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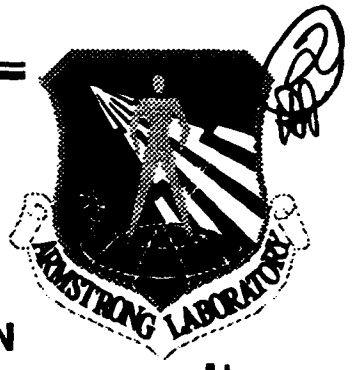

AN INFORMATION PROCESSING CLASSIFICATION OF BEYOND-VISUAL-RANGE AIR INTERCEPTS

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This research produced a descriptive classification of the task behaviors and cognitive processing associated with performing a beyond-visual-range (BVR) air combat mission. An F-15C defensive counter air mission scenario was analyzed to identify the critical tactical decisions required of the pilot, the information that must be processed in order to make these decisions, and the overt behaviors associated with pilots' information processing. The goal of this classification scheme was to determine observable behaviors that can be used as overt indicators of cognitive information processing. For future research purposes, the classification will provide a framework for identifying observable task behaviors that may be worthy candidates for developing and testing measures of performance. Such measures are essential for assessing the effectiveness of simulator-based training programs for enhancing the cognitive skills necessary for BVR employment.

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PREFACE

This effort represents a portion of the training technology objectives of the Armstrong Laboratory, Aircrew Training Research Division (AL/HRA). One of its goals is to develop and maintain enhanced job performance and combat readiness by identifying and demonstrating cost-effective ways of developing and maintaining new skills. The work described in this report was conducted under Work Unit 1123-25-11, Multiship Tactical Training Technology Evaluation, supported by Flying Training Research Support, Contract No. F33615-90-C-0005 with the University of Dayton Research Institute (UDRI). Dr. Herbert H. Bell (AL/HRA) was the technical monitor for this project.

The authors thank Dr. Wayne L. Waag (AL/HRA), Dr. Gary Thomas (UDRI), Dr. Bell, and Major Steve Ulosovich, EdD (USAF, Human Systems Division) for providing comments on an earlier draft. We also thank Mrs. Marge Keslin for preparing the final manuscript. Finally, we express gratitude to the F-15C instructor pilots at Nellis Air Force Base (AFB) who shared with us their time and expertise in support of this work.

AN INFORMATION PROCESSING CLASSIFICATION OF BEYOND-VISUAL-RANGE AIR INTERCEPTS

INTRODUCTION

Pilots of modern air superiority fighters, such as the F-15C, must train for an expanded combat environment that demands an even greater repertoire of skills than in the past. With the aid of modern sensors and stand-off weapons such as pulse-doppler radar, electronic identification (EID), and radar-guided missiles, much of air combat is conducted beyond visual range of the adversary. The principal objective of beyond-visual-range (BVR) employment is to successfully complete an air intercept--which begins when the F-15C flight detects a threat and commits to attack and culminates in either the launch of air-to-air missiles or in a within-visual-range (WVR) battle. During the BVR portion of an air combat mission, most of the pilot's knowledge of the enemy is provided by onboard sensors (mainly air-to-air radar) and communications. Using these various sources, an F-15C flight must actively acquire, assimilate, and interpret critical information to be cognizant of the situation and to make appropriate tactical decisions. As a result of its complex information processing demands, BVR employment requires extensive cognitive resource management and decision-making abilities, much like electric power plant operation (Bolt, Beranek, & Newman, Inc., 1981) or military command and control (Stubler, 1990).

With simulator technology advancing at a rapid pace, it is often suggested that multiship simulation be used to train pilots' cognitive processing for BVR employment. In fact, F-15C pilots have provided favorable evaluations of such training programs (Houck, Thomas, & Bell, 1989; 1991; Thomas, Houck, & Bell, 1990). While pilot opinion on such matters is persuasive, more objective data are needed to measure the effectiveness of training systems and methods. Scoring procedures are needed that reflect aspects of air combat performance that improve as a result of simulator-based training. Because of the substantial information processing demands of modern air combat, these measures must address cognitive processes such as decision making, situation assessment, problem solving, cognitive resource management, and flight coordination. These measures can then be used to evaluate the efficacy of simulator technologies and training methods for BVR employment.

The purpose of the present research was to take the first step in developing measures of performance for BVR air combat. This first step involved a descriptive analysis of the task behaviors and cognitive processing associated with performing a BVR air combat mission. Our analysis classified the critical tactical decisions required of the pilot, the information that must be processed in order to make these decisions, and the overt behaviors associated with pilots' information processing. The virtue of this

classification scheme is that the observed behaviors may be used as overt indicators of covert information processing. For future research purposes, the classification will provide a framework for identifying observable task behaviors that may be worthy candidates for developing and testing measures of performance.

Performance measurement research, in particular, has been troubled by several persistent and fundamental problems: (a) determining the covert aspects of cognition that affect complex human performance, (b) developing general theories of human performance that are applicable to real-world tasks, and (c) establishing criteria to assess operational performance under naturalistic task conditions (Jones, Hennessy, & Deutsch, 1985; Vreuls & Obermayer, 1985). In response, the National Research Council has recommended a strong course of action for performance measurement research: "Used in concert, analyses of cognitive processes and knowledge and their expression in human performance models provide a strong mechanism for guiding research on behavioral issues in simulation and translating the results into design practice" (Jones, et al, 1985, p. 45). In the same vein, Vreuls and Obermayer (1985) offered several practical suggestions for measuring complex human performance that we have followed in our approach to the present research: (a) conduct a thorough front-end analysis of behavioral requirements and cognitive processing of the task at hand, (b) specify expected levels of expert performance in the operational environment, and (c) use the expertise of subject matter experts (SME) throughout the research, including measuring performance through the development of structured observational techniques.

APPROACH

We began by analyzing the BVR intercept portion of a defensive counter air (DCA) mission scenario with the purpose of eliciting the critical aspects of performance required to achieve mission objectives. This mission scenario was selected from those used in the earlier evaluation of simulator-based BVR air combat training conducted by Houck et al. (1991). A more detailed description of the simulator system supporting this mission scenario can be found in McDonald, Broeder, and Cutak (1989).

Our mission analysis involved a four-step process. We first partitioned the mission scenario into the four sequential phases shown in Table 1. The phase delineations and definitions that we arrived at are similar to that of Kacena (1985)[1] and are based on

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[1]USAF Fighter Weapons Review is not an authorized source of official US Air Force policy or procedures.

Table 1. Phases of Beyond-Visual-Range Air Intercept: Defensive Counter Air Mission

	PHASE	DESCRIPTION
I	Combat Air Patrol (CAP)	CAP orbit formation
II	Ingress/Intercept	CAP departure to approximately 20* nmi from the threat
III	Beyond-Visual-Range (BVR) Attack	Within approximately 20* nmi of the threat to visual range
IV	Merge and Post-Merge Operations	Short-range attack or BVR reattack options

*Ranges are notional, based on the specifics of the given simulated scenario (i.e., altitude, weapons, threat types) reported in Houck, Thomas, & Bell, 1991.

the changing goal and task structures over the course of mission execution. Next, we identified the critical tactical decisions required of the pilot to attain the goals within each phase. Finally, we specified the information that is necessary to make each decision and determined the overt behaviors or activities that the pilot performs to obtain this information or to fulfill the mission objectives. As such, the performance of these behavioral activities provides, albeit at a broad level, observable indications of the pilot's decision making and information processing.

Subject Matter Experts

All aspects of the development of this classification involved extensive interaction with SMEs. The third author of this report, a recently retired USAF fighter pilot, served as the primary SME, and provided the major source of information for the initial analyses and classification. This SME graduated from the USAF Fighter Weapons School, was a former aggressor pilot, and had extensive fighter (2,100 hours in F-4 and F-5) and combat experience (350 F-4 hours). In addition, he has had significant

experience in directing and conducting operational tests and evaluations of advanced tactical weapons and systems.

An additional six SMEs were employed to critique and refine the results of our initial analyses and to verify the accuracy and completeness of the final classification. These SMEs were active-duty USAF F-15C instructor pilots assigned to Nellis Air Force Base. Each SME had over 1,000 fighter aircraft hours and graduated from the USAF Fighter Weapons School.

Scope of Classification

The F-15C is employed in several types of air superiority missions for both offensive and defensive counter air missions (Shaw, 1985). We focused on the BVR segment of a single DCA mission scenario because it is a primary F-15C mission and it requires most of the offensive and defensive capabilities of the F-15C weapons system. The purpose of the DCA mission is to defend a military asset against enemy air attack. The scenario for the DCA mission analyzed for this effort (see Fig. 1) was a "point defense" of a surface target involving a two-ship flight[2] of F-15Cs (i.e., flight leader and wingman, supported by either an airborne or ground-based air weapons controller [AWC]). The flight's objective was to defend a ground target against a strike package composed of two MiG-27 fighter/bombers escorted by four MiG-29 or Su-27 fighters. Each F-15C carried a standard combat load of four AIM-7M radar-guided missiles, four AIM-9M infrared missiles, and 940 rounds of 20 mm ammunition; enemy aircraft were supplied with appropriate fuel and weapons stores. The F-15C flight's mission objective was to prevent the enemy from bombing the surface target. This objective could be accomplished by shooting down the bombers, forcing them off course, or forcing them to defend themselves, thus requiring them to jettison their bombs away from the target. The four BVR intercept phases for the DCA mission scenario used in our classification are shown in Table 1.

Mission Analysis

In order to classify any domain of human performance, it is necessary to first identify and describe the critical activities required of the operator to successfully complete his or her

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[2]The term "flight," in standard Air Force usage, refers to a unit of four aircraft which is composed of two "elements" with two aircraft in each. For the analysis presented herein, however, we refer to the two-ship unit of F-15Cs as a "flight." The main reason for using this terminology is that the two-ship F-15 unit in the given scenario operates independently as would a four-ship flight. Use of the term "element" throughout this report would erroneously imply that the two-ship unit in question may be subordinate to additional flight-level command.

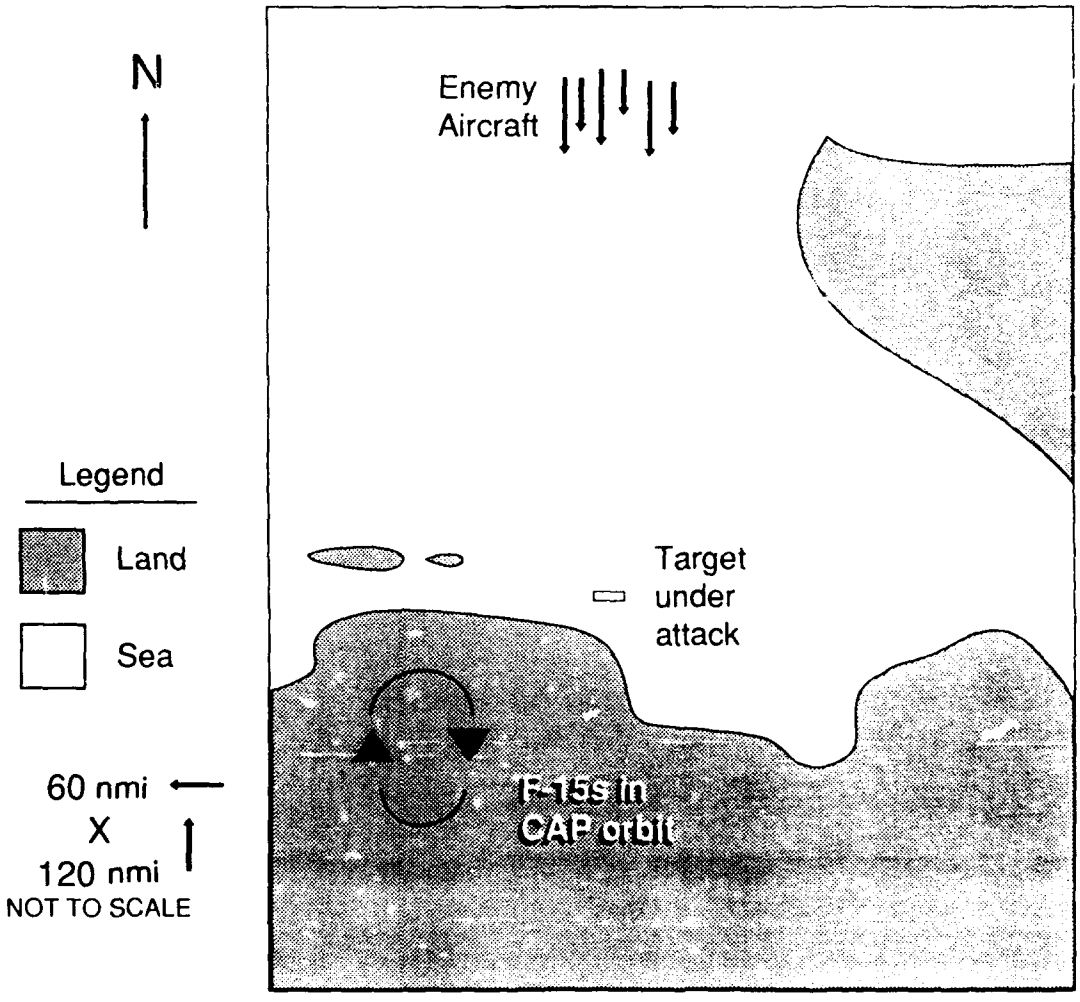

Figure 1
Starting Conditions for the Defensive Counter Air Scenario

mission. Our mission analysis was conducted to serve this purpose. It focused on the eleven critical BVR task categories, shown in Table 2, that in our previous research were rated by F-15C pilots as being most amenable to training in multiship simulations (Houck, et al., 1989, 1991; Thomas, et al., 1990).

Based on a review of Air Force air-to-air combat employment and training documents (see Appendix A) and interviews of experienced F-15C pilots, we produced an initial profile of tasks required in a BVR air intercept as specified in a standard DCA mission plan (see Appendix B). This profile served as a starting point for a more extensive analysis of mission performance which was accomplished with significant input from our primary SME. For each mission phase, we identified the significant types of decisions required of the flight, the information required for making these decisions, and the activities performed to acquire this information. The entire set of critical pilot decisions and activities included in this classification are listed in Appendix C, Tables C1 and C2. For the purposes of this classification, we define activities as a broad class of behavior, composed of an interrelated sequence of specific actions performed to achieve a common goal. The activity of "operating onboard sensors," for example, would be composed of several specific actions including adjusting the radar controls to acquire the threats, visually monitoring the effect of these adjustments, and locking the radar onto targets. After several iterations of analysis and review, a draft mission analysis description was created and was then submitted for review by additional SMEs to ensure accuracy and completeness.

OVERVIEW OF BEYOND-VISUAL-RANGE AIR COMBAT EMPLOYMENT

Throughout the course of a BVR air intercept, the pilot attempts to comprehend the tactical situation in terms of the spatial and temporal relationships between his[3] flight, other friendly flights, and the enemy. To formulate this assessment of the situation, the pilot must integrate information from sources both internal and external to his aircraft. Furthermore, the pilot must develop and maintain this comprehension of the situation while engaging threat aircraft that are maneuvering to confuse and negate his attacks, as well as to counterattack. The time constraints imposed on the pilot are tremendous given that his aircraft is

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[3]The masculine pronoun, "his," is used in reference to F-15C pilots throughout this report rather than the non-sexist, "his or her," because at the publication date of this report, women in the USAF are not eligible to be pilots of combat aircraft including the F-15C. Please note that "his or her" is used in reference to air weapons controllers whose numbers include both men and women.

Table 2. Critical Beyond-Visual-Range Air Intercept Tasks

Mission Planning (pre-mission briefing, tactics, operations, and post-mission debriefing)
Intraflight Communications
Air Weapons Controller Interface
Radar Employment--Search
Radar Employment--Sorting and Sampling
Electronic Identification
Electronic Countermeasures
Tactical Intercept
Missile Employment
All-Aspect Defense
Separation

closing on the threat aircraft at approximately 20 nmi per minute. A model of this BVR information processing, adapted from a generic human performance model developed by Pew and Baron (1978), is depicted in Figure 2. As shown, pilots monitor information sources, assess the tactical situation, coordinate with other pilots in the flight and with air weapons control, and decide on and execute courses of action. All of these processes are guided by the mission plan which has been developed to fulfill the objectives of the mission.

The key to effective BVR employment lies in comprehending the three-dimensional spatial layout of the tactical situation. To achieve this state, a pilot must integrate information from various sources within the cockpit: offensive data on the left side (i.e., air-to-air radar display), defensive data on the right side (i.e.,

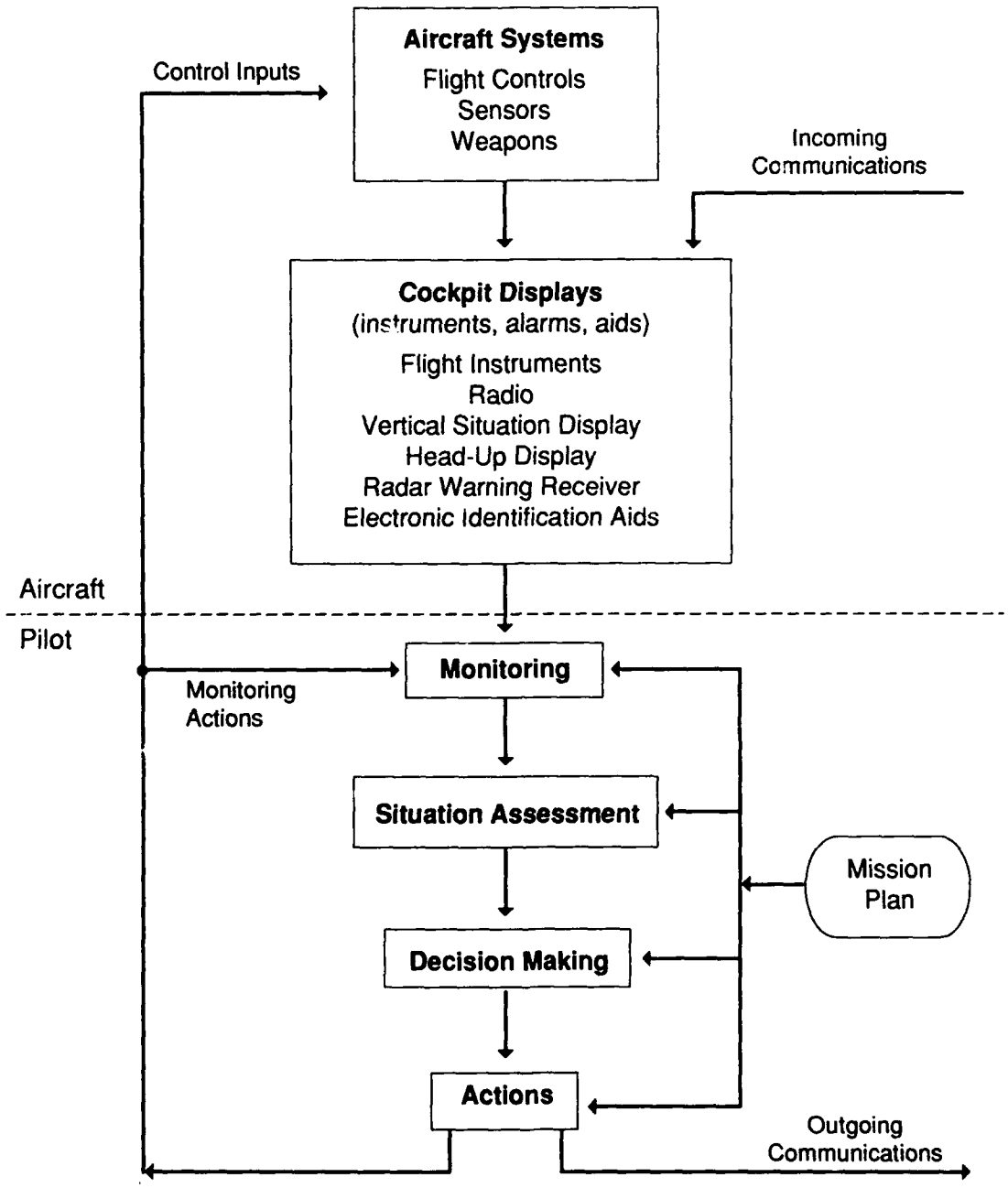

Figure 2
Model of Pilots' Information Processing in BVR Air Combat
(Adapted from Pew & Baron, 1978)

radar warning receiver [RWR] and electronic warfare warning system displays), and navigation and aircraft status information spread throughout the cockpit. Of these, pilots consider the air-to-air radar display the most important source of threat-related information. Radar information is provided to the pilot in a two-dimensional format (i.e., azimuth and range, along with some digitally presented information such as altitude and closure rate). During the BVR portion of the mission, the radar system represents the pilot's only direct window on the threat. Furthermore, pilots consider it to be the most trusted and reliable source of information, as well as the only system over which they can exert real-time control.

The flight lead and wingman perform these activities in parallel, with the flight leader having responsibility for integrating their separately derived, and possibly contradictory, information into a composite representation of the tactical situation. For example, the flight leader may have to evaluate whether the target on his nose at 20,000 ft altitude is the same or a different target that his wingman has at 10° azimuth and 20,000 ft altitude. Additional data are available from the AWC, on the ground or airborne, who provides general information regarding the overall tactical situation. The flight leader's task of integrating AWC information with that from the cockpit is not straightforward because of the difference in update rates of the F-15C radar compared to AWC radar (i.e., the pilot's radar is updated every 2 to 3 s whereas the AWC's radar display is updated only every 10 to 15 s).

Cognitive Processing Characteristics

The inherent nature of the BVR combat environment places enormous demands on the pilot's cognitive resources because of task saturation, time compression, and incomplete or unconfirmed information. According to Wickens (1984), these resources are limited; when task demands exceed the available resources, the pilot either suffers a decrement in task performance or must prioritize the tasks and execute only those that can be supported by available cognitive resources. Another dimension of Wickens' (1984) model is that there are multiple pools of cognitive resources, such that each pool is specialized for processing different cognitive demands. As a result, when the pilot must perform two tasks simultaneously that draw from the same pool, they will interfere with one another if their joint requirements exceed the available resources. Conversely, when two tasks performed simultaneously draw from different resource pools, they are less likely to have mutual interference and each may be performed as well together as separately.

The implication of this model for BVR employment is that, for any given tactical situation, the pilot must learn to prioritize

tasks in terms of (a) their importance for attaining mission objectives and survival, (b) the extent to which they can be performed concurrently, and (c) the total cognitive resources available for each task. The result of an appropriate prioritization strategy is that the pilot will be able to allocate available resources to successfully complete the most critical (and highest priority) activities. As an overview of BVR employment, activities which require one of the following will demand greater resources to be accomplished successfully: integrating and interpreting information derived from several sources, maintaining situation awareness, and adjusting the mission plan in response to the changing threat situation.

Information Integration and Interpretation

Many activities required in BVR air combat place the responsibility for integrating information with the pilot instead of the information sources themselves. When competing task demands require that the pilot forego some aspect of a task, he can do so by ignoring some sources of information or by using heuristics to expedite the integration of information he does acquire (Klein, 1989). The sources of information (sensors and radio communications) most likely to be ignored are those that usually provide less information, those that are often redundant with other sources, or those that tend to be unreliable under the given circumstances. The heuristics the pilot may substitute to replace more complex integrations are rules of thumb, instances from prior experiences in BVR engagements, two-dimensional instead of three-dimensional analysis, and pattern recognition (Klein, 1989). Both methods of shedding resource demands--abbreviated information or heuristics--often yield satisfactory results in typical situations. Nevertheless, they can be disastrous in novel or unexpected circumstances.

Situation Awareness

Maintaining accurate and timely awareness of the ongoing and evolving situation is a critical prerequisite for most of the activities in BVR air combat. Situation awareness has a variety of meanings; it is used here to describe the ability of the pilot to know what is going on with his aircraft, his flight, other friendly forces, and the threat forces. Situation awareness is updated as needed by obtaining and integrating new information and by monitoring the consequences of one's own actions. In the complex BVR combat environment, maintaining sufficient situation awareness can require all the cognitive resources that the pilot can muster. When these resources are not available for this critical function, poor situation awareness results as the pilot misses essential information, forgets critical parameters, or fails to update current knowledge of the situation quickly enough. In the rapidly moving world of the BVR battle, these errors which result from overloading the pilot's available cognitive resources can be fatal.

Mission Plan Adjustments

Competing activities and time-pressure overwhelm the pilot's limited resources and preclude examining all reasonable alternatives to the current mission plan. Therefore the pilot must rely on streamlined decision-making strategies that can be executed with a limited allocation of cognitive resources. The most common of these strategies is called "satisficing" (Klein, 1989). Satisficing is a means of picking a plan which appears to be good enough to accomplish the goal, without expending the resources necessary to search for the optimal plan. Such satisficing solutions are essential for maximizing limited cognitive resources during the fast-moving BVR battle; however, they must be acquired and refined through previous experience or training. Typically, pilots specify contingency plans in their pre-mission plan so that adjustments can be made on-the-fly in response to anticipated situations.

CLASSIFICATION OF BEYOND-VISUAL-RANGE AIR INTERCEPT

The classification is documented in two formats. The format presented in this section provides a detailed description of the BVR air intercept in terms of operational employment aspects as well as the nature of the cognitive information processing in which the pilots engage. A tabular overview of the entire classification is presented in Appendix D. Both formats describe and classify the decisions, information requirements, and activities involved in each phase of the BVR air intercept within the DCA mission scenario.

Phase I: Combat Air Patrol

Phase I begins with the enemy strike package located approximately 60 to 80 nmi north of and heading toward its intended target. At this point in the DCA mission, an F-15C flight frequently elects to fly in a formation known as a combat air patrol (CAP) orbit. The CAP formation usually involves a counter-rotating "racetrack" orbit (i.e., a circular route with one F-15C pointing toward the threat at all times). As a result, one of the two aircraft is always in a position to monitor the threat with onboard radar. The CAP orbit provides the flight with certain tactical advantages: the aircraft are already deployed in the air, anticipating an attack, and prepared to engage the enemy. It also permits the flight sufficient time to use radar to search for, detect and monitor all targets within the expected attack axis. The location of CAP orbit is usually away and slightly behind the defended point to prevent cuing the enemy as to the target location and to provide additional distance for the F-15Cs to regroup into tactical formation prior to initiating the intercept. The flight may forego the CAP orbit, however, if it has (as in the present mission) AWC coverage and a well-defined axis of threat attack.

The relative disposition of the F-15C flight to the threat in Phase I is primarily neutral because neither is within weapons parameters. The considerable distance of the threat allows the flight ample time to process information and make decisions. On the other hand, the distance prohibits the flight from obtaining more than coarse information regarding the threat. Until more specific information is forthcoming as the threats get closer, the F-15C flight's expectations of the situation and its mission plan remain the primary influence on its actions. The foremost decision to be made in this phase is choosing the optimal time to depart the CAP orbit and begin the ingress/intercept phase. This decision is based on the flight's mission plan, which stipulates the tactical criteria for initiating the attack, and on the flight's ability to recognize whether these criteria have been met.

Decisions

The following are critical decisions that the F-15C flight should make in Phase I:

- Perform the mission plan as briefed or make adjustments
- Use onboard or off-board sources of information to perform search activities
- Maintain or depart CAP orbit
- Communicate or not

Information

In order to make these decisions, the flight needs to obtain the following information:

- General threat location(s), relative to a fixed point
- Number of threat formations
- General altitude of threat formations (i.e., high, medium, low)
- General direction of threat movement
- Differentiation of enemy bomber from fighter formations

Information about the F-15C flight should also be monitored and includes:

- Relative location of wingman[4] (if not in visual formation)
- General operating status of wingman relative to mission plan

Activities

Communicate with Air Weapons Controller (AWC). Typically, the AWC alerts the flight regarding the presence of threats and is the principal source of general information for supporting the flight's initial threat observation. While in the CAP orbit, at this considerable range from the threat, pilots rely on AWC for cues to orient their radar search patterns. In addition, AWC provides the initial indications of enemy formations and composition (e.g., low, slow aircraft may indicate bombers).

Communicate with Wingman. Initially, little communication between pilots should be necessary because the mission plan governs the flight's activities and AWC provides the primary information. At this point, both pilots are performing radar activities in parallel in accordance with their assigned responsibilities. Communication in this phase should be descriptive, relaying what each pilot discovers while employing onboard sensors to observe and collect data regarding threat aircraft. Directive commentary is required only when adjusting the mission plan, which should not be necessary at this early stage.

Operate Onboard Sensors (i.e., radar, EID). Information collected from onboard sensors is primarily used to determine the current status of the mission and to interpret the threat situation. Initially, the F-15C flight's primary source of threat information is the AWC. Guided by the AWC-provided information, each pilot controls his own radar system to search for threats in his assigned area of responsibility, as specified by the mission plan. To perform this activity, the pilot must select the appropriate modes of radar operation and use search techniques that assure proper coverage of azimuth, elevation, and range.

As they search for, detect, and monitor the threats, pilots perform "scope interpretation," which involves decoding information on the radar display to understand the relative positioning of threats and to infer their intentions. Pilots use a technique

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[4]The term "wingman" is used in two respects throughout this report. When referenced in conjunction with the flight lead, it refers to the specific sense where the wingman is in a subordinate position in relation to the flight lead. In contrast when the term "wingman" is used by itself, as in this example, it simply refers to the general sense where the wingman is the other pilot in the flight.

called "sampling" in order to obtain more detailed information about each threat formation. Sampling is conducted by locking the radar onto each threat formation or aircraft individually to extract more detailed information (i.e., specific altitude, closing velocity, and direction of movement). EID systems may also be used to obtain supplemental information to help clarify the threat situation, such as in discriminating bombers from fighters.

Integrate Onboard Data. Interpreting the threat situation requires the pilots to develop and maintain comprehension of the spatial layout of the engagement. To accomplish this goal, they must be cognizant of the modes selected for their systems, observe threat information provided by the sensors, and integrate all this to conceptualize the current threat situation.

Correlate Onboard with Off-Board Data. Phase I begins with the F-15C flight using the AWC as a primary off-board source of threat information. Initially, the flight focuses its radar scan patterns to the general threat location provided by the AWC. By the close of Phase I, however, the flight is nearly self-sufficient in terms of obtaining threat information and AWC becomes a secondary information source.

Adjust Mission Plan. Phase I should not require substantial changing of the mission plan. The separation between the F-15C flight and the threat is still great enough to minimize time constraints. Any tactical changes affecting the mission plan, however, must be approved by flight lead (e.g., criteria for leaving CAP orbit). Changes that do not affect the overall mission plan (e.g., radar mode selection, EID system selection) need not be approved by flight lead.

Fly CAP Orbit, Fly Formation, and Navigate. In Phase I, these activities mainly involve executing routine procedures set forth in the mission plan.

Phase II: Ingress/Intercept

Phase II begins when the flight leaves the CAP orbit and is characterized by the pilots concentrating on their onboard sensors (i.e., radar, RWR, EID) to understand the composition and intentions of the threat formations. With the increasing level of detail provided by the radar, the flight lead and wingman begin to integrate the results of their individual radar search and sample activities to form a coherent comprehension of the overall threat situation. This process of developing and updating a mutually agreed-upon mental picture of the entire threat situation is called radar sorting. Sorting requires that the flight distinguish all potential targets in terms of azimuth, elevation, range, and velocity. This information should then be used to ensure that the flight targets the maximum number of threat groups or threat aircraft. Proper communication of radar information ensures that

both pilots and the AWC share and maintain an identical mental picture of the continually changing engagement. This mental picture of the entire situation is especially important because neither pilot's individual radar screen may display the entire engagement at any given time.

The principal decision for the flight in this phase is selecting the threat formation(s) to attack. While attacking, the flight must not only control the attack profile, but must also reevaluate its decisions in relation to the actions of the enemy fighters attacking them. Since the F-15C flight also may be attacked during this phase, the pilots must begin to maintain an optimal balance between offensive (i.e., attack) and defensive (i.e., survival) operations. By the end of Phase III, the flight should be in position to launch BVR weapons.

Decisions

The following are critical decisions that the F-15C flight needs to make during Phase II:

- Perform current mission plan or make adjustments
- Use onboard or off-board sources of information to perform search activities
- Select threat formation(s) to attack
- Commit attack against targeted threat formation(s)
- Communicate or not
- Employ electronic countermeasures (ECM) or not
- Abort attack(s) against targeted formation(s)
- Defend against enemy attack(s)

Information

In order to make these decisions, the pilots must obtain the following general threat information:

- Changes to previous information
- Direction of threat movement
- Number of threat formations
- Location of threat(s), relative to a fixed point

- Geometric relationships between F-15C flight and threat(s)

More specific threat information should be acquired and includes:

- Range to nearest threat
- Azimuth of threat(s)
- Altitude of threat(s)
- Identity of threat aircraft by type (e.g., Flanker)
- Observed threat tactics
- Weapons launches against F-15C flight

Information concerning the F-15C flight must also be monitored. This information includes:

- General location of wingman (if different than planned)
- Tactic being executed (if different than planned)
- Operating status of wingman (i.e., offensive or defensive)

Activities

Operate Onboard Sensors (i.e., radar, EID). During Phase II, the flight tries to maintain awareness of the evolving threat situation and the status of the mission. The pilots continue to use radar to observe all threat formations within their area of responsibility. EID systems should be employed to identify the bomber formation and to determine the types of fighters that may be encountered.

The flight leader's decision to attack should be based on priorities established in the mission plan (e.g., attack bombers first, attack as far away as possible from defended point) and on information provided by onboard sensors and communications from the wingman and AWC. This decision requires information that is of sufficient detail for employing weapons. Such information is obtained by locking the radar onto individual target aircraft. A final lock is not yet necessary; rather, the pilot should continue to differentiate (i.e., sort) individual aircraft according to their geometric relationships within the targeted formation. Sorting is similar to sampling except that pilots may use different radar modes (e.g., high data-rate track-while-scan mode) to obtain more detailed target-related data.

React to Electronic Countermeasures (ECM). During this phase the F-15C flight's radars may be jammed by the enemy. Because the radar is the flight's most indispensable source of information, the demand on cognitive resources increases dramatically when jamming degrades the radar information. To counter ECM, the pilots must observe the jamming, interpret its effect on their radars, decide what action to take to negate the ECM, and determine if changes to the offensive plan are needed. As a result, the pilot must engage in extensive problem-solving activities which may interfere with the performance of other activities.

Integrate Onboard Data. Detailed information gathered from onboard sources must be integrated to construct a composite three-dimensional mental image of the spatial disposition of the threat. This activity is necessary as well as difficult, because no single display contains or combines all information required to identify the status of the mission and interpret the threat situation. Therefore, the flight leader must obtain and interrelate all relevant information from its disparate sources and then communicate an interpretation of the overall situation to the wingman and AWC. Because the flight's knowledge of the tactical situation needs to be periodically updated and verified as the threat situation changes, this activity must be performed on an iterative basis. In general, this type of information integration is among the most resource demanding processes (Rasmussen, 1986).

Communicate with Wingman. Since the only means of relaying threat information between flight members is by radio, it is essential that this information exchange remain open. Communications jamming by the enemy may be defeated or reduced through use of briefed brevity codes. The flight's dialogue should center on a descriptive summary of the results of each pilot's information gathering and interpretation. Directive communication may also be necessary if changes to the mission plan are made; if no directive communications are made, the pilots should assume that the existing mission plan remains valid.

Communicate with AWC. As the F-15Cs and the threat aircraft converge during this phase, AWC becomes less accurate for threat information and becomes a secondary source of information. Nevertheless, the AWC remains a useful source of information regarding the overall situation, especially since each individual F-15C narrows the focus of its radar to specific assigned areas. The AWC maintains responsibility for providing general information of the entire fight, monitoring untargeted threats, and detecting threats not previously observed. To avoid adding to the pilots' already heavy workload, the AWC should provide only essential information that has not been exchanged between the pilots or updates of previously transmitted data. In addition, AWC should communicate when the flight's communicated information is inconsistent with that on the AWC's scope. Although this activity requires minimal cognitive resources for the pilots, they must

allocate sufficient attention to detect, comprehend, and acknowledge these communications. Since humans allocate less attention to infrequently used information sources (Hockey, 1970), needed information provided by the AWC during this phase may be missed, overlooked, or ignored by the pilots.

Correlate Onboard with Off-Board Data. Starting in Phase II, correlating information from various sources becomes a demanding task. This activity represents 'conflict resolution' for the pilots, whereby they attempt to determine the validity of their conceptualization of the threat situation and the status of the mission. To accomplish this goal, each pilot compares and contrasts his information with that obtained from sources external to his own sensors (e.g., AWC, wingman, military intelligence). This process is complicated by the human tendency to retain the first hypothesis supported by incoming evidence (Tversky & Kahneman, 1974). The pilot may later have difficulty rejecting this initial view of the world in favor of one more fully supported by subsequent information. The pilot samples information from a continuous stream of potential information being presented by his displays. Sometimes the sample favors one conclusion and sometimes another. For example, the momentary airspeed of a threat aircraft may favor the decision that it is a bomber; however, a later momentary sample indicating a faster airspeed may favor the decision that it is a fighter. In addition, information is stochastic and there is random fluctuation in the accuracy of the information sampled by the pilot from his displays. This random fluctuation, coupled with deliberately falsified enemy information and a changing tactical situation, means that the task of determining reliable information and drawing valid conclusions demands large amounts of cognitive resources.

Fly Offensive Profile (i.e., intercept, formation). After deciding which threat formations to attack, the flight must become more specific in controlling the intercept geometry. Until this point, employing general rules of thumb (e.g., offset west or east, stay at high altitude) was sufficient. Now, however, controlling the intercept geometry of the engagement is crucial for maintaining an offensive posture and achieving advantageous weapons parameters. Proper radar scope interpretation is essential for the accurate and timely updating of threat tactics and reactions. The pilots must also remain aware of their location relative to the defended point.

RWR Interpretation. The RWR provides an additional source for threat indications and is the only onboard system which informs the pilot of detection and attack by a BVR threat. Based on RWR information, the pilot can determine the status of the mission in terms of whether he is offensive or defensive. At this point in the mission, the pilot's survival depends on timely detection and correct interpretation of RWR indications. Since, however, the RWR is passive and does not require pilot control, pilots must periodically attend to this system. While only minimal cognitive

resources need be allocated to monitoring the RWR, once an indication occurs it must be given immediate attention.

Fly Defensive Profile (i.e., ECM, chaff, and maneuvers). This activity may not be necessary if offensive operations are successful. If the attack is not successful, however, defensive actions may become the only activities that the flight performs for the remainder of the engagement. Upon determining that he is in a defensive posture, the pilot must evaluate alternative actions. While performing the selected defensive action, the pilot must assess its effectiveness and decide whether to resume offensive operations.

Adjust Mission Plan. In this phase, adjustments center on the execution of the purely offensive plan, the purely defensive plan, or some mixture of the two. For example, the wingman may be forced to become defensive while lead maintains an offensive posture. All flight members and AWC must accurately communicate their perceptions and intentions, if different from the mission plan, so that the mission plan can be appropriately modified. After the flight leader determines that adjustments are required, he must decide on what should be accomplished, evaluate alternative courses of action, and formulate a new plan. Usually these adjustments are derived from contingency plans developed as part of previous mission planning. Nevertheless, it is essential that all members of the flight clearly understand and acknowledge these revisions to ensure execution of the same plan.

Fly Attack Formation and Navigate. Activities in Phase II must be accomplished within the context of cooperation within the flight. If outside of visual formation, navigation-related communication should be expressed in reference to the "bull's-eye" position (a fixed point on the ground), which is usually set as the defended target or the CAP location. The use of the bull's-eye prevents confusion among the pilots and AWC and avoids additional calculation demands during this period of heavy workload.

Phase III: Beyond-Visual-Range Attack

In Phase III, the balancing between offensive and defensive operations increases in importance, the sequence of events becomes more rapid, and decision events occur more frequently. As the flight draws within approximately 15 nmi from the threat, determining the precise location of each target is essential for obtaining radar locks and weapons parameters. Weapons employment is the culmination of a decision-making process involving target identification, weapons selection, and attaining optimal weapons parameters. The flight members must coordinate their individual attacks to ensure they respond to all threats and to prevent inadvertently attacking the same threat. Defensive considerations are also important, especially after the pilots have launched AIM-7M radar-guided missiles.

The events of this phase are even more difficult to predict and sequence than in the previous phases. The flight's activities may be more dependent on what has transpired in the previous phases than on the original mission plan. If all has gone according to plan, however, the flight will launch AIM-7M radar missiles and then proceed to short-range operations using AIM-9M infrared missiles and guns. Conversely, if radar sorting procedures did not differentiate each individual aircraft, the flight may have to continue sorting into closer range of the threats to improve the ability to isolate targets. As a result the flight may opt to forego BVR missile employment and proceed directly to short-range operations.

Decisions

The following are critical decisions that the F-15C flight should make during Phase III:

- Perform current attack plan or make adjustments
- Select target(s) from threat formation(s)
- When to launch AIM-7M missile(s), (i.e., fire point selection)
- Abort attack or not
- Fly defensive profile or not
- Reattack or not
- Communicate or not

Information

In order to make these decisions, pilots need to update previously received threat information. This information includes the following:

- Range, altitude, and azimuth of closest threat
- Range, altitude, azimuth, and aspect of target(s), (if target is not closest threat)
- Untargeted threats
- Identity of threat fighters
- Threat tactics
- Threat reactions to F-15C flight's missile launches

- Results of F-15C flight's missile launches (i.e., chaff, ECM, maneuvering)
- Weapon launches against F-15C flight

Information concerning the F-15C flight must continue being monitored and includes:

- Location of wingman (if different than planned)
- Tactic (if different than planned)
- Status of wingman (i.e., offensive, defensive, or reattacking)

Activities

Operate Onboard Sensors (i.e., radar, EID). The key to success in this phase is the flight's ability to complete radar sorting prior to reaching maximum missile launch range. In addition, each pilot has responsibility for monitoring his assigned airspace for undetected threats. If the sorting of the threat formation is successful, each pilot should use the radar to select the appropriate target, lock on, and fire AIM-7M missiles after achieving acceptable weapons parameters. Successful target sorting is dependent on the pilot's proficiency in radar scope interpretation and mode selection. Sorting is difficult within 15 nmi of the threat because of the rapid changes in threat azimuth and altitude. The pilot should attempt to attain weapons parameters, achieve proper guidance for the missile's time of flight, and monitor for threat maneuvers that could defeat a missile launch. EID systems are usually not relevant unless previous attempts have been unsuccessful.

React to ECM. As in Phase II, an effective reaction to ECM requires the pilot to detect and identify the type of jamming and predict its effect on his systems.

Interpret RWR. Accurate and timely RWR interpretation is essential for successful Phase III employment. Information provided by the RWR helps the pilot decide whether to continue offensive actions or to execute defensive actions for survival. The pilot must discriminate whether radar locks onto his aircraft are by the threat or his own wingman (i.e., "buddy-spikes"). Buddy-spikes must be promptly communicated to avoid fratricide. Monitoring the RWR requires minimal cognitive resources; however, under pressure from competing task demands, this minimal attention may not be allocated. If the pilot does detect an RWR indication, the immediate demands for resources will peak as the pilot decides whether to switch to defensive operations.

Integrate Onboard Data. This activity is the same as in the previous phases except now the rate of change and increased maneuvering of the F-15Cs and threats can cause considerable confusion integrating data to make tactical decisions. Klein (1989) contends that this time-pressured decision making is characterized by heavy reliance on previous experience and very limited consideration of alternative plans of action. As Klein (1989) has found in other domains of expert performance, experienced pilots may be able to use pattern recognition as a strategy to integrate the separate sources of information. Based on the extent of training and experience, the pilot may be able to avoid extensive analysis by recognizing familiar patterns in the current information that were salient in similar circumstances in previous missions. Virtually automated application of prior solutions allows the proficient pilot to execute mission activities within the conditions of time-pressure and cognitive overload experienced during this phase.

Correlate Onboard with Off-Board Data. During Phase III, information from onboard sources is far superior to that from the AWC (see "Communicate with AWC" below). As a result, little correlation of onboard and off-board data is performed. Use of off-board information is likely to be omitted as resources are increasingly required by demands from concurrent activities. Since this information should be used only for confirmatory purposes, it may be relegated to a less important role and may seldom be processed.

Fly Offensive Attack Profile. In Phase III, the primary goal of the offensive profile is to obtain valid weapons parameters for launching BVR missiles. Attaining weapons parameters requires a mixture of aircraft control, radar scope interpretation, and knowledge of weapons capabilities. The pilot compares his planned tactics to the threat's tactics and flies his aircraft within the missile launch envelope. Proper missile guidance involves flying the aircraft while maintaining radar lock for the duration of the missile's time of flight. The pilot must also interpret the radar display to determine whether threat maneuvers will defeat his missiles and whether a backup shot is required. Confusion often results in interpreting threat aircraft maneuvering because threat maneuvers and F-15C maneuvers interact as the target symbol moves on the radar display.

Fly Defensive Profile. If successful, prior use of ECM and chaff has negated threat attacks long enough for the flight to achieve the first missile launch. At the time of the missile launch, the pilot must also engage procedures to defend against possible enemy missiles (i.e., maneuvers and chaff). If the RWR indicates an enemy missile launch, the pilot must determine whether he is truly defensive by interpreting and integrating relevant information--RWR, radar, wingman and AWC calls. If defensive, the pilot may be forced to abort the attack, along with active

missiles, and perform appropriate defensive maneuvers (e.g., beam, drag, S-turn).

Communicate with Wingman. Communication at this point should be descriptive commentary of changes or corrections to previously transmitted information--particularly changes to the mission plan. Listening during this intense workload phase is essential, but each pilot's limited cognitive resources may be spread too thin to comprehend important communications. "Buddy-spikes" must be communicated and attended to when in the act of launching missiles to prevent fratricide.

Communicate with AWC. Information from AWC can be used as a backup if the pilot fails to properly integrate onboard data; however, with the rapidly changing circumstances, the timeliness of AWC-provided information lags behind the present situation and can cause confusion. Therefore, use of AWC information during this phase is best limited to confirmation of information obtained from onboard sources. As a result, pilots allocate few of their scarce resources to monitoring this communication. Nevertheless, the AWC should continue to update the overall situation, monitor untargeted threats, listen for and correct pilots' confusing or inaccurate comments, and respond to requests for information (e.g., safe areas for evading threats).

Adjust Mission Plan. The mission plan in this phase is flexible by necessity. Time pressure precludes the communication of mission plan changes before executing them.

Fly Attack Formation and Navigate. After a successful attack (in DCA missions), it is advisable for the F-15C flight to drop back toward the defended position to regroup and assess the situation. Otherwise, if a pilot is defensive (and the aircraft possibly battle damaged), he will need to navigate to a safe area to escape further attack. The AWC has a major role in guiding the pilot under these circumstances.

Phase IV: Merge and Post-Merge Operations

By the conclusion of Phase III, the flight has entered the merge (10 nmi or less from target) and is within visual range of threat aircraft. At the merge, each pilot must decide whether he is offensive or defensive, and whether he should attack or abort. If deciding to attack at the merge, the pilot must execute short-range operations which rely on air combat maneuvering and tactics, AIM-9M infrared missiles, guns, and visual contact rather than sensors. On the other hand, a follow-on BVR attack may be attempted if the pilot had previously ceased offensive actions to perform defensive maneuvering (e.g., beam, drag, etc.) to gain sufficient lateral separation. In this case, the pilot would revert to activities described in Phase II or III, depending on the range from the threat. Finally, Phase IV may not occur at all

depending on the degree of success of previous phases. If mission objectives are attained, the flight may suspend offensive action. Conversely, if one or both aircraft are battle damaged, out of weapons or fuel, or outnumbered, there may be no choice but to abort attacks.

During Phase IV, the pilots rely on the mental picture of the threat situation developed in the previous phases, along with updates about the success of friendly attacks and the location of additional threats. This phase is characterized by extreme time compression and maximum uncertainty. All or any of the activities occurring in previous phases may be required; however, the pilot may have as little as 30 seconds to successfully accomplish the same tasks that he previously could perform in three minutes or more. As a result of the extremely dynamic nature of this phase, the following analysis is not as extensive as in the previous phases.

Decisions

The following are critical decisions that the F-15C flight must make in Phase IV:

- Perform attack plan and when to initiate it
- Use onboard information sources to perform search activities (and type, i.e., auto or manual)
- Use out-the-cockpit visual information to perform search activities
- Launch missile(s) and select type (i.e., AIM-7M or AIM-9M)
- Defend against attack(s)
- Communicate or not
- Employ ECM or not

Information

In order to make these decisions, pilots must obtain the following information:

- Range, altitude, azimuth, aspect and type of closest threat
- Untargeted threats
- Results of F-15C flight's attacks

- Threat reactions to F-15C flight's attacks
- Weapons launches against F-15C flight

Information concerning the F-15C flight must also be monitored. This information includes:

- Updated location of wingman, relative to a point or another aircraft.
- Updated status of wingman (e.g., dragging, engaged)
- Tactics, if different than planned

Activities

Communicate with AWC. The role of the AWC is significant in Phase IV because he or she is the only team member likely to comprehend the overall tactical situation. Although each of the pilots may be tracking a threat, chances are that neither pilot will be able to track all threats. Thus, the decision to commit at short range by either or both pilots may depend on AWC-provided information. After the initial BVR attack, the pilot may change priorities and attend to the AWC calls rather than to onboard sensors.

Communicate with Wingman. The primary emphasis on all communication between the pilots should be descriptive information. That is, each pilot communicates his status in relation to the agreed-upon tactical mission plan. It is imperative to transmit and acknowledge whenever one pilot has decided that circumstances dictate that he must change the plan. This acknowledgment must include the new plan and as much supporting descriptive information as possible.

Interpret RWR. Effective RWR interpretation determines the direction or flow of short-range operations or the BVR reattack. This system can provide the pilot with the most timely and accurate information used in determining the severity of the threat. In addition, the pilot must discriminate whether radar locks onto his aircraft are by threats or buddy-spikes.

Correlate Off-Board with Onboard Data. Prior to entering this phase, pilots may need to rely on off-board target data provided by his wingman and AWC. This situation will occur if the pilot is aimed away from threat aircraft. As the pilot turns toward the threat, onboard data should be used primarily to confirm or deny his perceptions established from off-board sources (e.g., correlation of RWR with AWC-provided threat information).

Fly Defensive Plan. Defensive operations in this stage involve coordination of flight lead and wingman, chaff and flare

employment, and maneuvering. Flight coordination is more important in this phase than in previous phases. Flying in visual formation is not necessarily the only means of achieving coordination; rather, the most important aspect is that both pilots understand and adhere to their agreed-upon plan. If either cannot meet these expectations, he must immediately inform his wingman.

Depending on the pilot's previous actions, he may be clear of threat aircraft; however, unless absolutely certain that he is not subject to attack, he must initially think defensively during this phase. The pilot should plan on employing all of the all-aspect considerations listed in Phase III. For example, if there are no RWR indications, emphasis should be placed on infrared countermeasures (e.g., use flares and do not use afterburner). If RWR indications are present, then all-aspect defense procedures for countering medium-range missiles should be employed, followed by procedures to counter short-range missiles.

During defensive turns, the pilot must think and fly defensively. For example, range to the nearest threat will most likely dictate whether the turn should be a maximum performance turn or an energy conserving turn. In addition, other turn considerations are important such as staying low in the ground clutter and using a good defensive infrared background rather than pitching back and up into a clear blue-sky background. The primary factor in defensive operations, however, is the ability to react to and maneuver against threat missiles anytime during this phase. The planning of these defensive actions must have been completed and practiced extensively prior to this mission; there is no time for the processing of anything but spatial information during these maneuvers.

Fly Offensive Attack Plan. The two key elements of an offensive attack plan involve selecting the flow of and controlling the geometry of the engagement. Selecting the flow of the engagement is most often accomplished through combining onboard RWR information with off-board data. The desired flow can be preplanned (e.g., drag southwest into the sun, setting up a reattack with the sun behind) or an adjustment to the overall offensive plan (e.g., dragging any direction away from an undesirable engagement). If the plans for the previous phases were substantially changed, however, the flight may enter this phase without much planning. Once committed to a short-range attack or BVR reattack, there will not likely be time to perform a tactical intercept. Although there may not be a tactical intercept per se, the pilot must still fly his aircraft such as to control the geometry and obtain the best offensive position for follow-on merge and postmerge conditions.

Perform Visual Search. Within the merge, the pilot will probably spend a majority of his time keeping track of threats already visualized or searching for undetected threats (e.g., 75% visual search and 25% radar search).

Operate Onboard Sensors (radar, EID). Although the pilot may rely predominantly on direct visual target acquisition, radar search is still important for acquiring targets at short range. Automatic radar modes, such as auto-guns, will most likely be used. If possible, the transition to short-range search should result in the selection of large volume coverage (e.g., 120° azimuth and 6-bar elevation). Time pressure precludes target sorting and sampling, and the detection and identification of a target should be immediately followed by weapons release. Time compression is obvious throughout this phase, but each pilot is still responsible for searching his area of responsibility to avoid untargeted threats. Also due to time compression, the pilot will most likely be unable to react to ECM, which may prevent successful locking of AIM-7M missiles. Due to the uncertainties inherent in this phase, it is important for the flight to get positive visual or electronic identification of targets prior to missile launches to avoid fratricide. Only when absolutely certain of his wingman's location should a pilot launch a missile without first verifying that the intended target is the enemy.

Select and Attain Weapons Parameters. The primary decision for the pilot will be to select the optimal weapon to employ for the given situation. After weapons selection the pilot must attain sufficient weapons parameter as opposed to the best weapons parameters--the time between sufficient parameters and best parameters may be the difference between life and death.

Adjust Mission Plan. Owing to the uncertain and rapidly changing circumstances, the plan for this phase is not likely to have much detail. Much of the activity within Phase IV involves reactions to the outcomes of the previous phases, which cannot be predicted, and therefore must be executed on-the-fly.

GENERAL SUMMARY

The objective of this research was to determine observable behaviors that can be used as overt indicators of cognitive information processing. Our approach was to develop a descriptive classification of the task behaviors and cognitive processing associated with performing a BVR air combat mission. An F-15C defensive counter air mission scenario was analyzed to identify the critical tactical decisions required of the pilot, the information that must be processed in order to make these decisions, and the overt behaviors associated with pilots' information processing. For future research purposes, the classification will provide a

framework for identifying observable task behaviors that may be worthy candidates for developing and testing measures of performance. Such measures are essential for assessing the effectiveness of simulator-based training programs for enhancing the cognitive skills necessary for BVR employment.

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APPENDIX A: SOURCES OF INFORMATION

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APPENDIX B: MISSION PLANNING AND BRIEFING

Preparation for a combat mission is critical for success. In order to understand the performance of aircrews during a combat mission, it is imperative to know what they had planned to do. The mission plan provides the necessary perspective for observing and evaluating mission performance.

The mission plan should provide the overall mission plan and stipulate flight objectives, timing of the mission, and each individual's assignments, responsibilities, and goals. A poorly conceived plan will most likely be doomed to failure; however, a good plan can also fail because of unforeseeable events. Knowledge of the aircrew's plan, however, can help differentiate whether poor mission performance was attributable to a faulty plan, errors in employment, or for lack of a better term, bad luck.

The flight lead is responsible for planning the mission and conducting the briefing. The tactical flight briefing for the DCA mission should address certain essential information; a concise listing of this information appears in Appendix B, Table B1. During the tactical briefing, flight lead should clearly communicate the elements of the mission plan and each participant's responsibilities (i.e., lead, wingman, and controller). Each participant should thoroughly understand his or her mission role and responsibilities before leaving the briefing. Aircrews view the mission plan as a "contract" among themselves. This contract obliges each member to perform his or her assigned functions in return for the other members performing their assigned functions. Through this process, the trust and confidence necessary in combat is established among the flight members.

During an ideal mission, flight lead coordinates the intercept, has primary authority for radar searching and sorting, is the primary source of visual and electronic identification, is the primary shooter, and communicates with the air weapons controller (AWC). The wingman supports flight lead, provides backup radar searching and sorting, and is the secondary shooter with lead's authorization. The AWC is responsible for monitoring long-range threats, alerting the flight to new threats, and maintaining radar lookout outside the F-15Cs' radar coverage. Specifics regarding these responsibilities must be worked out in the briefing and understood by all flight members. Whenever these responsibilities cannot be fulfilled, that flight member is obligated to communicate this to the other flight members.

Table B1. Components of Flight Briefing for Beyond-Visual-Range Air Intercept

Responsibilities:	Lead Wingman Air Weapons Controller (AWC)
Avionics Setup:	Radar scan Defensive systems
Formations:	Type Airspeed Turns
CAP Pattern:	Type Location Airspeed
Commit Criteria:	Range from threat
Intercept Options:	Single-side offset, bracket, etc.
Intercept Flow:	Radar sample and sort ranges Airspeed by specified ranges and at the merge Radar search pattern Radar sort profile Altitude Attack formation Target assignments
Abort Point and Criteria:	Lead and wingman offensive Lead offensive/wingman defensive Lead defensive/wingman offensive Lead and wingman defensive
Merge Options:	Blow through Turn (offensive/defensive)
Contingencies:	Remaining ordnance load Lead and wingman clues Electronic countermeasure response Communication jamming response Weather strategy Surface-to-air missile (SAM) strategy

APPENDIX C: CRITICAL PILOT DECISIONS AND ACTIVITIES IN DEFENSE COUNTER AIR MISSION

Table C1. Critical Beyond-Visual-Range Decisions

Perform mission (attack) plan or make adjustments
Use onboard or off-board search
Maintain or depart CAP orbit
Communicate or not
Employ ECM or not
Select a threat formation for attack
Commit against targeted threat formation
Select a target from threat formation for attack
Weapon selection (AIM-7, AIM-9)
When to launch weapon
Abort attack or not
Fly defensive profile or not
Reattack or not
Defend against attack

Table C2. Critical Beyond-Visual-Range Activities

Communicate with AWC
Communicate with wingman
Operate onboard sensors
Integrate onboard data
Correlate onboard with off-board data
Adjust mission plan
Fly CAP orbit formation
Navigate
Fly offensive (attack) profile (i.e., tactical intercept)
Interpret RWR
Fly defensive profile
Perform visual search
Select and attain weapons parameters

APPENDIX D: SUMMARY OF CLASSIFICATION FOR BEYOND-VISUAL-RANGE AIR INTERCEPT

Phase I: Combat Air Patrol (CAP)--CAP orbit

	DECISIONS	INFORMATION	ACTIVITIES
Threat-Related	Perform mission plan as briefed or make adjustments Use onboard or off-board search Maintain or depart CAP orbit Communicate or not	General location of threats Number of threat formations General altitude of threats General direction of threat movement Differentiation of bomber and fighter formations	Communicate with AWC Communicate with wingman Operate radar Operate EID systems Integrate onboard data Correlate onboard with off-board data Adjust mission plan, if necessary
Flight-Related	Perform mission plan, as briefed, or make adjustments	General location of wingman General operating status of wingman, i.e., offensive or defensive	Fly CAP orbit Fly formation Navigate Adjust mission plan, if necessary

Phase II: **Ingress/Intercept--CAP departure to 20 nmi from closest threat** (Sample, sort, select threat formation to attack, and commit on threat formation)

	DECISIONS	INFORMATION	ACTIVITIES
Threat-Related	Perform current mission plan or make adjustments Use onboard or off-board search Select threat formation(s) to attack Commit against targeted threat formation(s) Communicate or not Employ ECM or not Abort attack(s) against targeted threat formation(s) Defend against attack(s)	Changes to previous information General direction of threat movement Number of threat formations General threat location Geometric relationships Range to nearest threat Specific azimuth of threats Specific altitude of threats Specific identity of each threat aircraft, e.g., flanker Observed threat tactics Weapons launches against F-15 flight	Operate radar Operate EID systems React to ECM Integrate onboard data Communicate with wingman Communicate with AWC Correlate onboard with off-board data Fly offensive profile, e.g., intercept, formation Interpret RWR Fly defensive profile

Phase II: Ingress/Intercept, Cont'd.

	DECISIONS	INFORMATION	ACTIVITIES
			Adjust mission plan, if necessary
Flight-Related	Perform current mission plan or make adjustments	Location of wingman Tactic, if different than planned Operating status of wingman, i.e., offensive or defensive	Fly attack formation
			Navigate
			Adjust mission plan, if necessary

Phase III: **BVR Attack--Less than 20 nmi from threat** (Sort, commit, lock, and launch on individual target)

	DECISIONS	INFORMATION	ACTIVITIES
Threat-Related	Perform current attack plan or make adjustments Select target(s) from threat formation(s) When to launch AIM-7M missile (fire point selection) Abort attack or not Fly defensive profile or not Reattack or not Communicate or not	Range, altitude, azimuth of closest threat Range, altitude, azimuth, aspect of target(s) Untargeted threats Identity of threat fighters Threat tactics Threat reaction to F-15 flight's missile launches Weapons launches against F-15 flight	Operate radar React to ECM Operate EID systems Interpret RWR Integrate onboard data Correlate onboard with off-board data Fly attack profile: (a) control intercept geometry (b) attain weapons parameters (c) launch missile (d) guide missile Fly defensive profile: (a) operate ECM (b) employ chaff (c) maneuver, e.g., beam, drag, S-turn Communicate with wingman Communicate with AWC

Phase III: BVR Attack, Cont'd.

	DECISIONS	INFORMATION	ACTIVITIES
			Adjust mission plan, if necessary
Flight-Related	Perform current mission plan or make adjustments	Location of other aircraft in flight Tactic, if different than planned Operating status of wingman, i.e., offensive or defensive Results of wingman's attack(s)	Fly attack formation
			Navigate
			Adjust mission plan, if necessary

Phase IV: **Merge and Post-Merge Operations--Within 10 nmi of threat** (Short-range attack, BVR re-attack, or abort)

	DECISIONS	INFORMATION	ACTIVITIES
Threat-Related	If and when to perform attack Use onboard search (auto or manual) Use visual search Launch missile and select type (AIM-7M/AIM-9M) Defend against attack Communicate or not Employ ECM or not	Range, altitude, azimuth, aspect, and type of closest threat Untargeted threats Results of F-15 flight's attacks Threat reactions to F-15 flight's attacks Weapons launches against F-15 flight	Communicate with AWC Communicate with wingman Interpret RWR Correlate onboard with off-board data Fly defensive plan: (a) employ chaff/flares (b) maneuver to defeat attack/missiles (c) maintain mutual support Fly attack plan: (a) select direction of attack (flow) (b) control geometry Perform visual search Operate onboard sensors (a) operate radar (b) react to ECM (c) operate EID systems

Phase IV: Merge and Post-Merge Operations, Cont'd.

	DECISIONS	INFORMATION	ACTIVITIES
			Select and attain weapons parameters
			Adjust mission plan, if necessary
Flight-Related	Perform current mission plan or make adjustments	Updated location and status of wingman, i.e., dragging, engaged Tactics, if different than planned	Fly attack formation (planned or adjusted)
			Fly attack plan, e.g., planned and adjusted flow, geometry, pre-merge, merge
			Navigate
			Adjust game plan, if necessary