Employing Mission Essential Competencies in Situation Awareness Assessment

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ABSTRACT

Tactical training specialists recognize the critical role that situation awareness (SA) plays in effective tactical performance in dynamic, high performance training environments. Yet assessing the role of SA in particular performance problems remains an elusive and primarily subjective process. Well documented and validated measurement tools such as SART and SAGATare effective discriminators of situation awareness in research, system design, training and other environments; however, their employment within a tactical training context typically requires either intrusive or delayed data collection. This paper proposes examining situation awareness from a training development standpoint in distributed mission operations (DMO) using decomposed mission essential competencies (MECs) as a framework. It explores the potential for developing tools to support the tactical trainer in assessing the role of situational awareness in observed performance. The paper briefly discusses two well known SA measurement techniques and moves to an examination of SA within the MEC framework for air combat and the application of a MEC decomposition process to identifying task SA requirements. The potential of modeling approaches to implement the MEC decompositions to organize the necessary data for cue development is explored. The discussion concludes by developing requirements for data collection in both individual and team SA estimation techniques employing local data sources as well as HLA and DIS network architectures within DMO.

ABOUT THE AUTHORS

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INTRODUCTION

Situation awareness (SA) is widely accepted as a design criterion for system development in hardware design and operator situation display mechanizations. In designing or improving a display interface, both designer and operator seek to improve the operator's knowledge of the battle space affecting operations. Research subjects are normally selected based on operational certification (ie; combat ready crewman) and a statistically significant sample size is employed to draw valid comparisons of changes to SA related to system changes. Literature published on situation awareness research suggests that the focus remains heavily weighted toward display design and information flow in development of new tactical and operational interfaces. This area of research is fundamental to producing effective tactical systems in the increasing complexity of information flow in modern warfare.

Situation awareness is also fundamental to understanding how the operator functions within an established group of systems. In the training environment, a *system* of knowledge and skill building exercises must be developed and employed to bring the operator of existing systems to the desired level of *combat readiness.* Instructors in air warfare disciplines appreciate the role SA plays in effective execution of tactics. In AFRL's Mission Essential Competency (MEC) development studies, SA exists as a supporting competency in all C2 and shooter disciplines (Colegrove & Alliger 2002). A recent survey of grading practices at the USAF's Weapons Instructor Courses (WIC) showed deliberate grading of SA exists as a separate line item for each mission flown in simulation or live-fly among all aircraft syllabi. Additionally, most written critiques of student performance relate to the presence, absence, or degradation of SA as a factor enhancing or degrading performance of tactical execution. So it appears that not only is SA a valid marker for system design dynamics, it is also fundamental to trainee dynamics within a training system and a valued indicator of student competency. The survey also suggests that instructional analysis of SA is formulaic enough to be modeled and perhaps automated to some degree.

Examinations of how trainee SA is assessed by the instructor force at the USAFWS were conducted during recent large force integration exercises with all WICs participating. Responses varied from system to system but remained focused on information triggers the instructors considered essential to the execution of tasks required in each tactical scenario. The instructors could break down the task set and relate information requirements that would be required to make decisions regarding execution paths. The most striking consistency of the survey was that the only accurate assessments of SA were made *after the mission* was completed, debriefed, and analyzed in detail using recording of pilot displays and communications. The ability to accurately assess SA *in flight* varies with mission and instructor and is used only as a real-time safety of flight control due to its very subjective nature. An instructor might call off an engagement due to poor SA, but it is rarely invoked in practice. However, the real-time tactical SA assessment provides the instructor with a framework to analyze SA processes in detail after the mission. Only detailed analysis and carefully written critiques are used to provide guidance for how the next mission might be adjusted to improve weaknesses, but few mechanisms are afforded for fixing problems during the mission short of terminating the engagement to avoid safety problems. Such is the nature of large force training – once you board the train, you are along for the ride until it stops.

Distributed mission operations (DMO) are entering a mature phase in which training at the tactical and operational levels of air warfare are being realized. Recent Virtual Flag exercises conducted at the USAF's Distributed Mission Operations Center (DMOC) brought together a complete USAF theater C2 structure and multiple tactical simulations in a realistic (yet synthesized) theater of war. In the last of these exercises, VF04-3, over 20 distributed sites participated in large force integration training. One of the goals established for DMO is the ability to assess training deficiencies concurrent with mission execution and adjust scenario attributes to affect improvements in weak areas. Since SA is fundamental to proper tactical execution, it follows that it must be a target for assessment during mission conduct. Researchers at AFRL's Mesa site have demonstrated the ability to adjust scenario attributes to affect skill development (Symons, France, Bell, and Bennett, 2003). The next evolution of adjustment will be to apply assessment results to adjust attributes within the same training session and possibly within contiguous engagements. An essential component in driving mission adjustment will be valid assessment of problem areas including SA gathering and maintenance.

SA ASSESSMENT TOOLS

A brief survey of research projects involving SA measurement suggests two primary tools are popular choices for SA estimation. These tools are generally employed in the realm of system design and involve both during mission and post-mission assessment strategies. Situation Awareness Rating Technique (SART) provides a subjective rating of SA by operators. The technique is based on post-mission examination of 14 components that have been analyzed previously to be relevant to pilot SA (Endsley, Selcon, and Hardimann, 1998). Advantages suggested by the authors include a wide applicability to varying task types, simulations as well as live-fly, and no need for customization from event to event. The broad applicability of SART is based on the general nature of the 14 areas of examination and it has been employed in tactical training situations. However, the data produced is generally difficult for an instructor to apply in training regimens. Table 1 shows an example of the SART response sheet and rated categories.

Another popular estimation technique, Situation Awareness Global Assessment Technique (SAGAT), is an objective technique in which periodic and randomly timed stops in a simulation are employed to query an operator about tactically significant attributes in the scenario (Endsley, Selcon and Hardimann, 1998). Processing of SAGAT responses relies on in-depth cognitive task analyses of the tactical domain it is employed in. The strength of the SAGAT technique is the potential for detailed analysis given an accurate CTA foundation.

Table 1. Example SART Survey Sheet

Situation Awareness Rating Technique (SART) Response Sheet

Name ________________________ Watchstation ________________________

Condition/scenario __________________ Date/time ________________________

Difficulty ___________________

	Low						High
	1	2	3	4	5	6	7
1. Demand							
2. Instability							
3. Complexity							
4. Variability							
5. Supply							
6. Arousal							
7. Concentration							
8. Division of Attention							
9. Spare Mental Capacity							
10. Understanding							
11. Information Quantity							
12. Information Quality							
13. Familiarity							
14. Situational Awareness							

Limitations in both techniques preclude their use as tools for SA examination during DMO training. The SART technique's post-mission timing precludes real-time assessment. Additionally, SART relies on the operator to rate his/her own SA, allows for post-mission time to influence responses (known as studied responses), and a potential to tie performance inappropriately with SA estimation (Endsley, 1993). The SAGAT approach limits the potential for studied responses through structured questioning at random stops during the simulation (Endsley, Selcon and Hardimann, 1998). The freezing of simulation is proposed to be a non-issue during assessment since the stops are random and the operators do not have time to prepare for the 2-5 minutes of questioning required for an SA sample (Endsley, Selcon, Hardimann, 1998). The stops employed to assess SA would be the principal disadvantage when considered for DMO integration. In DMO operations, multiple sites engage in synthetic battle space and are integrated at a hub in the DMO Network. Timing of systems is critical to operations and the broad variety of systems creates a severe sensitivity to *start-stop* operations. Additionally, random freezes of 2-5 minutes during large force training are disruptive to practiced tactical processes and would prove disastrous to system synchronization in synthetic battle space. Since SA is foundational to conducting tactical missions, and SA is a desired target of assessment to understand the effects of DMO training programs, a non-intrusive method that takes advantage of automated data collection capabilities to support objective assessment of SA during DMO training is a research and development goal.

SA ESTIMATION REQUIREMENTS

Before discussing an approach for addressing the assessment challenge in DMO, it is necessary to frame the concept of SA and how it might be exposed during normal operations in the DMO environment. A good starting point is to understand the relationship of information and situation awareness. Researchers focused on SA note that more information does not correlate to higher SA. In fact, information overload is often a factor in reduced SA (Endsley and Garland, 2000). So, the presence of information is a factor, but to understand SA, we must analyze deeper. Other research has noted that situation awareness and situation assessment are linked together with situation awareness being a form of metacognitive projection of information requirements and gathering strategy based on observations taken in situation assessment (Endsley, 2000). A general definition of SA found to be a valid roll-up of awareness and assessment has been developed by Endsley. SA is described as "the perception of the elements in an environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 2000). A restatement from the tactician standpoint might go like this, "the sorting and perception of information related to the current and projected tactical situation, the comprehension of their effects on the tactical situation, and a clear mental model of decision outcomes based on available choices". Going back to the WIC grade sheet study mentioned in the introduction, a tactical operator is said to have good SA when he *understands the battlefield sufficiently enough to make choices which achieve his objectives for the mission.* Tactical instructors know that good SA is rarely ever total SA of the battlespace and SA is not monolithic in time or across mission teams. Understanding what information is needed as complement to knowledge and experience formed expectations is a good starting point to begin solving the problem.

The tactician begins SA building by first establishing a mental model (or template) of the situation. The mental model is a result of previous training experiences that purposely build knowledge and perceptual skill baselines for the purpose of rapid recognition of similar situations. This is much like an intelligence officer would project a situation through the process known as intelligence preparation of the battlespace (IPB). In IPB, a carefully devised formula of data gathering and assessment is employed to understand the nature of tactical or operational problems. The aerial tactician relies on a much more generic and automated IPB that is achieved through repetitive conditioning of training scenarios in which the processes are trained to a level bordering on automaticity. Based on this trained-in template, the tactician starts with a set of expectations and critical information gathering points. The intelligence officer would call the expectations a potential *course of action* (COA) and the critical information requirements *named areas of interest* (NAI). The relationships noted here show that the processes of establishing SA at any level follow an established and predictable methodology. At the operational level, deliberate decision making can be time consuming, and at the tactical level, it is a flash of mental processes, but they are essentially on the same track, just moving at different speeds and sensitivities to information depth. The operational analyst has considerably more time to sort through information and assemble a picture of the battle situation. The aerial tactician's time to assemble SA can be measured in single-digit seconds. Yet, though they are executed at a very high speed, the tactician's solution templates provide an excellent framework to model SA requirements and make comparisons of projected versus demonstrated performance.

SA ESTIMATION SYNTHESIS

Researchers at AFRL are addressing the study of SA in DMO training using existing SA rating techniques and the decomposition of mission essential competencies (MEC). Decomposition of air superiority MECs enable researchers to assess combat ready performance by relating discrete execution tasks to applicable knowledge and skill sets (Denning, France, Bell, Symons and Bennett, In Press). The MEC decomposition study also opens a path to understanding information requirements in the tactical domain to support decisions required for task selection and execution. The decomposition of MECs includes an extensive analysis baseline of enabling tasks and discrete tasks. At the discrete task level, information gathering requirements and decisions are also mapped in detail and form a complete structure of information-decision-task relationships.

Table 2. Mission Essential Competencies

MEC
1. Organizes forces to enable combat employment
2. Detects factor groups in the area of responsibility.
3. Intercepts and targets factor groups.
4. Employs ordnance against valid hostile targets and/or denies enemy weapons IAW mission objectives
5. Determines and initiates appropriate follow on actions
6. Remains oriented to force requirements.
7. Recognizes the trigger events/ situations that require a shift from one phase to the next.

AFRL researchers are employing the discrete tasks of decomposed air superiority MECs 1-4 with a situation awareness construct for MECs 5-7 to build SA estimation templates. A principal strength of the SAGAT method is the employment of focused questioning at highly detailed levels to reduce sensitivity to subjective values of the trainee or observer. Discrete task lists associated with MEC decomposition provide a ready reference to limit subjective inputs to binary forms. In most cases, the input can be valued as yes-no, true-false, or is-is not. The current evolution of performance measurement capabilities requires extensive use of observer-based inputs. However, efforts are underway to provide automated objective inputs through analysis of pilot interface display data in context and voice message format and content processing algorithms. As these programs mature, the logical framework developed from discrete task maps will be able to shift more into automated domains.

The primary strength of the SART technique from an instructional standpoint is the post-mission context in which it is conducted. When attempting to characterize SA estimates, it is important to project the expected level of SA as well as the dynamic nature of real-time SA. Mental templates employed by tacticians contain expectations of what information is important at what time and how the information needs change as the situation unfolds. The SART strategy provides a more studied look back at SA levels during a mission. This is a dual-edged sword, but the good side is one of reflective analysis of SA within the context of a complete understanding of the ground truth of a mission. This technique is the norm in instructional debriefing of tactical events. It requires a disciplined approach and is not without some vulnerability to studied responses or miscalculated perceptions of SA. The discipline is enforced by adherence to the preferred solution template for a problem. To this end, a semi-automated strategy must be sensitive to contexts and expected levels of SA. For instance, it is not uncommon for a flight to be committed into an air superiority engagement with little to no SA of the tactical problem. The flight lead may have knowledge only of entities crossing a set of trigger criteria to start closing the distance. His wingman may only know that the flight is turning hot to start an intercept. Employing the SA expectation template that is companion to the tactician's execution template can enable a spectrum of latent analysis similar to SART's post-mission wrap-up and also maintain a disciplined examination that avoids subjective corruptions as noted in the limitations of SART.

An execution template is normally recognized as a series of steps to complete a problem. Its complementary expectation template provides potential COAs and their critical information requirements. Merging these two together in time requires modeling the sequence as it would be driven in a tactical scenario. Employing this concept within the MEC framework, discrete task mapping can be used as a starting point to develop models of expected information gathering strategies within dynamic tactical contexts. The demonstrated performance can then be compared to model-based performance on observable variables to suggest potential differences from the optimum SA building strategy taught as convention in the air superiority community. Much of the problem with SA assessment is intangibility of actual states. Modeling accepted solutions provides a capability to compare the surrounding evidence of performance that is measurable, place it into context, and infer estimates of the presence or lack of SA based on divergences from the model baseline.

It should be noted that in instructional circles it is agreed that even the most carefully undertaken examination of SA during a mission debrief is subject to error in estimation of actual SA states at any given time. The limitations of SART also exist in the mission debriefing room. Instructors are trained in methods to gather evidence of SA and note the relationship of performance to the suggested SA evidence. In the end, the analysis of SA remains a

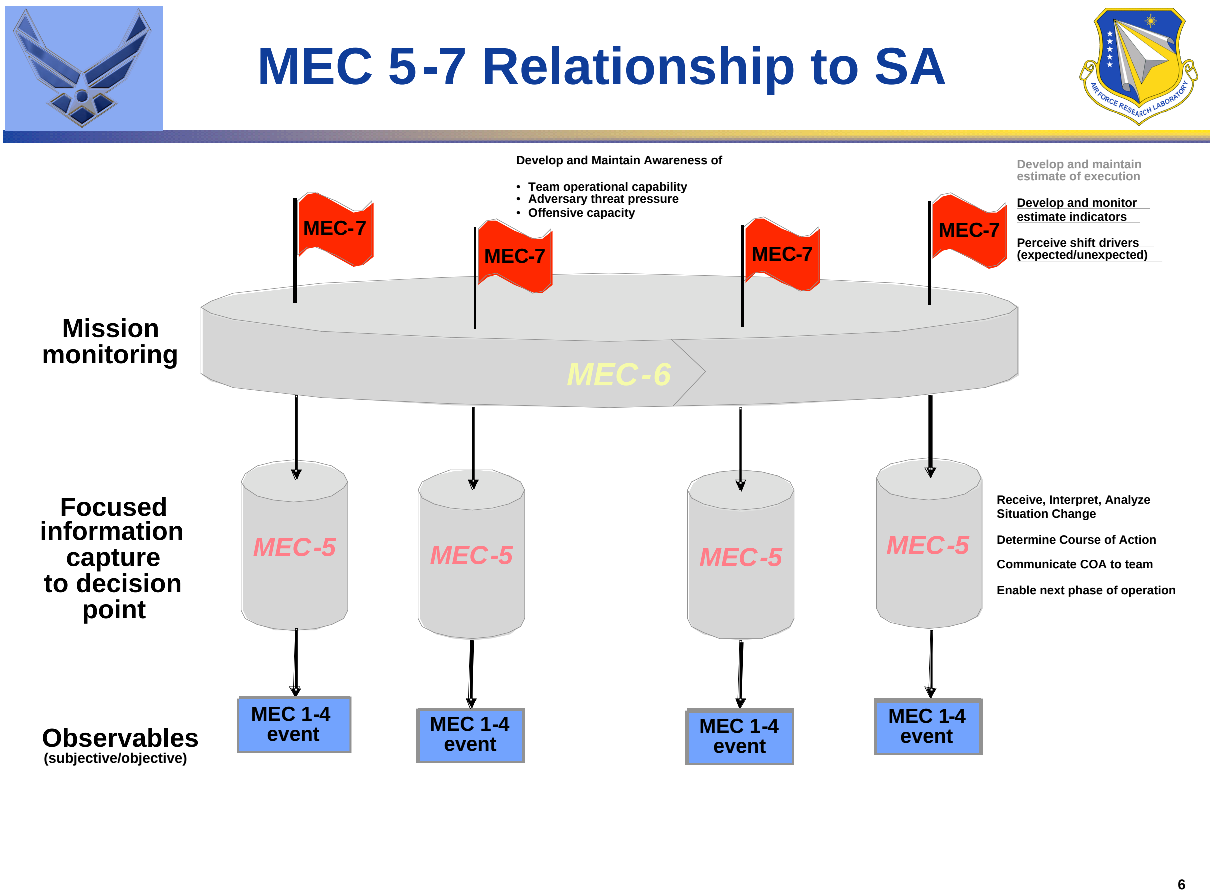

Figure 1 Mission Essential Competency and Situation Awareness Relationships

subjective but informed judgment by the instructor based on the observed evidence. The instructor is likely to comment, "Your SA appears to be low here and this is the information that appears to be missing." Automated or semi-automated support for the examination of SA states would conform to the instructional approach and produce probabilistic assessments of SA.

SITUATION AWARENESS AND MISSION ESSENTIAL COMPETENCIES

Development of the situation awareness assessment strategy begins with an understanding of the MEC relationships to SA. As noted in the decomposition study (Denning, France, Bell, Symons and Bennett, In Press), MECs 5-7 have strong relationships to situation awareness in the form of situation assessment and information gathering. Figure 1 shows a simplified diagram of MECs 5-7.

We employed MEC 6 (Remains oriented to force requirements) as the overall observer of expected events leading to course of action shifts. The purpose of MEC 6 as stated from the original survey is: *Individual, flight and force management and orientation during execution of prescribed mission.* Building on this purpose, we established MEC-6 as the sorter of critical information. The trigger of critical information is the focus of MEC-7 whose purpose is: *Recognizing trigger events/situations that require a shift from one phase to the next.* Triggers represented by flags in the pool of all available information cue the gatherer that a new requirement for information and/or action exists. The focused gathering of information is the central theme of MEC-5. When information is sufficient to proceed to action, an observable sequence with MECs 1-4 is carried out to enable tactical execution.

For the demonstration of concept, mapping events and observables related to SA was accomplished by developing a matrix of major trigger events in the conduct of an aerial engagement. Simplified descriptions of required information and actions were aligned to observable events resident in MEC 1-4

Table 3. Situation Awareness Trigger Matrix

MEC-7 ACBT PHASE TRIGGERS (In general order of occurrence)	**PARAMETRIC DEFINITION (observable conditions in the battle space)**	**STIMULATED PROCESSES (the next phase of conduct produced by the trigger event that is preceded by a MEC-5 intel gathering to decision)**	**DECOMPOSITION OBSERVABLE EVENTS (may be objective or subjective inputs required)**	**REAL-TIME INFORMATION REQUIRMENT (must be collected from sensors in the battle space)**	**BACKGROUND SKILL or KNOWLEDGE REQUIRED (supporting framework or conditioning from planning or mission study)**
Presence of targetable entities in the fighter area of responsibility 7.2	Targets present in the fighter AOR and with EW or AI detection range	Detection phase begins in earnest with combined EW and AI involvement to gather intelligence on force size, composition, and movement	1) EW communications reporting targets in AOR 2) Fighter AI displays presenting targets with histories 3) Fighter communications reporting confirmation of targets in AOR	1) Reported presence using BE or BRAA by offboard EW 2) Detection and correlation of AI targets in AOR 3) Reported presence from team AIs using BE or BRAA	1) AOR dimension parameters relative to bullseye or current position of fighter group 2) Reporting formats and contracts (in/out) 3) AI display interpretation 4) Current position relative to threat axis 5) AI operations related to detection
Commit criteria met 7.3	Closest target group crosses commit line (or distance from fighters) with defined aspect (normally >120 degrees aspect angle)	1) Departure from CAP point to close to weapons employment range 2) Enhanced detection effort to gather intelligence on force *intent* along with continuing collection on size, composition, and movement	1) Commit call by fighter flight lead with confirmation of receipt by team members 2) Fighter aircraft depart CAP position in direction of adversary force	1) Adversary position relative to commit line (or condition) 2) Adversary track direction 3) Commit command 4) Team confirmation	1) Commit line placement in AOR and relative to BE or fighter current position 2) Contract commit criteria 3) COA when commit is called 4) Who has commit authority 5) Who can recommend a commit via communications 6) Contract report responsibilities
Abort criteria met 7.4	Target groups change direction of movement to cross line or distance from fighters that suspend need to close for weapons employment	1) Passive monitoring of adversary force flow 2) Deliberate slowing or stopping of closure toward DEZ 3) Fighter team repositioning to original CAP position	1) Abort call by fighter flight lead with confirmation of receipt by team members 2) Fighter aircraft conduct contracted commit abort plan for orderly withdrawal from commit geometry	1) Adversary position relative to commit line (or condition) 2) Adversary track direction 3) Abort command 4) Team confirmation	1) DEZ dimensions relative to BE (and commit line) 2) Contract abort criteria 3) COA when abort is called 4) Abort authority 5) Report criteria

decompositions. The matrix was then used as a guide to structure event sequences related to SA gathering and maintenance with MECs 1-4 in the decomposition database. Additional fields were added to identify SA-related items and numeric sequences were assigned to enable logical processing of observations from AFRL's Performance Evaluation and Tracking System (PETS). Table 3 provides a section of the matrix used as a guide.

The matrix and decomposed MEC database provides essential elements for logical modeling within a probabilistic network. The MEC database relates observable discrete tasks to the larger framework of SA capture and maintenance for focused events on the tactical timeline. An excerpt of the MEC decomposition database shown in Figure 2 denotes the organization of SA-related discrete tasks to establish situation awareness of detectable entities entering the fighter area of responsibility (AOR).

The principal focus of understanding whether SA is present on targets that enter the fighter AOR exists within the enabling task of *recognize and report detections*. This enabling task is broken into the discrete tasks required to operate detection systems and communicate situations to the fighter team. The series of 7.2.x.x numbers relate discrete task lines that demonstrate presence of knowledge about targets in the AOR. It should be noted that the nature of the database divides tasks into tactically relevant domains; hence there are equal numbers in different task lines that relate to accomplishing the same task in different tactical contexts. This distinction is required for some analyses but for SA it is not essential to divide them.

141	M7.2 Trigger: Targets appear in fighter AOR	Targets present in the fighter AOR and within EW or AI detection capability	
142	Recognize and report detections		7.2.1
143			
144	**Collect situation awareness beyond targeting range (TR)**		
145			
146	**Perceive and recognize visual display targets**	`	7.2.1.1
147	Corral and catalog altitude data to respective detections		
148	Update detections in AZ/EL AOR		
149			
150	**Perceive and recognize communicated targets**		7.2.1.2
151	Corral position to communicated detection location		
152	RWS B Spotlite or other radar detect enhancement		
153	Assess altitude for detection (communicated or self-detected)		
154			
155	**Collect situation awareness within targeting range**		
156			
157	**Percieve and recognize visual display targets**		7.2.1.1
158	Corral and catalog detections with respective altitudes in AOR		7.2.1.1.1
159	Report detections IAW communication standards		
160			
161	**Perceive and recognize communicated targets**		7.2.1.2
162	Corral position movement to detection location		
163	RWS B Spotlite or other radar detect enhancement		
164	Verify EL control for communicated altitude		
165			
166	**Collect situation awareness from radar warning receiver**		7.2.1.3
167	Perceive and recognize sensed adversary radar presence		
168	Analyze threat level presented in real time		
169			
170	**Communicate detected targets to combat team**		7.2.1.4
171	Use contract report criteria		
172	Use contract report brevity format		7.2.1.4.1
173			
174	**Merge intelligence inputs to build mental commit picture**		7.3.1.1
175	Recognize identification (ID) estimate(s) and commit influence(s)		7.51.1.
176	Recognize range or azimuth array		7.5.1.2
177	Recognize factor and bounding range parameters		7.5.1.3
178	Recognize acceptable versus unacceptable tactical problem		7.4.1.1
179			
180	Assess commit criteria		7.2.2
181			
182	**Determine geographic position of leading edge (LE)**		7.2.2.1

Figure 2. MEC 2 Detection Database Excerpt

The MEC decomposition database also relates discrete tasks to applicable team member and whether the observation is currently an objective or subjective measure. These issues become important when establishing the evaluative method to target SA measurement at the proper individual and to bring in the correct observations at the proper times in a tactical event. One of the complications of dealing with tactical situations is their tendency toward greater uncertainty as the situation matures. After all, both sides are engaged in a fluid contest of wills that has as its centerpiece a deliberately deceptive nature. The tactician is not immune from the fluidity. In fact, the nature of tactics requires a strong attempt to overwhelm the senses and break down the opponent's perception of events as well as decision making abilities. This makes broad assessments during an engagement or an entire mission difficult at best. The bridge to reliable and valid assessment can be achieved by paralleling the method tacticians use to immunize themselves from the time compression and deceptions of adversary forces. This method of error mitigation is to scope the assessments down to short periods leading to key engagement decisions and actions, then to scale up using the conventions of fighter employment as they are taught and practiced. Referring back to Figure 1, small scale assessments involve the vertical process from the trigger to the MEC 1-4 outcomes. Each of these assessment periods exists at a tactical crossroads where the friendly course of action will be determined based on perceived information and observed outcomes of decisions. The observed outcomes can then be measured against accepted solution models to establish measures of divergence from the expected decision path.

MODELING & ASSESSMENT – STATIC

A small initial study of this method is currently in development. In this study, high level triggers are the primary candidates for evaluation. These represent the *paved roads* of the tactical mission. Even as such, the information gathering and decision outcomes are relatively short bursts in time for shifting between important phases of the mission. For example, the first trigger event occurs when detectable entities present themselves in the fighter team's AOR. Entities in the AOR triggers the critical observations related to the enabling task of *recognize and report detections*. Figure 3 illustrates a preliminary concept of relationships that support assessment of SA for Entities in AOR as a simple example.

The network shown relates background knowledge of the battle space with observable events surrounding the presence of entities in the AOR. In the DMO system, the ground truth of entities in the fighter AOR is an objective observation that can be employed to trigger the assessment of SA of one or more members of the team. For simplicity, the explanation here will keep to a generic sense.

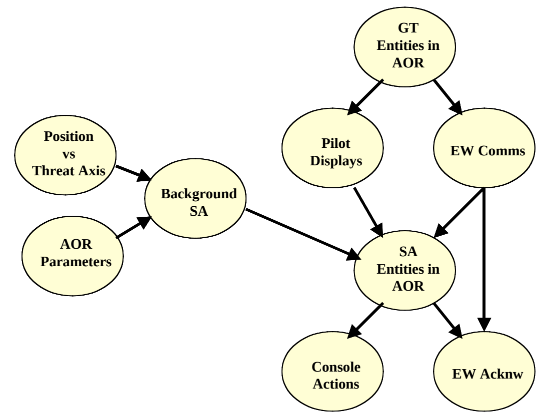

Figure 3. Assessment of SA - Targetable Entities in the AOR

The trigger event at the top right establishes a starting point for probabilistic assessment and also sets the record straight that entities do exist in the AOR. Modeled from an instructional analysis method, the next significant cues of SA perception will be the presence of target detect files on the pilot display and may include early warning communications (EW Comms) if the targets are outside the fighter radar's detection range. The bottom right blocks are responsive actions from the fighter. In the Console Actions node, certain movements of tracking and volume control features on the radar that would clue the instructor in to the presence of SA are employed to establish a good probability of recognition of the event. An acknowledgement (or report) of detection is also strong evidence the SA exists for this event.

The weights of the various connections and their effects on the probability of SA are modeled using subject matter expertise to approximate the analysis that an expert instructor would carry out after observing the same events in a mission playback. For instance, the presence of ground-truth entities sets the stage for SA assessment; but if radio transmissions are made that falsely report entities, SA may temporarily be judged incorrect. The flight may simply be reporting false targets and resolve the issue within the next few seconds. Likewise, if a report is made acknowledging entities, and ground truth is positive, a strong case can be made for valid SA on presence of entities.

Initial review of preliminary models shows a strong potential for agreement with the subjective evaluations of instructor pilots conducting SA judgments in post-mission debrief conditions. In DMO, many observables used by the instructor to capture this judgment will be available in real time through the system of communications between DMO sites and on-site data processing for displays. This will allow not only post-mission assistance for the instructor, but also opens the possibility for assessing SA real-time for training interventions during the mission. This will add capability to future DMO goals of adaptive training through real-time scenario modifications.

The models established for major trigger events in an aerial engagement are microcosms of SA. Typically, an instructor is interested in this level to establish a sense of the cues and decision processes relevant to a failed point of execution in order to correct the deficiency. This level of SA is simply an assessment of knowing what is going on in the tactical sphere that has immediate relevance to mission objectives. In some literature on SA, a case is made that this is not all of the makings of SA (Nofi, 2000); however, within the realm of tactical training it is the part that the instructor can improve through structured training interventions. These micro-models of information gathering and decision quality, when combined with the complementary evaluations of PETS-based performance measures support effective instruction at the individual trainee level.

MODELING & ASSESSMENT – DYNAMIC

Connecting the dots between micro-analyses of SA would seem to be a daunting problem. After all, the ebb and flow of tactical situations affects SA levels in all participants to varying degrees. While the micro-models of information and decision quality are important indicators, they are nonetheless static markers of finite elements of SA at a given point in time. To understand the SA process in a dynamic environment, modeling must put the same motion to the SA construct as is occurring in the tactical situation. In the instructional component of aerial warfare, skill development is enforced through repetitive exposure to scenarios in the training program. In air superiority operations, the need for rapid assessment and decision making has fostered a common approach to dealing with adversary tactics. Fourth generation aircraft, with their similarity of weapons capabilities, pulse-doppler radars, and fire control systems produce a common and recognizable pattern of information gathering and decision making which, when combined with classified targeting conventions, frames a predictable path of SA development. An example of the information/decision process is shown in Figure 4. This framework was developed by air combat experts at the USAF Weapons School as a teaching aid for tactical execution.

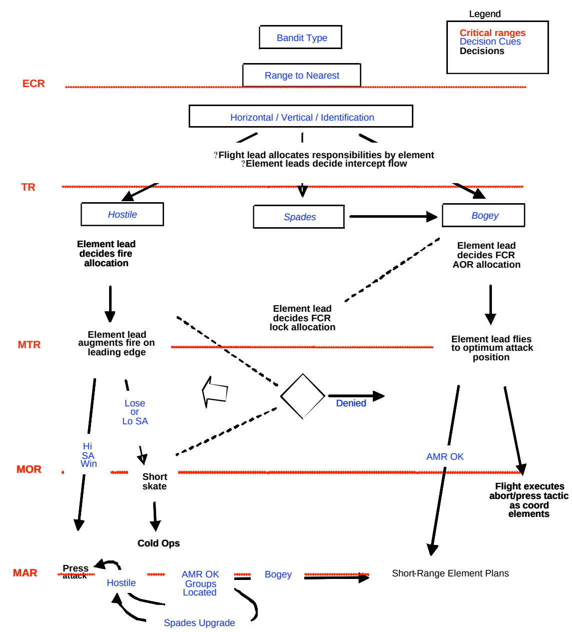

Figure 4. Air Superiority Information-Decision Path

At the outset of a tactical engagement, any of the fighters is likely to begin the process with little to no usable SA on the attacking force. In fact, the adversaries are likely to present geometries to deceive the fighters and compress decision times. The fighters build SA on the tactical problem focusing on the primary decision cues shown in blue. As these decision cues are presented and validated, members of the flight take on decision responsibilities which, in turn, express observable performance measures through manipulation of systems and communications exchanges. Any of the fighters' responsibilities can be traced through this framework to establish time-stamped information requirements and decision points. These tracings then provide the basis for an expert model of an accepted solution that can be used as a standard to measure against demonstrated performance. Therefore, it represents a construct to link the micro-analyses of information and decision quality to present a mapping of SA performance over the total time of an engagement in the same way instructors examine the process in post-mission analysis.

MODELING AND ASSESSMENT – TEAMS

The preceding discussion related an ability to thread static observations of information/decision processes into a dynamic pattern for any one of the members of a team of fighters. The diagram in Figure 4 speaks primarily to the flight lead and element lead processes at the top of the diagram. In addition to the framework shown, *targeting conventions* and *element fire contracts* used in the tactical arena must be employed to examine wingman SA levels. This is primarily due to the different targeting strategies that may be invoked in certain tactical situations. The wingman is typically a doer and not a talker. Judging SA levels in the wingman's domain requires understanding the contracts between the flight or element lead and his wingman and what these contracts drive in terms of observable outcomes. The bond of responsibilities between a leader and wingman are the strongest link in tactical teamwork. They are generally taught as non-negotiable mandates of expected performance. These contracts between the leaders and wingmen can be used to establish a model of the expert wingman and provide measurable expectations. It is then possible to employ discrete task mapping in an integrated assessment of leader and wingman performance to assess both team members' dynamic SA levels throughout an engagement.

The relationship between the overall flight leader (#1) and his element leader (#3) is characteristically less rigid than between the leaders and wingman. This is a necessity of the tactical domain; however, it does not present ambiguities to SA assessment. The #3 aircraft also works under contractual relationships with #1 and these are primarily manifested through the *targeting and maneuver* contracts established in doctrine and the flight brief. In fact, Figure 4 is the roadmap we use to define #3s team contributions to information sharing and firepower allocation. A brief example is shown in Figure 5. When measuring team SA, the anchor point is information attained versus required and performance in comparison to the tactical contract. These components can potentially be modeled in probabilistic terms using the instructional context discussed previously.

It should also be noted that contractual relationships are abundant in C2 doctrine directing support of the fighter flight. The AWACS or CRC weapons director (WD) in direct communication with the fighter flight formats his/her communications in a doctrinally prescribed manner that is primarily aimed at providing the information at the proper pace and depth to foster the fighter flight's SA build-up during the engagement. To assess this team level interaction requires building integrated models that synchronize fighter information needs with the delivery schedule of the WD. With this team level model in place, automated support for comparisons of performance can be generated using real time information in DMO to provide an assessment of the team's performance in the same manner the instructors would complete it at the end of the mission.

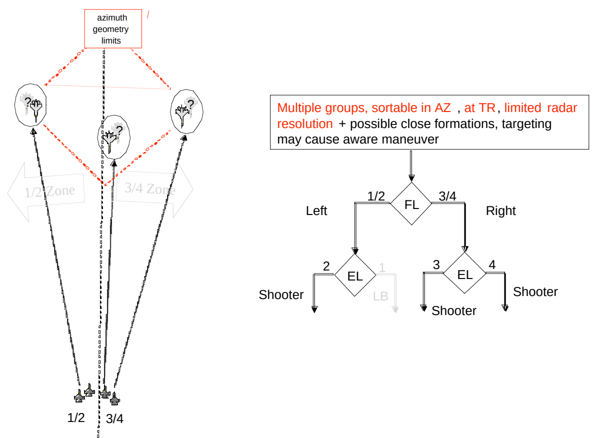

Figure 5. Example Targeting Contract

There are several key issues that require attention to produce team SA estimation tools. Those are:

1) Understanding the doctrinal relationships between members of teams and how they share information about tactical situations
2) Development of MEC sets for the mission areas involved in the team
3) Decomposition of MECs into enabling and discrete task sets
4) Development of expected performance models which relate discrete task levels in team interactions
5) An understanding of the key triggers that relate task sequences to SA building
6) Improvements in access to performance data within DMO sites

At the present time, AFRL is engaged across the spectrum in these areas with expert operators and instructors at the USAFWS. Although much of the work is in its infancy, demonstrations of concepts are proving to be valid analytical representations. The examination of these processes within the air superiority domain is charting a course for larger domains with broader mission diversity.

CONCLUSION

With the availability of previously untapped data streams in tactical simulations, SA assessment tools for DMO training may now follow the construct of what tactician instructors have been developing for many years – an assessment capability of information flow and decision quality that supports mission objectives. These instructional methods have been carefully constructed over many years and serve as valid and reliable models for automated processing. In live-fly training they are consistently used in post-mission analysis. With the advent of DMO (and the wealth of information flowing through its systems in real time) there is a potential to accelerate the timeline of assessment and have it ready to present or ready to act upon immediately within the training session. With integration of assessment and intelligent scenario generation and modification methods, technology can make the proven strategies of many years of tactical instruction on SA collection and management have staying power into many future generations of aerial combatants at a much reduced investment of time and aircraft O&M costs.

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