5-2000

An evaluation of the situational awareness display format in the F/A-18 aircraft

Gregory Clark Huffman

To the Graduate Council:

I am submitting herewith a thesis written by Gregory Clark Huffman entitled "An evaluation of the situational awareness display format in the F/A-18 aircraft." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

William D. Lewis, Major Professor

We have read this thesis and recommend its acceptance:

U. P. Solies, Fred Stellar

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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Associate Vice Chancellor and
Dean of the Graduate School

AN EVALUATION OF THE SITUATIONAL AWARENESS DISPLAY FORMAT IN THE F/A-18 AIRCRAFT

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

Gregory Clark Huffman
May, 2000

DISCLAIMER

The display information and technical data contained in this thesis are the result of actual flight simulator and flight evaluations of the combined Situational Awareness format in the F/A-18 aircraft. All deficiencies and enhancements attributed to the display are the opinion of the author and may or may not represent the official position of the Naval Air Warfare Center (Weapons Division), the Naval Air Systems Command, or the United States Navy. The recommended corrections to the deficiencies documented by the author should not be considered attributable to any aforementioned authorities for any purpose other than fulfillment of the thesis requirement.

ABSTRACT

This thesis evaluates the design, functionality and information display of the combined Situational Awareness format in the F/A-18 aircraft The combined Situational Awareness format fuses information and avionics controls from three existing display formats into a single display format The design is driven by the advent of improved data link capabilities and a new comprehensive electronic warfare system The combined Situational Awareness format is currently undergoing flight test and evaluation as part of the 15C/18EI System Configuration Sets for the F/A-18

Aircrew surveys of situational awareness following simulator sessions with and without the combined Situational Awareness display constitute the majority of test data for the thesis The thesis evaluates specifically the tactical utility of the pushbutton controls and display presentations taken from the Horizontal Situation Indicator, Situational Awareness and Electronic Warfare formats

The combined Situational Awareness format is enhancing to the overall situational awareness of F/A-18 aircrew The fusion of information from several sources into a single format reduces aircrew workload by providing one format for the majority of tactical information Despite the enhancing nature of the combined Situational Awareness display, several deficiencies still exist These are addressed in the conclusions and recommendations section

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LIST OF ABBREVIATIONS

A/A Air-to-Air
ADU Azimuth Display Unit
A/G Air-to-Ground
AUTO Automatic
CLSA China Lake Situational Awareness
CMDS Countermeasures Dispensing System
DCLTR Declutter
DDI Digital Display Indicator
EW Electronic Warfare
FLIR Forward Looking Infra-Red
HAFU Hostile Ambiguous Friendly Unknown
HMD Helmet Mounted Display
HOTAS Hands of Throttle and Stick
HSI. Horizontal Situation Indicator
HUD Head-Up Display
IDECM Integrated Defensive Electronic Countermeasures
L-H Liveware-Hardware
L-S Liveware-Software
MC. Mission Computer
MIDS Multifunction Information Display System
MPCD Multipurpose Display Group
NAV. Navigation
OBJ Onboard Jammer
PB Pushbutton
REJ Reject
REQD Required
RF Radio Frequency
RWR Radar Warning Receiver
SA Situational Awareness
SCL Scale
SEQ Sequence
SUPT Support
TAC. Tactical
TDC Throttle Designator Controller
UFC. Up-Front Control
WYPT Waypoint

1. INTRODUCTION

BACKGROUND

The US Navy is currently conducting developmental test and evaluation of two new avionics systems for the F/A-18 Hornet. These systems, the Integrated Defensive Electronic Countermeasures (IDECM) and the Multifunction Information Display System (MIDS), greatly increase the amount of tactical information available in the cockpit to the F/A-18 aircrew. An effective means of transmitting this new information within the current architecture of F/A-18 displays is also being evaluated concurrently with the IDECM and MIDS systems. The means of information transmission under consideration involves a modification to the existing Liveware-Hardware and Liveware-Software interfaces of the existing SHEL model resident in the F/A-18 [1] The format chosen to support IDECM and MIDS information, as well as general situational information, is the combined Situational Awareness (SA) format.

A series of simulator evaluations and design advisory group meetings between F/A-18 aircrew and design engineers beginning in 1995 resulted in the selection of the Situational Awareness display as the most appropriate medium for the display of the new information [2]. The simulator evaluations consisted of realistic tactical scenarios with and without improvements to the SA format. After each session, the aircrew completed qualitative questionnaires relating to their relative level of situational awareness and their satisfaction with the pushbutton controls on the SA format The combined Situational Awareness format was the result of these surveys

The intent of the combined SA format is to reduce aircrew workload in the tactical environment by fusing the most useful elements of the Horizontal Situation Indicator, Electronic Warfare format, Situational Awareness format into a single display. Prior to this fusion, tactically critical information from the IDECM and MIDS systems would have to be displayed separately on the Electronic Warfare and Situational Awareness display formats respectively. Since the F/A-18 has only three display indicators, the EW, SA and HSI formats can only be displayed simultaneously at the expense of other tactically essential formats The existing solution to the display limitations of the F/A-18 is to use a Hands-on-Throttle-and-Stick (HOTAS) mechanization to allow the aircrew to rapidly switch formats The HOTAS mechanization tree is described in chapter two.

The author has participated in the design and conduct of the flight simulations, acquiring approximately twenty hours of simulator time Additionally, the author is currently flying evaluations of the combined SA format with twelve flights totaling approximately eighteen hours.

PURPOSE AND LIMITATIONS TO SCOPE

The purpose of this paper is to examine the changes to the L-H and L-S interfaces between the aircrew and the traditional situational awareness display formats The existing mechanical interface (HOTAS selection or direct pushbutton actuation of display formats) is being replaced with a single format encompassing the priority information from the three displays. The functions and format of the combined SA display are described and evaluated The effectiveness and utility of

this single display format in tactical scenarios are also addressed. The IDECM and MIDS systems are complex subsystems and involve an extensive array of controls and interfaces within the architecture of the F/A-18 aircraft. This paper does not examine the nuances of the IDECM and MIDS systems. The discussion of those systems will be limited to their contributions and interfaces displayed directly on the combined SA format

AIRCRAFT DESCRIPTION

General

The F/A-18 aircraft is a single or dual-seat multi-mission fighter aircraft operated by the US Navy and Marine Corps The aircraft is powered by two turbofan engines with afterburner [3]. The aircraft has an all-weather intercept, identify, destroy, and ground attack capability that is supported by a wide variety of air-to-air and air-to-ground weapons. The F/A-18 utilizes three master modes of operation: Navigation (NAV), Air-to-Air (A/A), and Air-to-Ground (A/G) [4]. The two mission computers, labeled MC1 and MC2, tailor the display formats and controls based upon the master mode selected by the aircrew. Mission Computer One handles general aircraft systems and navigational tasks. Mission Computer Two provides tactical and weapons delivery processing as well as a limited backup to MC1 Tactical, navigational, and system information is primarily conveyed to the aircrew through the Multipurpose Display Group. The Multipurpose Display Group consists of two Digital Display Indicators (DDIs), a Multipurpose Color Display (MPCD) and a

Head-Up Display (HUD) [3]. The cockpit layout of the F/A-18 is depicted in figure A-1.

Electronic Warfare Suite

The current electronic warfare suite consists of a Radar Warning Receiver (RWR), an Onboard Jammer, and a Countermeasures Dispensing System (CMDS). Control of these systems is accomplished through the Electronic Warfare display format presented on any one of the three main displays The Electronic Warfare suite provides the aircraft defenses against both airborne and surface threats by cueing the aircrew to Radio Frequency (RF) threats, jamming those threats, and providing the opportunity to deploy expendable decoys to defeat threat radar or missiles.

Sensors

The primary sensor of the F/A-18 is the onboard multi-mode radar. The radar provides information necessary to target and employ weapons against airborne and surface targets. The controls for the radar and the information provided by the radar are presented on the Attack format This format may be displayed on either one of the DDIs By convention, the Attack format is displayed on the right DDI almost continually by F/A-18 aircrew. The functions of the onboard radar are augmented by a Forward Looking Infra-Red (FLIR) targeting pod. This sensor is used primarily in the air-to-ground role, but also has functionality in air-to-air missions as well

Aircrew view information from the FLIR on a unique video format displayed on one of the DDIs (typically the left DDI).

Displays

The F/A-18 aircrew relies on the three primary cockpit displays of the Multipurpose Display Group mentioned previously for sub-system controls and display of mission information. The two DDIs are physically identical and interchangeable. They are the primary source for most tactical information The MPCD is also capable of displaying any format, but is used primarily for the Horizontal Situation Indicator (HSI). The MPCD is measures 6 25x6 25 inches, while the DDIs measure 5x5 inches. All three displays are ringed by twenty pushbuttons that are used to select the proper function and mode for display indications [4]. An example of an F/A-18 display and pushbutton nomenclature is depicted in figure 1-1. On all formats pushbutton eighteen is labeled "Menu" Actuation of the Menu pushbutton changes the display to the Tactical (TAC) menu or Support (SUPT) menu, providing the aircrew with different format options for display

In addition to the pushbutton functionality described above, the MPCD is underlayed with a color moving map representation of the current aircraft location as an enhancement to situational awareness The DDIs and MPCD are also night vision device compatible and capable of displaying three colors: red, yellow and green

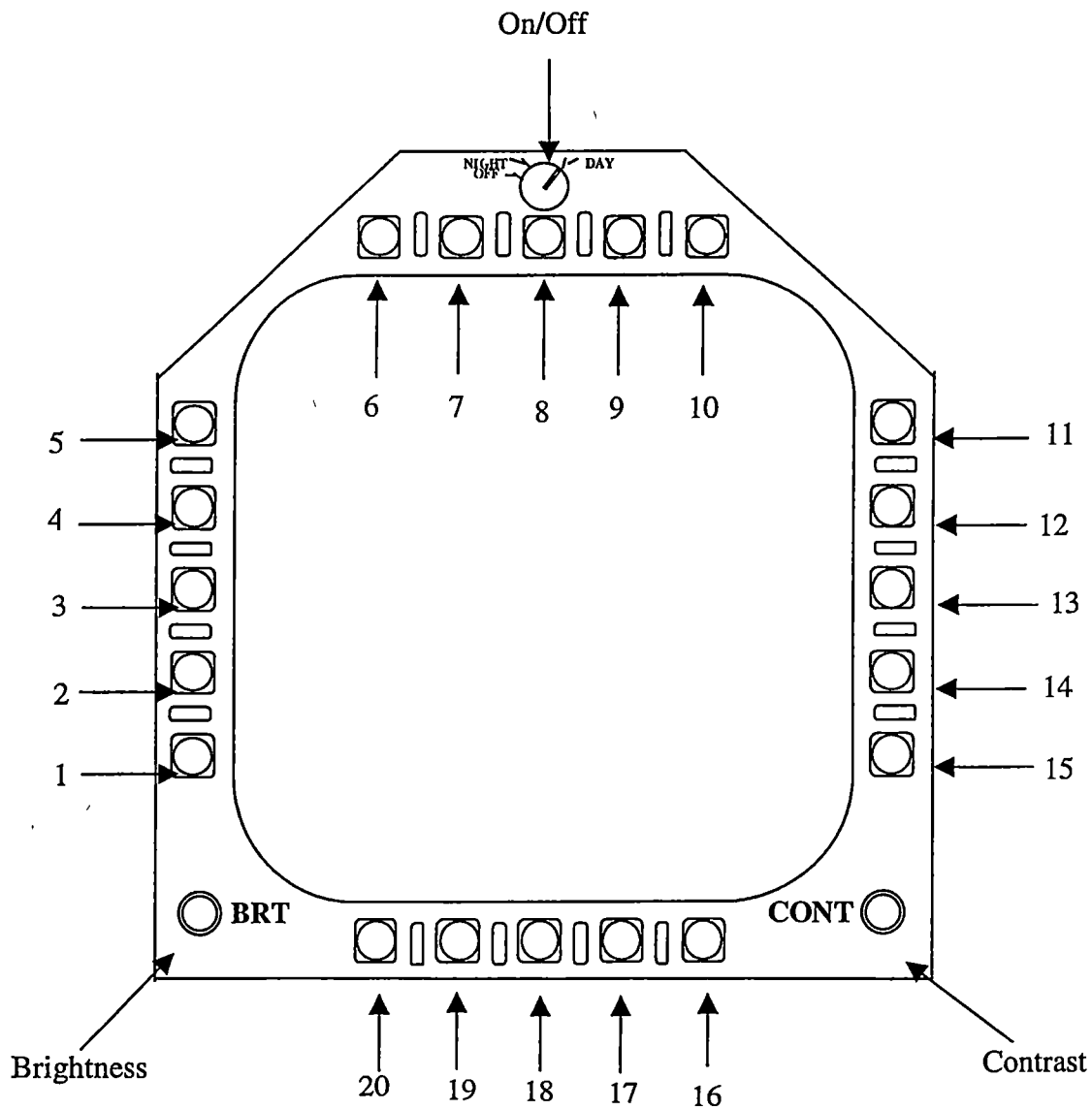

Figure 1-1.

F/A-18 DDI with pushbutton nomenclature

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 15C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1999

Hands-on-Throttle-and-Stick

The F/A-18 is equipped with several control switches located on the throttles and control stick. These switches allow the aircrew to rapidly change displays, select weapons, or change operating modes without removing hands from the primary controls of the aircraft [3] The Sensor Control Switch located on the control stick, depicted in figure A-2, is used to assign the Throttle Designator Controller (TDC) to various displays. The Sensor Control Switch, also known as the castle switch, is a four-position switch. Actuating the castle switch toward a display assigns the TDC to that display. If the TDC is assigned to the display already, the actuation will command sensor acquisition or change the display format, depending on the display in question. This allows the F/A-18 aircrew to rapidly change displays without relinquishing direct control of the aircraft.

By convention, F/A-18 aircrew place the HSI on the MPCD for most operations This provides positional situational awareness through the use of waypoints and the tactical map presentation. As with the DDIs, the castle switch can be actuated toward the MPCD, thereby assigning the TDC to the HSI display. A subsequent actuation toward the MPCD changes the display format to the SA page with the TDC assigned. A further actuation toward the MPCD cycles the display to the EW format. Actuating the Sensor Control Switch toward the MPCD again results in a return to the HSI.

2. CURRENT DISPLAY FORMATS

HORIZONTAL SITUATION INDICATOR FORMAT

The Horizontal Situation Indicator format, depicted in figure 2-1, is the primary means of obtaining overall navigational awareness for F/A-18 aircrew. The display is formatted as a top down view of the aircraft position, with an aircraft symbol located at the center of the display. The display is a "track-up" style with the aircraft fixed and the display area moving around it [4]. Surrounding the aircraft symbol is a compass rose. The compass rose is comprised of tick marks every ten degrees with a numerical indication of direction every thirty degrees beginning at north

Aircrew have the option of selecting a north-up or a true-up orientation. With the north-up orientation, the aircraft symbol changes orientation as north always remains at the twelve o'clock position of the display With the true-up orientation the aircraft symbol always points toward the twelve o'clock direction and the compass rose rotates as the aircraft maneuvers. As an enhancement to navigation, a color digital map depiction of the current location is displayed beneath the aircraft symbol The map also moves or remains fixed based upon the orientation selected by the aircrew The scale of this map changes in accordance with the range scale selected by the aircrew Range scales are available in increments of 160, 80, 40, 20, 10, and 5 nautical miles. The distance depicted by the range scale is measured from the fixed aircraft symbol to the edge of the compass rose Map depictions are only available in the 40 nm and smaller range settings.

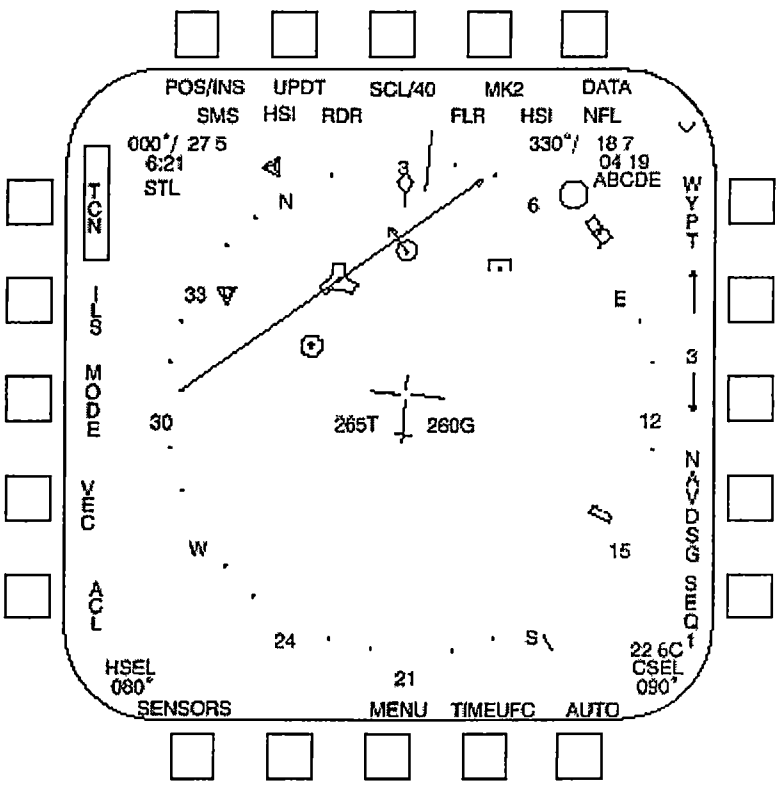

Figure 2-1 Horizontal Situation Indicator

Source: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 15C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1999

The pushbuttons of the HSI allow the aircrew to enter and select navigational information. The principle means of tailoring navigational data to the mission is through the use of waypoints and sequences of waypoints The selected waypoint is displayed between pushbuttons twelve and thirteen. On either side of the waypoint number are arrows that allow the aircrew to increment or decrement the selected waypoint. Actuation of pushbutton eleven, labeled WYPT, boxes the legend and enables steering to the indicated waypoint Steering cues are provided in the HUD and on the HSI. The HSI cue takes the form of a triangle on the inside of the compass rose with one of the points oriented towards the selected waypoint. When the selected waypoint lies within the range scale of the HSI, the geographical position of the waypoint is displayed as a small circle on the HSI and serves as a ready reference to aircraft position. Bearing, distance and time to the indicated waypoint (at present aircraft groundspeed) are displayed in the upper left corner of the HSI. Aircrew have the ability to designate a waypoint as a target through the use of the "WPDSG" pushbutton option located at pushbutton fourteen, as shown in figure 2-1 Actuation of this pushbutton makes the selected waypoint the target and slaves all sensors and steering information to that position

Aircrew can enter and manipulate the latitude, longitude and elevation of specific geographic locations or targets, depending on the requirements of the mission. Specific data for each waypoint is displayed when the HSI DATA sublevel is accessed through pushbutton ten. Selection of the data option changes the display

to the format shown in figure 2-2. Data entry is performed through the Up-Front Control (UFC) keypad.

The mark option located at pushbutton nine allows the aircrew to note the current aircraft latitude and longitude. Actuation of the option enters the aircraft position into the data field of the mark (essentially a waypoint) and increments the pushbutton to the next highest mark number, up to a total of nine. This information can then be retrieved at a later time to determine the location of an area of interest.

As a further aid to situational awareness, up to fifteen waypoints can be linked together into sequences. Sequences are used most often to display tactical ingress or egress routes A total of three sequences can be created, but only one sequence can be displayed at a time. Pushbutton fifteen controls the current sequence and allows the aircrew to switch between sequences. The option defaults to sequence one at aircraft start-up. In order to select the sequence for display, the aircrew must actuate the pushbutton; this places a box around the legend indicating that the selected sequence is enabled for display. Subsequent actuation of the pushbutton unboxes the current sequence number and increments to the next sequence. Sequences are displayed as a dashed line between selected waypoints, as shown in figure 2-3. As with waypoint data entry, selection of the HSI DATA sublevel provides the aircrew with an option to create and tailor sequences through the UFC.

Aircrew can select automatic sequential steering for the current sequence through the AUTO option located at pushbutton sixteen on the HSI. When pressed this pushbutton boxes the AUTO legend and provides steering cues to the first

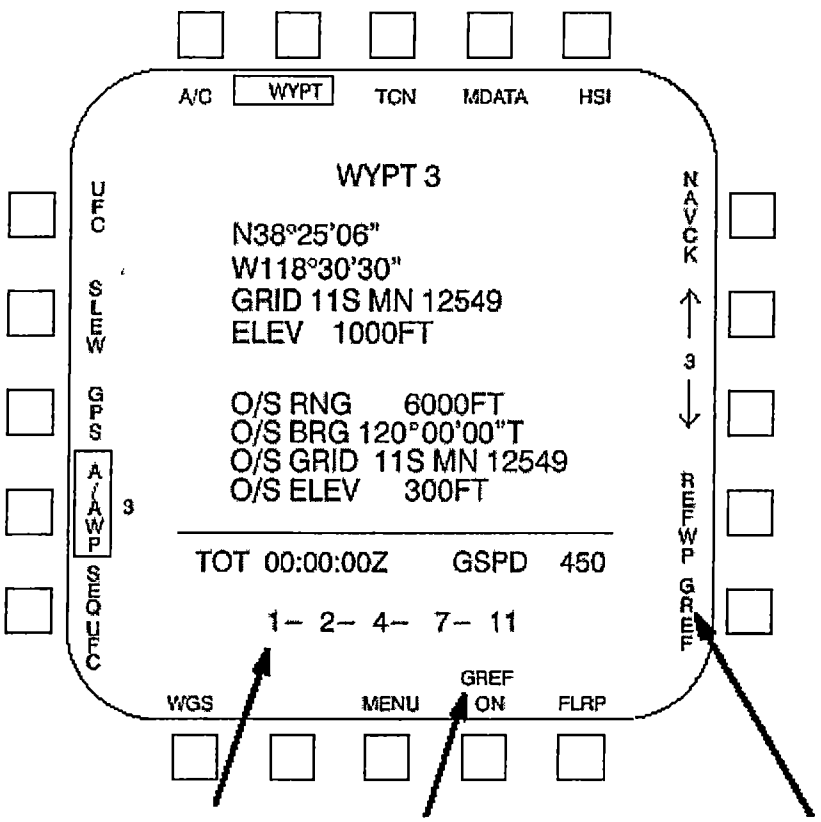

Figure 2-2 HSI Data sublevel

Adapted from. Operation of the F/A-18 Avionic Subsystem for Aircraft with the 15C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1999

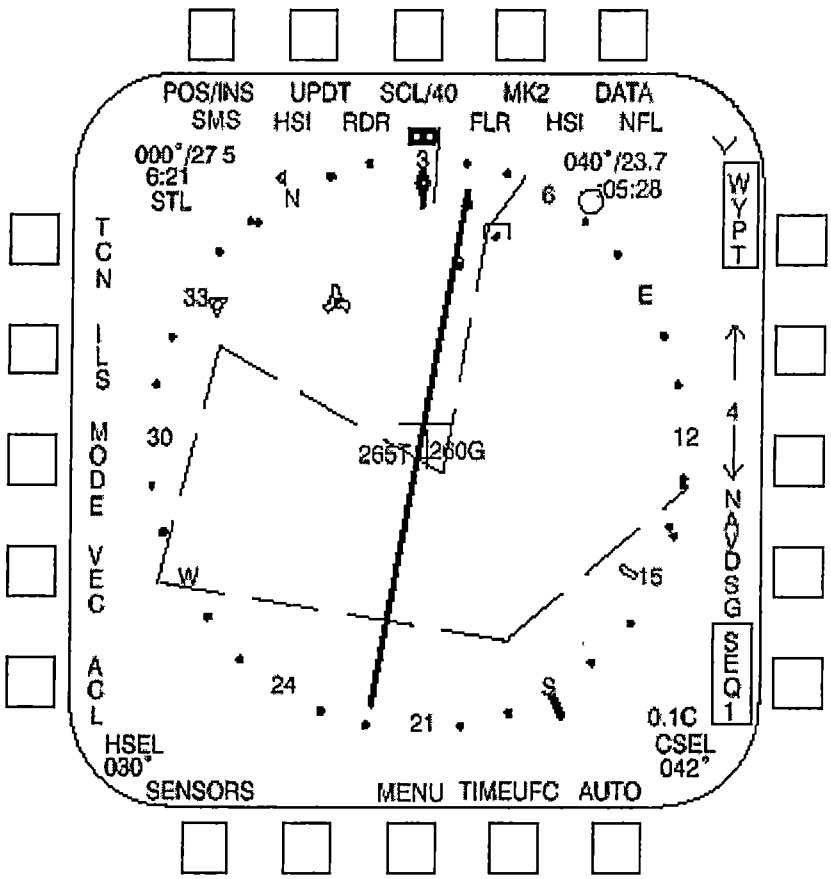

Figure 2-3 HSI Sequence Lines

Adapted from *Operation of the F/A-18 Avionic Subsystem for Aircraft with the 15C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1999*

waypoint of the selected sequence. As the sequence is flown, the steering information automatically updates to the next waypoint in the sequence If the aircrew enters a desired time on target and selects the AUTO option, the aircraft calculates and displays the current groundspeed required to fly the sequence and arrive at the target at the specified time. The required groundspeed is displayed on the HSI immediately below the actual groundspeed, as shown in figure 2-3. HUD cueing is also provided for groundspeed calculations

The HSI also provides the option to select a TACAN station as the primary means of navigation Tactically this is not useful as most scenarios will not involve the employment of a friendly TACAN as an aid to an attack profile Other HSI options, depicted in figure 2-1, are considered viable only in non-tactical situations and are not relevant to this discussion.

ELECTRONIC WARFARE FORMAT

The Electronic Warfare format is relatively new in the F/A-18 Early versions of the aircraft had limited EW equipment and control of the EW suite was accomplished through switches located on the center pedestal, shown in figure A-1. Threat information display was solely through the ADU and the HUD, also shown in figure A-1. As the aircraft has matured, more sophisticated electronic warfare equipment has been introduced This has resulted in the creation of the EW format for display on the Multipurpose Display Group The EW format, depicted in figure 2-4, provides a central location for the control of all EW equipment on the aircraft [4]. The controls are assigned to pushbuttons depending upon which particular EW

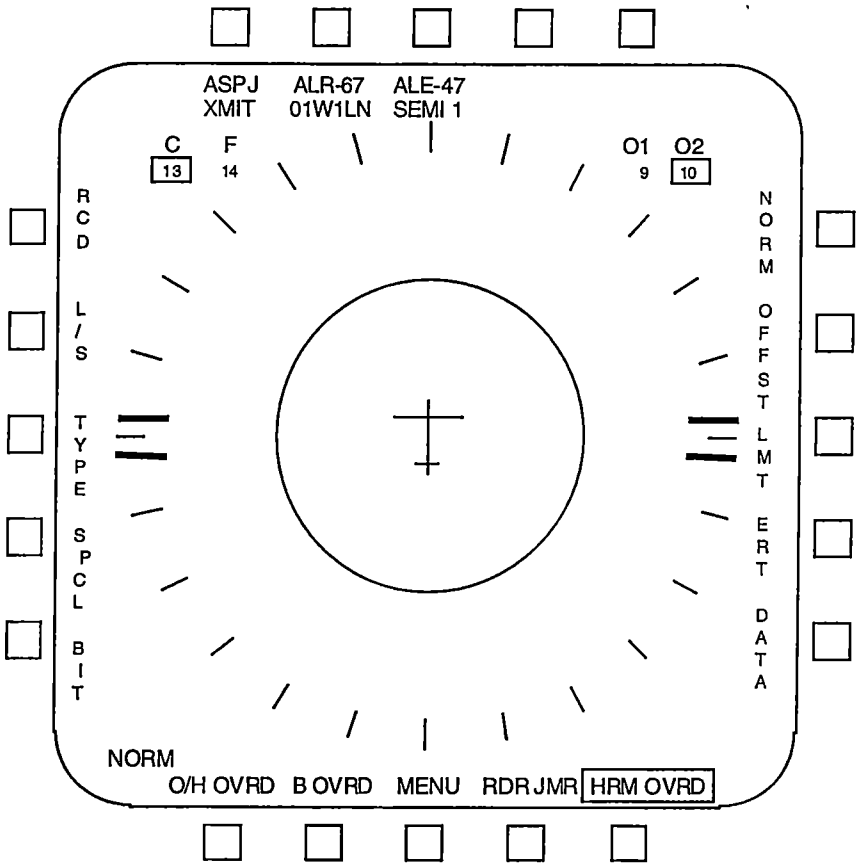

Figure 2-4 Top Level EW Format

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 15C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1999

component is selected. In order to set the desired parameters for each system, the aircrew must select each system individually, set the options, and then move on to the next system. There is no single format that allows all systems to be manipulated at once. EW systems are typically preset prior to entering the tactical arena, so manipulation of the pushbutton controls in tactical situations is not normally required.

The center of the EW format display is a lethality-based series of circles surrounding an aircraft symbol. The outer circle consists of relative bearing lines placed radially at fifteen degree intervals. The relative bearing circle is not labeled with respect to actual aircraft geographical orientation. Neither the aircraft symbol nor the relative bearing lines move from their orientation as the aircraft maneuvers. Instead, threat symbology rotates around the display [4]. Threat symbology is placed upon the circles based on the level of the threat to the aircraft. The threat symbol consists of the numerical identification of the threat system inside a "doghouse". The doghouse symbol indicates that the threat is a surface-to-air system. Ship based systems are augmented with an arc under the doghouse. Airborne threats are displayed as trackfiles, exactly as they appear on the Radar Attack format. At the 9 o'clock and 3 o'clock positions are beam maneuver cues that aid the aircrew in placing the threat in the beam position when conducting defensive maneuvers. The tactical region of the EW format with typical symbology is shown in figure 2-5

The EW display also provides a graphical presentation of the current expendable inventory of the CMDS. The expendable inventory and status is displayed in the upper right and left corners of the display, as shown in figure 2-5. Each type of expendable and a numerical indication of quantity are listed. A box

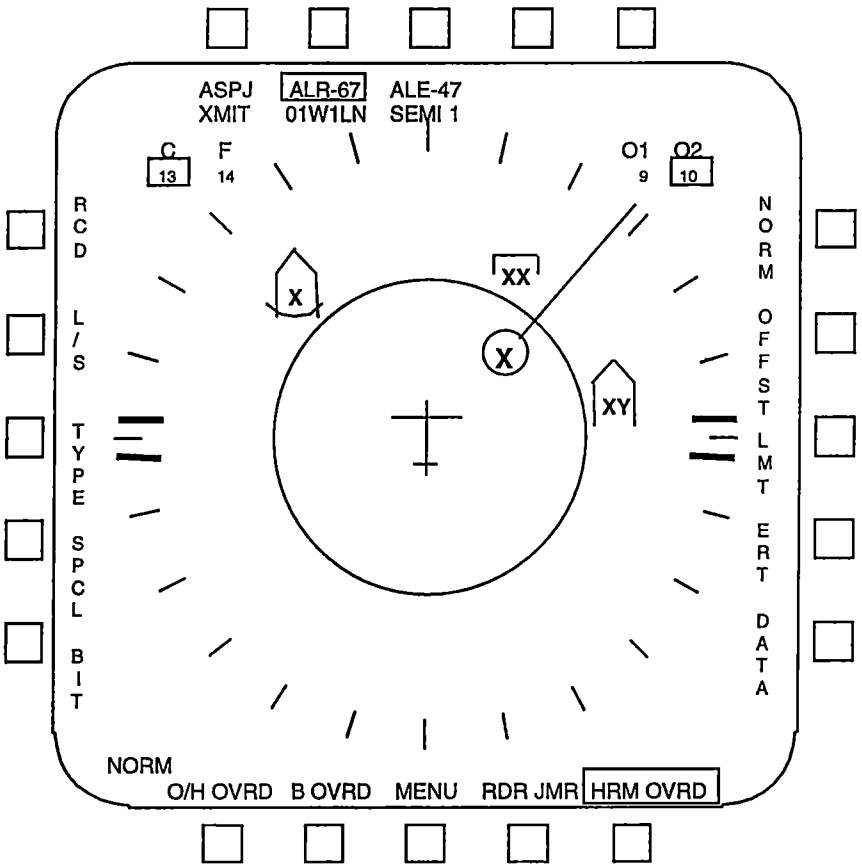

Figure 2-5 Typical EW Format symbology

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 15C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1999

surrounding the quantity indicates that the aircrew has enabled that type of expendable for dispense. A line through the number indicates that the aircrew has depleted or reached a minimum quantity of that particular expendable. This expendable information, presented on each version of the EW format, is not available in any other location in the cockpit

SITUATIONAL AWARENESS FORMAT

The Situational Awareness format is the primary format for the control and display of the data link information on the F/A-18. The format is shown in figure 2-6 As with the HSI page, the digital map representation is depicted beneath the SA page in the 40 and 10 nm scales. The SA page incorporates an aircraft symbol located at the center of the format as well as a labeled compass rose identical to the HSI compass rose. A solid ring surrounds the aircraft symbol and is normalized to reflect half of the range scale selected by the aircrew. The digital map defaults to display, but the aircrew may deselect the map display through the use of pushbutton six if desired. Once the datalink has been energized through the UFC, the center, or tactical, region of the display may show airborne or surface target trackfiles that are linked to the F/A-18 by other surveillance platforms Targets generated by the F/A-18's onboard sensors are also displayed.

In order to differentiate between airborne onboard and offboard (data link) contacts, the SA page uses a HAFU (Hostile Ambiguous Friendly Unknown) symbol either above or below the synthetic contact Ambiguous and unknown contacts are

displayed with a half-square (also referred to as a "staple"), friendly contacts are assigned a half-circle, and hostile tracks a half-diamond Onboard trackfiles place the HAFU symbol above the contact while offboard HAFU symbology is presented below the contact. In the case that a trackfile has both onboard and offboard contributions, the HAFU symbols are joined to form a complete square, circle or diamond. Figure 2-6 also presents the various types of trackfiles. The aircrew can then designate appropriate targets through the TDC or use the information to enhance situational awareness regarding aircraft that the F/A-18's sensors may not be targeting. As a further aid to situational awareness, trackfiles are colored according to allegiance. Ambiguous or unknown contacts are colored in yellow, friendlies in green, and hostiles in red. This color scheme augments the HAFU symbol change and provides a rapid means of determining trackfile allegiance on a display that can have a high density of information [1]

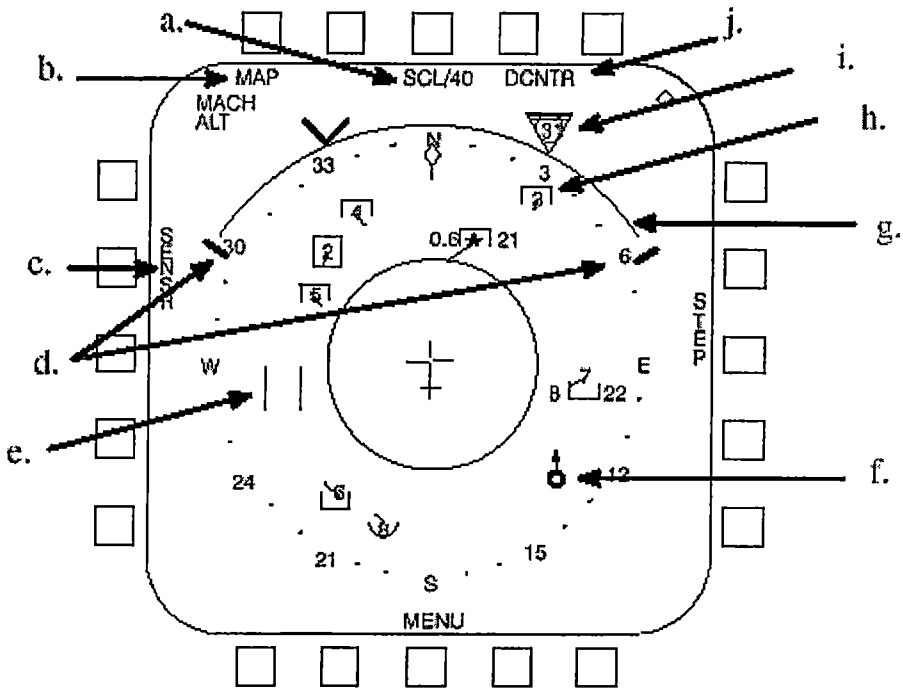

Figure 2-6 SA Format

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 15C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1999

3. DESCRIPTION OF THE COMBINED SITUATIONAL AWARENESS FORMAT

During Air-to-Air missions most F/A-18 aircrew use the DDIs to display the Radar Attack and Azimuth/Elevation formats. During Air-to-Ground missions the aircrew typically place the FLIR and Radar Attack pages on the DDIs. This setup is required to effectively prosecute airborne and surface targets. This convention leaves the MPCD as the only available source for the HSI, SA, or EW displays. Switching between display formats on the DDIs or MPCD is accomplished by manually actuating the Menu pushbutton (located at pushbutton eighteen), and then selecting the desired display format pushbutton. As mentioned in the Introduction, the current solution to this high workload tasking is the use of HOTAS controls to switch between formats. This mechanical modification improves the speed with which aircrew can select display formats, but still requires a deliberate mechanical action to obtain mission critical information resident on different displays.

The use of HOTAS to rapidly switch displays greatly improves the L-H display interface in the F/A-18, but it still remains cumbersome and unworkable during the high workload scenarios encountered by single seat aircraft in tactical scenarios. It has been demonstrated that information will be lost if mechanical switching of displays is required, even if this can be accomplished rapidly [15]. It is clear, then, that under the existing L-H display interface, information unique to any one of the formats would be lost during high workload scenarios as the aircrew

switched from one display to another, regardless of the speed of the HOTAS mechanization.

While the use of HOTAS to switch between display formats was deemed an acceptable improvement in the past, the advent of the new information-based systems further reduces viability of this L-H interface. The limited number of display surfaces available will only be exacerbated by the inclusion of the MIDS and IDECM systems, both of which promise to increase dramatically the amount of information flowing into the F/A-18 cockpit.

The second area that the combined SA format affects is the L-S interface for displays. The traditional source for situational awareness has been the HSI, this role (in a tactical environment) is now performed by the SA page. Similarly, threat information previously displayed on the EW page or ADU is now presented in a different, more intuitive, manner on the SA format.

Previous sections of this paper described the individual display formats that are being fused into the combined SA page. This section outlines the composition of the combined SA page and describes the components from each of the individual displays that comprise the new fused format.

NAVIGATION DATA

The new SA page incorporates the ability to select waypoints through the use of pushbuttons eleven through thirteen. The location of the waypoint pushbuttons is identical to their location on the HSI. Additionally, the mechanization of the waypoint selection function is identical to that of the HSI [5]. This commonality with

the established criteria for waypoint pushbutton location and usage makes the SA page implementation transparent to the F/A-18 aircrew. As with the HSI, the selected waypoints appear as small circles on the tactical region of the display format. The waypoint steering cue is also a triangle located on the interior of the compass rose that the HSI employs. As with the waypoint designation feature of the HSI, the aircrew can actuate pushbutton fourteen and designate the current waypoint as a target for sensor slaving.

Sequences can be accessed and displayed on the new SA page through pushbutton fifteen. As with the waypoint functionality, the mechanization of sequence information on the SA page is identical to the current HSI functionality. Sequences appear on the SA format as dashed lines, the same presentation as the HSI. Functionality and location of the AUTO sequence pushbutton is the same between the two displays, but the SA page differs in the location and display of the groundspeed information. On the combined SA page the current groundspeed information is now located at the bottom center of the display, outside the tactical region. The calculated groundspeed required is displayed next to the actual groundspeed with the legend "REQD". In order to highlight this information and differentiate it from pushbutton legends, the symbology is displayed at 150% size of other legends. Figure 3-1 illustrates the navigational features and symbology transferred from the HSI to the combined SA page.

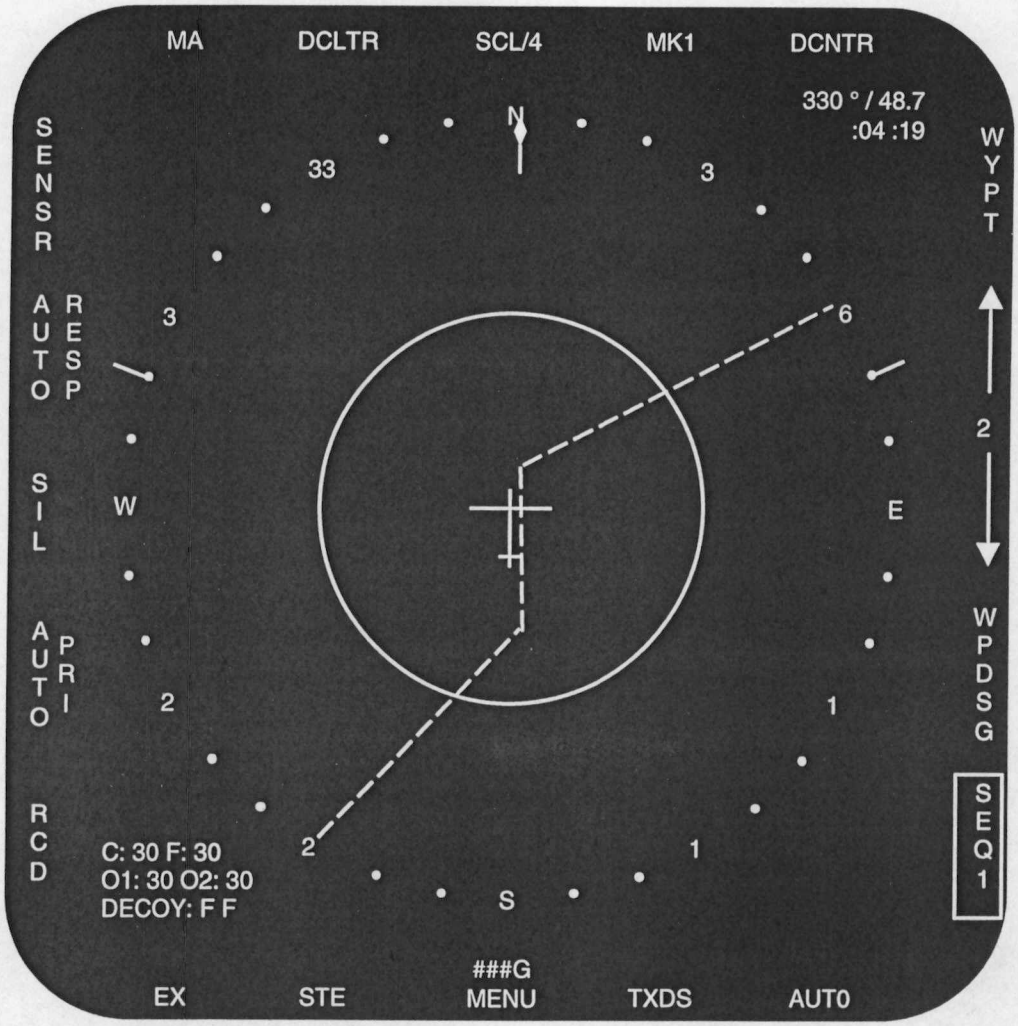

Figure 3-1 Navigation features of the combined SA format

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

EW DATA

The IDECM system contribution to the combined SA page is threefold: pushbutton controls of the entire EW suite, range-based display of threat locations and threat lethal zones, and current inventories of expendables. Pushbutton one provides an indication of the operating mode of the EW suite. The legend indicates which of the four available IDECM response modes (Automatic, Preplanned, Semi-automatic, and Manual) is currently selected Depressing the pushbutton changes the SA display to a sublevel that indicates all four options positioned at pushbuttons two through five [5], Figure 3-2 illustrates the EW suite control functionality. Selection of a particular mode of operation returns the SA page to the top level format with the newly selected mode indicated at pushbutton one.

The combined SA page, like the HSI, is a range-based depiction of the aircraft situation. In contrast, the EW format depicts threats based upon lethality. While the EW page presents an immediate indication of the most immediate threat, the lack of range information does not complete the positional picture. The situational awareness of the aircrew is greatly increased if a geographic depiction of the threat environment surrounding the aircraft, rather than just an indication of lethality, is presented [6] On the combined SA format threats are depicted in just such a manner. The type of threat is presented in exactly the same manner as on the EW format with threat identification number inside a doghouse Since the effective range of most surface-to-air threats is known, this range is also depicted as a circle of varying radius on the display In this manner the aircrew are presented with an immediate indication of a threat's location as well

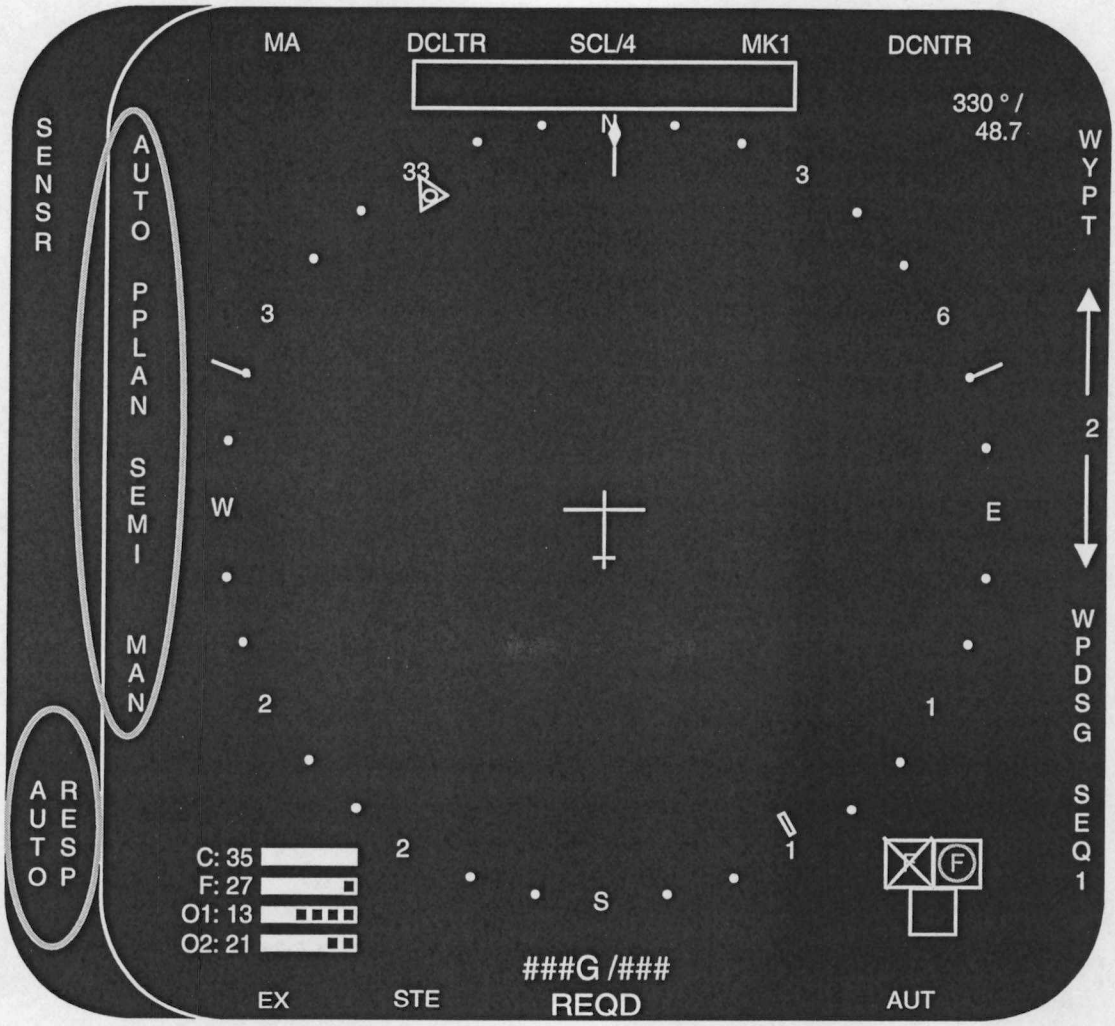

Figure 3-2 IDECM Response Mode selections

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

as the host aircraft's proximity to the lethal range of the threat system Allegiance of surface to air systems, when known, is depicted through the color coding scheme outlined in section two (red = hostile, yellow = unknown/ambiguous, and green = friendly) A typical depiction of threat systems is presented in figure 3-3.

An additional aspect of the threat position information is the ability to pre-plan and display known threats. Whether a threat system is active or not, the aircrew have a graphical reference of the potential threat location and maximum lethal envelope. Pre-planned threats are displayed with a dotted line for the threat lethal radius. Threats that pop-up during a mission are correlated between the RWR and other EW systems. These threats are displayed as a dashed line around the site. If the current active threat (that displayed by the RWR) correlates with one of the pre-planned threats, the lethality ring will become solid. This is a cue to the aircrew that one of the pre-planned threat systems is now active. Threats that exhibit missile launch indications flash on the display to draw aircrew attention. Figure 3-3 shows the different types of threat rings possible. Threats that the RWR senses but cannot resolve in range or angle are placed at the top of the SA page in a rectangular box known as the "dugout". Threats that the IDECM system is actively countering are displayed with "countermeasures in progress" symbols on either side of the threat symbol The dugout is depicted in figure 3-3 as well

Figure 3-3 also displays the final feature that the IDECM system contributes directly to the SA format In the lower left and right corners of the SA format are indicators of current expendable inventories In the lower left corner is the inventory of the countermeaures dispensing system. The inventory is shown both as a numeric

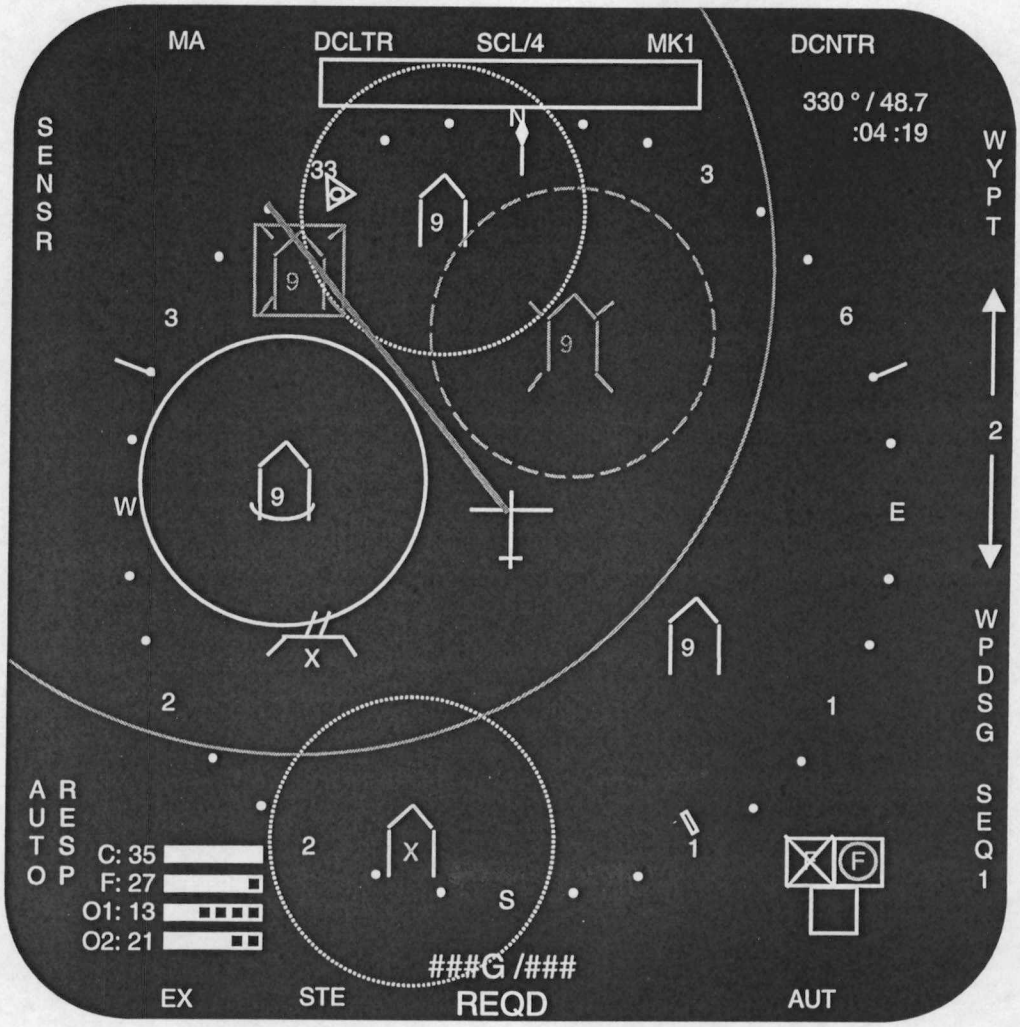

Figure 3-3 Threat Symbology on the SA format

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

readout of the inventory and as an analog "tape" of expendable status. As the number of expendables decreases, the bar shrinks to the left. This provides a rapid means of determining current inventory. On F/A-18E/F variants, the lower right portion of the display is a graphical representation of the towed decoy system. The three boxes are arranges as they are installed in the aircraft. Within each box is a legend describing the type of decoy loaded in that position, the status of the decoy (stowed of deployed), and the health of the decoy (fully operational or degraded). As with the CMDS status indicator, the graphical representation provides a rapid means of determining towed decoy status

DATA LINK

The original SA format was designed to support the display of data link information with only minimal control. The MIDS data link brings the possibility of greatly increased amounts of information from other sources that the current data link system cannot support. While previous data link systems were relatively limited in the number of participants and information available, the MIDS system operates more as a network, necessitating the redesign of data link controls. Rather than change the current symbology, the MIDS portion of the SA format displays information in the trackfile convention already present in the aircraft [7].

Examples of trackfiles linked to the F/A-18 are shown in figure 3-4 Trackfiles can apply to both airborne and surface contacts, and to both linked contacts and onboard sensor contacts Airborne contacts are displayed on the combined SA format exactly as they appear on the current SA format described in section two.

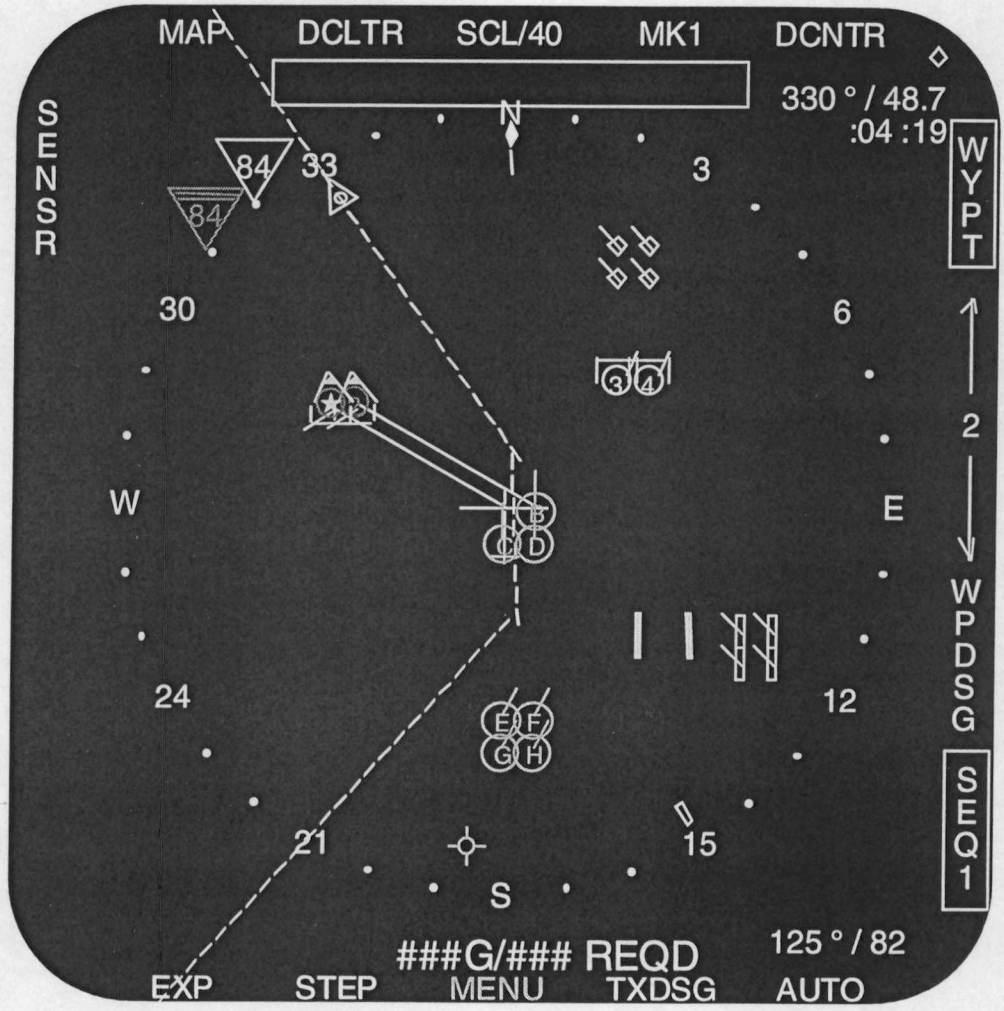

Figure 3-4 Data Link Trackfiles on the SA format

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

Surface contacts, however, are displayed in the format used by the EW page described above. The numerical identification of the threat system along with the doghouse is identical to the implementation used on the EW format. If the contact is exclusively from data link information, the associated lethality ring is a dotted line identical to the pre-planned symbology As with pre-planned threats, once the contact is correlated with onboard sensor information, the circle becomes solid Similar to the current SA page, color coding of trackfiles based upon known allegiance is used as an aid to trackfile discrimination.

The combined SA format also provides the aircrew with the ability to obtain detailed tactical information regarding trackfiles that are generated from the MIDS or IDECM systems This is accomplished through the use of the cursor. When the cursor is moved over a trackfile, detailed information regarding type of threat, targeting, and source of information are presented in the lower left corner of the SA page. This information replaces the expendable inventory as long as the cursor remains over a trackfile. Once the cursor is moved to open space, the expendable inventory returns [5,7].

The combined SA format adds a display declutter option at pushbutton seven as shown figure 3-5. This option, when selected, changes pushbuttons seven through ten to a declutter sublevel with four options: REJ1, REJ2, MREJ1,and MREJ2 Reject option one (REJ1) removes the data for each individual trackfile, so that only the symbol remains Reject option two removes the threat lethality rings from the display. The other two declutter options are manually tailored by the aircrew Each

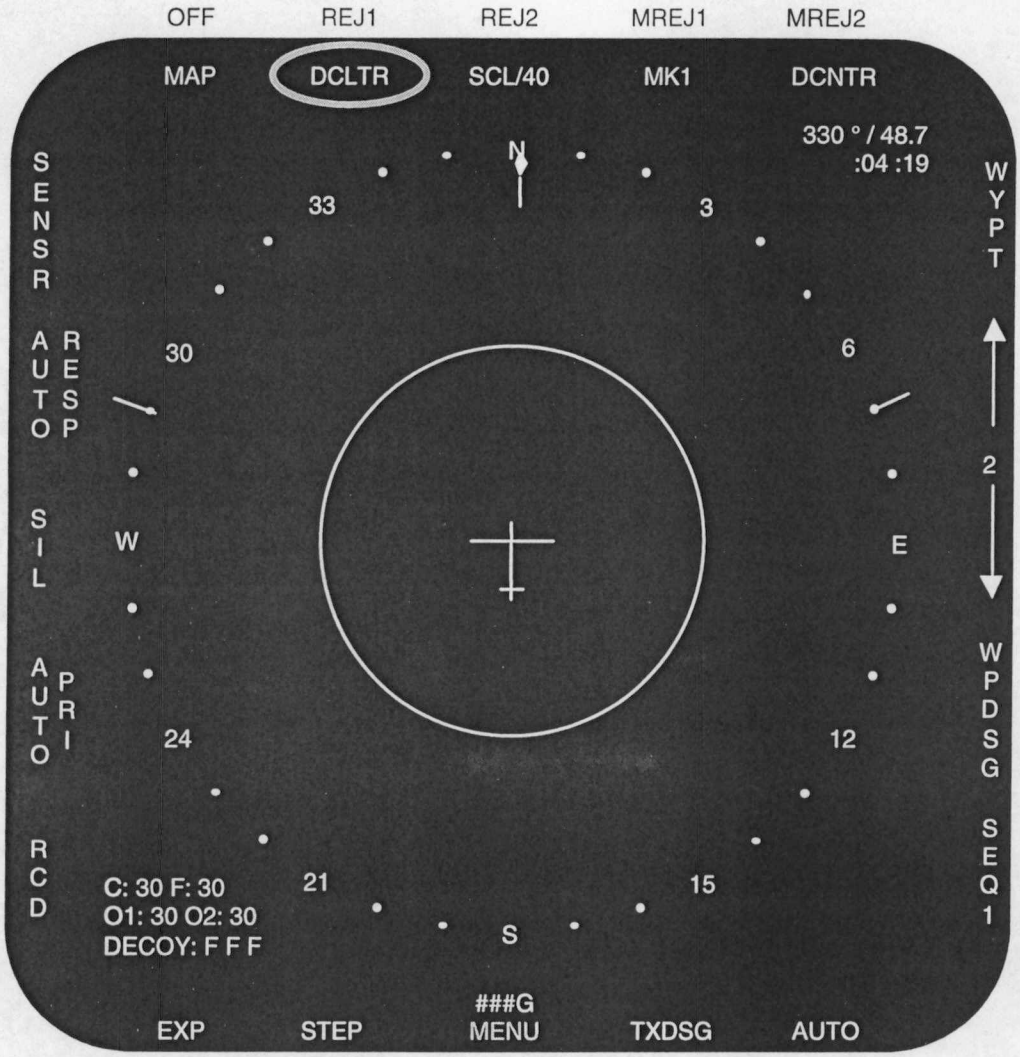

Figure 3-5 SA Format declutter options

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

aircrew can determine which symbology to suppress based upon preference and the tactical situation The two manually tailored options permit the aircrew the greatest flexibility and control in choosing which information is to be displayed

While the combined SA format modifies the L-H interface for the display formats, it has not changed the fundamental requirement for the aircrew to go 'head down' in the cockpit to retrieve situational information This 'head down' time is increased by the size of the symbology The relatively small size of the display limits the size of the symbology, forcing the aircrew to scrutinize the format for longer periods of time Additionally, the current use of audio cues to identify threats has not been updated Different frequency tones delineate threat lethality, but do not specify the type of threat or direction of arrival The aircrew must determine which threat is associated with each tone and mentally correlate the tone to a particular direction

4. EVALUATION OF THE COMBINED SITUATIONAL AWARENESS FORMAT

As a single-seat, multi-role fighter attack aircraft, the tasks required of the F/A-18 on a typical mission are varied and complex. The F/A-18 aircrew is required to navigate to a target on a precise timeline while maintaining visual mutual support between aircraft in a two-plane or four-plane formation The aircrew is also required to detect, identify, and prosecute any airborne contacts encountered during the mission. Simultaneous with these tasks, surface to air threats must be avoided or defended against. Once in the target area, the aircrew must change to an attack mode to deliver ordnance on target, and then egress successfully. These many phases of the mission require every skill that an F/A-18 aircrew possesses and involve an extremely high task loading. The intent of the combined SA format is to place the most tactically useful items from other formats into a single page in an effort to reduce aircrew workload while maintaining the existing physical architecture of the F/A-18 cockpit. While the combined SA format does reduce the overall aircrew workload, the display can become too cluttered with symbology in a high threat environment. Figure 4-1 illustrates an example of the display in a high density scenario

The utility of the combined SA page for accomplishment of F/A-18 missions begins with the use of a top-down geographic display with an aircraft symbol at the center, a compass rose and a moving map underlaying the symbology This configuration is the accepted convention for positional awareness in the F/A-18 community and allows the aircrew to rapidly orient themselves to their exact

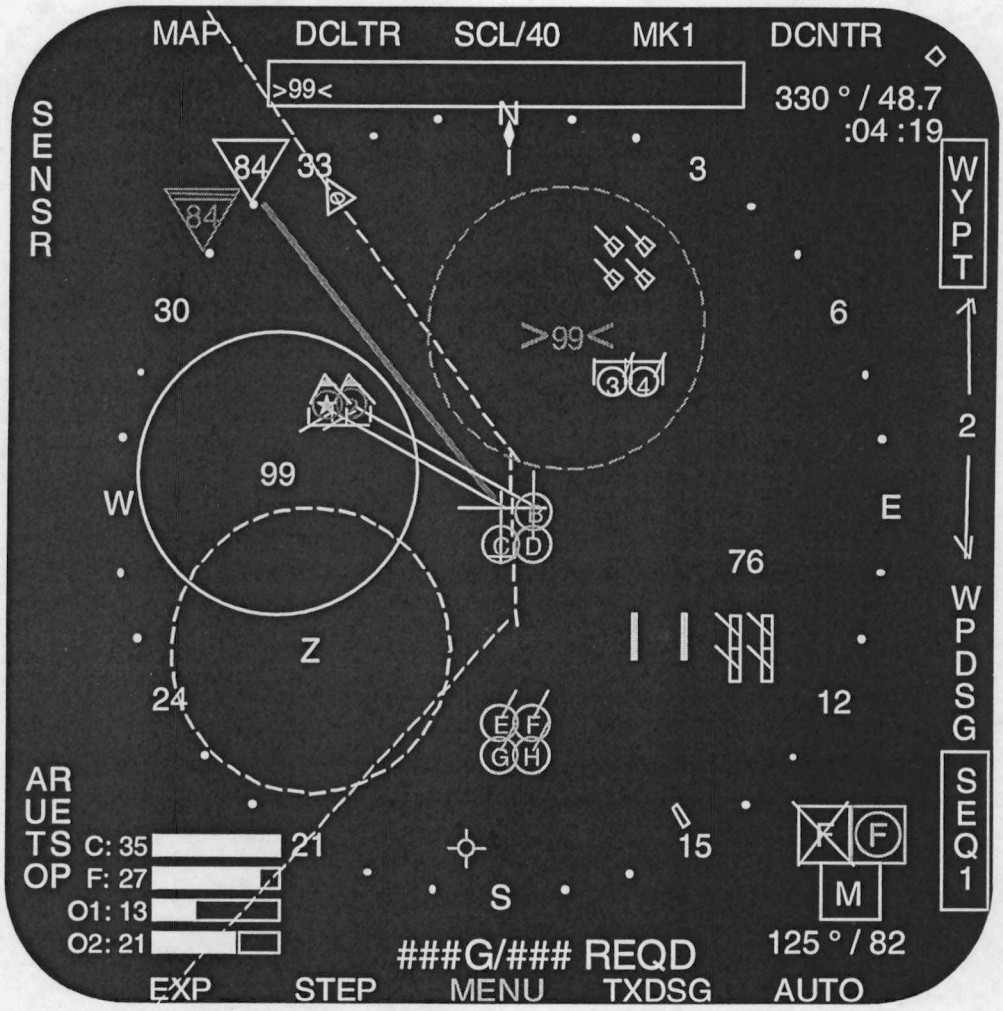

Figure 4-1. Combined SA format in a dense threat scenario

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

geographic location and aircraft heading. This type of positional representation is also the most realistic for maintaining aircrew positional awareness [1].

Workload in the F/A-18 cockpit is greatly reduced through the use of preflight mission planning tools. These allow the aircrew to create a strike route using waypoints, link them as a sequence, and download them directly into the aircraft through a data file. This places a dashed reference line for the selected sequence within the tactical portion of the display. The rapid assessment of positional awareness afforded by the combined SA format is further enhanced by the sequence reference line which allows the aircrew to ascertain the aircraft's status with respect to the strike route. These navigation waypoints, sequence lines, steering commands and their pushbutton controls appear on the combined SA page exactly as they do on the HSI. This commonality and the accepted community employment of waypoint steering enhance the navigational elements of the combined SA page.

While utilizing the HSI for tactical navigation, the aircrew has the option to select automatic sequence steering. This automates the navigation process by updating the selected waypoint for steering cues as the route is flown. The same automatic cueing is available on the combined SA format through the 'AUTO' pushbutton. This reduces the navigation workload for the single seat aircrew The automatic steering function also computes and cues the aircrew to the groundspeed required to reach the target at a predetermined time. This cueing is displayed immediately below the tactical region of the display in the form of an oversized digital groundspeed and groundspeed required The automation of required groundspeed is extremely valuable, but the display of this information on the SA

format is not necessary because it is displayed in analog fashion on the HUD For this reason the oversized symbology at the bottom of the display adds clutter with little benefit for the F/A-18 aircrew. Figure 4-2 illustrates the SA format with the groundspeed cueing removed.

The preplanning tools of the F/A-18 also allow the aircrew to mark the locations of known surface to air threats. While this capability exists on the HSI, it is in a rudimentary form only and requires the aircrew to mentally assess distance from the marked location to determine potential threat lethality. Additionally, the HSI marks do not identify the type of surface to air system, requiring the aircrew to keep track of which threat was loaded into each waypoint. The combined SA format removes this mental workload from the aircrew by depicting the type of threat system, lethal range, and allegiance of the threat system In this manner the aircrew can avoid the threats by remaining outside the depicted range ring. The concept of depicting surface threats in a geographic manner, rather than strictly by lethality, makes avoidance easier and more intuitive.

In dense threat environments, however, the combination of overlapping threat symbols is very confusing and actually reduces the aircrew's ability to assess which threat is lethal The reduction in situational awareness is compounded when several threat rings flash to indicate lethality The amount of clutter can be significantly reduced by displaying the threat system symbol while removing the lethality rings until the aircraft approaches within a given range of the lethal area. In this way symbology which is not relevant at the time is suppressed until it is needed Additionally, lethal zones of threat systems that are limited by altitude would not be

Figure 4-2. SA format with groundspeed cueing removed

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

displayed as long as the F/A-18 remained above the threat's effective altitude. Applying these rules to the display of lethality rings will reduce the amount of information required for processing and allow the aircrew to focus on the most immediate threats, both of which should improve aircrew performance [15]

The lower corners of the combined SA format are dedicated to the display of expendable inventory in both analog and digital formats. This information is important to the aircrew, but through most portions of a mission the exact quantity is irrelevant. The expendable count becomes important when the aircrew begins to run low, until that time the exact number is not required. Removal of this extraneous information until it is needed will improve the performance of the aircrew [15]. Currently the aircrew have the ability to set a minimum (or 'bingo') value for expendables In order to continue using the CMDS once this bingo value is reached, the aircrew must override the preset minimum Since the logic already exists to allow the aircrew to set minimum values of expendables, the display of this information should be inhibited until the low states are reached. Additionally, the current depiction is not intuitive in that the analog tape symbol decreases to the left as expendables are used. A vertical depiction, with the tapes decreasing down, would be interpreted more readily as an indication of expendable count. Figure 4-3 shows the combined SA page with the expendable inventories realigned and non-lethal threat rings removed.

One of the greatest sources of information on the combined SA page comes from the MIDS data link system. The information available covers both surface and airborne contacts of all allegiances. This information can vastly increase the

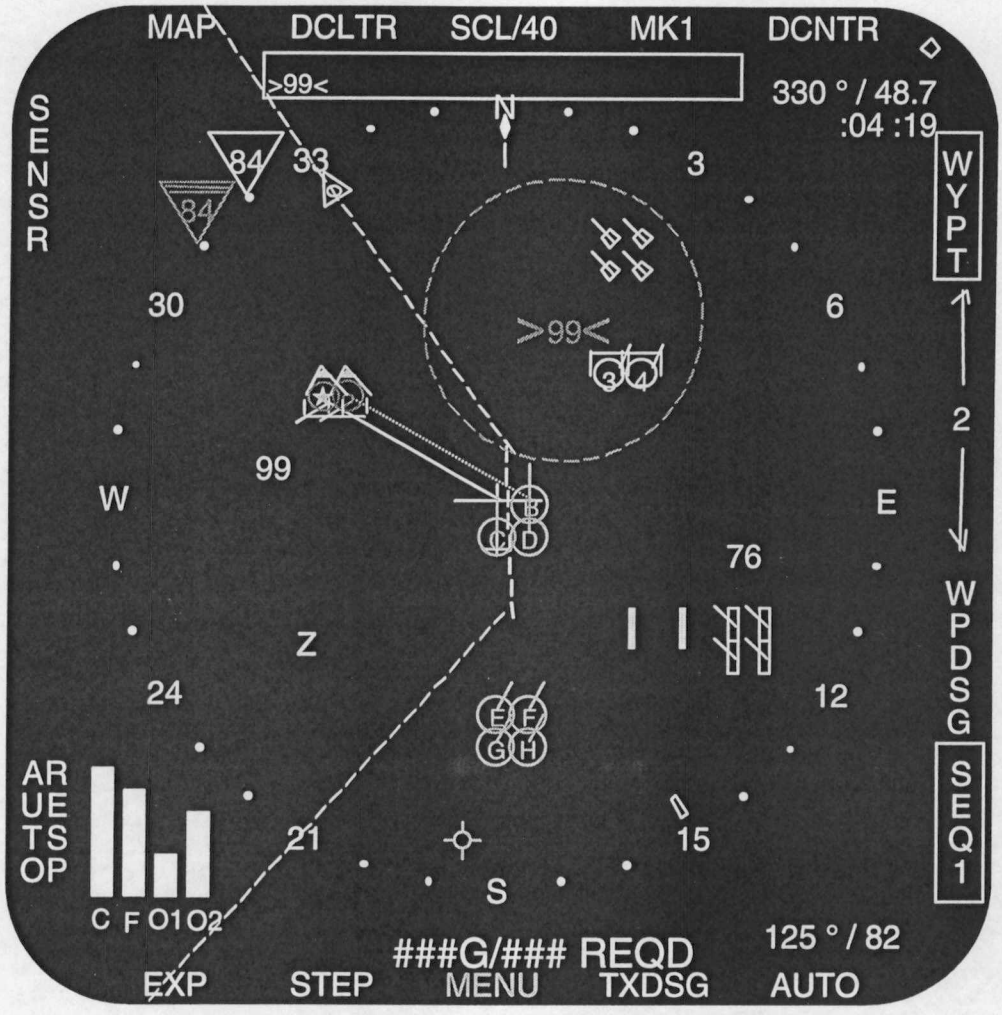

Figure 4-3. SA format with expendable inventory modified and threat rings removed

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

aircrew's situational awareness because contacts from other sources can be displayed. However, contacts that are beyond the F/A-18's range of influence are superfluous. Additionally, contacts that another section of fighters might be assigned to intercept may be linked to the F/A-18 In scenarios with few trackfiles this information may enhance the tactical picture, but in high threat density environments the information is extraneous and reduces the aircrew ability to accurately discern the tactical picture.

When prosecuting targets F/A-18 aircrew use the formats displayed on the DDIs, and not the formats available on the MPCD. Placing MIDS generated trackfiles on the MPCD that can be designated for attack represents more than just an increase in information for situational awareness. It is also a new L-S interface for attack procedures. Since the Radar Attack format is the primary means of executing intercepts against airborne contacts, MIDS tracks that are in the radar scan volume should be placed on the Radar Attack format and not on the combined SA page. This would still allow the aircrew to accomplish critical mission tasks without placing redundant information on the SA format.

As single seat, multi-role fighter attack aircraft, the F/A-18 relies upon section or division formations to effectively conduct missions. This makes the task of maintaining mutual support between aircraft critical to mission success The requirements to go 'heads down' to control sensors, navigate or perform administrative duties reduces the time available to physically keep sight of wingmen. From this perspective, the friendly symbology present on the SA format through the MIDS data link enhances the F/A-18 aircrew's ability to rapidly ascertain the location

of supporting aircraft. Figure 4-4 depicts the SA format with much of the unnecessary symbology removed.

The amount and type of data link information presented on the SA page can be very enhancing in low threat density scenarios, but the aircrew must be able to create and enable declutter options to remove unnecessary information when it is outside the F/A-18's sphere of influence. For this reason the options presented to remove symbology are crucial to the utility of the SA format.

SIMULATOR EVALUATION

The primary means of evaluating the combined Situational Awareness format has been a series of simulator evaluation sessions [8]. The purpose of the initial simulator sessions was to aid in design of the format through the use of aircrew opinions and reactions to tactical scenarios Later simulator sessions involved fleet aviators of varying experience levels as a validation of the format as an aid to situational awareness. In both types of simulations aircrew were tasked with performing identical missions with and without the combined SA format. In order to compensate for any influences of a "learning curve", one-half of the aircrew flew the missions with the combined SA format first, while the other half first used the standard cockpit architecture [8]. As flightworthy MIDS and IDECM hardware and software has become available, flight test with the combined format has been explored. Information on the acceptability of the flight tests is captured in aircrew flight reports.

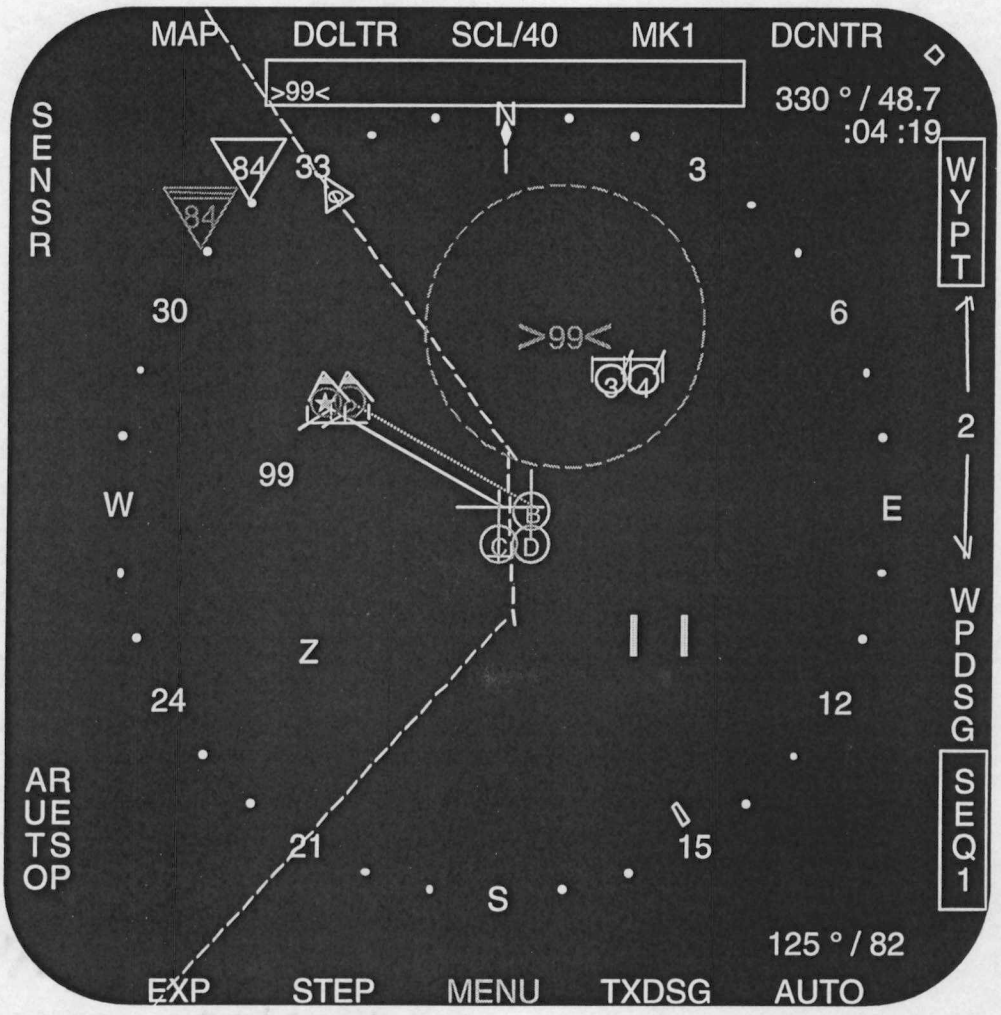

Figure 4-4. Decluttered SA format

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

During the design and evaluation simulations a total of twenty-four different aircrew evaluated the utility of various aspects of the combined SA page through questionnaires that employed acceptability and situational awareness rating scales. The simulators accomplished two tasks· rating specific aspects of the SA format for aircrew acceptability and evaluating the combined SA format aircrew from a mission systems standpoint as an overall contributor to situational awareness Since the mission task requirements of the F/A-18 did not change with the advent of the combined SA format, the focus of the evaluations was the qualitative assessment of the single format concept as an improvement over the physical changing of displays Removing the physical requirement to cycle display formats reduced the workload for the aircrew, but the utility of the display symbology and included information required further assessment [15]

The qualitative questionnaires used in the design phase, included in Appendix B, consisted of a series of questions directed at the acceptability of different specific aspects of the SA format as they related to overall aircrew situational awareness. The questions included a seven-point rating scale with choices from "excellent- no changes needed" to "unacceptable" [8]. The rating scale used for this phase of development equates to the China Lake Situational Awareness (CLSA) scheme outlined by Gawron, Weingarten, Adams and Hughes and included in Appendix B [17] The CLSA scale is a modified Bedford workload rating scale aimed directly at measuring situational awareness derived from cockpit displays through different phases of flight. Because the early simulator sessions involved the actual design of the display, the seven point rating scale reflects the acceptability of the symbology

and is not a direct measure of situational awareness. The questions supported by the seven-point scale, however, do equate closely to the ratings used in the CLSA. By rating the symbology in relation to situational awareness, the particular utility of the design implementation was determined. In addition to the rating of the symbology, the aircrew were encouraged to suggest methods of improving the format design. A core group of eight developmental test aircrew participated in all the simulators, while the remainder of the test aircrew came from operational test and tactics instruction units.

The final session of simulations focused exclusively on overall situational awareness as an evaluation of the final display design. Design comments were limited and a different rating scale was utilized. For this simulator evaluation a group of sixteen developmental and operational test aircrew was employed. The five point scale used in the later simulations required the aircrew to rate their perceived level of situational awareness, with a "five" indicating complete awareness, and a "one" signifying no situational awareness whatsoever. The five point scale employed in the final sessions follows exactly the ratings and objectives of the CLSA [17].

The evaluation simulation itself consisted of a tactical self-escort strike scenario in which the aircrew were required to navigate along a specified strike route and attack a target with non-precision ballistic weapons. Hostile surface-to-air threats were positioned at various locations along the strike route and in the target area. Additionally, the aircrew had to defend against hostile aircraft. Aircrew tactical decisions were completely independent, with no single correct response to the scenario.

SIMULATOR RESULTS

Questions from the design phase focused on the utility of specific display items. The aircrew involved rated the combined SA format overall as a Two, "Good – could benefit from minor refinements" with respect to its enhancement in the aircrew ability to manage threat systems [8] The aircrew noted that the combined SA page was a marked improvement over the existing display architecture. Comments from the questionnaire include the following " SA greatly enhanced throughout ingress, target area, and egress." Specific symbology that the aircrew rated highly as strong contributors to overall situational awareness included the threat lethality rings and the expendable inventory counters [8].

While the aircrew overwhelmingly rated the combined SA page as an enhancement to tactical situational awareness, several noted that the display contained too much information most of the time This was especially true when aircrew were actively defending against some threats while other, non-critical threats, continued to be displayed Several studies illustrate the fact that time spent accessing information from a crowded multifunction display can adversely affect flight performance [15] Recommendations from the evaluation aircrew included the use of manually tailored options to declutter the display [8]

The five-point scale used in the later simulations was designed to capture the overall utility of the SA format without examining specific design items on the display. As with the previous simulator results, the aircrew overwhelmingly rated the

combined SA format as a distinct aid in achieving and maintaining tactical awareness throughout the strike scenarios [9].

The surveys used in the simulator evaluations captured the subjective situational awareness perceptions of the aircrew. Objective data on the utility of the combined SA format was gathered by measuring the following parameters: number of air-to-air exchanges won, time spent in surface-to-air threat envelopes, targets destroyed, mission aborts, and fighter losses through hostile action [8,9] Overall the parameters were grouped into lethality (the ability to destroy hostile forces) and survivability (the ability to either avoid threats or survive an engagement with threat forces). These correlate roughly to offensive and defensive capabilities

The missions flown with the combined SA format rather than the current architecture requiring the aircrew to mechanically switch between displays achieved greater mission successes in all areas. Most notable was the reduction of time that the aircrew spent exposed in threat engagement zones and the more efficient use of expendables [8,9]. These results are corroborated by the findings of a similar evaluation of advanced multisensory display concepts conducted by Logicon Technical Services in 1997 [10].

5. SUMMARY

The challenge facing the future design and development of the F/A-18 is to increase the information flow into the cockpit while maintaining the existing hardware Since the aircraft is physically limited to three displays, the only viable answer is the fusion of data into formats that can convey information effectively The result of this design effort is the combined SA format a unification of information normally contained in three separate displays into a single location

The displays and cockpit architecture of the F/A-18 aircraft are extremely versatile and pilot friendly. The original versions of the aircraft possessed limited sensors and three displays were adequate for most tactical situations As the aircraft matured and acquired new missions, sensors, capabilities, the number of displays became a limitation Aircrew were forced to choose which display formats to use based upon personal preference and tactical utility Completing the tactical missions assigned to the F/A-18 within this architecture greatly increased the workload of the aircrew In an effort to improve the mechanical interface between the aircrew and the display formats (the L-H link) and therefore reduce the workload of the single seat aviator, HOTAS architecture to automatically change displays was developed

The HOTAS scheme used the MPCD, the primary source for maintaining positional awareness, to link the HSI, SA, and EW formats Each format contains information vital during different mission phases that is not

displayed on any other page The advent of advanced information systems has necessitated the need to revamp the current display scheme Rather than force the aircrew to physically change display formats through HOTAS actuations, portions from all three formats have been combined into a single display The decision to fuse information onto a single display as a means of reducing the time required to access information is consistent with the findings of Francis and Reardon in their study of multifunction display and control systems [15]

The resultant combined Situational Awareness format incorporates aspects from the HSI, SA, and EW pages that are the most useful during tactical scenarios Aspects of the combined SA page constitute a change to the current L-S interface in the F/A-18 While the basic reliance on artificial symbology for situational awareness is still utilized, the combined SA format has changed the nature of the display. Basic navigation information has not changed with the new display, but the presentation of potential threat systems has changed Since the combined SA page is constructed using the same top-down view as the HSI, threat depictions based upon range with threat engagement rings provide greater situational awareness than the lethality based indications provided on the EW format This change to the L-S interface for threat presentation improves the aircrew's ability to avoid threat envelopes

Added to the information transferred from the EW and HSI display formats is the increased amount of information available from the IDECM and

MIDS systems Simulation and flight test results from this program and others have demonstrated an improvement in the tactical situational awareness of the aircrew using an integrated situational display such as the combined SA format [15] Despite the improved performance and awareness resulting from the new format, there are still deficiencies that exist in the design

The most obvious deficiency, and the one most commented on throughout the testing, is the potential to overcrowd the display to the point of confusion Complicating the retrieval of information through display clutter can severely reduce the aircrew performance [15] The remedy to this problem is the removal of extraneous information and the use of declutter options The fusion of vital tactical information into a single display reduces the aircrew workload when attempting to access information contained on different formats, but runs the risk of becoming unusable if the amount of information presented overwhelms the aircrew's ability to process it

6. CONCLUSIONS AND RECOMMENDATIONS

The combined SA format is an attempt to reduce aircrew workload in the face of increased information input while maintaining the existing architecture of the F/A-18 cockpit The following list summarizes the results of the simulator evaluation and conclusions from the thesis

1 The combined SA format enhances situational awareness as evidenced by multiple simulator results

2 The combined SA format can be easily cluttered in a high threat environment

3 The aircrew is still required to go 'head down' in the cockpit to retrieve information

4. The display is difficult to read quickly due to its small size.

5. Audio cues of threat lethality have not been updated to facilitate situational awareness

6 The scale used to display expendable inventories is not intuitive

The following are recommendations to further improve the utility of the SA format and the situational awareness of the single seat aviator

1 Remove the extraneous information on the display to include groundspeed required, non-lethal threat rings, expendable inventories, and irrelevant data link trackfiles

2 Reorient the expendable inventory (when displayed) to vertical

3 Increase the size of the display by at least fifty percent to improve the readability of the symbology and reduce the time spent inside the cockpit retrieving mission critical information

4 Incorporate a three dimensional audio system to enhance directional cueing to threats and friendly elements

5 Integrate a Helmet Mounted Display with a directional tracking device This will alleviate the need to go 'head down' to access mission critical information The tracking device will enable accurate directional cueing for threat symbols and audio when the aircrew is not looking directly ahead

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26 Kindley, D , "F/A-18 AWL Aircrew Daily Report number F2/488", NAWC China Lake, CA 1999

27 Huffman, G , "F/A-18 AWL Aircrew Daily Report number F2/483", NAWC China Lake, CA 1999

28 Huffman, G , "F/A-18 AWL Aircrew Daily Report number F2/490", NAWC China Lake, CA 1999

29 Huffman, G , "F/A-18 AWL Aircrew Daily Report number F2/491", NAWC China Lake, CA 1999

30 Huffman, G , "F/A-18 AWL Aircrew Daily Report number F2/492", NAWC China Lake, CA 1999

APPENDICES

APPENDIX A

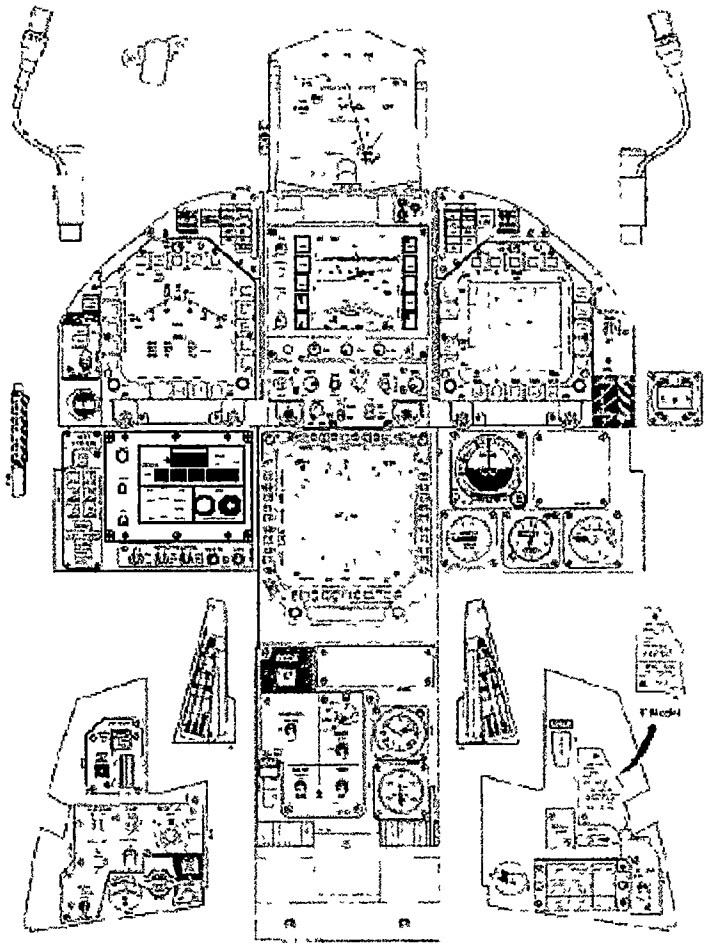

Figure A-1 Cockpit Layout of the F/A-18

Adapted from: Operation of the F/A-18 Avionic Subsystem for Aircraft with the 15C System Configuration Set, Naval Air Warfare Center, China Lake, California, 1999

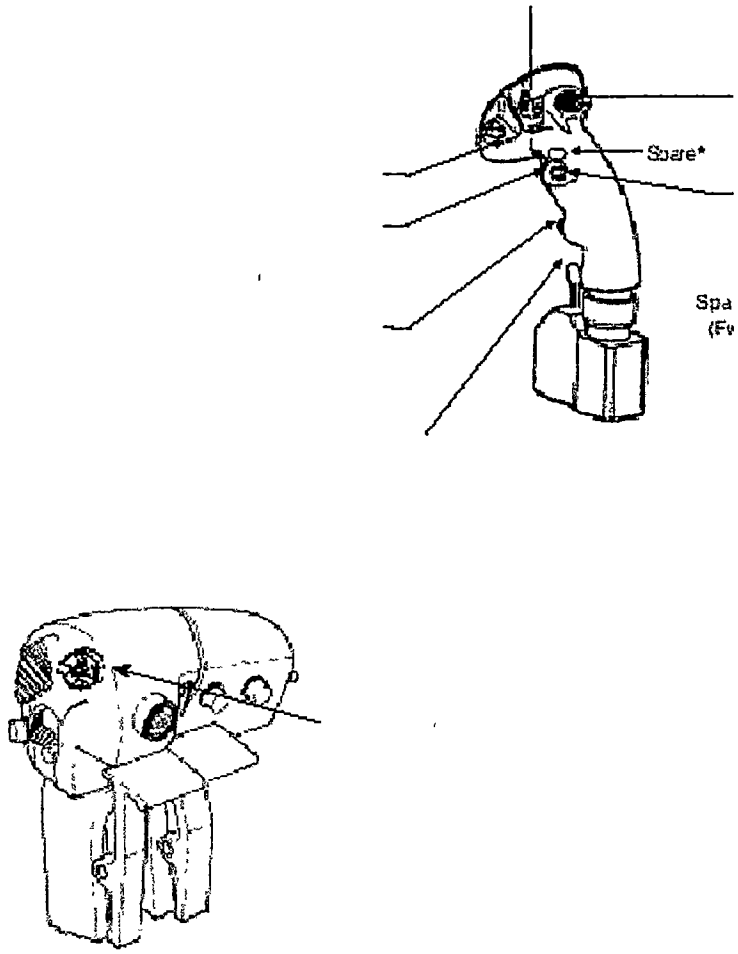

Figure A-2 HOTAS Controls

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

APPENDIX B

Rating Scale

1 = EXCELLENT – NO CHANGES NEEDED
2 = GOOD – COULD BENEFIT FROM SOME MINOR REFINEMENTS
3 = FAIR – WORKABLE, BUT NEEDS SOME MINOR IMPROVEMENTS
4 = NEUTRAL
5 = POOR – NEEDS SIGNIFICANT IMPROVEMENTS
6 = BAD – PROPOSED MECHANIZATION WOULD RESULT IN SOME OPERATIONAL DEGRADATION
7 = UNACCEPTABLE

Assigning a rating of 1-3 indicates subjective acceptability of that aspect of the design Assigning a rating of 5-7 indicates unacceptability of that particular aspect of the design A rating of 4 indicates no opinion either way for that particular aspect of the design

Questions

1 THREAT MANAGEMENT, SA, WORKLOAD
- 1 1 Did IDECM concept improve your SA, Workload, Threat Management capability?
- 1.2 What display formats or display symbology were most valuable in increasing your situational awareness?
- 1 3 What additional capabilities/data/improvements would be valuable to the pilot for improving SA and aiding in responding to threats?
- 1 4 What capabilities were not useful or of little value and should be deleted?
- 1 5 Would you agree that the threat data and the quality of the data presented increases the pilot's ability to manage pop-up threats?

2 SA FORMAT DISPLAY ISSUES
- 2.1 Rate the OVERALL effectiveness of the demonstrated SA Format symbology to enhance threat SA/management
- 2.2 Rate the acceptability of the use of line texture to enhance threat management/SA
- 2 3 Target Under Cursor data content includes. Threat ID, Mode, Range confidence, Trackfile contributors Which of these improves SA? Which are unnecessary?
- 2 4 Rate the acceptability of the Target Under Cursor Date Page Format Consider the operational utility of providing a data page capability
- 2 5 Rate the acceptability of the Inventory Status in the lower left data window
- 2 6 Rate the acceptability of the Beam Maneuver Cue on the SA format

Figure B-1 Design Simulator Evaluation Questionnaire

Adapted from: Besancenez, Roger, "Results and Minutes", Simulator Evaluation Session, St Louis, Mo., March, 1997

Aircrew Survey of F/A-18E and C Cockpit Environments

Explanatory Material

The purpose of this survey is to measure aircrew attitudes towards differences in the SA displays of the F/A-18E and C that may influence aircrew situational awareness. Please read each statement and circle your level-of-agreement using the following five point scale:

Statement Level-of-Agreement

1	2	3	4	5
Strongly Disagree	**Disagree**	**Undecided**	**Agree**	**Strongly Agree**

The tone of the statements *does not* imply the survey evaluators believe the E cockpit has more SA enhancing features than the C cockpit. *Your* responses, via the above scale, will decide that issue.

Most of the statements have a second five point scale (shown below) that asks for your input on the relevance of the statement feature to your SA. It is possible that some features between the displays *are* different but, in your opinion, have little bearing on your SA. This second scale will help evaluators break out the differences that aircrew believe are truly related to SA. We suggest you first indicate your level-of-agreement for all items, then go back and provide the SA relevance scores.

SA Relevance

1	2	3	4	5
Never important	**Not very important**	**Somewhat important**	**Very important**	**Critically important**

Figure B-2 Second Design Simulator Evaluation Questionnaire

Adapted from: "Results of Comparison Simulator Evaluation", China Lake, California, February, 1999

SA SCALE VALUE	CONTENT
1 – VERY GOOD	Full knowledge of aircraft energy state/tactical environment/mission Full ability to anticipate/accommodate trends
2 – GOOD	Full knowledge of aircraft energy state/tactical environment/mission Partial ability to anticipate/accommodate trends No task shedding
3 – ADEQUATE	Full knowledge of aircraft energy state/tactical environment/mission Saturated ability to anticipate/accommodate trends Some shedding of minor tasks
4 – POOR	Fair knowledge of aircraft energy state/tactical environment/mission Saturated ability to anticipate/accommodate trends Shedding of all minor tasks as well as many not essential to flight safety/mission effectiveness
5 – VERY POOR	Minimal knowledge of aircraft energy state/tactical environment/mission Oversaturated ability to anticipate/accommodate trends Shedding of all tasks not absolutely essential to flight safety/mission effectiveness

Figure B-3 China Lake Situational Awareness scale

Adapted From. Gawron, Valerie J., Weingarten, Norman C., Adams, Steven and Hughes, Thomas, "Verifying Situational Awareness Associated with Flight Symbology", AIAA, Aerospace Sciences Meeting and Exhibit, Reno, Nevada, 1999

VITA

Gregory Clark Huffman was born in Monterey, California on August 30, 1967 He graduated from George Mason High School in Falls Church, Virginia where he earned an International Baccalaureate degree He entered the United States Naval Academy in 1985 and earned a Bachelor of Science in History, graduating with honors and distinction in May, 1989 Following commissioning as an Ensign in the United States Navy, he received a Master of Arts in History from the University of Maryland in December, 1989 He then proceeded to Pensacola, Florida for flight training, completing the syllabus in 1992 He was assigned to fly the F/A-18 Hornet in Jacksonville, Florida In 1996 he was named F/A-18 Pilot of Year for Strike Fighter Wing, Atlantic Fleet Following completion of his fleet tour he was selected to attend the U.S. Naval Test Pilot School in Patuxent River, Maryland. Upon graduation from test pilot school he was assigned to his current billet at the Naval Aircraft Warfare Center, Weapons Division at China Lake, California where he serves as an F/A-18 developmental test pilot for the F/A-18 E/F aircraft