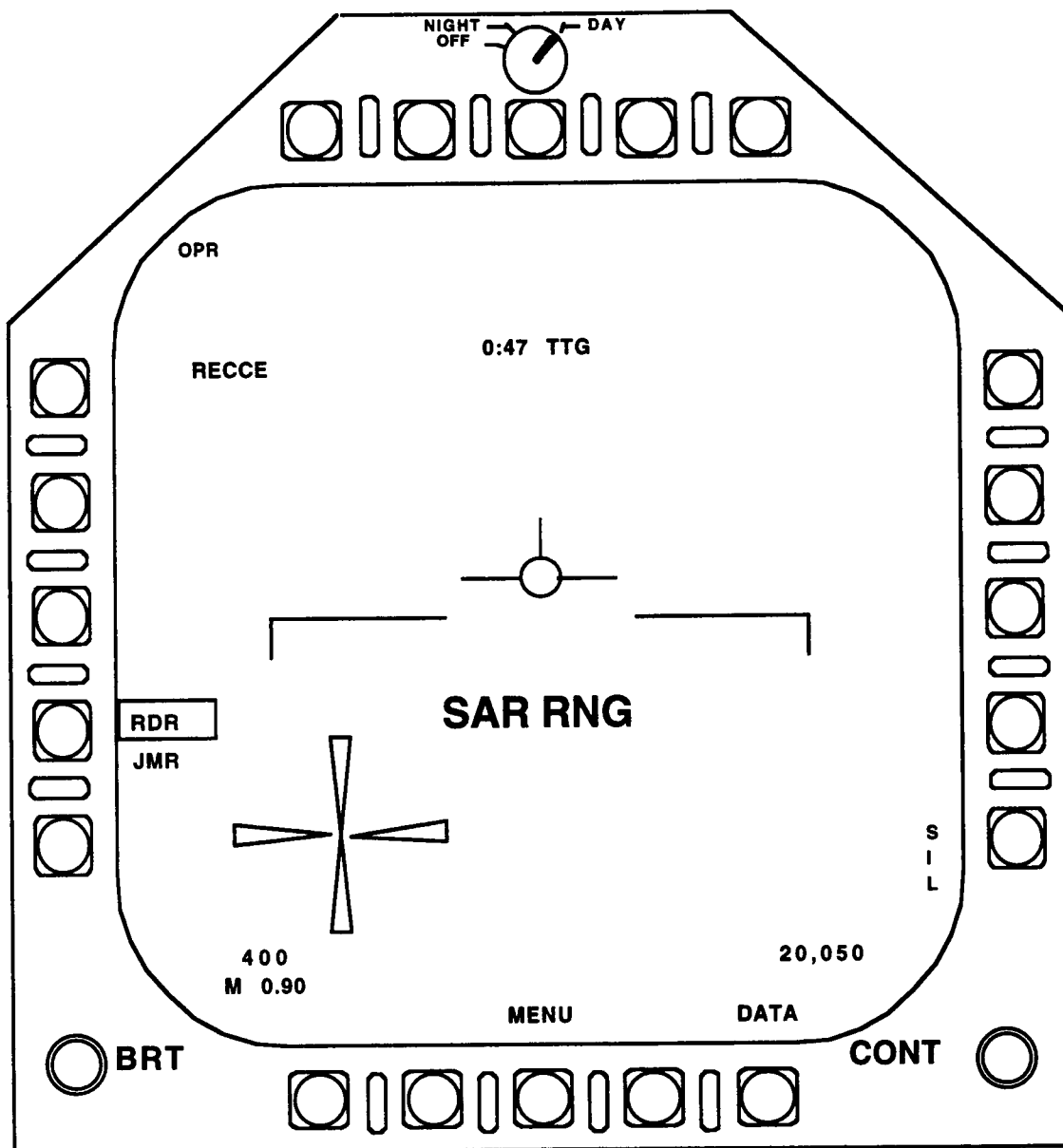


Figure 3-5. Radar/Attack Display, Reconnaissance, Time-to-go

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

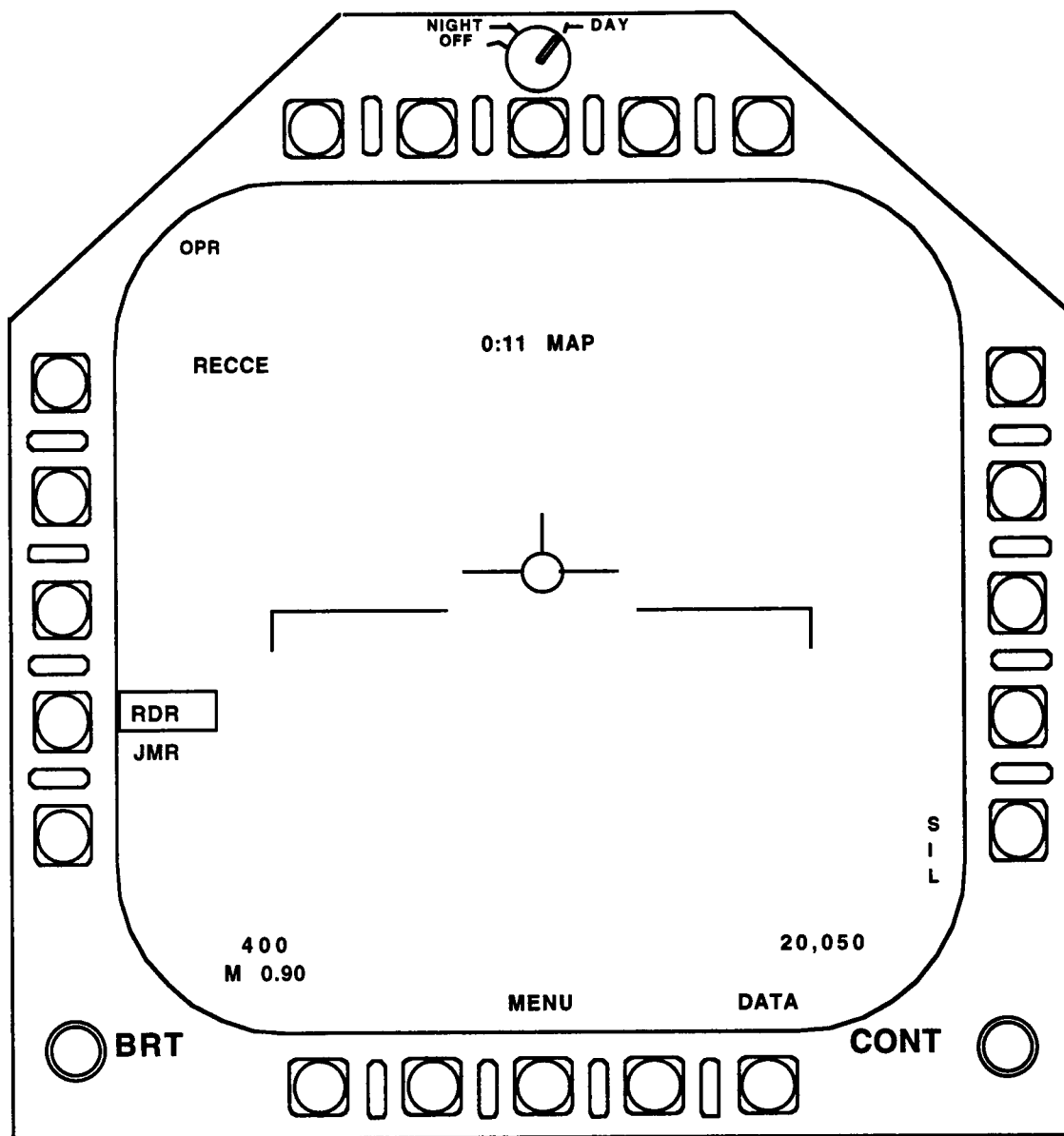


Figure 3-6. Radar/Attack Display, Reconnaissance, Map in Progress

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

The other legends on the reconnaissance radar display have the same meaning and functionality as they do on the air-to-air and air-to-ground radar display formats. This is compatible with existing radar displays in the F/A-18 and is well integrated.

If the aircrew have the aircraft avionics configured in the air-to-air master mode, the radar will be prohibited from collecting radar imagery. This is indicated to the crew by the removal of the record option on the reconnaissance displays. A good feature of the ATARS integration is that if the crew is recording a radar image and must immediately defend themselves, all the pilot must do is select an air-to-air weapon and the aircraft immediately terminates SAR data collection and reconfigures the radar for air target search and attack. This transition takes less than one second to complete. This mechanization makes the F/A-18D(RC) a more survivable aircraft in hostile environments [16].

Horizontal Situation Display Format

The reconnaissance system displays important navigational information on the horizontal situation display (HSD) format. Pre-briefed reconnaissance targets, Joint Services Imagery Processing System (JSIPS) positions, and one of the reconnaissance sensor's footprint are displayed [1]. The HSD is designed for rapid assimilation of navigational information. The aircraft's present position is usually centered on the display format with a compass ring at a selectable number of miles from the aircraft figure. Headings and distances to inertial navigation points and navigational radio

stations are shown both graphically on the moving map and numerically outside the compass ring [7]. One glance at this display and the crew's situation awareness is increased significantly. The HSD depicts a "God's eye view" of the aircraft present position in relation to its surroundings, including reconnaissance targets.

Pre-briefed reconnaissance targets are displayed on the HSD regardless of aircraft master mode. The HSD places pre-briefed reconnaissance target symbols over the moving map in correct relationship to the ATARS aircraft and the other map symbols. Of the twelve pre-briefed targets, two may be displayed at a time. The reconnaissance target selected on the programming sublevels is one of the two targets that may be displayed. The other target displayed is one that has been declared 'current' by the reconnaissance system [1]. Pre-briefed point targets are depicted with the legend PXX where XX is the pre-briefed number assigned to the target. Strip targets are represented by an S with the two-digit target number at both the start and stop point. In the example HSD provided in Figure 3-7, the arrow displayed between the two S02 symbols indicates the direction that the strip is to be flown. Depending on the distance between the two points and the crew selected map scale, the arrow might not be displayed due to lack of room.

An asterisk above a target legend indicates which pre-briefed target is declared current by the reconnaissance system. The circle around the P01 legend in Figure 3-7 is a display of the recorder activation range. To record LAEO imagery of reconnaissance target number one, the pilot would turn the aircraft roughly forty-five degrees to the left.

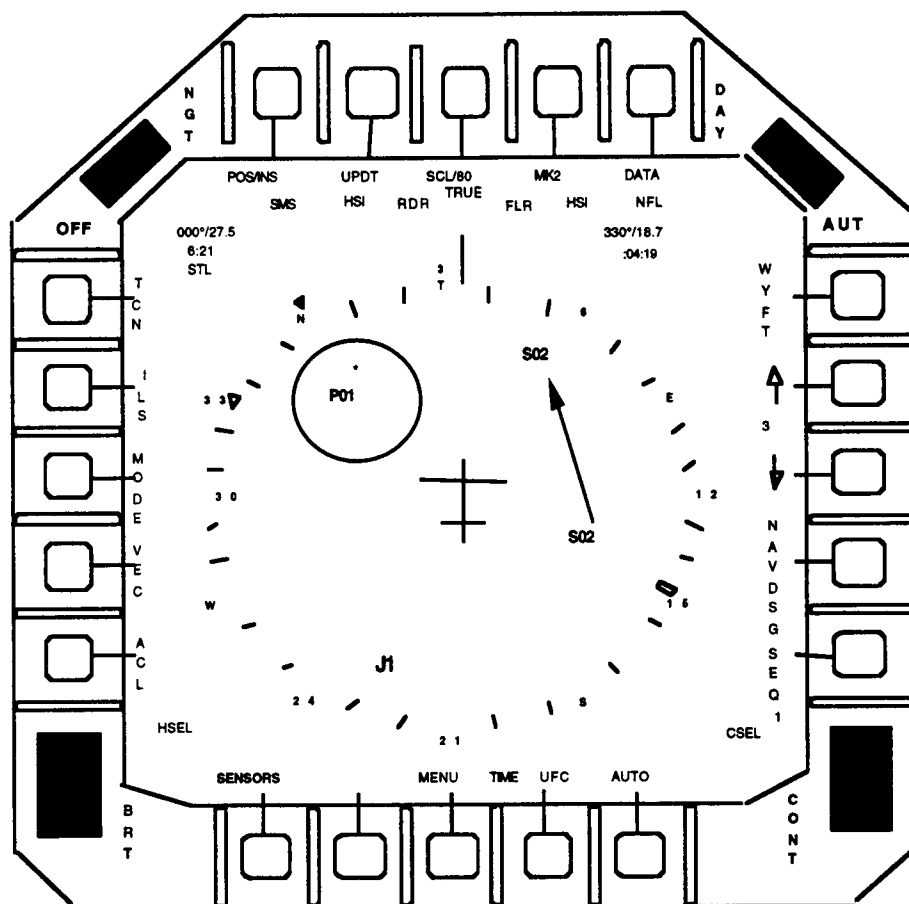


Figure 3-7. HSD Format, with Reconnaissance Targets

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

When his aircraft crossed the recorder activation range circle the LAEO would commence recording. Figure 3-8 provides example area target symbols. The four lines connecting the A04 legends represent the recorder on and off lines. The recorders automatically turn on when the aircraft crosses one of the four lines entering the area. Likewise, the recorders shutoff when the aircraft crosses one of the four lines exiting the area target.

It was observed in flight test that if the aircrew entered the area coordinates in an incorrect order the HSD would display a bow-tie shaped figure. Even though it displayed a bow-tie figure the recorders came on when the aircraft crossed the imaginary lines connecting the four points.

The author found that getting into a position where the aircraft-to-target geometry was acceptable for SAR imagery collection was difficult and perplexing [17,18]. The reconnaissance crew must solve the geometry problem complicated by maximum and minimum acceptable ranges, maximum and minimum allowable radar gimbal angles, and crosswinds. **The author recommends that when radar reconnaissance is being performed that the HSD display a pie shaped sector indicating to the crew a region of acceptable geometry.** The pilot could then simply fly the aircraft to place the area of acceptable geometry over the target symbol.

Sensor Footprints

In all F/A-18s the SENSORS (footprint) push-tile is used to display to the crew where air-to-ground sensor footprints are located on the surface of the earth [1]. With

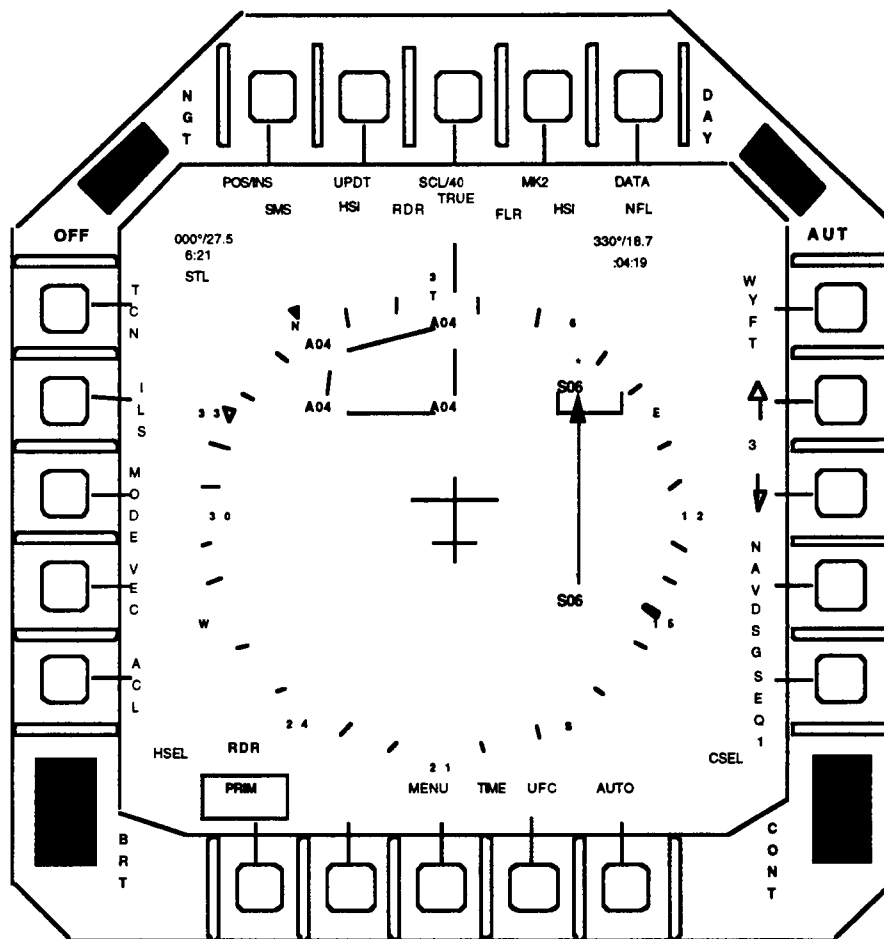


Figure 3-8. HSD Format, with Radar Footprint

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

the integration of ATARS the crew also has the ability to see the reconnaissance sensor's footprints overlaid on the moving map. Only one reconnaissance sensor's footprint can be displayed at a time. Selecting the SENSORS option on the HSD enables this feature. This option is not available when the aircraft is in the air-to-air master mode [19]. The SENSORS option, at push-tilt twenty, functions as a rotary selector, with the default setting being sensor footprints not selected [1]. This is consistent with existing F/A-18 convention. The first time the option is selected the legend SENSORS becomes boxed and the aircraft air-to-ground sensor footprints are displayed. When the SENSORS option is depressed a second time the boxed legend PRIM replaces the boxed SENSORS legend. Above the boxed PRIM legend is the legend for the sensor assigned to the primary recorder. Figure 3-8, on page 44, shows an example where the sensor assigned to the primary recorder is the radar, and the RDR legend is displayed. In the example, the radar footprint is bracketing the end point of strip number six indicating the strip image is almost complete. When push-tilt twenty is depressed a third time the legend reads SCND and it is boxed. Above the boxed SCND legend is the legend for the sensor assigned to the secondary recorder. An example is provided in Figure 3-9 where the sensor assigned to the secondary recorder is the low altitude electro-optical sensor so the legend is LAEO. In the example, the LAEO footprint is almost directly below the aircraft as the aircraft approaches reconnaissance point number one. A fourth depression of push-tilt number twenty will complete the rotary sequence and deselect all footprint displays.

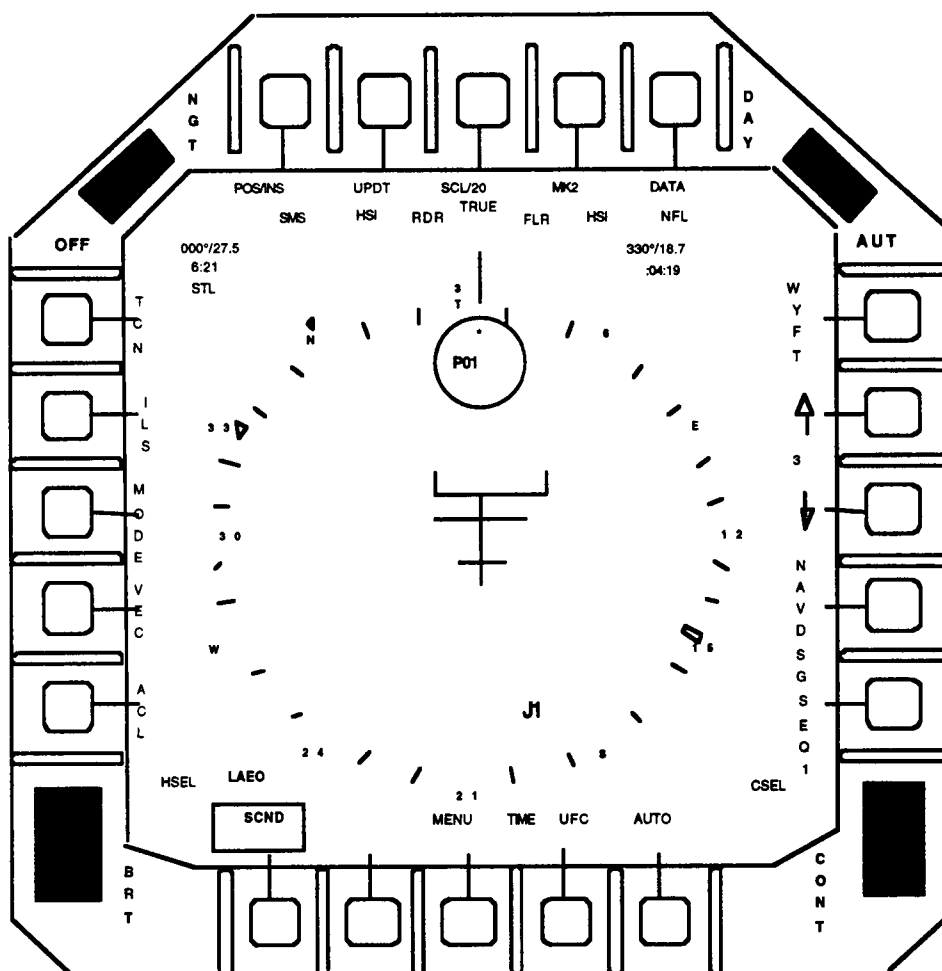


Figure 3-9. HSD Format, with JSIPS Station Location

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

Footprint cues are very useful, giving the crew immediate feedback that the aircraft is properly positioned to image the target. The SENSORS push-tile is used minimally in non-reconnaissance F/A-18s so it is logical to leave the sensor select option unboxed for display clutter purposes in those aircraft. Aircrews flying F/A-18D(RC)s are interested in where their sensor footprints are located for the majority of the tactical portions of their flights. The sensors footprint mechanization would improve mission effectiveness even when in the air-to-air master mode [19]. **The author recommends that the sensors footprint option default to PRIM 'boxed' when ATARS is loaded in the aircraft. It is also recommended that the system maintain the footprints on the HSD when in the air-to-air master mode.**

RECONNAISSANCE DISPLAYS

Reconnaissance Display Format

The reconnaissance display format is initially accessed from the tactical menu by depressing push-tile number fourteen labeled RECCE. The reconnaissance display format is a top-level display format from which four other reconnaissance display sublevels can be accessed [1]. The use of sublevels is acceptable and conforms to F/A-18 display conventions. The reconnaissance display format, as depicted in Figure 3-10 provides current status of the sensors and recorders, along with options to change the current operating mode, and sensor positions [1].

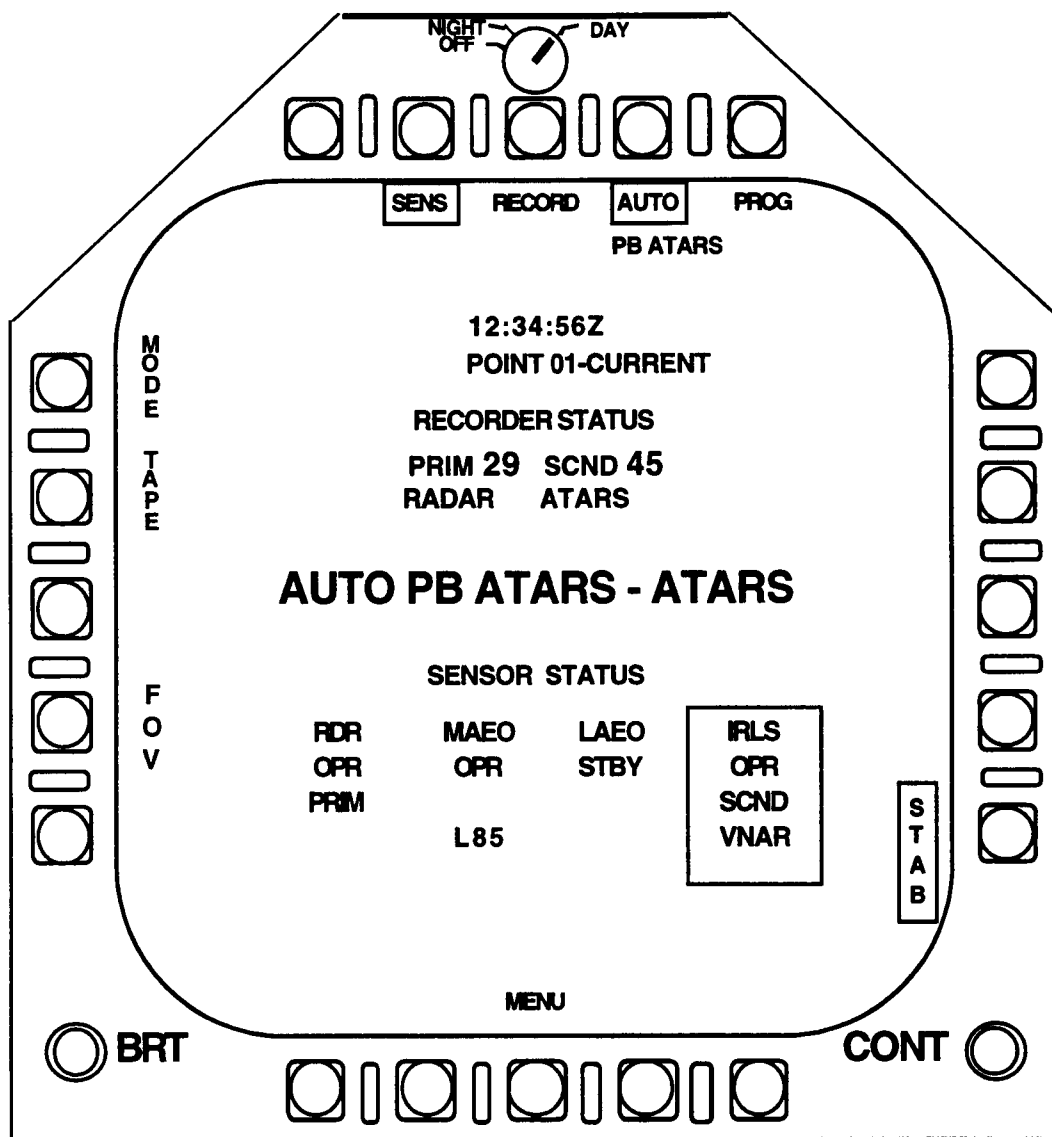


Figure 3-10. Reconnaissance Display Format, Top-level

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

The information on the reconnaissance display is monochrome green, neatly arranged, and easy to read. The top line of the display shows the current zulu time. Below the time is the 'current' pre-briefed reconnaissance target type and number. Under the RECORDER STATUS line is critical information about the digital tape recorders [1]. The legend PRIM (SCND), referring to the primary (secondary) recorder, tape time remaining, in minutes, next to it and missionization status below. The missionization legend displays either RADAR for radar assignment, or ATARS for EO/IR sensor assignment. Recorders in a non-operational state are crossed out [1]. The flight test crew easily overlooked this. **The author recommends the use of color coding on the reconnaissance display formats for recorder non-operational.** Color coding would immediately catch the attention of the crew who could then take appropriate action.

The center of the reconnaissance display format is a large font ATARS status line. There are twenty-one plain language messages that can be displayed on this line, all pertaining to normal and degraded ATARS conditions [1]. These plain language messages make heavy use of appropriate abbreviations and acronyms. The author found these messages very useful.

The bottom half of the display describes the status of each of the ATARS sensors that are installed in the aircraft. Under the individual sensors are their operating mode legends, tape recorder assignment legends, and sensor field of view information. One of the sensors and the column of information below it will be boxed. This box is

called the 'current selected sensor box' and is used to change the legends next to push-tile numbers one through five on the left side of the display. Depressing push-tile seven, labeled SENS, steps the selected sensor box from one sensor to the next going from left to right across the display and then starting over again at the left when the box has reached the last sensor on the right [1]. This is excellent software implementation because it is consistent with stepping convention already established on the F/A-18.

Push-tile number eight labeled RECORD will be discussed here although this same function can be accomplished from any of the eight reconnaissance displays and through activation of HOTAS and hand controller switches. The RECORD push-tile allows the operator to command recording and monitor the record status of the digital tape recorders. The RECORD legend will box automatically when the aircraft enters the recorder activation range circle on the HSD [1]. This mechanization offers the crew multiple ways to control the record function from multiple displays and switches throughout the cockpit. This level of redundancy is ideal for a mission function as critical as controlling the recorder and increases the mission effectiveness of the crew.

Push-tile number nine displays to the operator the method by which ATARS is acquiring imagery. Its function will be discussed here although this same function can be accomplished from any of the reconnaissance displays. ATARS has one automatic and one manual method of collecting EO/IR imagery and two manual methods of acquiring radar imagery [1]. Push-tile number nine acts as a rotary switch cycling the legend and system configuration with each depression. The legends at push-tile nine adequately

describe to the operator which reconnaissance collection method is in use. If the reconnaissance system is set up (or missionized) to collect only EO/IR imagery then the two legends pertaining to radar will be left out of the sequence. If the system is set up to collect only radar imagery then only the two legends pertaining to radar would remain in the sequence [1]. The automatic removal of legends pertaining to methods that are unavailable is compatible software implementation that will reduce workload and confusion in the cockpit.

The push-tile number ten label is PROG. Depressing this push-tile will cause the reconnaissance target programming sublevel to replace the top-level reconnaissance format [1]. Once on a reconnaissance programming sublevel this push-tile is labeled RECCE and is used to return to the top-level reconnaissance display format. This is good integration because the operator quickly learns to enter and exit the reconnaissance programming sublevels by depressing push-tile number ten. The author was able to rapidly navigate through reconnaissance displays without actually reading the push-tile legends.

Push-tile number fifteen on the top-level reconnaissance display format is labeled STAB. When the STAB legend is boxed the MAEO and IRLS sensors are inertial or ground stabilized. When the legend is not boxed the MAEO and IRLS sensors are not stabilized; they point at a fixed angle relative to the aircraft wing line [1].

Reconnaissance Target Programming Sublevel

This programming sublevel is initially accessed by depressing push-tile number ten on the top-level reconnaissance display format. It can also be accessed by depressing push-tile number six labeled RCPT on any of the other reconnaissance programming sublevels. This sublevel allows the crew to verify and edit the type of target, target position, target elevation, recorder activation range, and target configuration range of the twelve pre-briefed reconnaissance targets that were loaded via the memory unit during ATARS initialization [1]. The display looks slightly different depending on whether the target is a point (defined by one latitude and longitude), a strip (two latitudes and longitudes), or an area (four latitudes and longitudes). Figures 3-11 through 3-13 show the different reconnaissance target programming displays.

Depressing push-tile number two, labeled DEL (for delete), clears the display, allowing the operator to entirely redefine the reconnaissance target [1]. Above the delete button at push-tile number three is the legend labeled TYPE. Pressing TYPE will change the labels at push-tile numbers three, four and five to allow selection of target type. Figure 3-11 shows an example of target type selections. This method of data entry is compatible with established F/A-18 conventions.

Push-tile number five is labeled POS1 UFC for point targets and POS1/2 UFC for strip and area targets. Additionally, for an area target push-tile number four is labeled POS3/4 UFC. Depressing push-tile numbers four or five configures the up front

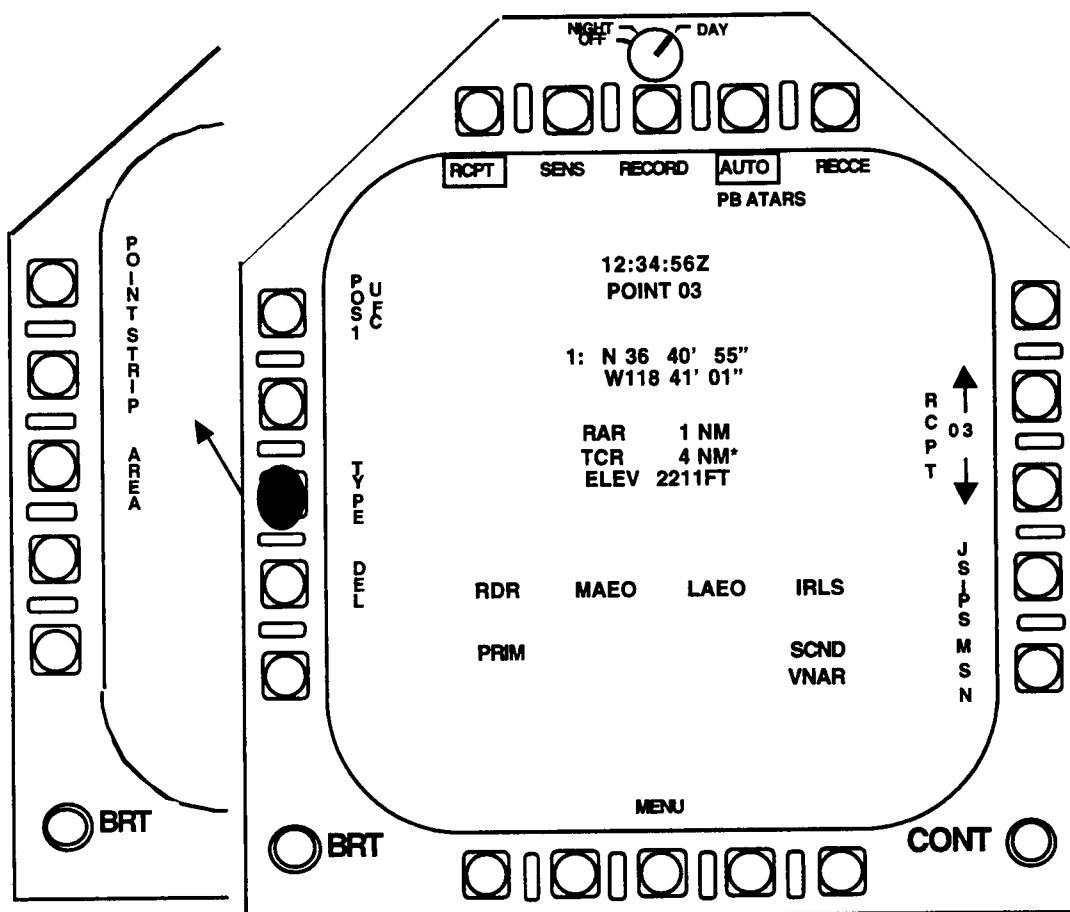


Figure 3-11. Reconnaissance Target Programming Sublevel, Point

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

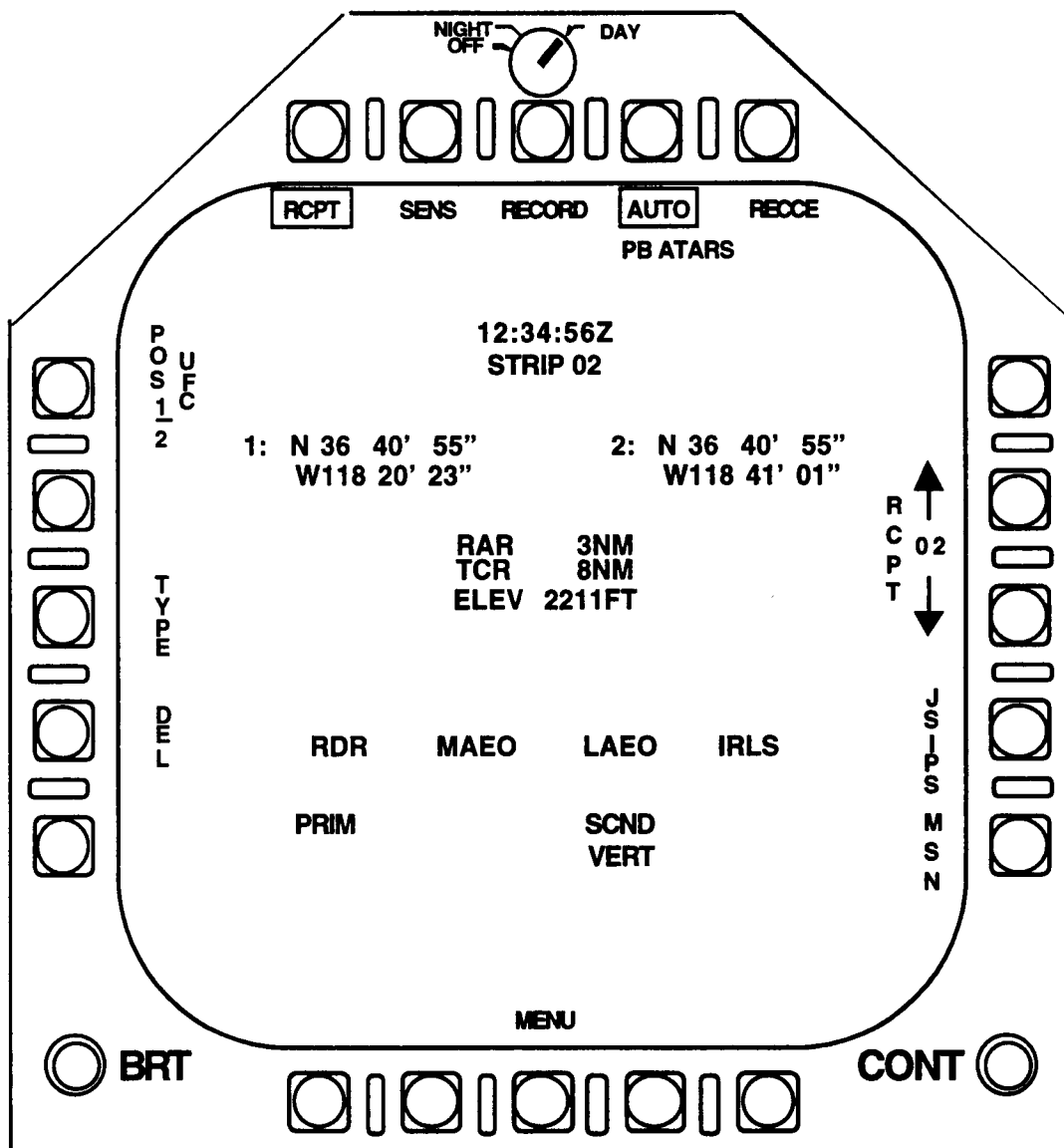


Figure 3-12. Reconnaissance Target Programming Sublevel, Strip

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

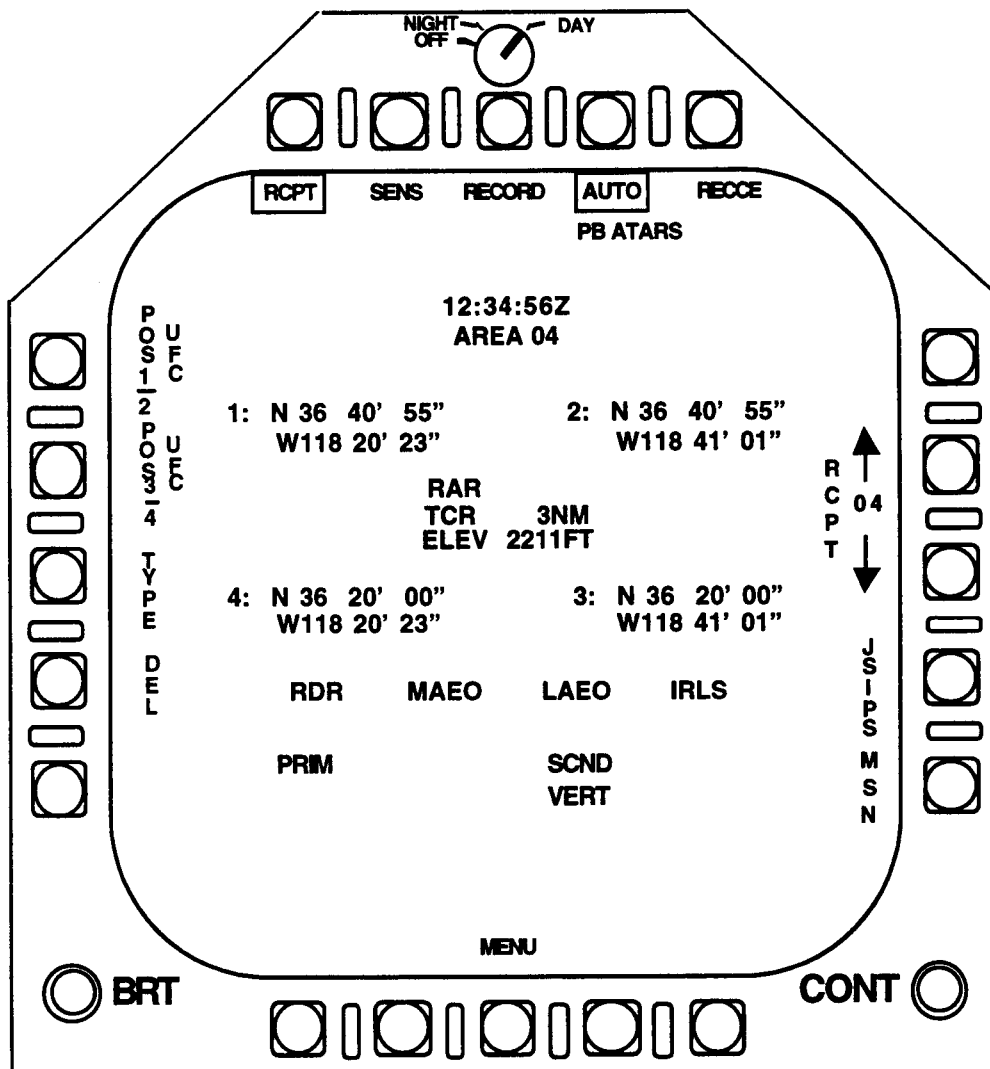


Figure 3-13. Reconnaissance Target Programming Sublevel, Area

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

control (UFC) to accept position data for the target. Actual entry of the data is discussed in the mission loading section of this paper.

To depart from the reconnaissance target programming sublevel the crew has many options. The sensor (SENS), Joint Services Imagery Processing System (JSIPS), or mission (MSN) programming sublevels can be accessed by depressing push-tiles number seven, fourteen or fifteen respectively. Any of the programming sublevels can be exited to the top-level reconnaissance display by depressing push-tile number ten labeled RECCE. Lastly, the crew can completely exit the reconnaissance displays by depressing the push-tile number eighteen, labeled MENU [1]. These options allow the crew a great deal of flexibility and ease of navigating through the displays. The logic is intuitive and compatible with F/A-18 conventions.

Reconnaissance Sensors Programming Sublevel

The reconnaissance sensors programming sublevel is accessed by depressing push-tile number seven labeled SENS on any of the other reconnaissance programming sublevels. This sublevel allows the crew to verify and edit the sensor assignment and field of view settings for the twelve pre-briefed reconnaissance targets [1]. The sensor programming sublevel is very similar in appearance to the reconnaissance target programming sublevel. The legend SENS at push-tile number seven is boxed indicating that the operator is on the sensor programming sublevel. The sensor select box is displayed around one of the sensors in the bottom third of the center of the display.

This sensor select box can be stepped from sensor to sensor by depressing push-tile number seven, the boxed SENS legend. This mechanization is similar to the top-level reconnaissance format. The purpose of this sublevel is to verify and modify sensor assignment to the pre-briefed reconnaissance targets so that the system automatically configures ATARS to collect the programmed imagery when the aircraft is in the vicinity of the reconnaissance target [1].

It is appropriate to review sensor assignment limitations at this point. Once a tape is missionized to accept radar data it can only accept radar data, thereby limiting all LAEO, MAEO and IRLS sensor assignments to the other recorder. If both tapes are missionized for EO/IR imagery then no radar data can be collected that mission. In addition, the LAEO and MAEO use the same electronics for image processing, therefore only one of these sensors may be used for recording at a time. The reconnaissance system design is complete in that these limitations are taken into account when legends are displayed. The system automatically does not display legends that cannot apply due to these limitations.

Push-tile number four is labeled TAPE. Depression of this push-tile allows the currently boxed sensor to be assigned to the primary, the secondary, or both recorders. The push-tile legends along the left side of the display change to allow selection of PRIM, SCND, P/S, or NONE, depending on which are available. If the primary recorder has been missionized for radar data and the sensor select box is around the LAEO the only options available after depressing TAPE are SCND and NONE since

the primary recorder is not available to record EO/IR imagery [1]. This sensor to tape assignment is for the pre-briefed reconnaissance target number that is listed at the top of the display and between the up and down arrows. If the IRLS has a sensor select box around it and is assigned to a recorder then push-tile number two will have the legend FOV to allow for changing the field of view of the IRLS. Depression of FOV will change the left most push-tile legends to enable IRLS field of view choices: WIDE, VNAR, RNAR, and LNAR [1]. This situation is shown in Figure 3-14.

The sensor programming sublevel is exited by the same methods described in the reconnaissance target programming sublevel. This level of commonality is good and will enhance operator effectiveness.

Reconnaissance Mission Programming Sublevel

The reconnaissance mission programming sublevel is accessed by depressing push-tile number fifteen labeled MSN on any of the other reconnaissance programming sublevels. This is excellent integration. The operator can access this display from many other related displays and will always find the selection button in the same location on those displays.

The reconnaissance mission programming sublevel is used to modify the mission number and air tasking order number that will be written to the digital tape recorders to identify the collected imagery and to control mission termination [1]. Typically, operational reconnaissance missions are assigned to units by a higher headquarters

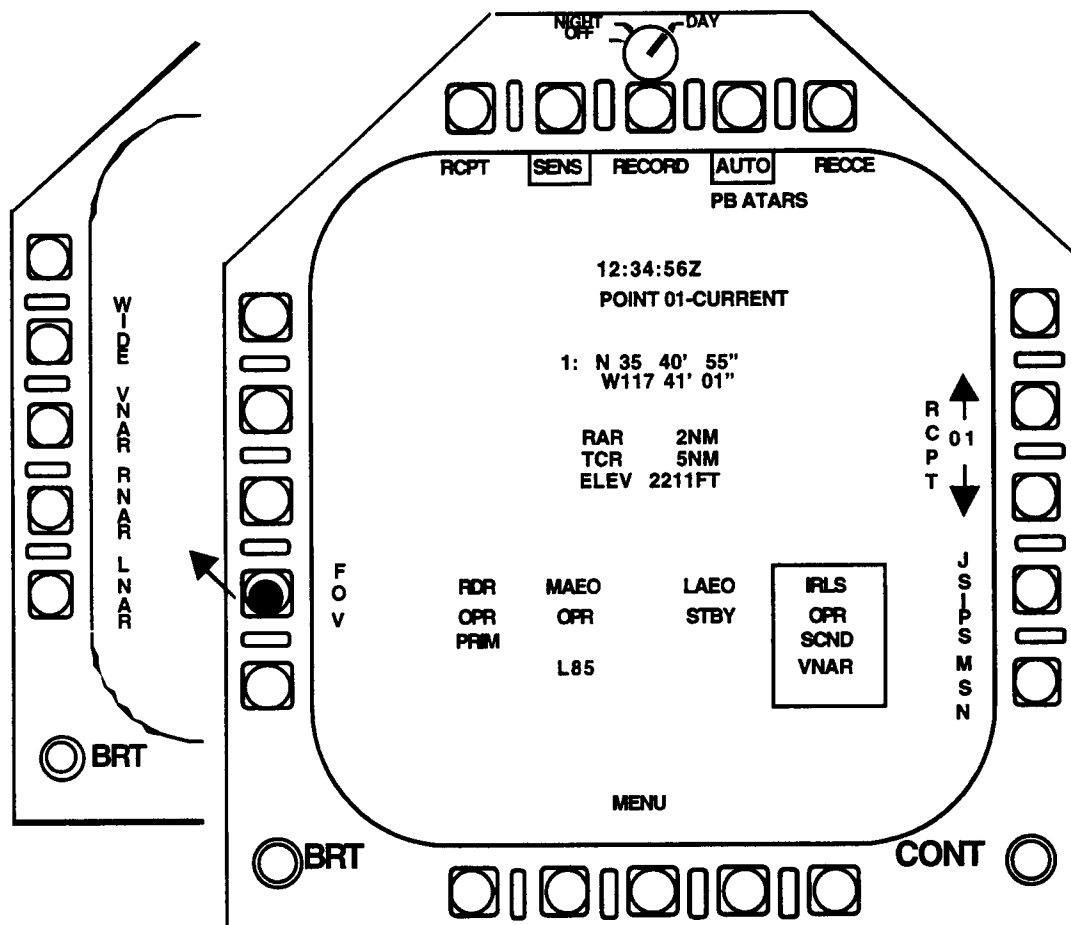


Figure 3-14. Reconnaissance Sensors Programming Sublevel

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

through the use of a document called the Air Tasking Order (ATO). The ATO will direct squadron flight operations for a certain duration of time. Each mission that a squadron is tasked to fly will be assigned a mission number. The mission number and ATO number uniquely define every mission tasked and flown. By attaching these numbers to the imagery, the imagery analysts have a historic record of who flew the mission, with what equipment, what the intended route was, and other important details.

Normally the mission number and ATO number are entered during mission planning and brought to the aircraft via the memory unit. If the aircrew desire to modify these numbers they must do it while ATARS is in the initialize mode after 'initialize complete' status is attained. This is because once the aircrew make the transition from initialize mode to an acquire mode the mission number and ATO number are written to the digital tape. The mission programming display format is provided in Figure 3-15.

To modify the ATO and mission numbers the operator must place the underline cursor symbol under the character they wish to change. The underline cursor is moved by depressing push-tile number eleven labeled ENTER. When ENTER is depressed the underline cursor moves right one place without affecting the character value above it. When the operator has the cursor under the character that he wishes to modify he will use the up arrow, push-tile number twelve, or down arrow, push-tile number thirteen, to adjust the value between the two arrows. The range of symbols in order is A-Z, 0-9, open quotation, dash, period, comma, colon, open parentheses, close

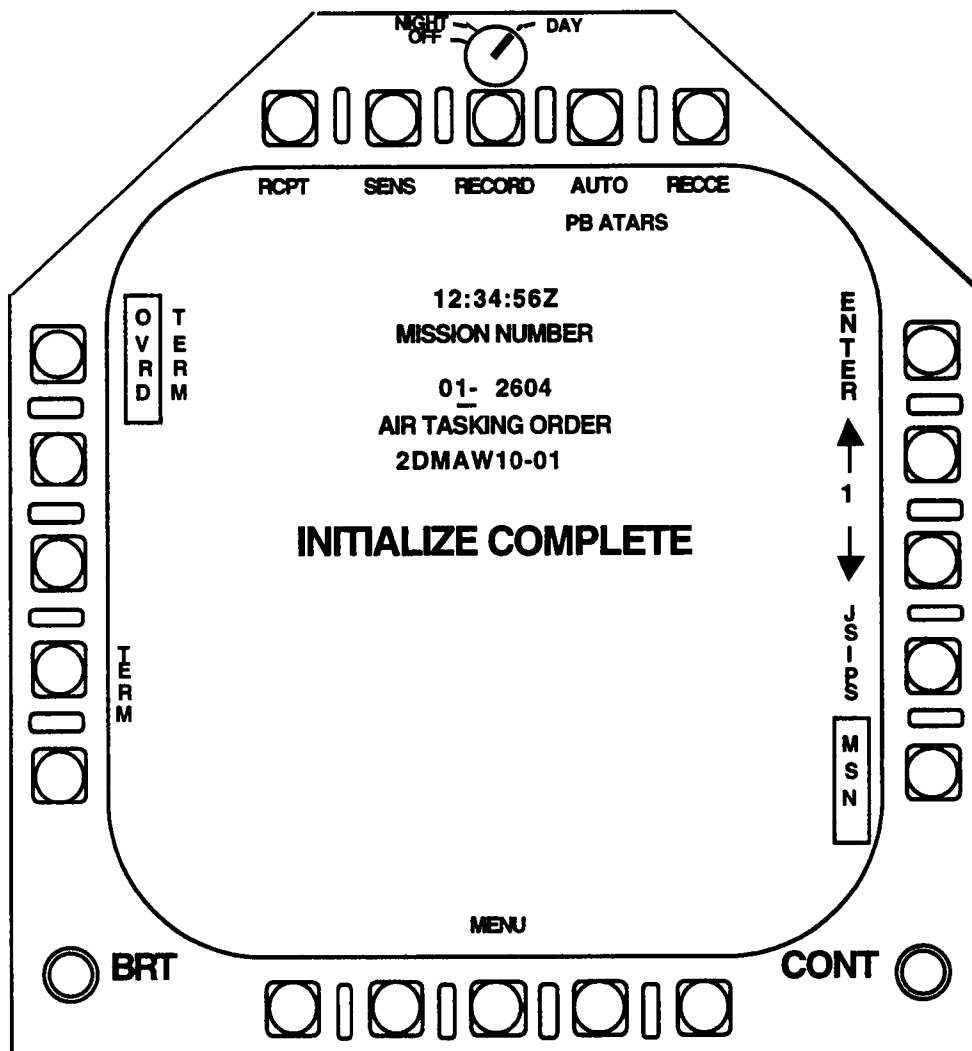


Figure 3-15. Reconnaissance Mission Programming Sublevel

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

parentheses, slash, close quotation. Continuing to depress the up arrow after the last symbol is reached will cause the scrolling to start over. If the up or down arrow is depressed and held the character symbols will scroll at five per second. This use of arrows is intuitive and consistent with F/A-18 convention. Once the character between the arrows is the desired character the ENTER push-tile is depressed to enter that value and move the cursor one space to the right. At the end of the mission number line the underline cursor steps down to the first character of the ATO identifier. At the end of the ATO identifier the cursor will reinitiate at the beginning of the mission number line [1].

The number modifying process is cumbersome since the crewmembers do not have access to a keyboard for character entry. The up front control (UFC) allows for easy entry of numerical information but does not allow for the entry of non-numerical characters. The modification process is acceptable since ATO and mission numbers rarely change from the time the mission is planned to when it is flown. The modification process is used primarily as a means to correct typographical errors made in the mission planning phase. **The author recommends that the aft cockpit of the F/A-18D be modified to include a flight-worthy keyboard for character entry.** The addition of a keyboard would only provide minimal improvement to ATARS today, but it would provide tremendous growth potential. Reconnaissance imagery could be labeled with notes. Additionally, other systems on the aircraft would benefit from having character entry capability via keyboard.

The push-tiles associated with the labels RCPT, SENS and JSIPS change the display format to the reconnaissance target, sensors, and JSIPS programming sublevels, respectively [1]. This is good man-machine interface in that it allows the operator easy access between the four programming sublevels and is consistent across all four programming sublevels.

Mission termination writes summary data to the tapes, rewinds them, and unthreads the tapes so that they are immediately ready for removal and processing upon landing. Termination can be accomplished automatically when the aircraft lands or manually any time. Automatic termination will not occur if OVRD TERM is boxed.

Manual termination is a two step process. Push-tile number two, labeled TERM, must be depressed when the crew wants to end the current mission and prepare for tape removal. Pushing TERM causes the push-tile number two legend to change to BEGIN TERM. Depressing push-tile number two in this condition commands the termination [1]. This two-step process is consistent with F/A-18 convention for inputs that are critical to mission success. Accidental mission termination at the beginning of a mission would cause the mission to be lost, so the two step process is a good integration.

Joint Service Imagery Processing System Programming Sublevel

The Joint Service Imagery Processing System (JSIPS) programming sublevel is accessed from any of the other programming sublevels by depression of push-tile

number fourteen labeled JSIPS. This sublevel allows the crew the ability to verify and edit the ground station three dimensional position and data link frequencies that were loaded via the memory unit during ATARS initialization. Position and frequency data can be entered for up to six ground stations [1]. An example is provided in Figure 3-16.

At the top center of the JSIPS programming display is the current zulu time in the same location as other displays. Below it is the JSIPS station number, one through six, to which the rest of the data will be associated. The up and down arrows at push-tile numbers twelve and thirteen are used to change the JSIPS ground station being edited and modified. The author found this easy to use because it was similar to changing the reconnaissance target number on other reconnaissance formats. Below the JSIPS number is the three dimensional position of the ground station defined by latitude, longitude, and elevation. ATARS needs this position information so that it can correctly determine the data link antenna pointing angle to commence communications with the ground station. In the center of the display is the frequency information. The frequency inputs are two or three digit channel numbers that pertain to an actual X-band frequency. The command channel is used by the aircraft to receive up-linked information from the ground station. The return channel is used to send the high bandwidth imagery to the ground station [1].

The UFC option is only displayed if the reconnaissance management system (RMS) is prepared to handle the change. The RMS is unavailable when it is recalling or transmitting imagery and when it is in BIT or terminate mode [1]. The author found this

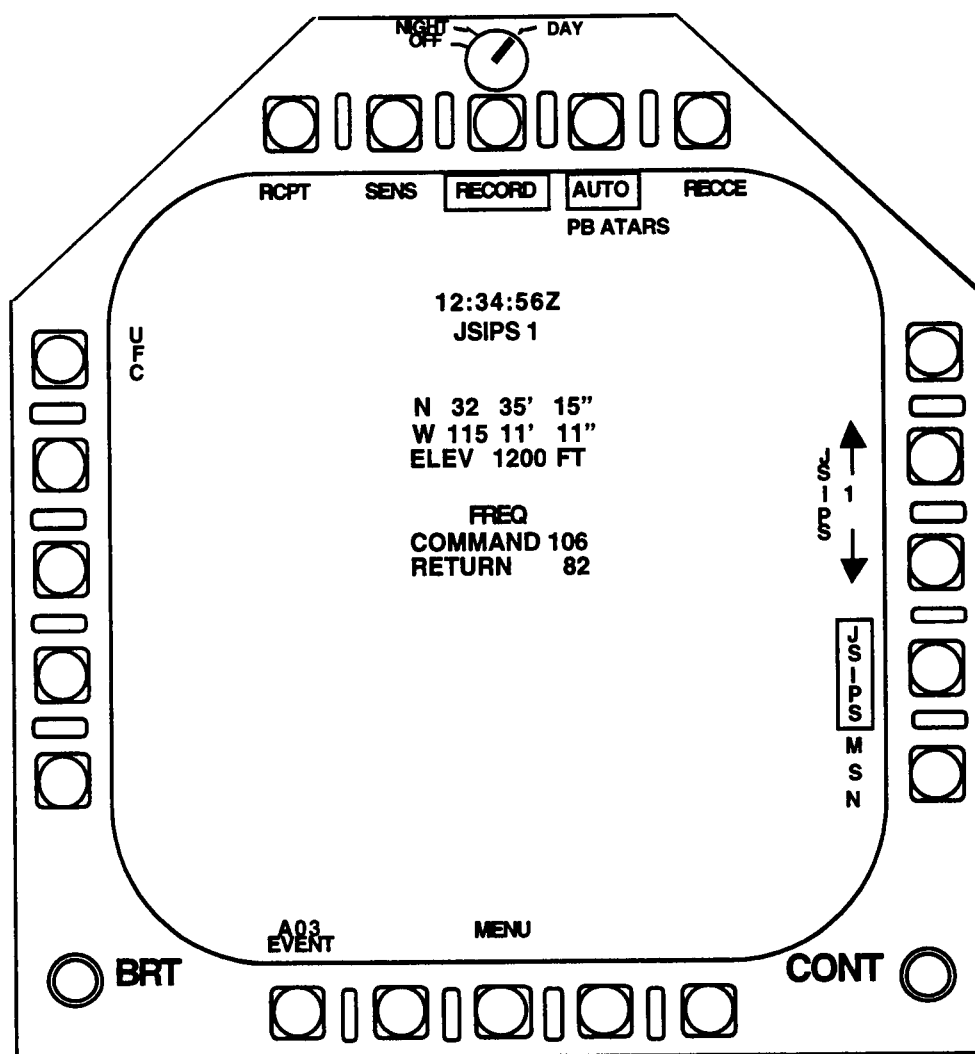


Figure 3-16. JSIPS Ground Station Programming Sublevel

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

a minor irritation in the following scenario. The WSO is in the process of recalling imagery in preparation for transmission. The WSO checks the JSIPS programming for correctness and discovers that one of the position numbers is incorrect. The WSO attempts to edit the JSIPS position in preparation for transmission but has no UFC option. This is confusing and disorienting to the operator who may not remember that UFC is not displayed when the RMS is unable to accept new data. **The author recommends that the RMS be changed to allow the modification of programmed JSIPS location and frequency data concurrent with recalling or transmitting data. Alternatively, it is recommended that the UFC legend be lined out or crossed out when it is not available, vice not displayed.** Evaluation of actual data entry is discussed in the data loading section of this paper. The other legends around the JSIPS programming display should now be familiar to the reader who has read the previous sections.

Reconnaissance Video Display Format

The reconnaissance video display format and its two sublevels provide the crew with the capability to view EO/IR imagery as it is being recorded and to command playback of recorded EO/IR imagery so that it may be reviewed, marked, and transmitted [1]. The capability to view imagery in the cockpit is a major man-machine interface improvement over previous film-based reconnaissance systems [20]. Imagery review empowers the crew to determine mission success or failure while they are still

airborne with the to ability to immediately re-fly portions of the mission, if necessary. An example reconnaissance video display is provided in Figure 3-17. The imagery scrolls from the top of the display toward the bottom and has pertinent collection information (aircraft position, time, speed) and system status information overlaid.

Depressing push-tile numbers one and sixteen, labeled REVIEW and D/L, accesses the review and data link modes, respectively. These legends are not displayed, and the push-tiles have no function, until the reconnaissance system has recorded imagery. Depressing either the REVIEW or D/L push-tiles changes both the display format and ATARS mode of operation [1]. These mechanization features are logical and consistent with existing F/A-18 conventions.

All three of the reconnaissance video display formats have legends at push-tile numbers eight, nine, and eighteen that are common with the reconnaissance display formats [1]. Allowing critical functions to be commanded from the same push-tiles on all reconnaissance displays represents an excellent man-machine interface.

The reconnaissance video display format has implemented many features that are compatible with existing F/A-18 display formats. A typical F/A-18 crewman is very familiar with freeze (FRZ), expand (EXP), reject (REJ), and image polarity (WHT or BLK) control functions from using other F/A-18 weapon systems. These controls perform 'expected' functions on the reconnaissance video display thereby increasing the mission effectiveness of the reconnaissance system.

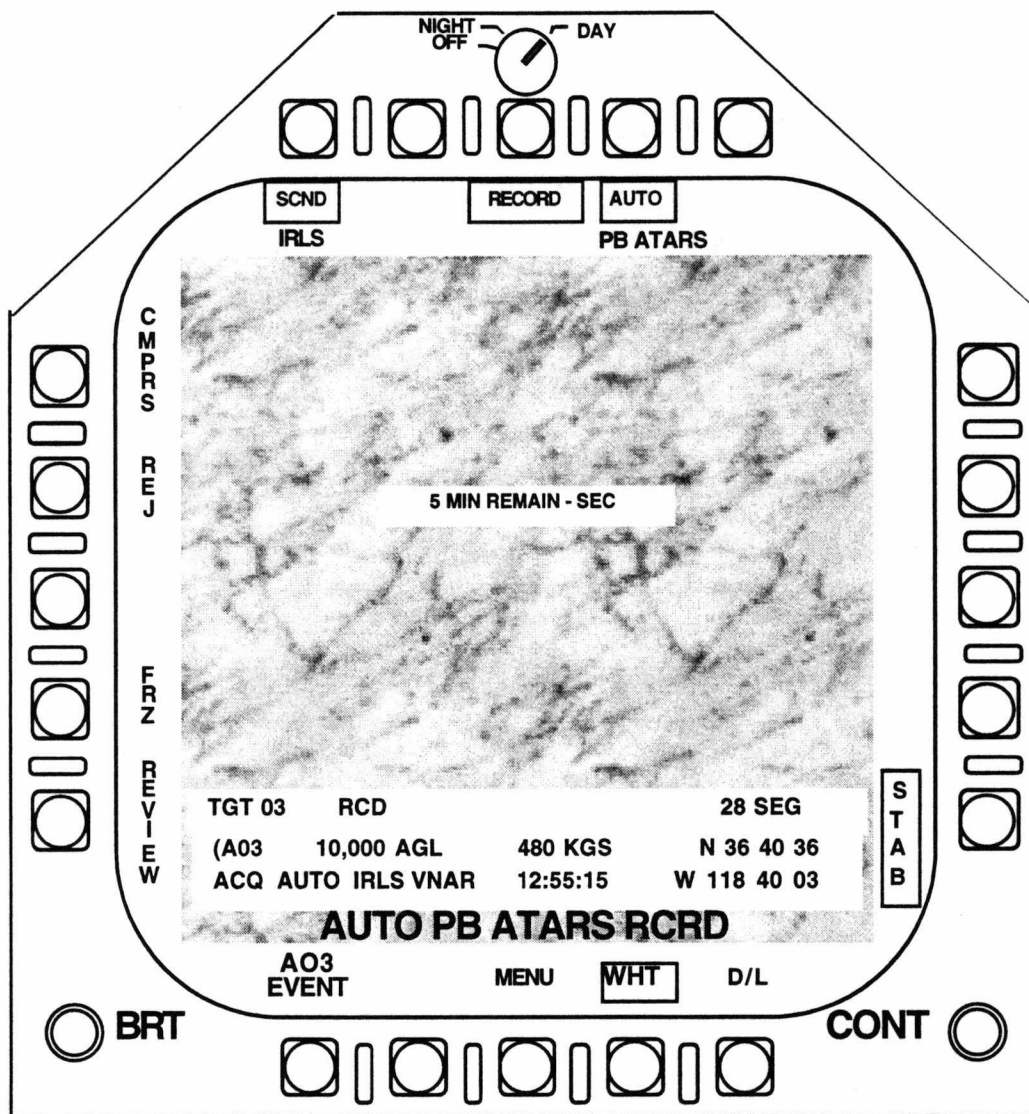


Figure 3-17. Reconnaissance Video Display

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

The author found one minor man-machine interface deficiency with the reconnaissance video display. The recorder abbreviations are inconsistent on the same display. PRIM (SCND) is used at push-tilt six and PRI (SEC) is used in reconnaissance advisory messages in the center of the display. This situation is depicted in Figure 3-17. The primary recorder abbreviations are similar enough that the author had no difficulty interpreting their meanings. The secondary recorder abbreviations are different enough to cause some minor confusion in the cockpit. **The author recommends that recorder abbreviations be made consistent throughout the reconnaissance display formats.**

The reconnaissance system has a major deficiency in that reconnaissance radar imagery, unlike EO/IR imagery, cannot be displayed in the cockpit. Radar is the only ATARS sensor capable of long range and all-weather reconnaissance [1]. As such, it will be heavily relied upon for imagery collection. The inability to view SAR imagery in the cockpit is a significant limitation of the system because the crewmembers do not have any immediate feedback that they accomplished the radar portion of the reconnaissance mission. The crewmembers are unable to make a real time decision to re-acquire the same imagery based on the quality of the first image. They are also unable to determine if there is anything of intelligence value at the location they imaged. **The author recommends that the high resolution SAR imagery be made available for viewing in the cockpit.**

Review Mode Sublevel

The review mode sublevel is accessed by depressing push-tile number one on the top-level reconnaissance video display or on the data link mode display. This display format allows the operators the ability to rewind and playback the digital tapes on the cockpit displays. Radar imagery is not available for viewing in the cockpit so if either tape is missionized for radar imagery collection playback from that recorder is not allowed.

The tapes may be rewound to a specific event mark (event recall), or to a specific time (time recall). Depressing push-tiles one or two, labeled EVENT and TIME, respectively, command the recall to occur. The recorders are controlled separately and selection is made by depressing push-tile number six labeled either PRIM or SCND [1]. An example review mode sublevel is provided in Figure 3-18. The operator inputs the desired event number that he would like to recall via up and down arrows at push-tile numbers twelve and thirteen. The placement of the arrows is common throughout all of the reconnaissance displays even though the arrows control different functions on different displays. This is a good feature that enables the crew to quickly become comfortable with the reconnaissance displays. The chosen event number is displayed in the middle of the review mode display format.

The operator can mark recalled imagery. The imagery recorded on the tapes is also marked automatically and manually with event marks during the recording process. All marks serve as bookmarks, points on the tape from which reconnaissance data link

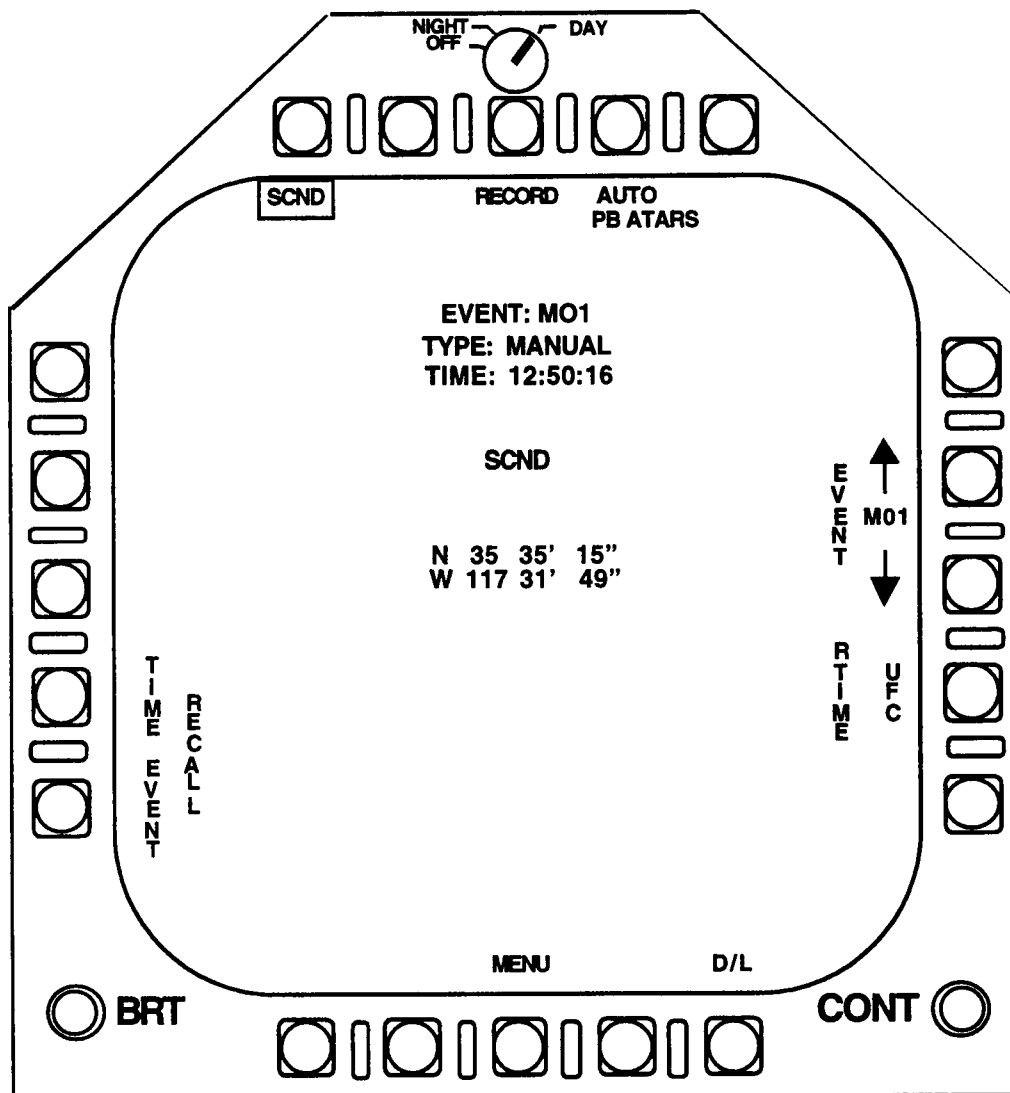


Figure 3-18. Review Mode Display

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

transmissions can begin. The ability to mark the recorded imagery helps the operator highlight areas of recorded imagery and reduce the volume of imagery transmitted.

The mark feature does not allow the aircrew to point to a specific target in the video and obtain that target's position. This is a significant limitation. If the crew were to find a high value, mobile target they would have no way of rapidly obtaining the precise position of the target so an immediate attack could be coordinated. **It is recommended that the review mode be mechanized such that the crew could point to a specific target and obtain precise coordinates of that target.**

Data Link Mode Sublevel

The data link mode sublevel is accessed by depressing push-tile number sixteen on the top-level reconnaissance video display or on the review mode display. The data link mode sublevel is shown in Figure 3-19. This display format allows the operators the ability to transmit both EO/IR and radar imagery previously recorded on the digital tapes. Data link transmission begins either at the beginning of a tape or at a specific event and continues until the end of the tape unless the ATARS operator or ground station terminates the transmission earlier [1].

The data link mode sublevel is a simple and effective way of controlling reconnaissance data link transmissions. The push-tile legends and functions are logical and intuitive, making the reconnaissance data link mode integration compatible with the F/A-18D weapon system.

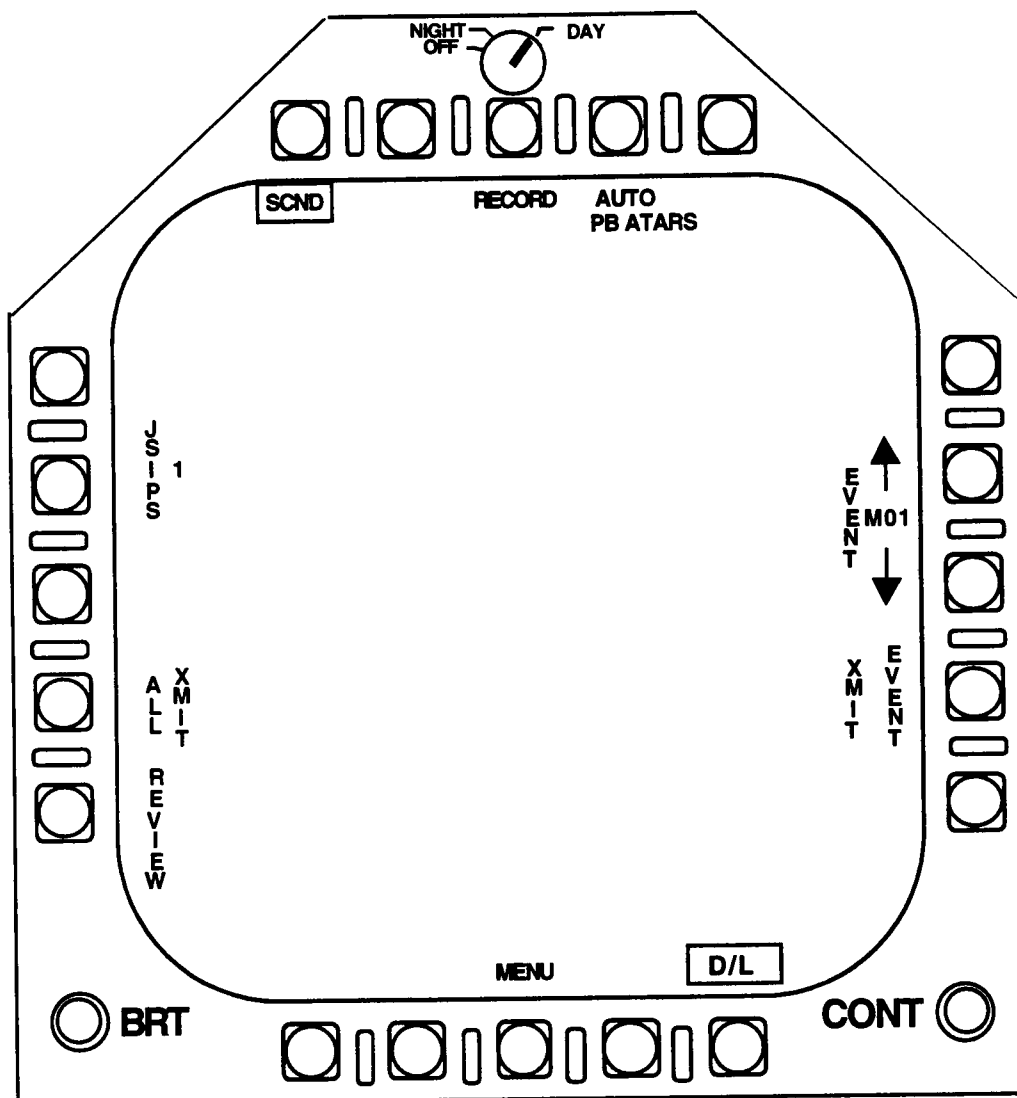


Figure 3-19. Data Link Mode Display

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

RECONNAISSANCE CAUTIONS AND ADVISORIES

ATARS integration on the F/A-18D aircraft has resulted in no new warnings, six new cautions and one new advisory [1]. The caution and advisory indications are listed in Table 3-1. All cautions were found to illuminate the master caution light. The advisory did not illuminate the master caution light. This represents good integration as it adheres to F/A-18 convention.

The caution and advisory logic is generally acceptable. The caution legends are sufficiently representative of what the condition is, and the abbreviation should have clear meaning to the average operator. The advisory legend is acceptable though it does not have clear meaning the first time it is encountered. The operators will likely be forced to look up its meaning in their flight manual.

The author objects to the use of cautions to communicate status of the tape recorders. Cold recorders is a normal, though undesirable, condition when starting the aircraft in a cold environment. The DTR1 COLD caution causes a DTR1 SHTDN caution. There is no danger to the aircraft, crew, or aircraft systems due to a recorder that has shutdown. Cautions should warn the crew of danger to themselves and their onboard equipment. The crew needs to know the status of the recorders for tactical reasons, but cautions are not the preferred method to communicate this information. **The author recommends that the DTR1 COLD, DTR2 COLD, DTR1 SHTDN, and DTR2 SHTDN cautions be removed from the caution logic.**

Table 3-1. Reconnaissance System Cautions and Advisories

Adapted from: NAVAIR A1-F18AC-NFM-000, F/A-18 NATOPS Flight Manual, Philadelphia, Pennsylvania, Naval Air Technical Services Facility, 1998

<u>Indication</u>	<u>Cause/Remarks</u>	<u>Corrective Action</u>
ATRS OVRHT	ATARS is reporting a subsystem over temperature condition. This indication does not include a Reconnaissance Data Link Pod over temperature condition.	1. ATARS Power Switch - OFF 2. CLP Power Knob - OFF <i>GROUND OPERATION:</i> 1. Radar Power Switch - OFF
DL OVRHT	The ATARS Data Link pod is reporting a subsystem over temperature condition.	1. CLP Power Knob - OFF
DTR1 COLD DTR2 COLD	ATARS tape deck is cold. This will typically occur at start-up on a cold day. Tape deck warm up varies from 5 minutes at 32°F, to 45 minutes at -40°F. The caution will be removed after the tape deck has reached an operational temperature.	1. ATARS Power Switch - ON 2. ATARS Preflight Checks - DISCONTINUE <i>When the caution is removed:</i> 1. ATARS Preflight Checks - CONTINUE
DTR1 SHTDN DTR2 SHTDN	The ATARS tape deck has reported either cold, critical over temperature, or a tape condensation condition. Record capability is disabled.	1. ATARS Power Switch - ON <i>IF caution remains on after 20 minutes:</i> 1. ATARS Power Switch - OFF 2. CLP Power Knob - OFF
RC DL (Advisory)	ATARS Data Link pod installed and ATARS is not powered on. The aircraft does not know the status of the data link pod.	1. ATARS Power Switch - ON <i>IF advisory remains:</i> 1. ATARS Power Switch - OFF 2. CLP Power Knob - OFF

Recorder status should be clearly communicated to the crew via the reconnaissance displays and the BIT displays.

LOADING OF RECONNAISSANCE MISSION DATA

Preflight planning for an ATARS mission is designed to be accomplished on the Tactical Aircraft Mission Planning System (TAMPS) machine. Formal preflight planning terminates with the generation of an ATARS mission data file that is loaded into the memory unit (MU) cartridge which is hand carried to the aircraft [1].

Loading Missions via Memory Unit

Loading missions via the memory unit is preferred over manually entering data in the cockpit via the MDIs and UFC. The ATARS mission data file consists of the following information: reconnaissance target locations, sensor configurations for each reconnaissance target, classification data for each target, and Joint Service Imagery Processing System (JSIPS) ground station locations [1]. The reconnaissance mission data remains on the MU until ATARS reports 'initialize complete' status, at which time the mission data is transferred to the RMS. This transfer process takes approximately five seconds to complete. If the automatic transfer of data is unsuccessful, the aircrew is notified both on the memory unit mission initialization format and on the top-level reconnaissance display format. On the memory unit mission initialization format 'RECCE' is displayed next to the word 'ERRORS' in the error region of the display. This is compatible with existing F/A-18 mission loading procedures. In addition, the

reconnaissance format displays RECCE MU LOAD FAILED on the status line. This is adequate warning to the crew that their mission has not properly loaded into the aircraft systems.

Manual Mission Loading – Up Front Control

The crew has the option to manually load mission data into the reconnaissance system via interface with the up front control (UFC). Loading of an entire mission this way is not recommended because it is time consuming and prone to errors. However, manual data entry is an acceptable back-up method of entering the entire mission should the mission data file fail to transfer from the MU. The capability to manually enter mission data is a good feature because it allows the aircrew the ability to edit portions of the mission should their tasking change once they are airborne. This gives the reconnaissance crew tactical flexibility which improves mission effectiveness and survivability. Manual data entry is a good integration feature that is consistent with F/A-18 convention.

When the aircrew desires to use the UFC to enter ATARS data they configure, or 'enable', the UFC to accept the particular information. To enable the UFC for reconnaissance target programming the operator must have the reconnaissance target programming sublevel format displayed on his MDI with the applicable reconnaissance target selected. If the reconnaissance target is a point target, the operator depresses the button labeled POS1 UFC. The UFC is now ready to accept latitude, longitude,

elevation, recorder activation range, and target configuration range data associated with that reconnaissance point. If the reconnaissance target is labeled a strip target, the UFC enable button is labeled POS1/2 UFC and the UFC is enabled to accept the start and stop latitude and longitude. The up front control display configuration is shown in Figure 3-20. If the reconnaissance target is an area target, the POS3/4 UFC push-tile enables the UFC to accept the third and fourth positions defining the area. This functionality is largely consistent with UFC enabling for other existing systems on the F/A-18, so the author found this mechanization relatively intuitive to use. It is when we examine the details of the integration that several problems surface.

When typing in reconnaissance targets via the UFC the aircrew is required to make extra, unnecessary steps to accomplish the procedure. Specifically, when POS1/2 UFC is pushed, none of the UFC options are pre-selected or 'pre-colonized'. Figure 3-20 depicts this situation. Reconnaissance target position entry is inconsistent with navigation point position entry that F/A-18 crew are familiar with. When entering twelve reconnaissance targets, half of which are strips requiring two latitudes and longitudes each, the aircrew is subjected to eighteen extra UFC keystrokes [21]. The effects are aggravating and more damaging than just the extra keystrokes would imply. The crew is typically typing rapidly having learned with navigation points to enable the UFC and then immediately start entering data. If the operator does this with reconnaissance points he will waste many more keystrokes for each position

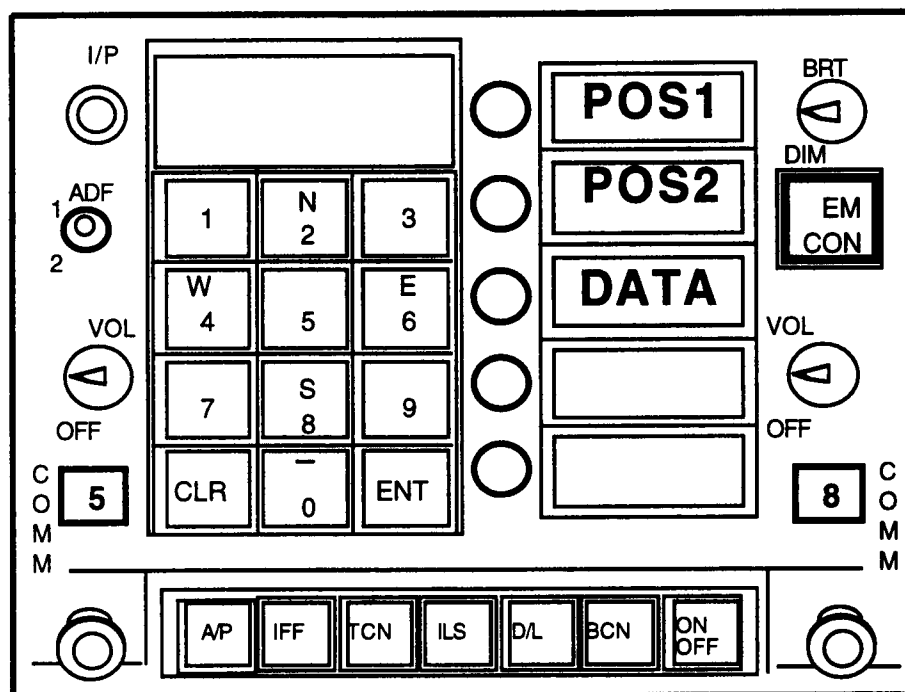


Figure 3-20. UFC, Reconnaissance Target Data, Top-level

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

entry attempt [22]. **The author recommends that when the UFC is enabled for reconnaissance target entry, the POS1 legend be pre-colonized.**

Once the latitude and longitude have been successfully entered, the operator must 'colonize' (put a colon in front of) DATA, wait approximately two seconds while the three data options shown in Figure 3-21 are displayed and then colonize ELEV to enter reconnaissance target elevation. The time delay for the UFC to reconfigure is unacceptable and inconsistent with normal UFC functions. **The author recommends the time delay to reconfigure the UFC to accept reconnaissance target DATA be eliminated.** By not pre-colonizing the ELEV option the operator must make a total of twelve additional, unnecessary keystrokes when entering reconnaissance target elevations [22]. **It is recommended that ELEV be pre-colonized when reconnaissance target DATA is selected on the UFC.**

To enable the UFC to accept JSIPS location and frequency data the operator depresses the button labeled UFC on the JSIPS programming display sublevel [1]. The UFC is now ready to accept latitude, longitude, elevation, command frequency code, and return frequency code associated with that data link ground station. The up front control display configuration is shown in Figure 3-22. The POSN option comes up colonized. This is a great, time saving, feature that is compatible with existing F/A-18 convention.

When the DATA option on the UFC is depressed, the up front control display is configured to accept JSIPS frequency data. This UFC display configuration is shown

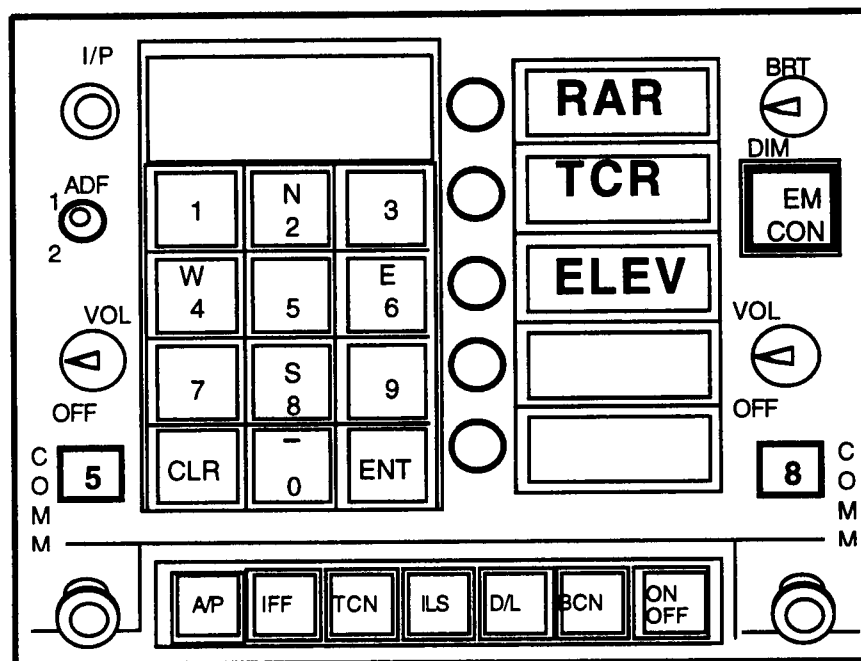


Figure 3-21. UFC, Reconnaissance Target Data, Data Sublevel

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

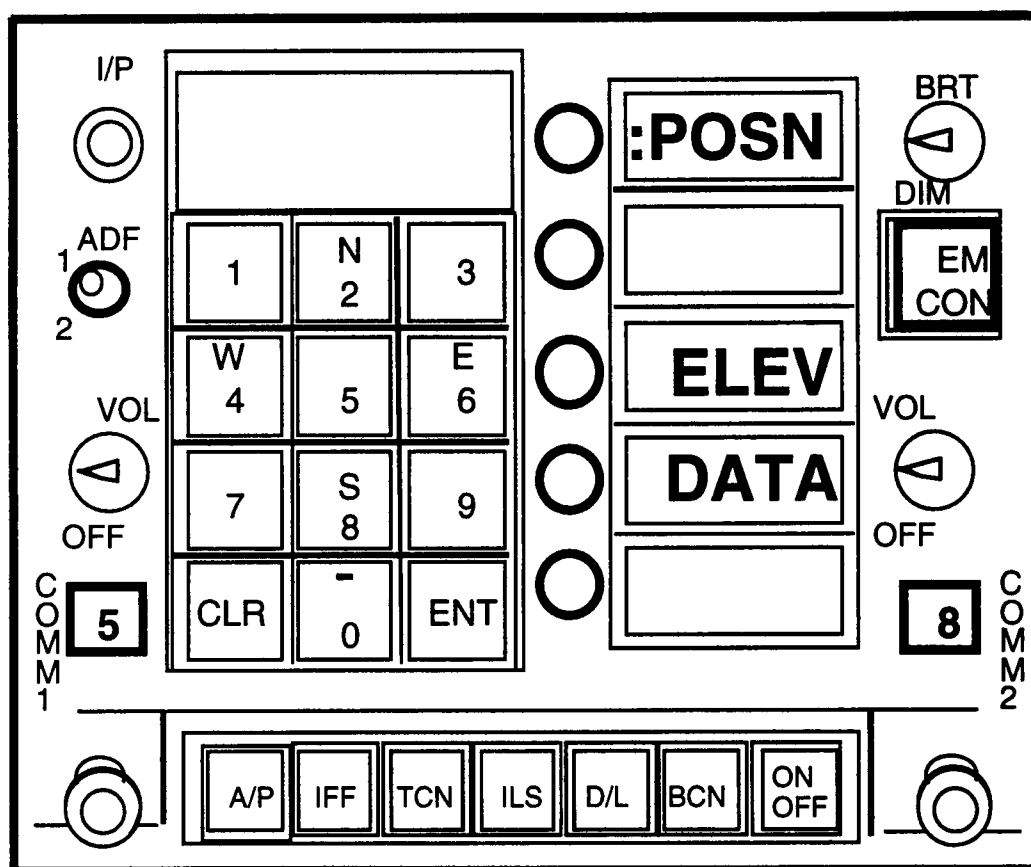


Figure 3-22. UFC, JSIPS Position Data

Source: *Operation of the F/A-18 Avionic Subsystem for Aircraft with the I3C System Configuration Set*, Naval Air Warfare Center, China Lake, California, 1998

in Figure 3-23. The CMD option comes up colonized. This is a good, time saving, integration feature that is consistent with existing F/A-18 convention. CMD is the legend meaning command frequency channel while RTN is short for the return link channel. The reconnaissance system is programmed to accept only certain channel numbers as valid. If the operator types in an invalid channel the UFC scratchpad window will immediately flash the word "Error". This is a good integration feature and consistent with current F/A-18 data entry conventions.

The author found one major shortcoming with the channel validity check; the set of valid channel numbers that the reconnaissance system accepts does not precisely match the set of valid channels that the ground station will accept [1]. The F/A-18 set is larger than the ground station allowable set. In other words, the ground station allowable set of channels is a subset of the F/A-18 allowable channels. For communication to occur both the ground station and ATARS must be tuned to the same channels. The ATARS mechanization is unacceptable because the F/A-18 crew could enter an invalid channel number in their reconnaissance system and be provided no feedback of the problem. They would fail to establish communication with the ground station. Since communication failure could be due to a large number of factors, it would not be immediately apparent that they have an invalid frequency entered in the system. **The author recommends that the valid set of JSIPS communications channels be made smaller to precisely match the actual channels that the ground station is capable of using.**

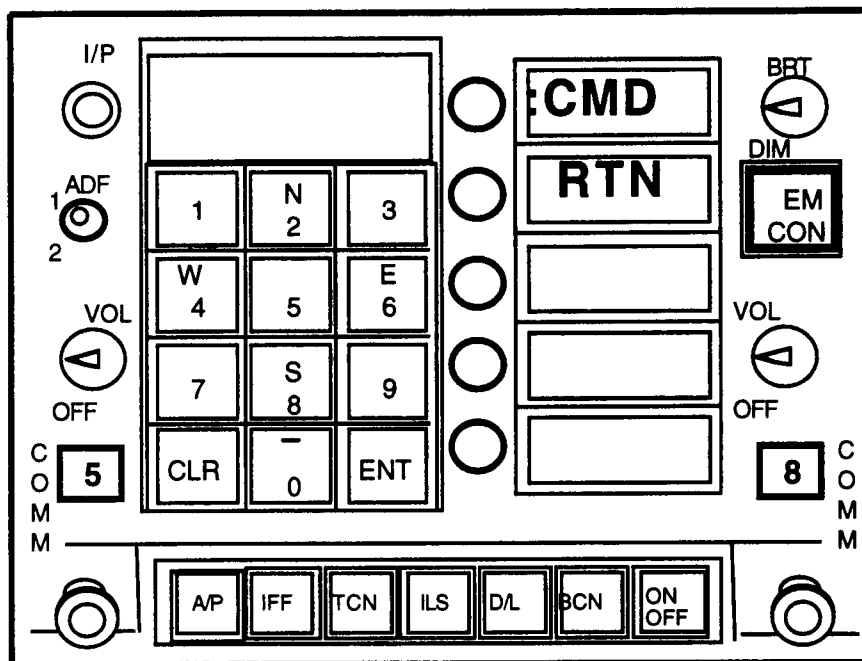


Figure 3-23. UFC, JSIPS Frequency Data

Source: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

The UFC is also used to input zulu time, which is used in the time recall procedure in the review mode. From the review mode display the operator would depress push-tile number fourteen labeled RTIME UFC to configure the up front control to accept a zulu time. This UFC configuration is shown in Figure 3-24. This mechanization is acceptable but only partially conforms to F/A-18 conventions.

The legend TIME in the center option window on the UFC is not pre-colonized. This is not a clean integration and does not conform to F/A-18 convention. It is a minor nuisance, but the operator must first colonize the TIME option before the UFC scratchpad window will accept a time. This one extra step is unnecessary. **It is recommended that the TIME option on the UFC be pre-selected when the UFC is configured to accept time recall data.**

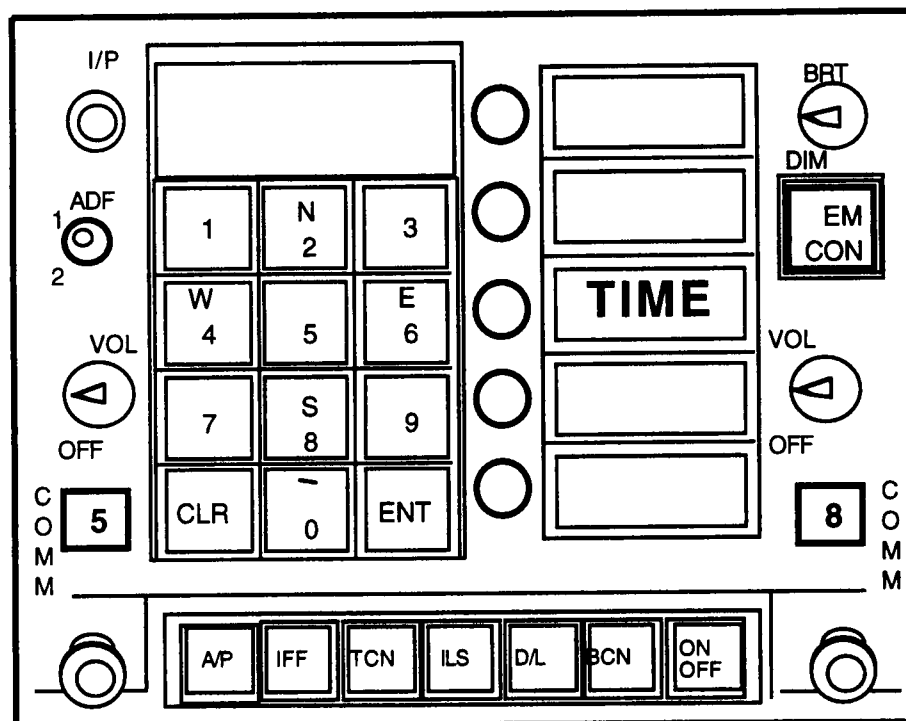


Figure 3-24. UFC, Time Recall Data

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

HANDS ON THROTTLE AND STICK (HOTAS)

Reconnaissance Event Mark Button

The flight control stick of the F/A-18D(RC) has an additional control button called the reconnaissance event mark button [1]. This small black button is unique, unobtrusive, and easily distinguishable even while wearing leather flight gloves. This is a good feature that allows easy switch recognition and therefore results in fewer errors in the cockpit. The author, during his evaluation, did not once inadvertently actuate the button. The reconnaissance event mark button gives tactile and visual feedback when depressed.

If recording is in progress and the reconnaissance event mark button is depressed, a manual event mark is alternatively opened and closed [1]. This is good because it allows the pilot the ability to mark the recorded imagery without having to remove his hand from the flight control stick. If recording is not already in progress, the reconnaissance event mark button will command ATARS to commence manual recording. The reconnaissance event mark button performs the same function as manually boxing the RECORD legend on any of the reconnaissance formats [1]. This is good because it allows the pilot the option to commence recording without removing his hands from the control stick. The reconnaissance event mark button cannot be used to stop recording in progress. This is logical and not considered a limitation because the 'stop recording' command is generally not time critical; the pilot or WSO can take the

time to reach up and deselect RECORD from a reconnaissance format on one of the MDIs.

The last function of the reconnaissance event mark button is to command manual review marks when ATARS is in review mode. Manual review marks are similar to manual event marks except they are made on the imagery being reviewed for the purpose of reducing the volume of data linked imagery [1]. The author believes that the reconnaissance event mark button will be rarely used to command review marks by the pilot because review mode is best controlled by the WSO. This is still a good feature because the button function is consistent from mode to mode and provides growth potential for ATARS in single seat aircraft.

Sensor Control Switch

The sensor control switch is commonly called the castle switch because of its shape. With ATARS, the pilot's sensor control switch, on the flight control stick, performs two new functions. When the sensor control switch is actuated towards the reconnaissance video display the throttle designator/controller (TDC) is assigned to the reconnaissance video display. Any further actuation of the sensor control switch towards the reconnaissance video display commands imagery to freeze and scroll alternatively [1]. The author found this functionality useful, intuitive, and compatible with existing sensor control switch functionality.

The WSO's two sensor control switches, one on each hand controller, perform the same ATARS functions as the pilot's single sensor control switch plus one additional function. The WSO can use the aft position of either sensor control switch to perform the same functions as the pilot's reconnaissance event mark button. The author found this functionality very useful. The WSO has the flexibility to perform the same functions with either hand controller or through interface with the reconnaissance display push-tiles. The ATARS functions are compatible with existing sensor control switch functions; therefore, the WSO will learn the new functionality quickly and make fewer errors.

Throttle Designator/Controller (TDC)

When the TDC is assigned to the reconnaissance video format it allows the operator to roam within frozen imagery. Once frozen, a magnification marker appears in the imagery. If the TDC is depressed and released the portion of the image within the magnification marker fills the entire display. A second depression of the TDC commands the unmagnified image to return. The TDC can be used to move around the magnified image or reposition the magnification marker within the unmagnified image [1].

The author found that the TDC slew rates were compatible with existing functionality. For a given force application, the motion was what the author expected. The use of TDC depressions to command changes to the image magnification is not consistent with existing F/A-18 convention. The FLIR and two ground attack missiles

use the raid switch to command magnification changes [1]. Although inconsistent, the author finds this mechanization acceptable since the raid button would be unavailable for ATARS use while the aircraft is in the air-to-air master mode. The author quickly adapted to the use of the TDC for reconnaissance functions.

4. CONCLUSIONS AND SUMMARY OF RECOMMENDATIONS

The Advanced Tactical Airborne Reconnaissance System is a major advancement for the F/A-18D aircraft. It returns to the United States Marine Corps an essential, survivable, reconnaissance asset which has been absent since the retirement of the RF-4B Phantom in 1990.

The ATARS man-machine interface on the F/A-18D is **satisfactory**. ATARS is sufficiently compatible with existing Hornet interfaces to allow fleet operators to quickly learn the new system and react promptly when operating the reconnaissance system in a tactical environment.

The integration of ATARS into the existing F/A-18D weapon system is sensible and organized, though not error free. Numerous human factors deficiencies exist. None of the deficiencies are severe enough to jeopardize the overall value of the system. A plan should be enacted immediately to address the human factors deficiencies and further enhance F/A-18D(RC) capabilities. In chapter three the author makes twenty-two specific recommendations to improve ATARS man-machine interface which are summarized and prioritized in the tables below.

The recommendations listed in Table 4-1 address major deficiencies with the current ATARS design and should be incorporated immediately, in the order listed.

Table 4-1. Ranked Listing of High Priority Recommendations

High Priority Recommendations	Pages
1. Test ATARS in an environment where tactical data link is utilized.....	32
2a. Display region of acceptable geometry for SAR imagery on HSD.....	43
2b. Default SENSORS footprint option to PRIM selected for ATARS missions.....	47
2c. Show sensor footprints on the HSD when in the air-to-air master mode.....	47
3. Pre-select POS1, ELEV, and TIME options on the UFC. Eliminate time lags.	80, 85
4. Improve the fidelity of the JSIPS channel validity check.....	83
5. Shorten ATARS IBIT to ≤ 3 minutes. Honor stop BIT command.....	29
6. Redesign the ATARS power switch and ICS switch arrangement.....	23

The recommendations listed in Table 4-2 address minor deficiencies of the current ATARS design. These recommendations, listed in order of priority, should be implemented once all the Table 4-1 recommendations have been implemented.

Table 4-2. Ranked Listing of Administrative Recommendations

Recommendations	Pages
1. Remove DTR cold and DTR shutdown cautions from caution logic.....	74
2. Enable the crew to cut all electrical power to the data link pod	24
3. Display a legend meaning 'recorders are in transition' in the HUD.....	32
4. Allow edit of JSIPS data concurrent with recalling/transmitting imagery.....	66
5. Cross out UFC legend when that function is not available.....	66
6. Make recorder abbreviations consistent across all reconnaissance formats...	69

The recommended enhancements, listed in priority order, in Table 4-3 will greatly improve the ATARS man-machine interface and F/A-18D(RC) mission effectiveness.

Table 4-3. Summary of Recommended Enhancements

Recommended Enhancements	Pages
1. Make high-resolution SAR imagery available for viewing in the cockpit.....	69
2. Enable the crew to obtain coordinates of reconnaissance targets.....	72
3. Color code information on the reconnaissance and other display formats.....	29, 49
4. Modify the aft cockpit to include a keyboard for character entry.....	62

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REFERENCES

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APPENDICES

APPENDIX A

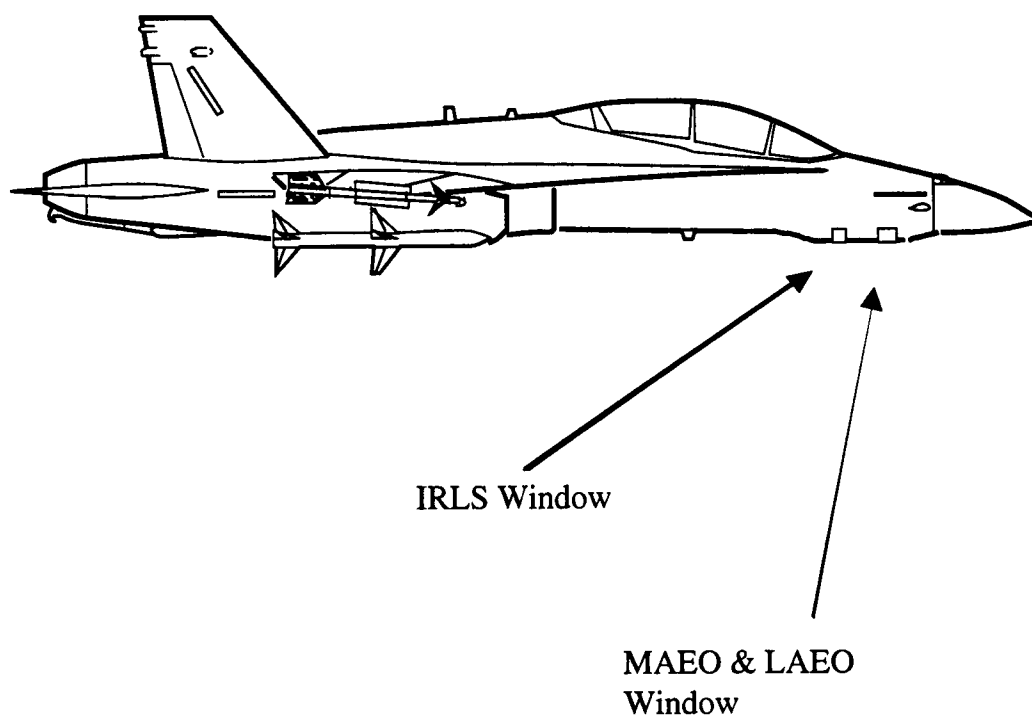


Figure A-1. Diagram of the F/A-18D(RC) Hornet Aircraft

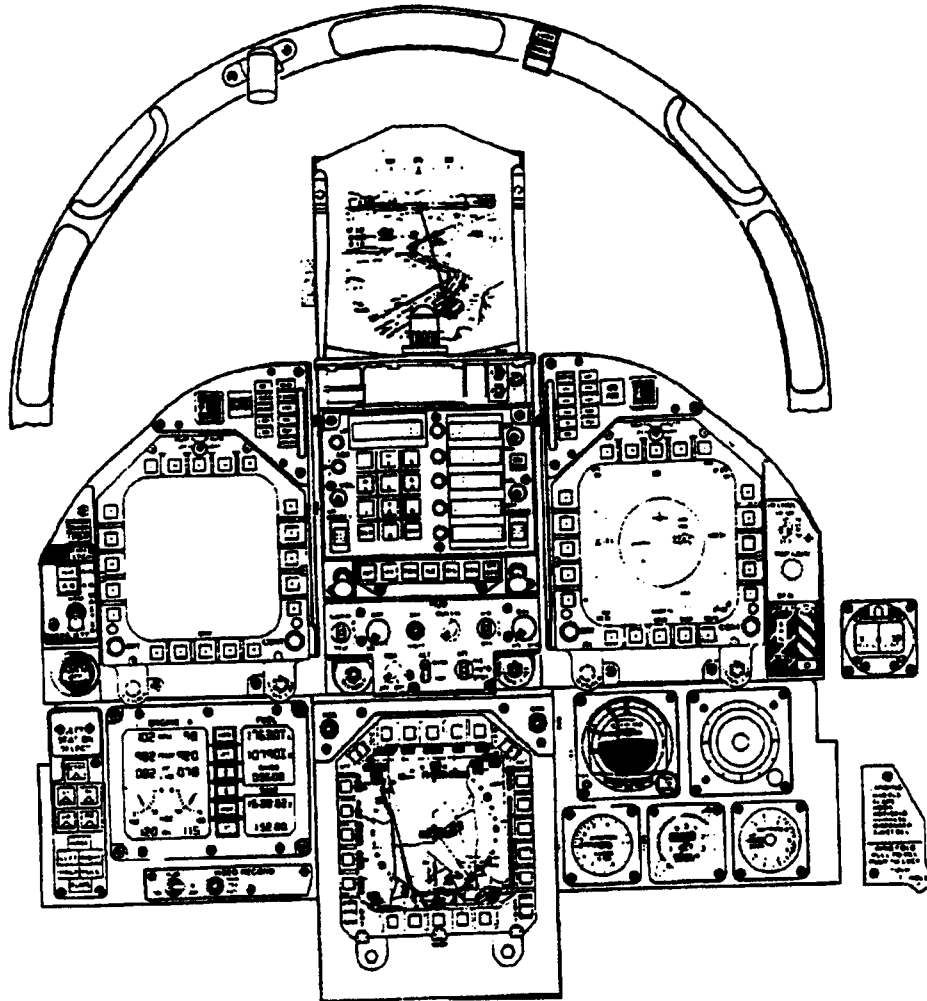


Figure A-2. Diagram of the Pilot's Instrument Panel

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

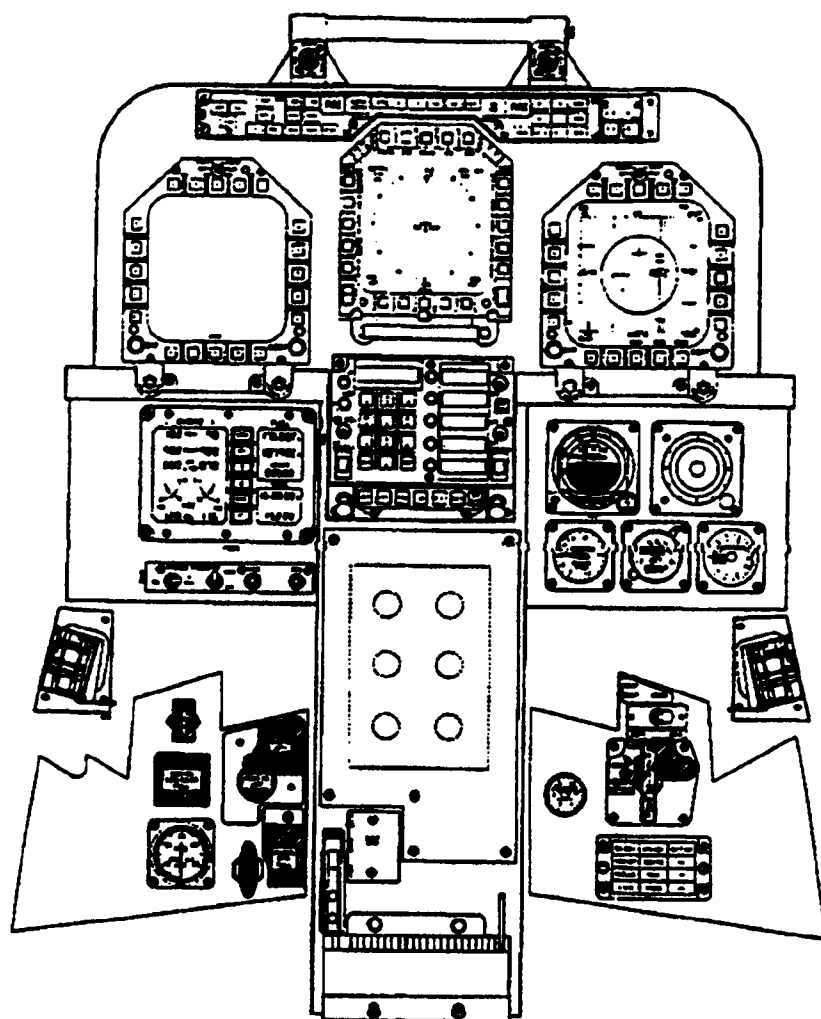


Figure A-3. Diagram of the Aft Cockpit Instrument Panel

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 13C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1998

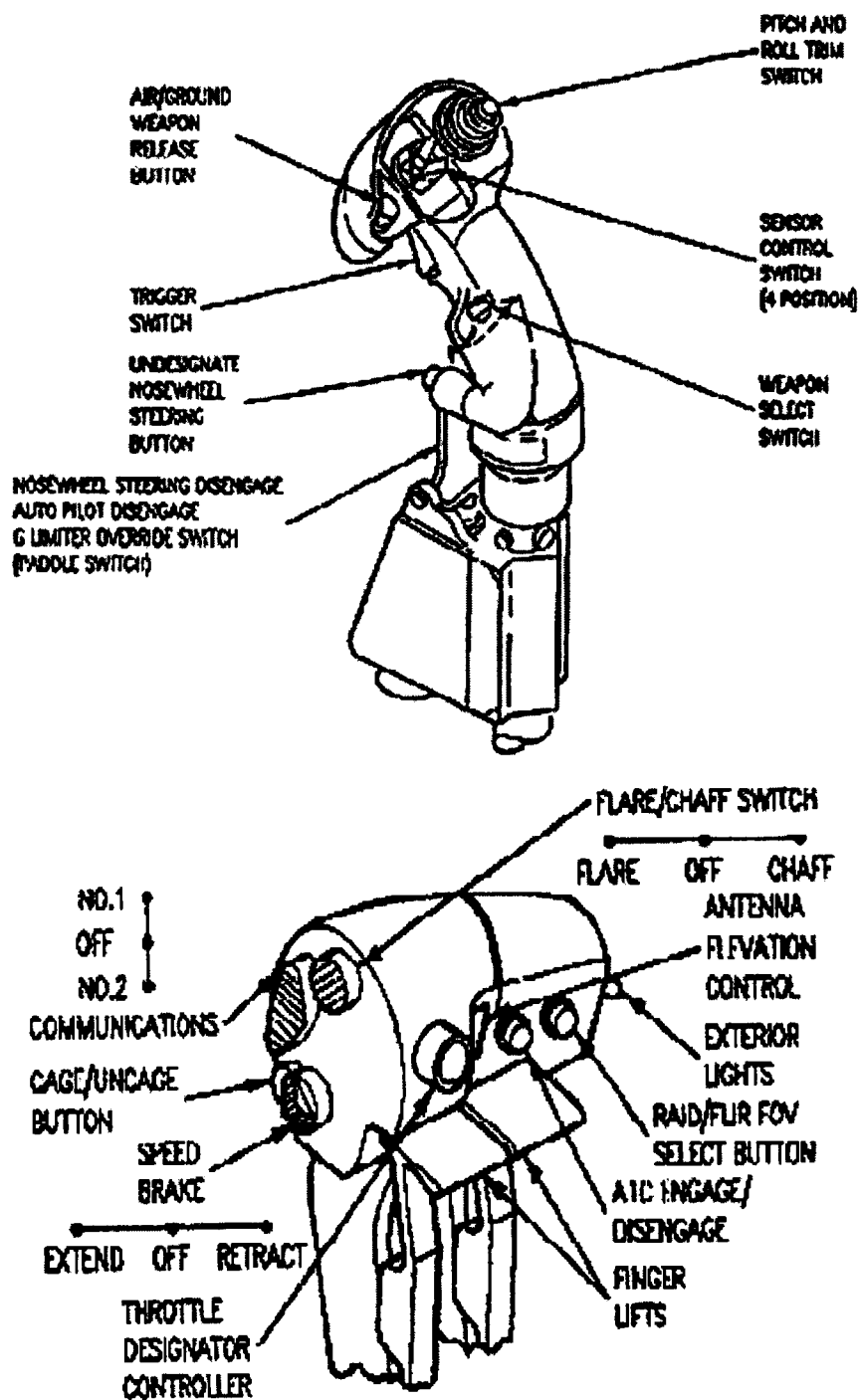


Figure A-4. Flight Control Stick and Throttles

Source: NAVAIR A1-F18AC-NFM-000, *F/A-18 NATOPS Flight Manual*, Philadelphia, Pennsylvania, Naval Air Technical Services Facility, 1998

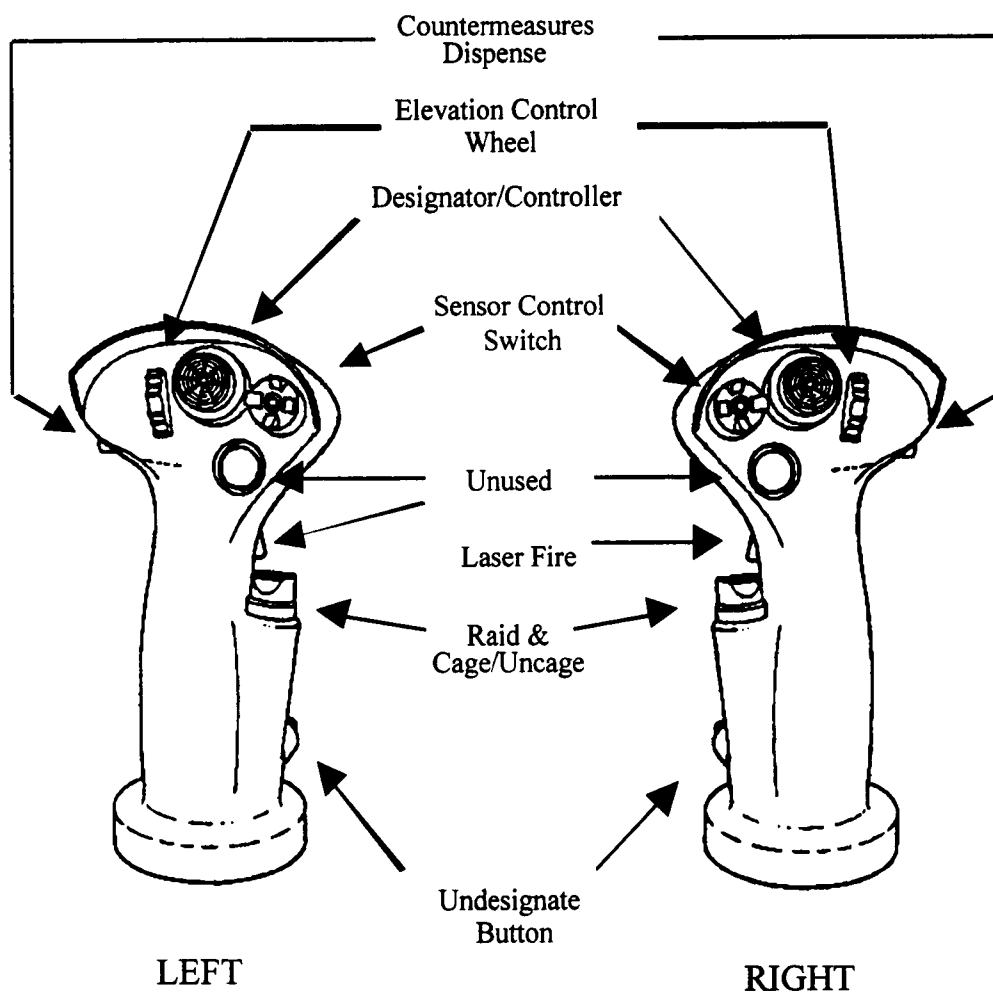


Figure A-5. Aft Cockpit Hand Controllers

APPENDIX B

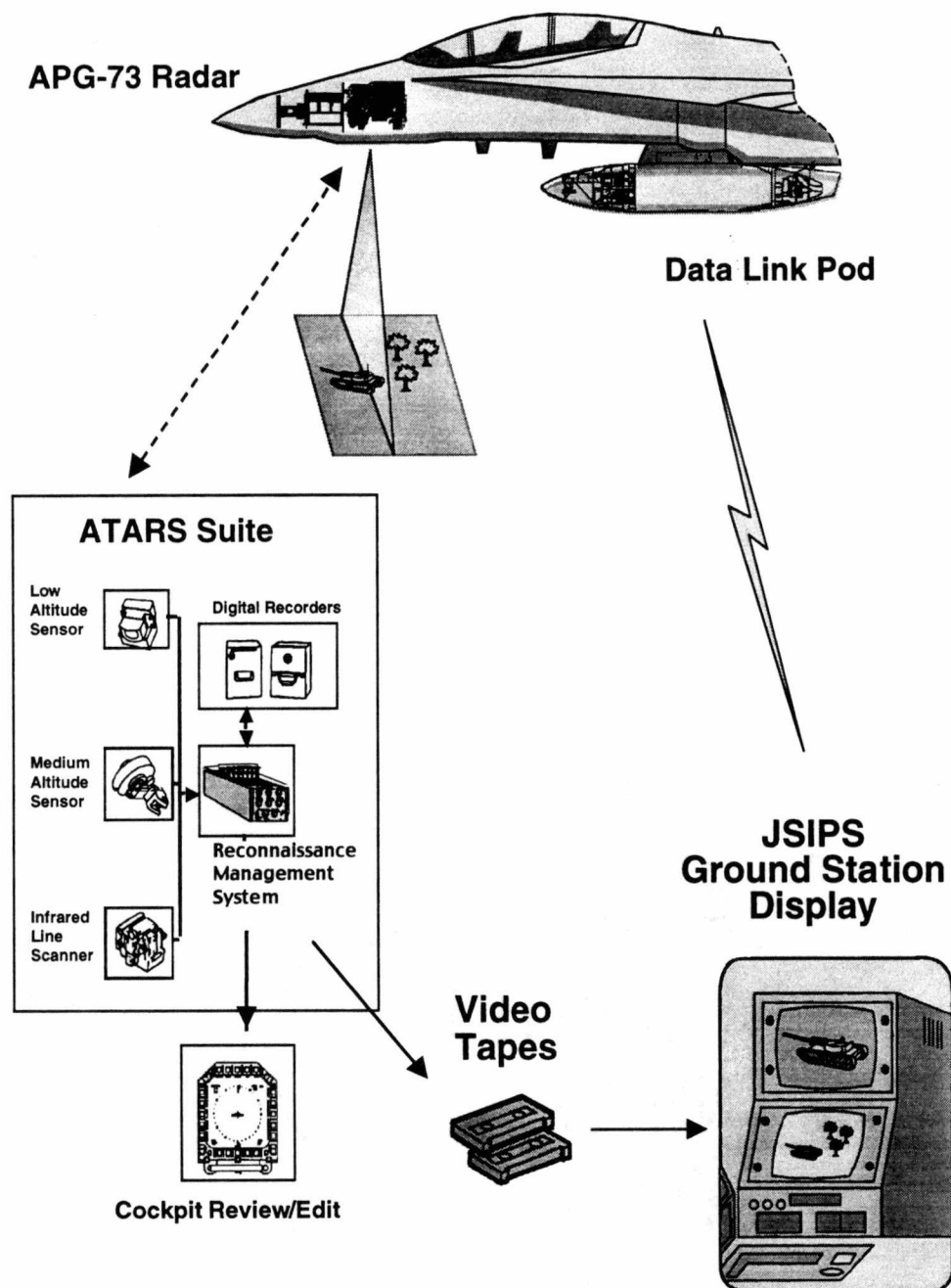


Figure B-1. F/A-18D(RC) Tactical Reconnaissance System

Adapted from: "F/A-18 Tac Recce" Briefing Presentation, St. Louis, MO.: Boeing Aircraft Company, 1997

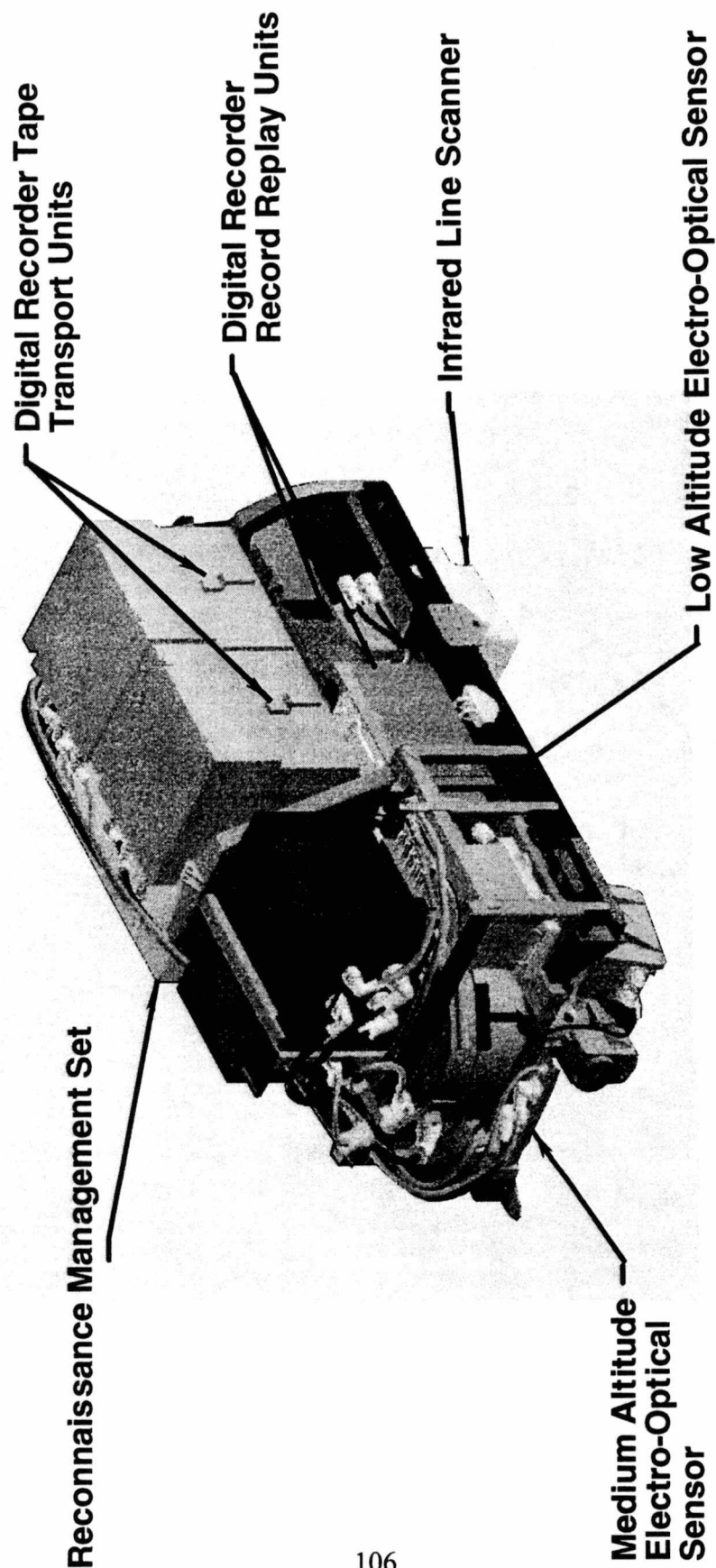


Figure B-2. F/A-18D(RC) ATARS Pallet

Source: "F/A-18 Tac Recce" Briefing Presentation, St Louis, MO.: Boeing Aircraft Company, 1997

APPENDIX C

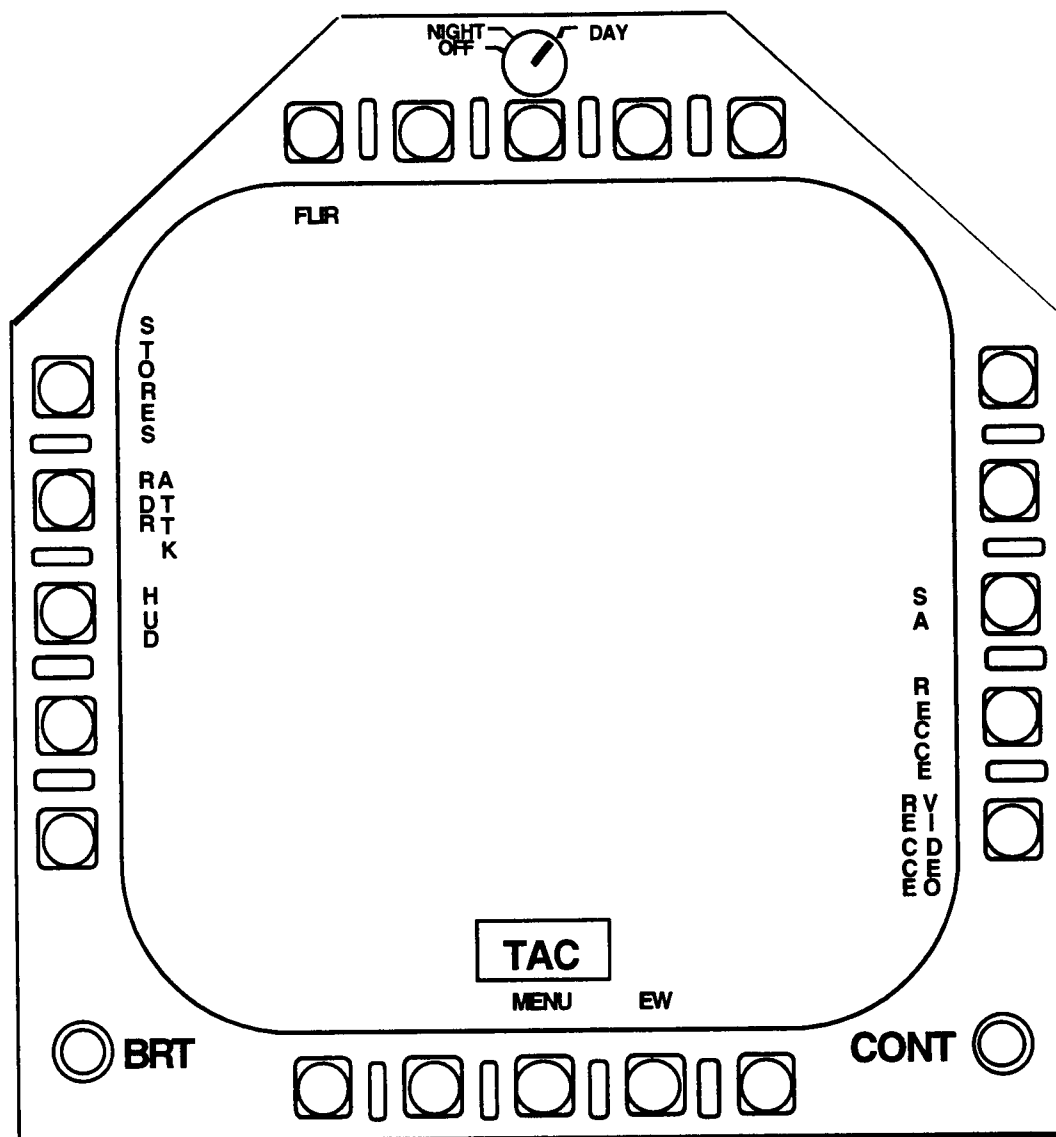


Figure C-1. Tactical Menu Display Format

Source: *NAVAIR A1-F18AC-NFM-000, F/A-18 NATOPS Flight Manual, Philadelphia, Pennsylvania, Naval Air Technical Services Facility, 1998*

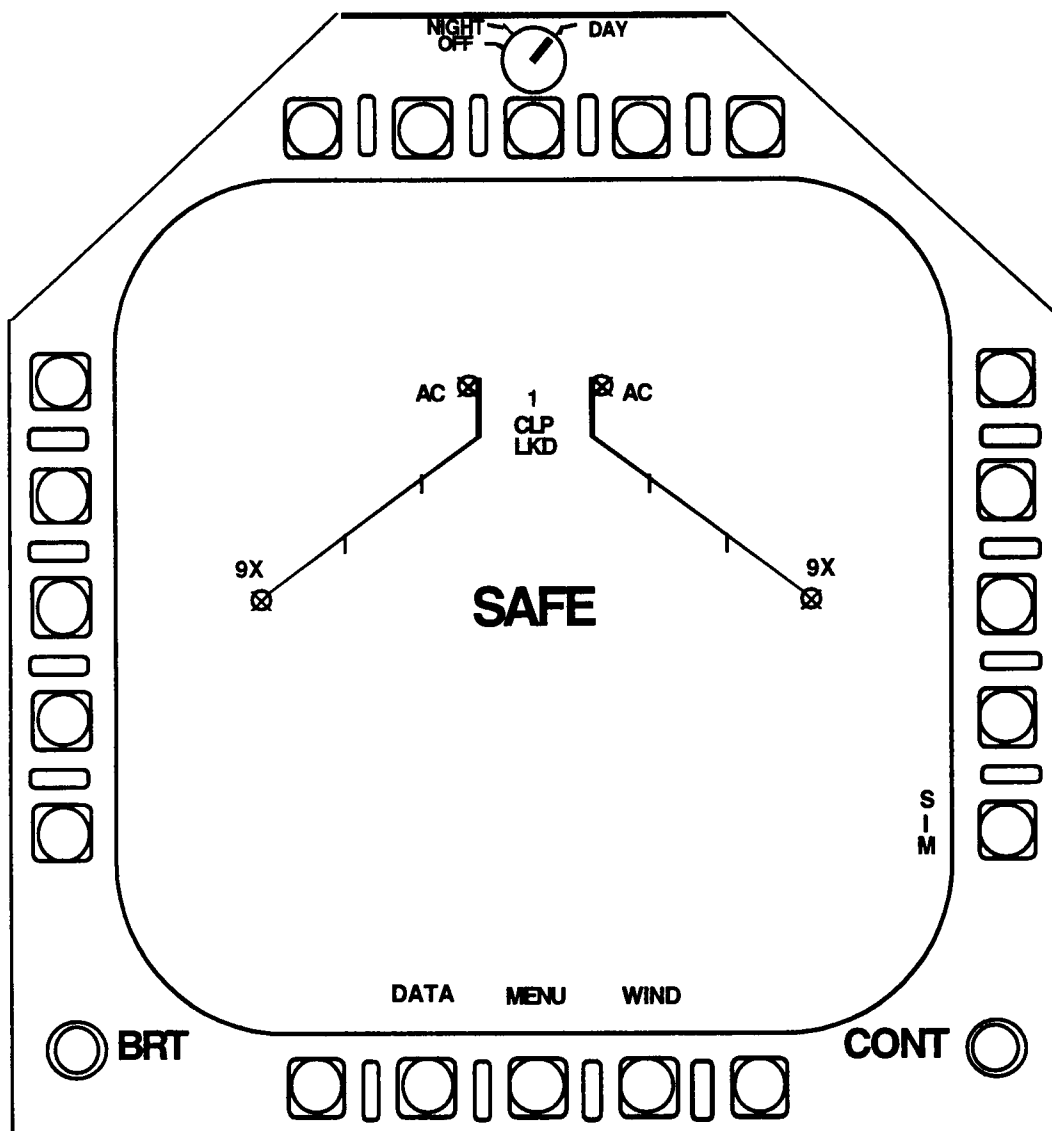


Figure C-2. Stores Display Format

Adapted from: NAVAIR A1-F18AC-NFM-000, F/A-18 NATOPS Flight Manual, Philadelphia, Pennsylvania, Naval Air Technical Services Facility, 1998

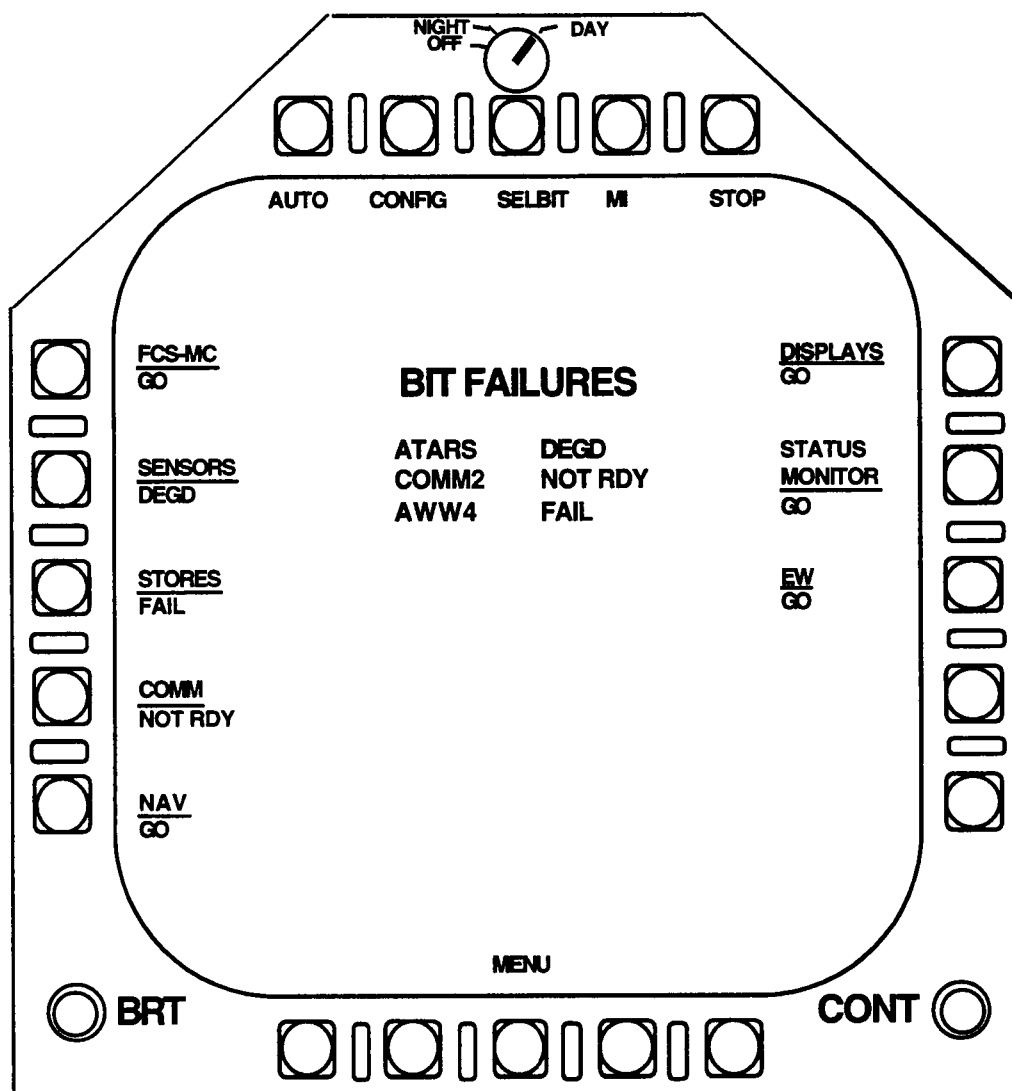


Figure C-3. Built In Test (BIT) Display

Source: *NAVAIR A1-F18AC-NFM-000, F/A-18 NATOPS Flight Manual, Philadelphia, Pennsylvania, Naval Air Technical Services Facility, 1998*

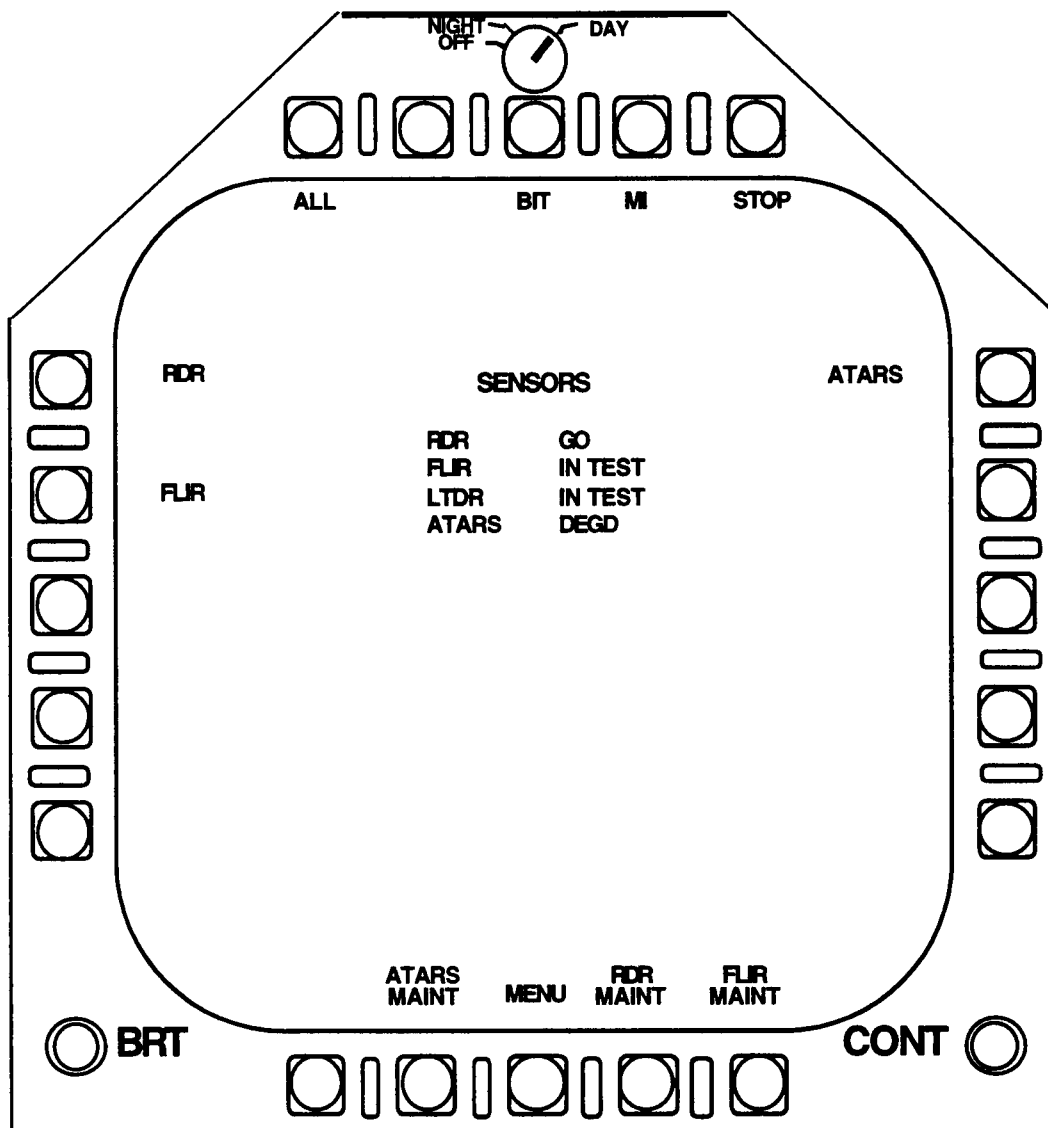


Figure C-4. BIT Display, Sensors Sublevel

Adapted from: NAVAIR A1-F18AC-NFM-000, F/A-18 NATOPS Flight Manual, Philadelphia, Pennsylvania, Naval Air Technical Services Facility, 1998

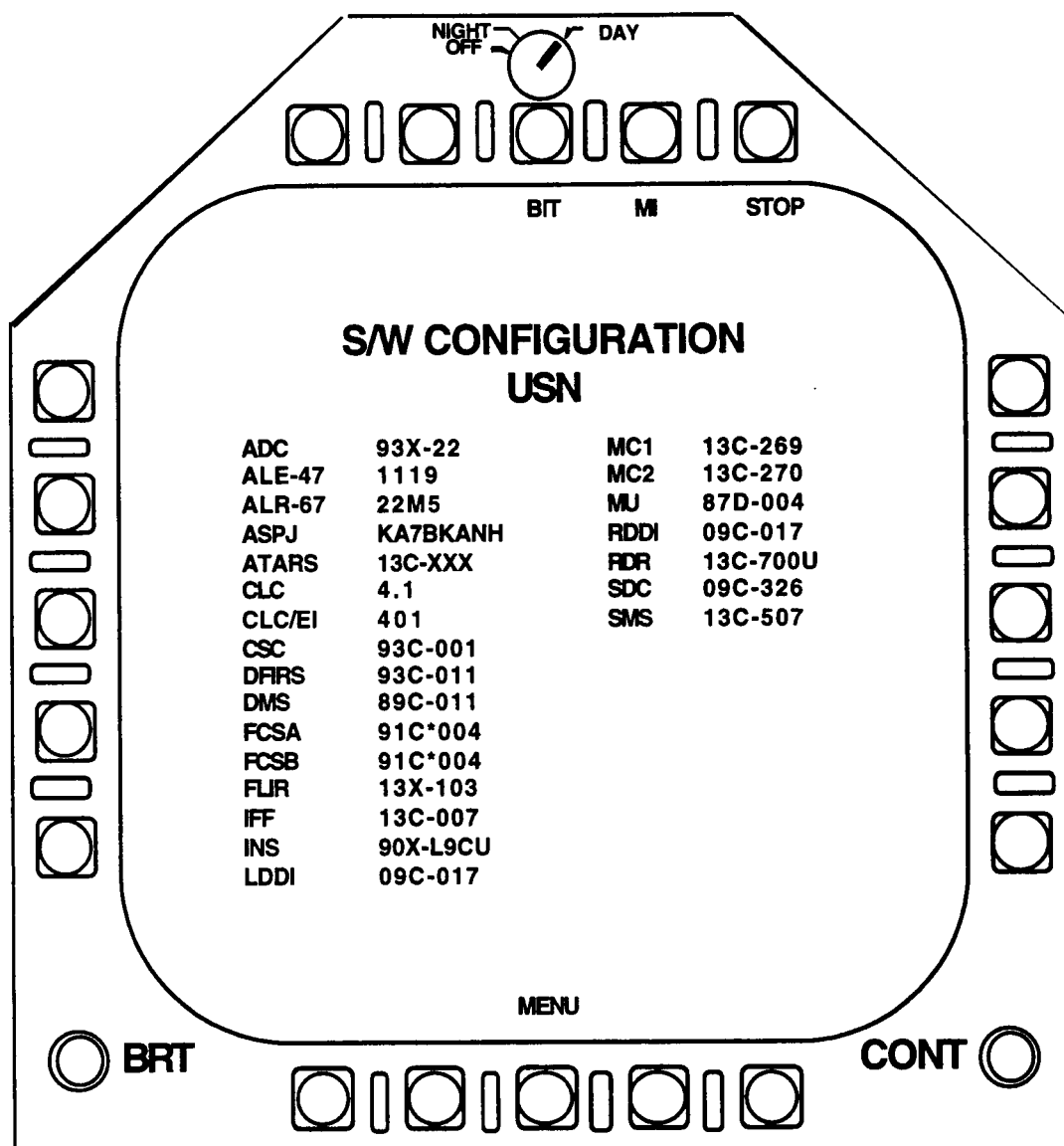


Figure C-5. Software Configuration Display

Adapted from: NAVAIR A1-F18AC-NFM-000, F/A-18 NATOPS Flight Manual, Philadelphia, Pennsylvania, Naval Air Technical Services Facility, 1998

VITA

Martin Gerard Rollinger was born November 11, 1960 in Des Plaines, Illinois.

He was raised in Saint Joseph, Michigan and graduated from the University of Michigan in 1982 with a Bachelor of Science in Civil Engineering. Martin was commissioned in the United States Marine Corps and sent to Pensacola, Florida in 1982 to attend flight training. After graduating from flight training in 1984 he was assigned to the Fleet Marine Force flying the F-4 Phantom aircraft at Marine Corps Air Station Kaneohe, Hawaii. In 1987 Martin was assigned as an Air Liaison Officer to 2nd Battalion, 9th Marines at Camp Pendleton, California. During this tour he also served as the Commander of Headquarters and Service Company, 2nd Battalion, 9th Marines. Martin returned to flying status in 1988 assigned to fly the F/A-18 Hornet aircraft at Marine Corps Air Station Beaufort, South Carolina. During this tour he graduated from the United States Marine Corps Weapons and Tactics Instructor Course. In 1995 Martin was selected to attend the United States Air Force Test Pilot School at Edwards Air Force Base, California. Upon completion of test pilot school he was relocated to his current assignment at the Naval Air Warfare Center, Weapons Division, China Lake, California; where his primary duty is serving as an F/A-18 developmental test pilot.