Performance Assessment in Distributed Mission Operations: Mission Essential Competency Decomposition

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ABSTRACT

Mission Essential Competencies (MECs) are in continuing development by the Air Force Research Laboratory for training program enhancement within all mission areas of Air Combat Command. They are unique to specific mission areas such as air combat, suppression, air-to-ground attack, etc. yet provide broad training assessment possibilities in large force team training. MECs are defined as the higher-order individual, team, and inter-team competencies that a fully prepared pilot, crew or flight requires for successful mission completion under adverse conditions in a non-permissive environment. As the definition suggests, MECs are conceptually impractical to use as a means of performance assessment. Decomposing the MECs into their component knowledge, skills and experiences with logical links from observable events represents the most appropriate approach. This paper discusses the approach to decomposition and linkage taken by researchers and subject matter experts to identify and quantify observable events at the task level and to define requirements for observation systems to produce data of sufficient fidelity to support assessment. Air to Air Task-to-MEC mapping links observable events in DMO through knowledge, skill, and supporting competency sets to ultimately make assessments that can be traced to the MEC level. The task mapping product permits objective data from the AFRL's Performance Evaluation Tracking System (PETS) to inform probabilistic assessments of competencies through separate logical constructs for instructional support. During the process, important lessons were learned about the initial MEC process and construct, quality of SME information, and how the development of MECs within a mission area may be improved to facilitate decomposition to observable and assessable levels. Applications of the decomposition product are presented to highlight confidence levels of objective and subjective grading requirements for PETS or similar data collection systems as well as logic techniques developed to bridge areas difficult to assess within existing DMO architectures.

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INTRODUCTION

Mission Essential Competencies (MECs) have been adopted by USAF's Air Combat Command as the principal training transformation model from mission based training to competency based training for distributed mission operations. MECs are defined as the higher-order individual, team, and inter-team competencies that a fully prepared pilot, crew or flight requires for successful mission completion under adverse conditions in a non-permissive environment. At this high level of composition, it is understandably difficult to transform MECs into concrete measures in training program assessment without a methodology to bridge MEC components to the traditional assessment targets of tactical instructors — performance of observable tasks. This presentation describes work performed to support detailed analytical breakdown of air superiority MECs to support performance assessment in the virtual environment of DMO and in the long term the entire training continuum.

Background

Researchers at AFRL's Warfighter Training Division are currently investigating several methods of linkage to extend the MEC concepts into training program development. These are taking place at both high and low levels of MEC application. In 2003, AFRL produced the first MEC-linked syllabus for use by the USAFWS F-16 weapons instructor course (Bennett, Crane, 2003). This effort was developed as an extension of existing training research using the MEC construct and a low sensitivity audience (in terms of training quality impact) of mission ready pilots conducting continuation training. The WS syllabus employs a method of specific behavior stimulation in carefully constructed scenarios employing experiences elicited in the MEC derivation process as well as others provided by WS instructor SMEs (Symons, France, et. al., 2003). The WS syllabus represents the one of several applications of non-decomposed MECs in a *formal training program* within ACC (Bennett, Crane, 2003).

A different path toward MEC-based training development has also been undertaken with the linkage of AFRL's Performance Evaluation Tracking System (PETS) to assessment of skill and knowledge levels using the Performance and Competency Evaluation Support (PACES) tool (Carolan, Schurig and Bennett, 2003). In PACES, cumulative observation and analysis of selected measures of performance are employed to suggest evidence of competencies development in combat employment (Carolan, Schurig and Bennett, 2003). The methodology used in PACES (Bayesian analysis) requires cumulative assessment to establish validity of reporting. Measures that feed PACES analysis must also accurately identify and assess key elements of performance each time they are reported to generate valid and reliable ground truth. One of the early aims in decomposition for PACES was to try to enhance the ability to make assessments valid and reliable for one-time or short-run sessions however, they are less likely to produce accurate capability in these situations. Accumulated assessment over multiple training periods should provide valid and reliable MEC based assessments.

Training Programs versus Instructor Needs

Cumulative assessment is a necessary consideration in day-to-day training management decisions. In current training methods, an instructor reviews grades and comments from previous missions to develop an estimate of the performance likely in the next training session. Over sustained periods of mission training, cumulative assessment also has merit in establishing estimates of combat capability. In a broad context, it provides tenable measures for leadership decisions as well as training program management.

In day-to-day training, an instructor charged with making improvements is primarily concerned with real-time, one-time assessment. In conducting the analysis of air superiority MECs, a goal was established to make the decomposition viable using tools developed that could exploit real-time measure and analysis for "on-the-fly" scenario control decisions. When in a hot simulation employing a single work station, instruction relies less on cumulative performance of previous training and more on the task-by-task analysis of correct or incorrect execution in accordance with established tactics, techniques, and procedures (TTPs). The *FREEZE* button is the simulator instructor's best resource to focus attention and make effective training interventions. The *REPLAY* function allows repeat visits to performance trouble spots while maintaining perfect scenario control. Once the student is in "the box," an instructor is less concerned with cumulative assessments and more interested in the detailed strengths and weaknesses of each specific training event. Training, no matter how grand the scale, ultimately boils down to individuals performing in a nearly binary assessment of correct performance or incorrect performance based on Tactics, Techniques and Procedures, or TTPs. The student either performed correctly or needs help (most likely immediately) to fix a problem. So, while cumulative look-back scoring is a necessary foundation for instruction, systems must also serve the needs of real-time instruction. For future growth in this area, our goals broadened to include extensive breakdown of tasks to enable assessment of discrete events familiar to instructors in one-on-one training sessions. Now, enter DMO and its unique attributes. The *FREEZE* and *REPLAY* are not easily mechanized in DMO and up to this point, the premier DMO exercise, Virtual Flag (VF), has not employed them at any level. When a system has problems in VF, it is taken off-line, fixed, and returned to the scenario at a later time. When trainees are having problems in DMO, they are not afforded the luxury of freezing the scenario to talk about it. As DMO networks grow and are utilized more frequently, training interventions are less able to follow traditional simulation methods and must rely more on real-time assessment and on-the-fly interventions to correct assessed deficiencies. The nature of distributed training requires investigation into effective real-time training intervention methods so corrections are possible during hot simulation in individual systems and not solely limited to after-action analysis.

Bridging from MEC to observable task using a detailed decomposition can accurately define what can be observed either *subjectively* or *objectively* about individual or team performance. This concept is important in the current state of information flow and bandwidth usage between distributed locations. The decomposition process needs to relate to tool builders what can and cannot be observed through information ports between the distributed sites. In traditional instruction, humans review and analyze the display data they interpreted during employment. In DMO, this data is not passed in the distributed bandwidth, yet it has not lost any of its instructional value. Decomposition of tasks and how to assess them provides a clear picture of what remains a subjective assessment requirement. It also establishes limits on subjective review. Subjective inputs run the risk of introducing large variations of measure on equal performances if poorly defined. Poor definition of a subjective input can skew assessments under certain conditions or blur validity when variations in grading are permitted under too broad an area to be assessed. Decomposing MECs to a detailed level provides the option not only to identify, but also to suggest methods to limit observation inputs to a narrowly-defined group of grading criteria. Another risk in subjective review is inundating the reviewer with required elements to rate which may prevent them from either rating all the desired elements or reducing the validity of subjective ratings. Ideally, the observer would be limited to answering questions about performance driven by TTPs and only where required to fill in what objective (system information) observation cannot measure.

With detailed decomposition, MEC sets can be linked to all levels of assessment required for training. Systems can be produced which can assess knowledge and skill capabilities for the individual and team not only to accumulate data on long-term performance for training and budgetary program management, but also to provide the means to accurately focus real-time training interventions in areas likely to produce the highest payoff for immediate improvement. During database creation for PACES, ***the MEC product and process*** were examined in this light for potential improvements in restructuring or reorganizing components for improved analysis. Valuable lessons were learned not only about decomposition mechanics, but also about the output of the MEC process itself, developing requirements for DMO terminal data capture, as well as information transfers between systems. The goal of the decomposition was to produce a broadly applicable database that extended beyond the PACES requirement to provide a complete analysis of the Air Superiority MEC set. The rest of this paper discusses the initial MEC decomposition project including lessons developed for decomposition efforts as well as future MEC analyses.

POINT OF DEPARTURE

The PETS system developed by AFRL employs information encoded in High-Level Architecture (HLA) and Distributed Interactive Simulation (DIS) formats to establish performance measures about tactical situations. It is maturing abilities to retrieve information on individual and team performance but has limited capability to support real-time assessment needs (Watz, Keck, Schreiber, 2003). At the outset of the decomposition project, PETS could provide very little hard data considered essential for real-time assessment in traditional instructor-student settings. Much of the data remains elusive due to limitations of HLA and DIS information architecture. However, in order to allow initial assessment capability to grow with PETS data-capture growth, decomposition aimed for a full examination of all aspects of air combat MECs to provide a prioritized requirements roadmap to PETS for data gathering evolution. The end state of the decomposition was to provide a fully assessed and mapped measure of supporting tasks within each MEC and how they relate to the knowledge and skill sets identified by subject matter experts during the MEC development stages.

Cognitive Task Analysis (CTA) on Steroids

A review of CTA literature suggests that elicitations may be helped during the process if the analyst is somewhat familiar with the subject. This knowledge helps to facilitate work with SMEs in gathering the details required for a CTA. In this project, AFRL turned the accepted practice around and employed F-16 subject matter expertise from within the ranks to *lead* the CTA breakdown with the *support* of experimental psychologists. The core decomposition team is lead by a long-time F-16 instructor pilot with training system development and training program command experience. Other F-16 team members have current formal course instructional expertise and two members were graduates of the USAF F-16 Weapons Instructor Course. The panel is heavily skewed toward F-16 operations since AFRL's DMO research platform is based on F-16 operations. To ensure accuracy of generalizations in air superiority, the team also includes F-15 instructor experience with training program management. Psychologists from AFRL, Micro Analysis and Design, and University of Dayton have assisted CTA structuring through supervision of all SME work sessions and interaction during analysis debates.

TASK ANALYSIS

In general, mission essential competencies 1 through 4 are well defined concepts, which an instructor cadre can readily break into subcomponents of tasks or objectives. The product of MEC analysis provides a clear definition of each competency and relates knowledge and skill sets as well as supporting competencies (Colegrove, Alliger, 2002). Additionally, starting and ending points establish identifiable boundaries to divide supporting tasks or objectives among the MECs. There are difficulties in the construct in MECs 5 through 7 and those will be discussed in a later section.

Table 1. Enabling Task Sets for Each MEC

MEC	Enabling Task Set
1. Organizes forces to enable combat employment	1.1 Position team for battle 1.2 Ready aircraft for battle
2. Detects factor groups in the area of responsibility.	2.1 Distribute sensors to cover battle space 2.2 Recognize and report detections 2.3 Assess commit criteria
3. Intercepts and targets factor groups.	3.1 Commit forces 3.2 Assess macro attack geometry 3.3 Distribute / assign / position sensors for attack 3.4 Position fighter elements for optimum attack geometry 3.5 Assess adversary group geometry 3.6 Position element team for optimum attack geometry 3.7 Maneuver for optimum visual fight geometry
4. Employs ordnance against valid hostile targets and/or denies enemy weapons IAW mission objectives	4.1 Validate ID status of targeted group 4.2 Select optimum weapon for situation 4.3 Achieve parameters for a valid shot 4.4 Engage target with adequate weapons for a kill 4.5 Maneuver to minimize defensive vulnerability 4.6 Employ countermeasures to enhance defense 4.7 Separate from fight space or closing threats
5. Determines and initiates appropriate follow on actions	5.1 Receive, interpret, and analyze situation changes 5.2 Communicate situation changes to team leader(s) 5.3 Determine course of action 5.4 Communicate course of action to flight/ combat team 5.5 Enable next phase of operation
6. Remains oriented to force requirements.	6.1 Develop and maintain awareness of team operational capability 6.2 Develop and maintain awareness of adversary threat pressure 6.3 Develop and maintain awareness of offensive capacity
7. Recognizes the trigger events/ situations that require a shift from one phase to the next.	7.1 Develop and maintain estimate of mission execution 7.2 Develop and monitor estimate indicators 7.3 Perceive and recognize expected shift drivers 7.4 Perceive and recognize unexpected shift drivers

The MEC construct, as developed, uses experience-oriented relationships to link MEC levels to knowledge or skill areas. In the decomposition project, a task-oriented dimension was employed linking *enabling task* sequences to MECs in order to establish discrete, observable events as well as facilitate instructor SME participation. *Enabling tasks*, represent principal tasks an instructor would evaluate before delving more deeply into root causes of execution quality. They exist at a level immediately below the MEC itself and are considered the essential task set required to demonstrate the mission essential competency. Breakdown of *enabling task* sets within each MEC were developed from command doctrine, tactics manuals, academic references, and instructional briefing guides used to teach the various task sets used in fighter combat. Table 1 shows the relationship of enabling task sets to the MEC architecture.

Enabling tasks were further decomposed to physical actions (switch movements, control inputs, etc.) residing within each section. After subsequent agreement of physical actions, the SMEs then identified decision processes required to support system management, and cueing required to stimulate and inform decision processes. These areas were validated through comparison to employment teaching strategies at formal training units including the USAF Weapons School's F-16 weapons instructor course. The resulting breakdown provides a detailed view of the cues, decisions, actions, and goals required of a fighter pilot to demonstrate competency in each MEC independent of a specific tactical situation. The complete set of physical and cognitive tasks with an *enabling task* are labeled *discrete task* sets. Space allotted in this discussion precludes more than a sample of detailed task inventories. Table 2 shows a breakdown of Enabling Task 3.3 (Distribute/assign/position sensors for attack) into its supporting sets of discrete tasks. Color codes employed relate to current PETS support. Yellow denotes data possible in near term. White represents data not available in DIS or HLA. Gray is redundant to another MEC area, but included for complete examination of processes.

VALUATION OF INFORMATION

The decomposition adds significant dimension to support a broad array of assessment strategies. At the finest resolution individual performance is broken down into the most basic cueing, decisions, and actions that occur in air combat tactics. They are presented to a level that remains independent of the specific influences of a given tactical situation. Within the database, each discrete task item is linked to specific parameters found in tactics manuals or flight instructions/directives that provide the assessment tool developer to measure performance against recognized standards of employment doctrine. The database also links each discrete task event to the MEC-based knowledge and skill sets produced during MEC derivation (Colegrove, Alliger, 2002).

Linkage from discrete event to knowledge and skill sets was the most time-consuming task of the decomposition and bears some discussion on the methodology and lessons learned. The first application of the database is to bridge objective and subjective observations to the PACES assessment tool. Since PACES requires valuation of links to support Bayesian processing, a method of consistent and meaningful weights had to be derived. An interesting observation of dealing with SMEs from disciplines of high automaticity is the difficulty in recognizing internalized processes that encompass much of the automated tasks they do. The initial attempt to assign measures to links was taken up in a freeform discussion forum. These measures were incapable of withstanding scrutiny in subsequent meetings to complete the project. It was decided after the first meeting that a structured approach must be developed. The discrete task breakdown was completed first to allow full visibility to the project. In addition, several tools were developed to enable SMEs to define values with consistent, arguable merit. Table 3 shows link-weighting definitions developed by the team. . Another potentially valuable tool derived from the process was a re-engineered knowledge and skill chart that will be discussed in a later section.

Table 2. Discrete Task Inventory Sample

Distribute / assign / position sensors for attack
Select targeting template (flight) for updated adversary attack formation(s)
Select / apply standard template
Modify for variations outside template capacity
Communicate decision to flight members
Use tactical frequency
Communication follows standardized brevity format
Team acknowledges decision
Reorient radar AZ/EL for meld and targeting
AZ position and scan width covers area of interest
EL control verified or moved to cover area of interest
Find and verify assigned target group
Correlate acq corral to detections and BE data
Compare label to B-scan geometry for visual verification
Verify / upgrade identification status
Recognize current ID status of targeted group(s)
Employ internal upgrade capabilities (if possible/required)
Request / receive offboard upgrade (if possible/required)
Optimize radar mode(s) employment for SA/firepower
Select/apply high fidelity track type on target group responsibility
Establish secondary track information fidelity
Establish scan sanitization (detection modes) volume and update rates
Assign detection responsibilities to untargeted fighters
See MEC-2 inside targeting range
Leaders assure <TR detection when priority targeting is completed

Additionally, the process of identification and weighting was formalized to capture and inventory of knowledge and skills before applying weights. The inventory method sped identification of weight-worthy items and allowed SMEs an opportunity to consider the completeness of selection before applying weights.

Table 3. Working Weight Definitions

1 – Knowledge or skill enhances <u>efficiency</u>. 10% • Makes task go smoother, better coordinated, less time/energy expended. • Lack of area is highly unlikely to decide success or failure; an issue of fine tuning. 90% probability of success
2 – Knowledge or skill enhances <u>effectiveness</u>. 25% • <u>Contributes to degree of task success</u> and impact on tactical outcome. • Lack of this area may degrade outcome; an issue of moderate performance change. 75% success
3 – Contributes to <u>successful outcome</u>. 50% • Provides <u>discriminator</u> K or S that drives task to successful end state. • Lack of this area establishes equal probability of success / failure.
4 – Essential for <u>basic task accomplishment</u>. 75% • Provides set of K or S elements required to <u>carry out execution</u> steps for desired outcome. • Lack of this area leaves the operator without clear direction on required actions. 25% probability of success
5 – Essential for <u>initiation, guidance, & completion</u> 90% • Provides set of K or S elements required to <u>select and prioritize</u> task within mission essential competency context. • Lack of this skill leaves the operator with little or no ability to recognize, understand, or execute what is required for the given situation. 10% probability of success

The first pass through the knowledge and skills within a *discrete task* line produced non-valued markers where SMEs agreed to applicability of the knowledge or skill to the selected task line. Pre-selection without regard to weight smoothed the weighting process that occurred next; however, the nature of air combat does not allow for monolithic consistency and agreement across the board. At each meeting, SMEs required at least 1 hour of review and validation of previous work before delving into uncharted areas. This period of recalibration at each meeting was critical to maintain consistency in valuation, even with existing weight definitions, as the process moved forward. Even with established definitions of weight and link rules, debates often produced different views of the same item and required extensive analysis to resolve SME differences. At the conclusion of the decomposition process, each discrete task line was tied to a unique set of knowledge and skill areas deemed required to conduct or enable the discrete task. Once all tasks within a MEC were linked to their appropriate knowledge and skill sets and weights were assigned, analysts reviewed the weights in a vertical dimension across the entire MEC to assess the discrete task inventory within each skill or knowledge as a cross-check of correct distribution. Subject matter experts were asked to review the vertical analysis to verify that the weights were appropriately distributed within each knowledge and skill, and that they continued to convey the proper balance with each discrete task line. A small sample of the outcome of task-to-K/S is shown in Figure 1. In this example, several of 600+ discrete line items are presented with linkages to only a sample of the 30+ skill categories.

Decomposition of the air superiority MECs 1-4 using the knowledge and skill linkages from the MEC derivation process produces a database with multiple capabilities for data gathering and assessment. Enabling and discrete tasks are immediately recognizable to traditional instructor disciplines. Layout of the data retains MEC organization throughout for MEC-based analysis. Knowledge and skills are cataloged by MEC organization for applications to instructional reporting or roll-up to command training management reporting. Each task line provides parametric data to compare to actual performance based on employment doctrine. Additionally, discrete tasks are identified as objectively or subjectively observable in terms of current technology available from PETS or observer-based methods and who the target of observation is in terms of individual fighter cockpit, leader, wingman, element group, or whole team. Application of the weighting construct in PACES is discussed in a paper presented at IITSEC 2003 (Carolan, T., MacMillan, J., Schreiber, B.T., 2003).

Tribulations of MEC 5-7

As noted previously, comparison of the first four MECs to traditional grouping of employment concepts in air superiority produces a strong correlation. The intuitiveness of MECs 1-4 are easily recognized by a fighter pilot or instructor. Customary practices in fighter briefings, discussions, debriefings, or academic presentations relate four major phases of an air combat event. Those phases are <u>administrative</u>, <u>intercept</u>, <u>engagement</u>, and <u>egress</u>. The first four MECs follow along the line of traditional instruction and employment and relate a similar structure. Differences between traditional thinking and the MEC construct exist only in where the demarcation lines have been drawn between major task groups. Table 4 shows the relationship between traditional employment teaching practices and the product of MEC derivation studies. The nature of MEC 1-4 are concrete actions required for successful air combat work. This was not the case with MECs 5-7.

	SKILL	(S1) 1.1 Interprets sensors: assemble revelant visual data	(S1) 1.2 Interprets sensors: assembles relevant aural data	(S2) 2.1 Listens: Prioritizes available comm. channels	(S2) 2.2 Listens: Captures relevant cues for situation	(S3) 3.1 Prioritizes comm: Transm priority to ensure relayed/understood	(S4) 4.1 Speaks Clearly: Appropriate descriptive/directive format and content	(S5) 5.1 Radar Mech: Single mode selection to maximize info capture	(S5) 5.2 Radar Mech: Scan volume placement to maxim info gathering	(S5) 5.3 Radar Mech: Control manipulation to locate relevant targets	(S5) 5.4 Radar Mech: Control manipulatio to track relevant targets	(S5) 5.5 Radar Mech: Mode mixing for optimum weapons employment	(S6) 6.1 Sorts relev info: Surveys available info from mult sources	(S6) 6.2 Sorts relev info: filters irrelevant info	(S6) 6.3 Sorts relev info: Promotes relevant info in decisions	(S7) 7.1 Builds / mx pix: Assembles relevant info from mult sources	(S7) 7.2 Builds/mx pix: Projects spatial geom of sit into accur mental model	(S7) 7.3 Builds/mx pix: prioritize info gathering to mx accur mental model	(S8) 8.1 Selects tactic: Recognizes need for maneuv based on current SA	(S8) 8.2 Selects tactic: Apply appropriate template for tactical situation
Determine horizontal / vertical parameters of adversary attack																				
Collect detected and reported locations to update picture		3			5					5	5		3			4				
Analyze azimuth angle and convert to distance relative to factor range		5															5			
Analyze axial range and calculate sweep angle of adversary formation		5															5			
Sample and update altitude displays of target groups		3								4								4		
Update and analyze identification (ID) mosaic of adversary attack																				
Correlate Bullseye (BE) data to detected and displayed track files for ID verification		4		5						4					2	3				
Assess criteria for and apply internal sensor updates		4									5									

Figure 1. Example Discrete Tasks (left column) Linked to MEC-Based Skill Catalog (top row)

Decomposition of MECs 5-7 were initially a low priority due to the lack of supportability from PETS data. Displays used by the pilot are the principal source of instructional analysis in live-fly training as well as stand-alone simulation. They are also the principal sources of information cues that support the decision processes of MECs 5-7. At AFRL's Mesa site, DMO play-back tools replicate the essential pilot interfaces that convey information about the tactical situation but are not included as resources for the PETS/PACES project. MEC-5-7 were also noted to be pervasively spread in time and task over MECs 1-4 and were not easily broken out from them.

Data streams such as search volume over time, acquisition symbol position versus track files displayed, lock and track versus assigned responsibilities are the targets of instructional debrief methodology. The data that supports analysis of employment is normally gleaned through visual review of recordings of the pilot's visual displays and communications. It is recognized that sufficient data exists at each DMO terminal to make instructional assessments; though it is not ported through HLA or DIS and hence not easily accessed for PETS processing in the current version or follow-on PETS2 configuration (Schreiber, Watz, Keck, 2003). This has less to do with PETS and more to do with the DMO information architecture. High-Level Architecture and DIS information streams do not distribute display data because their objective is to synchronize DMO, not to provide instructional analysis.

Table 4. Traditional Employment Compared to MECs

Traditional Phase	**MEC Phases**
Admin	1 Force Organization 2 Detection
Intercept	3 Intercept / Target
Engage	4 Employ Wpns / Deny Enemy Weapons
Egress	4 Deny Enemy Weapons

The decomposition project extended well beyond the limits of PETS/PACES thus allowing SMEs to work unhindered by system limitations. Given this freedom, MECs 1-4 came apart easily and in a straight-forward structure of enabling tasks and discrete tasks. Yet, MECs 5-7 remained untapped, amorphous concepts that SMEs could relate to but could not elicit well enough for inclusion in the PETS/PACES project.

Decomposition and linking of MECs 5-7 to observable events is still an elusive task due to their time and task diverse character. They are almost entirely made up of mental processing routines with the only outward indicator of completion being an expression of communication. A summary description of MECs 5-7 appears to be that they are the processes by which situation assessment is made and situation awareness is maintained throughout a mission. The fighter pilots interviewed and surveyed to produce the original MEC construct understood these to be important, but also cited <u>situation awareness</u> as a <u>*supporting competency*</u> within the MEC construct. Going back to the MEC process, a supporting competency is defined as "*important to the successful development of skilled MEC performance*" (Colegrove, Alliger, 2003) and "*sets of high-level skills. . .* [and] *some are applicable across all mission essential competencies, and others are applicable for only one or two mission essential competencies.*" (Bennett, Crane, 2003). Situation awareness and MECs 5-7 have an interesting relationship that must be explored in greater detail.

Table 5. Mission Essential Competencies 5-7

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.

In the decomposition of MECs 1-4, SMEs could easily plot the time and location of an enabling task or discrete task. In MECs 5-7, they appeared not only to happen at high iterative rates, but also to collect and process diverse data streams depending on the time and situation. In effect, MEC 5-7 appear as background information processing routines rather than as the situation/task-oriented MECs 1-4. As such, they present a challenge to accurately model and assess that will require considerable logical analysis in context of the multiple situations and variations of situations in which they will occur.

Survey Grain Size Irregularities

The original Air Superiority MEC set provided not only the mission essential competencies themselves, but also an inventory of supporting competencies, knowledge areas, and skill categories. The original objective was not only to decompose the MECs into PETS-observable events but also to link (by way of the weighting schedule) all of the observable events to their respective supporting competencies, knowledge areas, and skill sets. The CTA-style breakdown of enabling and discrete tasks proved a beneficial validation tool for the resolution and consistency of the various SC, K, & S sets returned from AFRL's survey technique. At the outset of decomposition, K&S grain sizes became an issue almost immediately and required retooling to continue the process.

In general, the grain size of knowledge areas and skill requirements remained consistent except for several areas the SMEs recognized as much broader than others. This grain size was a function of the MEC development process carrying forward some inputs from early fighter pilot interviews. Figure 2 shows an example segment of a working A-S MEC survey tool with original knowledge category breakdowns.

	Comm standards	*Commit criteria*	*Engage criteria*	*Follow-on options*	*Formation*	*Friendly capabilities*	*Mission objectives*	*Package composition*	*Phase of mission*	*ROE*	*Threat capabilities*	*Time restrictions*
MEC 3 Intercepts and targets factor groups												
Commit early – has not met criteria		X					X	X		X		X
Commit late – didn't know information		X		X			X		X			X
Commit late – didn't assimilate information	X	X		X			X		X		X	X
Commit late – miscommunication between AWACS and Four-Ship	X	X		X			X			X		
Doesn't accelerate	X	X	X						X			
Doesn't climb	X		X						X			
Uses incorrect geometry	X		X		X	X		X			X	
Uses incorrect tactics	X		X		X	X		X			X	
Incorrect application of tactics			X	X	X							
Incorrect timing		X				X		X	X			
Flight lead "calls the play"	X		X	X		X	X	X	X		X	
Appropriate formation based on the play			X	X	X	X					X	
Losing track of one's assigned priorities (e.g., narrow focus)	X	X		X	X	X			X			X
Losing track of others' priorities (undertask or overtask)	X	X		X	X	X	X	X	X			
May not detect group			X	X							X	
May target wrong group			X				X					
May target nothing												
Lose declaration or have no ID	X	X	X	X		X				X		
No picture at picture range						X						
No targeting at targeting range (target too early, target too late)						X						

Figure 2. Air Superiority MEC Knowledge Categories (top) and Relationship to Error (side) (MEC-3 Only)

MEC Study	**SME Revised Area**
Friendly Capabilities (knowledge)	**K6** Friendly Capabilities 6.1 – Team competency 6.1.1 – Tactical plan coordination (synergy of interaction with team members) 6.1.2 – Team operating protocols (AFTTP 3-1 tactics) 6.1.3 – Tactical maneuver principles (historically proven) 6.1.4 – Team maneuver expectation templates 6.2 – Aircraft capabilities 6.2.1 – Basic aircraft functions (systems operation knowledge) 6.2.2 – Inoperative or degraded systems effects 6.2.3 – Proficiency of aircraft operation (application of systems) 6.2.4 – Aircraft/weapons physics (limitations and known capabilities) 6.3 – Current assessment of team capability (status of team members) 6.3.1 – Estimate of each man in the team 6.3.2 – Estimate of total team performance 6.3.3 – Estimate of aircraft contribution to team performance
Radar Mechanization (skill)	**S5** Radar mechanization 5.1 – Single mode selection to maximize information requirements 5.2 – Scan volume placement to maximize relevant information gathering 5.3 – Radar control manipulation to locate relevant targets 5.4 – Radar control manipulation to track relevant targets 5.5 – Mode mixing for optimum weapons employment / tracking / SA

Figure 3. Sample Knowledge and Skill Refinements for Deficiency Assessment and Reporting

Decomposition of enabling and discrete tasks within each MEC was undertaken independently of MEC survey data to provide an independent assessment option. Assigned SMEs conducted the CTA breakdown using basic and high-end formal course training materials as well as cross-checking with their own extensive (and current) experiences. When linkage to the survey-derived knowledge and skill areas was initially attempted, the large grains resulted in several areas from the original process becoming unwelcome gravitational fields for weight links. In the area of knowledge, the category labeled "Friendly Capabilities" is an example of why researchers need translators to talk to operators (and possibly vice-versa).

In the language of the fighter pilot, there are a number of phrases that have been over-used to the point of losing meaning or in this case, developing a broad set of meanings that vary widely over the whole operator group. "Friendly Capabilities" to the fighter pilot is a tidy way to visualize all that needs to be known about blue-force operations from top to bottom. The problem with this category when linking back from an observed error to a subject that may need instructional buttressing is where do you start? In the first of several attempts to link discrete tasks to original MEC guidelines, "Friendly Capabilities" was the logical place to assign much of the knowledge requirement. When examining how the PACES tool might point toward something useful for an instructor to talk about, it became apparent that linking to this large grain was equivalent to dropping him/her at a downtown bus station with no further instructions.

A new effort was undertaken in the decomposition process to reduce knowledge and skill granularity to consistent levels that would serve the instructional process more accurately. The enabling and discrete task lists were employed to break down large-grain areas to more instructionally relevant subcomponents without losing the original information produced in the MEC derivation process. Two examples of amplification are shown in Figure 3.

Analysis and leveling of knowledge and skill areas left only two of 30 intact. All other categories developed in the MEC survey process were broken down into at least 2 and as many as 11 subcategories. The resulting reorganization provided 42 knowledge areas and 52 skill areas versus the starting point of 11 knowledge and 19 skill categories. Once completed, the K&S reorganization made linkage and weighting of discrete events to knowledge and skill requirements come together more clearly. Leveling proved useful for this task, but at the higher echelon of MEC architecture, outputs are still likely to produce heavy emphasis of the large grains we identified in the process. This is not altogether bad as most of the reporting will be in a valid category. Large grain sizes fit well with program management at headquarters levels. For lower echelons, care will be required for managers to avoid false interpretation of the large grain viewed through their own prism. They will need to track the details down to finer resolution to assure effective decisions regarding training interventions. At the lowest level of training intervention, the instructor must have cogent information presented in a useful form. The detail of the decomposition breakdown can assist programmers to assure these paths remain true to local MTC systems as well as the overall DMO network.

Bridges Over HLA and DIS Chasms

At the present time, High-Level Architecture (HLA) and Distributive Interactive Simulation (DIS) data streaming is at best a very myopic view of operations in terms of what an instructor needs. It was not designed with the intent of examining and assessing instructional concerns. Instead, it is focused on situation ground truth balancing the domains of time and bandwidth. Attempting to use it to build a *complete* instructional picture would fall under the category of alchemy. Attempting to assess all that must be examined through these sources in an instructional context is an impossible task at the moment. However, several strategies can be employed using the decomposition product as a steering resource to improve training support. First, PETS can extract more information than PDU state information in its protocols if data is pieced together in context with other supporting guidance in the decomposition database. Second, the decomposition database, when properly constructed, can serve as guidance for required data to make assessments and focus research energy and budgets on high-payoff efforts within the DMO terminal.

In order to establish rules for collection, assessment, and reporting, the database can be used to formulate algorithms to elicit data and observer inputs as well as comparisons to existing doctrinal guidance. An example currently under investigation is provided in Figure 3. This figure presents a model for how the instructor identifies and collects data on an event and the process used to make a judgment on pass or fail criteria. In this case, PETS data provides the ground-truth conditions (its strength) as a starting point using a shot event as a flag to begin (from a weapons state PDU). This algorithm was developed directly from the decomposition database and links directly back to discrete events within it. The discrete events are shown as 430-series numbers. The assessment question posed at the top of the figure is an *enabling task* of MEC-4 (see Table 1, MEC 4, Enabling Task 4.4).

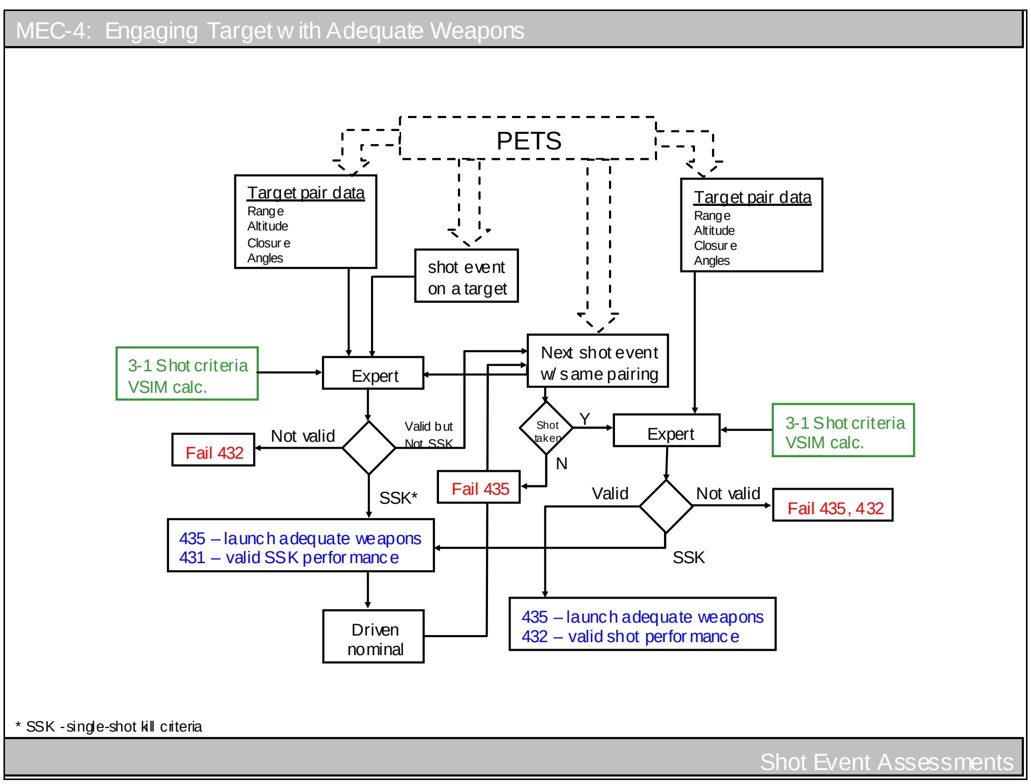

Figure 4. Assessing PETS Data in Context for Weapon Employment Adequacy.

When the *enabling task* algorithm is called by a shot event, ground truth data establishes a basic outlay of the tactical situation. An expert performance model is employed to merge doctrine, the shot, and valid weapon envelopes to assess the *discrete tasks* related to the *enabling task.* If the performance falls within boundaries established by the expert, a PASS condition is reported for tasks related to shooting a valid shot. If performance falls outside the expert parameters, a FAIL condition is reported for the assessed *discrete tasks*. Failure of certain discrete tasks may cause the enabling task to fail. In this case, the enabling task would also be reported as a FAIL. A later shot sequence that results in PASS conditions would not (and should not) overwrite the original FAIL for training purposes. This is one example readily extracted from current PETS data. Progress is underway in other areas to provide similar assessments. A discussion of the development of expert performance models and their employment using decomposed MEC tasks is presented in a companion paper in this conference (Carolan, Keller, Denning and Schurig, In Review).

Distributive simulation operates at both tactical and operational levels. There is a tendency at higher echelons to focus on issues and reporting capabilities that serve budget battles and general combat capability estimates. For example, it will be comforting for the Blue Force colonel to know that over a four day Virtual Flag exercise, virtual air superiority players improved target hit rates by 14%. At the operational level, reporting of this general improvement has meaning. At the unit level, for a Blue Force wingman that scored hits the first two days and missed the last two days in heated action, the result is entirely different. So too, should be the ability to report and service the training needs of each level. While the colonel is ready for a tall frost beverage based on the operational successes, lower assessments need to be telling instructor X about Lieutenant Y's inability to maintain track on his targets during missile time-of-flight. Decomposing MECs to instructionally relevant levels appears to provide detail necessary to steer program data gathering and assessment development to serve both levels. As we attack the problem of data accessibility, the decomposition database will serve as a beneficial requirements baseline to ensure resources are applied in the best manner.

LESSONS FOR MEC DECOMPOSITIONS

During the two-year decomposition project, several valuable observations have come to light. The following section is aimed at providing the lessons in order to make future MEC adaptations more efficient.

1. Do you need one in the first place?

The definition of Mission Essential Competencies warns of their high-level nature. The air superiority MEC breakdown is the first to be attempted; however, there are adaptations that have successfully circumvented the need for decomposition. The current USAFWS F-16 DMO syllabus and Mesa continuation training research syllabus are examples. They are aimed at a different goal than servicing the needs of programmers attempting to derive useful information from DMO information conduits. They also rely heavily on instructor involvement in brief, real-time observation, debrief, and instructional planning to develop the syllabus and are hence "manual mode" applications. In automated applications of MECs in DMO, decomposition appears to be a requirement to focus the efforts of those not intimately aware of employment and instructional disciplines. Decomposition of the MECs, regardless of the method, can identify areas of strong and weak structure, frame weak processes for further analysis, provide a roadmap for data gathering tools, and prioritize requirements and acquisition budgets to make the most of instructional tools developed from the exercise.

2. Who should accomplish the decomposition?

Our model appears to be a good one. The team was led by an F-16 weapons and tactics expert who had taught at all levels of employment training from basic to advanced instructor courses. His specialty area within the community was air superiority employment. Much of the path finding was accomplished by the leader. It should also be noted that a decomposition of this level of detail is not a trivial task that can be accomplished in a short time. The team's F-16 expertise was called upon to guard against personal interpretations and keep the process locked into doctrine. Where doctrinal guidance did not exist, the team's high experience level not only was able to develop consensus on grading criteria, but could generally cite the origins and customary practices of the larger community of F-16 pilots. Outside observers were critical in guarding against *groupthink*. Our best ally came from the F-15 community where concepts were strikingly similar, but different enough to warrant cogent questioning of methods and inputs. Oral defenses were a regular part of the debate process when assigning final links and weight values from discrete tasks to knowledge and skill areas. Additionally, the continuous observation by non-SME research psychologists who would employ the database aided against the groupthink problem as well as making sure the SMEs maintained a constant thought process and did not get buried in irrelevant detail.

3. Are MECs a bulletproof design?

Our experience with decomposition (while other MEC sets were being developed with our assistance) brought to light some interesting dynamics. A defining concept in MEC design is that they reflect the perceptions of the operators from within their systems. This is their strength as well as their instructional *Achilles Heel*. For example, comparing the air superiority MECs to the air-to-surface MECs showed a notable difference in the importance of planning as a MEC. The air superiority inputs did not include it, yet in the decomposition project, planning was continually cited as a shortfall in the MEC list as well as knowledge and skill categories. The reason the air superiority community did not value planning as a MEC is a result of the common perception of their mission as well as the initial MEC development guidance and survey processes. The initial guidance to SMEs was to focus on the kill chain and this tended to obviate the need to consider planning. Planning is a part of getting to the fight, but once in the fight, air superiority operations are very formulaic and automated. When asked how operators fulfilled the kill chain, only the automated portion of their mission was put into play; hence, no planning.

Another issue is the derivation process itself. In the first rendering of air-to-surface MECs the result was a substantial departure from the norm because of a dominant input of planning. Air superiority MECs required a leveling of instructional concerns in the knowledge and skill areas. Other MEC constructs reviewed to date by this team appear to have similar grain size concerns. Again, this is a result of the operator-to-researcher interface. MEC analysts weren't as tuned into the power phrases and lumping of concepts as an experienced operator/instructor might be after attempting to decompose and link knowledge and skill sets.. Even novice SMEs might not recognize them for what they are due to over familiarity with the mission and jargon. The MEC development workshops, fully attended by SMEs, stand as testimony. If MECs are to be employed in any form of automated assessment, they are going to have to be combed out and restructured to fit the needs of the application.

The final issue worthy of comment is that MECs are designed and derived on a multi-layered competency construct and with more deliberate team focus than previous mission training concepts. The high-level nature of MECs was a deliberate design characteristic which departs from traditional single-cockpit, single student, and task-oriented training interventions. This difference places MEC constructs in a new category of thought about mission training. Correspondingly, they require a new approach to enable adaptation to performance measurement. Our approach has provided one avenue of attack to bring the fresh dynamics of MECs into tangible tooling for distributed mission operations and the instructional tasks within.

THE ROAD TRAVELED AND ROAD AHEAD

Decomposition of the first set of MECs produced by AFRL is on a success track. An immediate product of the decomposition process was the ability to rapidly visualize, develop, and model a system for task complexity to support research at the Mesa site (Denning, Bennett, Crane, 2002). This product is moving on to support scenario characteristic selection in a follow-on project to automate the process in hot DMO sessions. In a second spearhead, breakdown of tasks to the instructional level provided instructors at the USAFWS with a clearer picture of MEC-based training methodology and supported development of the first group of MEC or competency based formal course training syllabi in ACC (Symons, France, 2003). The PACES project (Carolan, Schurig, and Bennett, 2003) has demonstrated initial capability and is progressing into more complex analyses using expert modeling (Carolan, Keller, Denning and Schurig In Review) and situation-context techniques to establish a methodology for real-time situation awareness assessment (Denning, Carolan, and Bennett In Press). Additionally, the database itself will provide the foundation for an Intelligent Scenario Generation tool to assess and direct attributes of training scenarios within DMO that target training deficiencies on individual and team levels.

Training tools for all levels of instruction will be required to fully exploit the advantages of DMO. Much of the lower end assessment still requires traditional instructor techniques. However, as DMO exercise scale grows, the competing demands of operational and tactical analysis will limit the time and resources available to fully address individual training needs. The PETS/PACES project bridged by accurately decomposed mission essential competencies has demonstrated initial capability for automated assessments using the data-rich information streams inside and between distributed sites. Decomposition of the MECs is providing a pathfinder for prioritized research into data sources within DMO. Using the MEC construct as both a program management concept as well as guidance for decomposition and analysis of mission training needs provides budgetary and training effectiveness synchrony from top to bottom.

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