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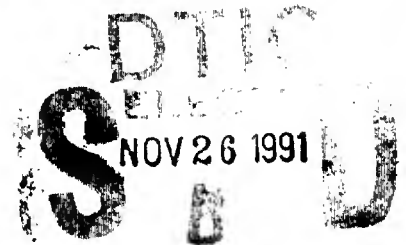
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**EVALUATING AIRBORNE WARNING AND CONTROL  
SYSTEM STRATEGY AND TACTICS AS THEY  
RELATE TO SIMULATED MISSION EVENTS**

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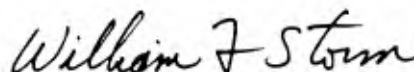
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This report has been reviewed and is approved for publication.



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List of Acronyms

ADF	Air Defense Fighter
AESOP	Aircrew Evaluation Sustained Operations Performance
AGL	Above Ground Level
AOR	Area of Responsibility
ATO	Air Tasking Order
AWACS	Airborne Warning And Control System
C <sup>3</sup>	Command, Control and Communications
CAP	Combat Air Patrol
DCA	Defensive Counter Air
EI	Essential Elements of Information
HCA	Heading Crossing Angle
I <sup>2</sup> F/SIF	Identification Friend or Foe/Selective Identification Feature
MSL	Mean Sea Level
OPORDs/OPLANS	Operation Orders/Operation Plans
ROE	Rules Of Engagement
RTB	Return to Base
SAR	Search and Rescue
S/A	Situational Awareness
SID	Situational Information Display
Viz ID	Visual Identification
WD	Weapons Director

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# **EVALUATING AIRBORNE WARNING AND CONTROL SYSTEM STRATEGY AND TACTICS AS THEY RELATE TO SIMULATED MISSION EVENTS**

## **BACKGROUND**

In response to a joint request by the U.S. Army and U.S. Air Force Surgeons General to evaluate the effects of antihistamines on complex decision-making tasks under sustained operations, the simulators in the Aircrew Evaluation Sustained Operations Performance (AESOP) facility were configured to run an Airborne Warning And Control System (AWACS) Weapons Director (WD) scenario. A Defensive Counter Air (DCA) mission scenario was chosen. A primary goal was to measure observable changes in the performance of complex Command, Control and Communications (C<sup>3</sup>) decision making under the effects of antihistamines. Central to the ability to measure human decision-making performance is an understanding of what the decision-making strategies are and how they relate to the simulated mission events.

Before simulated DCA mission events can be related to evaluations of individual and team decision-making strategies, these events and strategies must be identified. Attacks by enemy aircraft on friendly territory and changes in Rules Of Engagement (ROE) make up the primary mission events. Individual and team decision-making strategies take into account concepts of flexibility, capabilities/limitations, constraints, maneuverability, responsiveness, and mobility.<sup>1</sup> Team strategies include (1) classical lane defense, (2) Navy chain saw, (3) DCA fighter sweeps, (4) use of aerial refueling, (5) Search and Rescue (SAR), and (6) apportioning individual workloads based upon team member strengths and weaknesses. Individual strategies and tactics fit within the framework of team strategies. They include: (1) developing situational awareness (S/A), (2) establishing priorities, (3) controlling the work pace, (4) applying target approach tactics, (5) tracking resources, and (6) maintaining engagement and readiness states. Evaluation takes a systems approach. The inputs are the mission events and the outputs are the results. Evaluating the results consists of examining how effective were the chosen strategies and how efficiently were resources employed.

## **PRIMARY MISSION AND SPECIALIZED TASKS**

The primary mission of the AWACS simulations is Warning, Command, Control, and Communications. Specifically, the simulations present a DCA mission with the supporting specialized tasks of:

- intelligence,
- weather service,
- aerial refueling, and
- aerospace rescue and recovery.<sup>2</sup>

## MISSION EVENTS

The mission events revolve around the execution of the DCA mission and its supporting specialized tasks. In these events, the WDs, both as individuals and teams, are required to respond with strategies and tactics for successful mission accomplishment. The primary mission events are:

- attacks of enemy aircraft on friendly territory, and
- aural inputs of the ROE changes.

## WAVES

Events within each scenario are broken down into 4 waves. The 1st wave is a flight of 3 hostile bomber aircraft performing a reconnaissance role. The Peacetime ROE in effect require the execution of a stern geometry and visual identification (Viz ID) tactic, within vertical constraints. The WD-controlled Air Defense Fighter (ADF) must have its armament checked safe. One hostile aircraft enters each WD's lane.

The 2nd wave is a combination of 12 attacking enemy bombers and fighter/bombers or fighters approaching in flights of from 1 to 3 aircraft. The ROE fall into the intermediate range between peace and all-out war. The ROE are reactive and constrain the use of force or violence. This transition period often proves difficult for WDs to execute because it puts the ADFs they control in greater jeopardy. The WDs react to actions rather than initiating them, thus giving up some control over the situation. They are constrained by the ROE from using tactics that enhance their controlled ADFs' survivability in any armed engagement. The geometry changes from stern to cutoff; the ADF weapons are kept safe; and the vertical constraints change. During this wave, the hostile aircraft provoke the WDs' restraint by committing hostile acts (i.e., shooting at ADFs). The controlled ADFs are at a disadvantage because they must wait for the WDs to get permission from the command authority to engage with weapons before they can retaliate. The overall situation deteriorates into an undeclared war. It becomes a conflict between successful mission execution and preserving assets.

The 3rd wave has 12 hostile aircraft; aircraft types and flight sizes vary. The 3rd wave arrives within possible engagement range and in time for the declaration of war. Once war is declared, the WDs may choose any tactic they wish. Simply put, the ROE don't constrain the WDs with geometry, altitudes, or the use of force.

The 4th wave has 16 hostile aircraft; aircraft types and flight sizes vary. The 4th wave arrives within possible engagement range and in time for the declaration of war.

All enemy aircraft, regardless of scenario, fly evasive routes. The more difficult scenarios are more evasive. Hostile aircraft use standard Soviet tactics. When certain parameters are met, the enemy aircraft attack friendly aircraft and shoot them down.

## STRATEGY AND TACTICS

Strategy is a plan of action for the conduct of large-scale combat operations. In our case, this is the DCA battle. Strategy encompasses, constrains, and is affected by tactics.<sup>3</sup>

Tactics is the technique or science of securing the objectives designated by strategy. Specifically, it is the art of deploying and directing aircraft in coefficient maneuvers against the enemy. For the most part, tactics are interchangeable standard blocks of actions/activities based upon aerospace doctrinal concepts and the underlying principles of war.<sup>4</sup>

## CONCEPTUAL FOUNDATIONS

Every strategy or tactic used and/or developed by the U.S. Air Force takes into account the following concepts:

- flexibility,
- capabilities/limitations,
- constraints,
- maneuverability,
- responsiveness, and
- mobility.

Flexibility is the capability to alter tactics rapidly, that is, leaving open the greatest number of options in any given situation. Flexibility is necessary even when the situation and tactic selected keep changing. You should be able to alter your actions to meet the unforeseen at will and with minimum cost.<sup>5</sup>

Capabilities/limitations include both friendly and enemy strengths and weaknesses in strategies, tactics, equipment, personnel, and leadership. A good strategy or tactic successfully exploits these capabilities/limitations.<sup>6</sup>

Constraints are those factors that limit the scope of activities and options available. Time and environmental factors such as distance, geography, and weather act as uncontrollable constraints. Desired objectives are self-imposed constraints. The ROI is the most obvious example of self-imposed constraints.<sup>7</sup>

Maneuverability deals with the ability to achieve a superior position. It is more of an individual weapons platform use in a one-on-one tactical sense.<sup>8</sup>

Responsiveness is the co-use of control over timing and tempo of operations.<sup>9</sup>

Mobility is the choice of moving the center of logistic support for a weapons platform closer to the air battle to gain a time-on-target advantage, rather than choosing the option of gaining a positional advantage. For example, changing an ADF's recovery

base to one that is closer increases the ADF's on-station time, thus lane coverage. Note that the ADF's maneuverability has not been increased. From an ADF's point of view, maneuver is a tactical consideration while mobility is a strategic concept.

## **TEAM STRATEGIES**

### Primary Mission

The members of the WD team are told that their primary mission is to achieve the DCA mission. If there is a conflict between a DCA task and a SAR task, they should do the DCA task first. Team cohesiveness is enhanced by group consensus on how to achieve the DCA mission. Priorities and workload divisions (who handles what when and any extra tasking) are set. Some of the factors considered are:

- types of DCA to use,
- types of aerial refueling,
- known capabilities of individual WDs, and
- Search and Rescue.

### Types of DCA to Use

#### Classical Lane Defense

The designated Area of Responsibility (AOR) of the primary region is the WD's *lane*. This primary region is rectangular based upon the controlled ADFs' combat radius and a potential adversary's combat radius from the adversary's air base.

Each WD acquires ADF resources and applies them against targets within the AOR. The main objective is air superiority in the lane. As a rule of thumb, a WD should try to have at least 1 ADF for every 2 targets in the assigned AOR.

Tankers can be used to extend an ADF's airborne time, thus extending the time an ADF can cover a WD's lane. Use of SAR increases the morale of the fighter pilots and returns combat aircrews to duty. Combat Air Patrol (CAP) points are used as general reference points, allowing 3 ways to lower the WD workload.

- First, it isn't necessary to give constant vector guidance directions to ADFs because the WD can tell the ADFs to orbit a CAP point. The WD is then free to concentrate on more pressing tasks and still keep track of the ADFs.
- Second, by selecting, moving, or creating CAP points, it is possible to achieve a dominant tactical position for ADFs in the WD's AOR, as well as

to create a barrier for any potentially hostile aircraft. The advantages are simplicity and economy of force. The major drawback is that it is reactive to the enemy. It gives up a lot of offensive capability and is susceptible to surprise.

- Third, a WD can increase the ADF's playtime by selecting, moving, or creating CAP points closer to a recovery base, thereby increasing the use of ADF assets, but at the expense of allowing hostile aircraft closer to friendly bases.

### Navy Chain Saw

This type of DCA mission was originally developed by the U.S. Navy for Fleet/Carrier defense. The center is the Aircraft Carrier. Airspace is divided into radials, with the main threat axis as the base radial. Pie wedges are then divided as AORs to be assigned to ADFs on both sides of the base radial. Tankers increase the number, range, and on-station time in the AORs of the ADFs, and increase the defensible range of the Carrier's airspace as well. They are critical to execution.

CAP points are reference points and route-way points. Assigning a fighter to a CAP point assigns a sector. Overall, assigning CAP points is a continuous flow of aircraft strategy. The first set of fighters goes to the most distant sector. Tankers are then put on-station. The next set of fighters goes to the tankers for refueling, then moves to replace the first set of fighters. The first set of fighters then refuels and takes up a CAP orbit in a secondary position. A third set of fighters is launched in time to replace the second set of fighters on the CAP point (farthest out).

Good timing, based upon threat assessment and fuel management, is critical to the execution of the chain saw. Even a minor glitch in threat assessment or fuel management throws the whole plan into disarray. Use of SAR increases the morale of the fighter pilots and returns combat aircrews to duty.

### DCA Fighter Sweeps

ADFs perform fighter sweeps outside friendly airspace, but not inside enemy airspace. This type of DCA mission capitalizes on the offensive, but sacrifices security and logistics. CAP points mark the return to friendly airspace rally points. Tankers increase the range in which the ADFs can sweep. Use of SAR increases the morale of the fighter pilots and returns combat aircrews to duty.

## Types of Aerial Refueling

### Normal Aerial Refueling

Refueling operations are conducted above 10,000 ft AGL (Above Ground Level). The refueling tanker sets up a standard left-hand turning orbit at a designated point or points. These points are known as the tanker's anchor. Aircraft needing refueling are brought in 1,000 ft below the tanker before hookup. Since they are considered high value assets, the safety and security of the tankers have the highest priority. Thus the location of the tanker's anchor must be secure and defensible. Threat calls to the tankers take a higher priority than target information to an ADF. Because of their slower speeds, tankers must be given early vectors for withdrawal from an attack to a more secure area.<sup>10</sup>

### Low Altitude Aerial Refueling

Aircraft are brought in to the tanker and refueling operations are conducted at or below 10,000 ft AGL, and at least 3,000 ft above the highest terrain feature. Low altitude anchors provide greater security against enemy detection, but sacrifice safety. Consequently, the restrictions for weather criteria require daylight visual meteorological conditions (no clouds, 5 nm visibility).<sup>11</sup>

### Emergency Aerial Refueling

Emergency aerial refueling may be conducted at any time to assist an aircraft in distress. The tanker is diverted from its anchor and is given close control guidance to a rendezvous point. The major difference is that the tanker is brought to the distressed aircraft.<sup>12</sup>

## Known Capabilities of Individual WDs

WDs with a greater capacity for workload are given a greater share of the burden. Usually WDs assume that the most experienced WD has the greater capacity. Other factors considered are types of experience and any instructor qualifications. WDs also form opinions of the capabilities of co-workers and avoid giving important or difficult tasks to one who may not be able to deliver. They will, wherever possible, try to mask, back-up, or prevent the errors of less able cohorts.

## Search and Rescue

SAR is the use of aircraft, surface craft, submarines, and other special equipment to conduct search and rescue operations. Frequently a WD initiates a SAR effort.

Usually an airborne on-scene commander assumes control of the overall SAR effort. In our simulations, this commander was in the SAR HC-130. The WD uses all possible means to assist and coordinate the rescue effort. This responsibility is not limited to control; it also involves the timely and accurate gathering and passing of information.<sup>13</sup>

## INDIVIDUAL STRATEGIES AND TACTICS

### Situational Awareness

To effectively deal with events in an air defense scenario, WDs must maintain an accurate picture of the battle. This picture defines WD awareness of the current situation. Through situational awareness, WDs choose among the tasks competing for their attention and then execute the most important. This decision-making process is more than the application of a predetermined set of priorities. In these scenarios, for example, the DCA mission has the highest priority. Yet, if a set of fighters is low on fuel and/or armament and an inbound wave of hostile attackers is approaching, the WDs must decide whether to commit the ADFs, recover them through RTB (Return to Base), air refuel them, initiate a scramble to replace them, or seek further information to help resolve the decision. The choice is a trade-off among what will increase options in the future, what will ease future workload, and what will be the easiest to implement.

Visual presentations on the situational information display (SID) take most of the WD's attention. Aural inputs come in second, and tend to be used as a supplemental information source. Finally, the sense of touch is used to break the attention focus of a WD. One WD will touch another WD to gain attention. As a WD's attention focuses on both visual and aural inputs, other sensual inputs become suppressed, submerged, and ignored.

### Visual Inputs

The most universal visual approach uses the clock-sweep technique. The most common starting point is at the 9 o'clock position. WDs scan the SID in a clockwise rotation. With more experience, they start at the outer edge of the threat axis wedge. Scale expansion settings determine the volume of airspace viewed.

Used in tandem with a large-scale expansion (2x, 4x, or 8x), the clock-sweep technique establishes the "big picture." The larger the volume, the more you see, but a saturation point is soon reached when details become obscured. To use analogy, it becomes impossible to pick out the wolves because of all the sheep. To get a better look at the wolves, there are 2 options. You may either zoom in on an area of interest or rid your picture of unnecessary details.

To zoom in means to offset and change to a smaller scale expansion. At smaller scale expansions (8x, 16x, 32x, and 64x), the clock-sweep technique becomes a back

and forth sweeping motion. This approach is used only in conducting intercepts. The WD looks at the object of the intercept, sometimes with a clock sweep around it, and then focuses on the interceptor, sometimes with a clock sweep around it. The WD repeats this process as the target and interceptor close on each other.

Offsetting is a 2-step procedure to change the center of the WD's SID. The first step always places the area of interest into the center of the SID. Then the offset is used again to refine the setup of the SID presentation. The second offset rule of thumb is to place the SID center where the primary object of interest will be when an event is expected to occur. An event can be anything from a position update due to the radar sweep to an actual intercept point.

Ridding the picture of unnecessary details requires resetting some of the feature and category select switches that control the amount and types of information presented on the SID. Normally, the WD will do a first setup and then turn off those details cluttering the view. Occasionally, the momentary setting for the feature select switches is used to highlight the most desired feature or detail. Nearly all of this highlighting deals with the present data returns of radar, Identification, Friend or Foe/Selective Identification Feature (IFF/SIF), or jamming strobes.

### Aural Inputs

Three options are available to control aural inputs. In the first option, the WD listens to everything all the time. The WD can prioritize each headset channel by individually adjusting the volume control to each channel; the loudest channel has the highest priority. Setting the master control volume gives a relative priority to non-channelized inter-team communications (i.e., NET 4). If the WD doesn't prioritize channels, then all channels will have an equal volume setting.

In the second option, the WD listens only to what is required. This option can also be prioritized.

The final option is more complex to execute. In the third option, the WD constantly adjusts between the preceding 2 options and the priority of the channels as the situational flow of the communications demands. The guiding principle is not to get caught in the "Tower of Babel" where the aural information flow is incomprehensible.

### Priorities

Priorities for the DCA mission change according to the ADF phase. These phases are different from those used in the calculation of intercept geometry. They are conceptual and therefore parallel the phases in intercept geometry. The phases are: CAP/Patrol, Intercept, and Engagement. Throughout these phases WDs have 4 priorities: (1) threat warnings, (2) control of individual fighters, (3) situation briefs, and (4) minimum risk/safe passage assistance.<sup>14</sup>

In the *CAP/Patrol* phase, the WD uses all available information to maximize aircrew S/A, i.e., a **PICTURE** brief. Appropriate information includes activities and location of other friendly/support aircraft, and the location of enemy air-to-air threats. When able to do so, the ADF should provide information to the WD, on low altitude targets, for example, that may not be available through other means.<sup>15</sup>

Once the ADFs are committed, the *Intercept* phase begins. The WD should concentrate on describing the target and other threats affecting the intercept. Target position, flight size, formation type, and altitudes should be passed to the aircrews. The fighter may now increase interflight communication. Fighters also pass radar contacts. The WD should be alert for these calls because they indicate fighter awareness. As fighter awareness increases, fewer WD transmissions will be required. The WD should continue to provide target information, especially changes in formations, until the fighter radios the WD to decrease information flow by transmitting **COMMITTED** (bearing and range), **JUDY**, or **ENGAGED**. Priority should be given to the fighter closest to the merge. As the fighters approach weapons parameters, or the merge, they may increase use of the radio for sorting/target assignment. Accordingly, the WD should limit calls to target maneuvers: drags, beams, brackets, and large altitude changes that may not have been detected by the fighters. The idea is to focus WD workload on updating the information the aircrews have already gained from visual sightings or from onboard radars.<sup>16</sup>

The *Engagement* phase begins when the fighters either (1) begin visual maneuvering against their adversaries, (2) attain weapons parameters, (3) reach the merge, or (4) call **ENGAGED**. The fighters usually increase radio use in an engagement for attack coordination and mutual support. Engaged aircraft may be in close proximity and headings, altitudes, and airspeeds may be rapidly changing. The WD should transmit only when necessary to provide information on threats entering, about to enter, or leaving the fight, or to get other fighters to the fight if required. The WD should pass information relative to the engagement in cardinal directions, for example: **2 BANDITS, SOUTH, 5, CLOSING**. Range calls are critical at this time; radar sweep delays must be considered. If unable to give accurate target information, WDs should transmit **UNABLE**. If flight members get split into separate fights, the WD should keep the flight lead advised of the wingman's position. The WD should also be prepared to give the flight the best bugout direction and assist the flight in regaining mutual support (i.e., rejoin separated flights), if required. When a fighter calls **BUGOUT**, the WD should check for any threat following the egressing fighters, provide bearing and range to other threats in the area, and assist in any requests for rejoin.<sup>17</sup>

For SAR and aerial refueling, the WD's priorities are (1) threat warning, (2) safe passage assistance, (3) coordination for support, deviations, and rendezvous, (4) deconfliction information, and (5) situational briefing.<sup>18</sup>

## Timing and Tempo

Timing controls when things happen; tempo is the rate at which they are performed. When more things need to be done, the rate at which a WD does them increases. To prevent overloading, WDs can somewhat adjust when things will happen. For example, in conducting 2 intercepts simultaneously, with all the parameters of each intercept equal, the WD can increase the speed or change the Heading Crossing Angle (HCA) of one of the intercepts to prevent simultaneous engagement of both aircraft with the hostile aircraft. Then the WD can control each intercept one at a time in tandem.

## Approach Tactics

Four types of DCA intercept geometry are used: *cutoff*, *stern*, *stern conversion*, and *pursuit*. For every type of intercept, there are 2 phases: approach and attack. The phases are based upon the time remaining to intercept. The approach phase starts at commit and ends at the beginning of the attack phase. The attack phase starts at 70 seconds to intercept. *Cutoff* geometry is a collision course to a point 3 nm astern of the target. *Stern* geometry is guidance to an offset point where the ADF begins a final turn to roll out 3 nm in trail of the target with an HCA of 0 degrees. *Stern conversion* is an approach phase with cutoff geometry and an attack phase of stern geometry. *Pursuit* is a vector heading equal to the targets bearing.

## Air Refueling Geometry

Three types of air refueling geometry are used: tactical rendezvous, point parallel, and 150/30 join-up. Tactical rendezvous are receivers given stern or stern conversion guidance with minimum tactical control.

In point parallel geometry, tanker and receiver turn following a specialized close control, 180 degree HCA sterns. The receiver must get to the tanker at the point in time and space that the tanker begins its normal anchor turn, and the receiver has entered offset for its final turn to roll out behind the tanker.<sup>19</sup> There are standard charts giving WDs guidance on how much offset to give the receivers and the speeds for each participant at each 1,000 ft interval above 18,000 ft Mean Sea Level (MSL).<sup>20</sup> This is the most difficult of aerial refuelings.

The 150/30 join-up is an AWACS-unique tactic for emergency aerial refueling. It is based on the degrees of turn the tanker and receiver make to get joined with 0 nm rollout for the receiver. The standard for the tanker is not to turn more than 150 degrees. The receiver turns no more than 30 degrees. This procedure is used for emergency refueling only. The philosophy is to turn the receiver as little as possible and bring it directly into a refueling position as quickly and as fuel efficiently as possible.

## Altitudes

Altitude has many aspects in the DCA mission. First, it greatly affects range and on station time. All aircraft have a most-fuel-efficient altitude. They also have maneuvering efficiency altitudes. For WDs, ADFs turn tighter at lower altitudes, which means that, for the same angle of banking, an ADF at a lower altitude has a smaller turning radius than at higher altitudes.

Tactical considerations must also be taken into account. Because of gravity, an aircraft at a higher altitude has an energy advantage for maneuvering over an aircraft at a lower altitude. For ADFs with radars, to keep targets within the parameters of the radar beam, the altitude separation must not be too great. The closer an ADF comes to a target horizontally, the less the altitude separation must be to maintain the target on the ADF's radar. A WD rule of thumb is 1,000 ft for every 10 nm. Related to the radar's capabilities, below 5,000 ft AGL, the ADF radars pick up more ground clutter when looking down at a target than looking up. Due to the structural aspects of enemy aircraft, an ADF can remain unobserved if it attacks from the rear and below the enemy aircraft.

Selection of altitudes greatly affects the type of air refueling. Above 10,000 ft AGL, normal air refueling is done. Below 10,000 ft, low altitude refueling is conducted. Weather restrictions on low altitude refueling are greater than they are at high altitude. The lowest air refueling base altitude is 3,000 ft AGL above the highest terrain/obstacle within 4 nm either side of track/centerline. Receivers can't descend below 1,000 ft AGL.<sup>21</sup>

Finally, there are ROE constraints on vertical separations of ADFs and targets. These constraints were established for all the scenarios.

## Speed

Aircraft speed is an important factor contributing to maneuverability. A faster aircraft can achieve a dominant position over a slower aircraft, as well as disrupt a slower aircraft's favorable tactical positioning. As a rule of thumb, WDs usually try to get a speed advantage of at least 1.2 (ADF's) to 1 (target's), permitting the ADF to overtake an enemy from the rear. A speed advantage can cause the ADF to overshoot and fly off from the enemy's flight path if the enemy appropriately attempts to turn into the ADF. Abrupt changes in speed can throw off or disrupt enemy attacks by throwing the enemy's timing off. A classic example is the "blow through" or cutoff only attack. When 2 fighters of comparable capabilities close on the front quarters of each other for a long distance radar shot, an ADF can accelerate rapidly upon entering weapons launch parameters, fire its weapons, and continue to fly past the enemy. Because of the unexpected change in closure rates, the enemy's timing for weapons launch is thrown out of whack, causing an aborted launch. Regardless of whether the ADF attack was successful, the ADF is out of the enemy's engagement range before the hostile has time to turn and engage the ADF again. The ADF may then be in position to attack an enemy formation behind the first enemy engaged. A greater speed adds to zoom energy in the vertical plane, allowing

the faster fighter to move rapidly beyond an enemy's radar parameters in the vertical plane, averting any targeting attempts.

Speed also affects fuel consumption. The faster an aircraft flies, the more fuel it burns. At every altitude, there is an optimum speed for fuel preservation, greatest maneuverability, and optimization of both (better known as tactical speed).

## Tracking of Resources

### Armament States

Armament states for ADFs consist of radar missiles, infrared missiles, and guns. The number of attacking passes available for each weapon type is critical. The parameters for the functioning of each type of armament were set for the simulation, and are not the actual ones used in the military. They do, however, reflect real world operating principles.

Radar missiles have the greatest range (10 nm) and work best on the front quarter of a closing enemy. The HCA must be greater than 120 degrees. To use radar missiles most effectively, apply cutoff geometry.

Infrared missiles have intermediate range (3 nm) and work best from a stern-fired position with a desired HCA of 120 degrees or less. They are best used with stern geometry.

Guns are effective from any quarter. However, their short range of 1 nm puts the ADF within range of an enemy's weapons. Guns should be used as a last resort; the best tactical position for their use is from behind an enemy's tail.

### Fuel States

Fuel states have many different constraining effects. A primary constraint is the decision on an aircraft's next assignment. If an ADF is low on fuel, it cannot be used to engage incoming unknown or hostile aircraft. It must be refueled or sent back to base. A less than optimum fuel state may force the selection of a lower speed than desired, resulting in a different geometry selection. For instance, a WD may wish to attack a target with a stern geometry to enhance the ADF's chance of survival. However, the ADF's fuel is too low to permit a 1.2 to 1 speed advantage; therefore, to prevent the loss of the ADF due to fuel, the WD selects cutoff geometry. Even at speed disadvantages, cutoff geometry allows successful intercept at a fuel efficient rate.

## Position

Position, both vertical and horizontal, is the relative reference point of the defending ADFs to attacking hostiles. It most often dictates which ADF is committed against which target. The rules of thumb are near-far, high-low, right-left, and exceptions based on higher threat.

Near-far refers to selecting targets of first engagement based on the nearest threat, in the horizontal plane, first. If there is a tie, or at least appears so, the WD moves to the next sorting criterion--high-low.

High-low targets are selected on the basis of position in the vertical plane. WDs treat targets at higher altitudes as the first priority. If there is still a tie, then the WD uses a right-left sort.

Right-left sort means going after the target on the right-hand side of the ADF's flight path. This is not as arbitrary as it seems. Since the standard is a 2-ship, right-echelon, most capable aircraft in the lead, going after targets to the right plays to the strength of fighter formations.

Exceptions to using the above methodology apply to those targets that pose a greater threat. For a DCA mission, these exceptions are, in order of their priority, enemy jammers, high fast flyers, fast flyers, enemy bombers, enemy fighter/bombers, and the most capable enemy fighter.

Enemy jammers are high priority targets because they interfere with the overall air defense system's ability to detect targets. Targets cannot be destroyed if they cannot be detected.

High, fast flyers are the most difficult type of target to intercept. Thus high, fast flyers stand the best chance of penetrating air defenses.

Fast flyers follow the same reasoning, but are not in the high altitude region.

Enemy bombers and enemy fighter/bombers are those aircraft that do the greatest damage if they get through. Ordinarily, they cannot be picked out from an attacking force without some additional information, usually from intelligence sources. The same applies to the most capable enemy fighter. Additional position tactics include its use for primary geometry selection. For WDs, the vertical plane is broken down into altitude bands. These altitude bands are *weeds* (below 100 ft AGL), *very low* (below 300 ft AGL), *low* (below 5,000 ft AGL), *medium* (between 5,000 to 25,000 ft MSL), *high* (25-40,000 ft MSL), and *tops/very high* (above 40,000 ft MSL). Below 5,000 ft AGL, the primary geometry is stern, with those targets below 300 ft AGL restricting all ADF altitudes to above the target's. Above 5,000 ft MSL, the primary geometry is cutoff.<sup>22</sup>

## Engagement Status and Readiness Status

### Lane Coverage

There should be sufficient ADFs to engage all the targets. Under the general rules for the conduct of war, for successful offensive operations the attacking force must have a superiority of power at the point of attack (engagement) of 3 to 1. As a result, WDs have a general rule-of-thumb that reverses this principle of offensive operations. They negate the enemy's guarantee of victory by maintaining a ratio of ADFs to attackers of 1 ADF for every 2 attackers. This is not a commandment chiseled in stone. Instead, it is a rule scratched in mud, meant for guidance of work between deluges.

Another aspect of lane coverage in addition to raw numbers is the overall time the lane is supported by fighters. Some assets should be protecting the lane. To actively protect the lane, the fighter has to be within the lane or the WD's AOR.

### Philosophy

Commit authority normally rests with the flight lead, subject to Operation Orders/Operation Plans (OPORDs/OPLANS), command authority, ROE, commit criteria, and force commander direction. The flight lead also has the authority to commit for the flight's defense or when the WD workload is saturated. In circumstances where the fighter initiates a commit, the flight lead transmits **COMMIT** and provides the WD with the bearing and range to the target. When a flight lead informs a WD of a commit, the WD will verify that the commit is on an appropriate target, and assist as necessary. If the situation dictates terminating the commit, the WD will transmit **SKIP IT** with appropriate directions. The **SKIP IT** call is directive, and the aircrew will disengage unless doing so will jeopardize the flight; in which case the aircrew will transmit **UNABLE**.<sup>23</sup>

As shown in Figure 1, there is a continuum of control generally grouped into 5 levels: close, tactical, broadcast, advisory, and autonomous. Within these levels of control is a prioritized format of information. The transition between levels of control depends upon the tactical situation and may occur rapidly and without warning.<sup>24</sup>

Within the control continuum there are certain aircrew and WD responsibilities common to all levels. For the aircrews these responsibilities include:

- a. Position the aircraft and flight as necessary to accomplish the mission.
- b. Acknowledge target information as the situation permits.
- c. Notify the WD if contact is lost on a target under his attack.
- d. Call off previously unreported contacts.
- e. Report essential elements of information (EEI)
- f. Report mission results.
- g. Advise the WD of fighter status.
- h. Comply with WD directions to **SKIP IT** unless doing so will jeopardize the flight.<sup>25</sup>

For the WD, these responsibilities include:

- a. Provide a situation brief (**PICTURE**) as time permits.
- b. Define commit objective (**KILL** or **ID**).
- c. Provide threat and potential threat information (numbers, formation, altitude, heading, and speed).
- d. Commit fighters to the highest priority target.
- e. Monitor the intercept/engagement and provide vectors and/or bearing and range to the target in the event the fighter loses the target.
- f. Monitor the area of responsibility for new targets, and, when necessary, skip the current engagement and recommit fighters to higher priority targets.<sup>26</sup>

Level of Control	CLOSE CONTROL	TACTICAL CONTROL	BROADCAST CONTROL	ADVISORY CONTROL	AUTONOMOUS OPERATIONS
	TARGET AND COMMIT INFO PROVIDED TO SPECIFIC FLIGHTS		TARGET INFO PROVIDED BUT NOT TO SPECIFIC FLIGHTS	RADAR TARGET INFO NOT AVAILABLE AND NOT PROVIDED	COMMUNICATIONS NOT AVAILABLE, NO INFO OR CONTROL PASSED
	COMMAND VECTORS GUIDE AIRCREW TO INTERCEPT	AIRCREW RESPONSIBLE FOR TACTICAL POSITIONING			

Figure 1. Control levels

### Close Control

Close Control provides the greatest degree of control in the continuum. It can vary from merely providing vectors to providing complete assistance (altitude, heading, and speed). Its use may be dictated by the mission or it may be initiated by the aircrew using the transmissions **GO CLOSE CONTROL** or **VECTOR** (if only vectors are required). The WD will transmit **UNABLE** when providing close control is not possible. In addition to the

general information previously discussed, close control should include the following, depending on the situation:

- a. **Vectors:** As briefed and based on the appropriate tactics. Tactics should be as briefed unless armament, environmental conditions, target altitude, or ROE dictate use of another tactic.
- b. **Altitude:** If necessary, an altitude will be directed.
- c. **Speed:** Airspeeds may be directed for battle management or for other command and control reasons.<sup>27</sup>

### Tactical Control

Tactical Control is the same as Close Control with regard to the type of information provided and aircrew/WD responsibilities. However, vectors are not provided to the aircrew by the WD. Tactical Control provides the aircrew target information and the commit objective (**KILL** or **ID**). Aircrews may request tactical control by transmitting **GO TACTICAL CONTROL**.<sup>28</sup>

### Broadcast Control

Broadcast Control is a means of passing target information by referencing a designated location, series of locations, or a grid system. Target information is not normally addressed to a specific aircrew. The aircrew/flight leaders must take the initiative of committing. Broadcast Control may be employed when directed in the Air Tasking Order (ATO), when deemed necessary by the WD, or when requested by the aircrew. Operational Commands will designate the system to be used within particular operating areas, and ensure aircrews and WDs are familiar with the designated system. For our simulations, WDs could use Broadcast Control for **PICTURE** briefs only. We limited them because of the difficulty in properly measuring their outcomes, workloads, and intercept skills.

- a. **Aircrew Procedures:** An aircrew may request Broadcast Control by stating **GO BROADCAST**. Upon implementation of broadcast operations, aircrews should call when committing to enhance the coordination among fighters on the same frequency. To further enhance the situational awareness of all players on the same frequency, commit calls should reference the broadcast point and/or grid system being used.
- b. **WD Procedures:** To indicate to aircrews that broadcast operations are being implemented, the WD will transmit **BROADCAST, BROADCAST**. The WD may implement a higher degree of control any time the task load permits. When able to identify friendly aircraft, the WD should provide **THREAT** calls as the highest priority.<sup>29</sup>

## Advisory Control

Advisory control is a radio monitor mode used when the controlling agency loses radar, shuts down radar to avoid attack, loses effectiveness due to enemy countermeasures, or when the fighters are outside radar coverage. Communications with aircrews may be maintained directly, through a radio relay, or through another agency/facility. It allows command authorities to monitor the air battle, manage fighter flow, pass intelligence, direct aircraft, and move CAPs. Advisory control was not allowed in our simulation because it defeated the purpose of measuring typical WD work. The WDs were allowed to put Advisory Control in effect when our simulation went offline.

- a. **Aircrew procedures:** As with Broadcast operations, aircrews operating under Advisory Control should call **CONTACT**, **COMMIT**, and **ENGAGED** to enhance coordination among fighters on the same frequency and to keep the controlling agency informed. If previously under Broadcast operations, the same reference system should be used when making these calls.
- b. **WD procedures:** To indicate that advisory operations are in effect, the WD will transmit **MIDNIGHT**, **MIDNIGHT**. The WD will then pass available information on threats, friendly forces, command decisions, and information requested by the aircrews when able to do so.<sup>30</sup>

## Autonomous Operations

Autonomous Operations occur when the aircrew cannot receive information or guidance from the controlling agency such as when communications are lost or degraded, or when fighters operate out of radio range. During Autonomous Operations that are not preplanned, both the aircrew and the WD will attempt to reestablish communications. When the controlling agency can resume providing information or guidance, the WD should transmit **SUNRISE**, **SUNRISE** or **MIDNIGHT**, **MIDNIGHT** as appropriate. The WDs were not allowed to institute Autonomous Operations. However, they were allowed to tell their pilots to go autonomous when the simulation went offline. They could also institute **SUNRISE** procedures when the simulation came back online.<sup>31</sup>

## **EVALUATIONS**

Individual and team decision-making strategies and tactics, developed and implemented in response to mission events, can be evaluated by subjective and objective performance measures. The development of these measures is discussed in Schiflett, Strome, Eddy, and Dalrymple (1990).

In accomplishing the DCA mission and its supporting specialized tasks, there are two basic questions:

1. Were the strategies/tactics *effective*?
2. How *efficient* were they?

To answer these questions, measures reflecting the activities of the teams and individuals were developed using a systems concept. WDs received inputs, performed actions, and produced results. The scenarios and their mission events were the inputs. The WDs' actions determined their performance. The scenario results were the outputs.

Several categories of WD activities that determine performance are:

- (1) producing outputs of a service, such as protecting friendly bases or giving guidance to ADFs.
- (2) acquiring resources such as scrambling ADFs, SARs, or tankers.
- (3) making use of inputs relative to outputs, such as destroying targets with ADFs.
- (4) performing technical and administrative tasks, such as determining which target to engage first with their ADFs.
- (5) conforming to codes of behavior such as following the ROE.

Accomplishing the DCA mission constituted the primary goal. Accomplishment of the specialized tasks depended upon their support of the primary goal, for example, using aerial refueling to extend ADF lane coverage time. The DCA mission itself breaks down into a subset of objectives leading to DCA mission accomplishment. It follows this general model:

DETECT → IDENTIFY → INTERCEPT → DESTROY = ASSETS PROTECTED

The primary goal of the DCA mission is to protect friendly assets, i.e., to prevent hostile aircraft from bombing friendly bases.<sup>32</sup> The primary output of asset protection can only be measured in a negative way--assets lost. A hostile strike completion means asset protection goal failure, hence DCA mission failure. This yardstick measures *effectiveness*.

*Efficiency* is indicated by the number of hostile strike completions in a scenario compared with the number of hostile attackers. These measures can apply to either a WD team or to the individual WD who failed to stop the hostile aircraft.

The same process repeats for each of the sub-goals of the DCA mission, such as destroy. In this case, the output would be the total number of hostile aircraft destroyed, which constitutes a service output count of effectiveness. An example of an efficiency measure is the kill ratio. The kill ratio efficiency measure is the ratio of WD inputs (ADFs destroyed) to outputs (number of hostiles destroyed).

In summary, evaluating WD performance relates mission events through WD activities to achieve goals in response to those events. The 5 categories of WD activities considered are:

- (1) output of service,
- (2) acquiring resources,
- (3) making use of inputs relative to outputs,
- (4) rationally performing technical and administrative tasks, and
- (5) conforming to codes of behavior.

The results of WD activities form performance measures when judged against goal attainment. Goal-oriented behavior is assumed. A hierarchy of sub-goal milestones leads to primary goal attainment. The primary goal is DCA mission accomplishment.

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