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## LINKING KNOWLEDGE AND SKILLS TO MISSION ESSENTIAL COMPETENCY-BASED SYLLABUS DEVELOPMENT FOR DISTRIBUTED MISSION OPERATIONS

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The U.S. Air Force Research Laboratory and Air Combat Command have pioneered the development of a new approach to defining warfighter training and rehearsal requirements based on the identification of a set of Mission Essential Competencies (MECs). 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. Targeting specific training objectives using these broad competency definitions is difficult; therefore, the MEC process also involves the identification of Supporting Competencies and more specific Knowledge and Skills. Research at the Air Force Research Laboratory has developed methods that permit quantitative links to be established between the MECs and specific Knowledge and Skills. These links are a critical step in the definition of mission performance requirements and serve as the drivers for the specification of training objectives and the design of scenarios for distributed training. This report describes the development of these links and will detail how the links have been used to define scenarios and syllabi. In addition, the paper will present data on pilot proficiency improvement resulting from the implementation of competency-focused scenarios and syllabi. Implications for future application of the quantitative links as a means of pinpointing proficiency gaps and performance shortfalls are also discussed.

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# LINKING KNOWLEDGE AND SKILLS TO MISSION ESSENTIAL COMPETENCY-BASED SYLLABUS DEVELOPMENT FOR DISTRIBUTED MISSION OPERATIONS

## SUMMARY

The U.S. Air Force Research Laboratory and Air Combat Command have pioneered the development of a new approach to defining warfighter training and rehearsal requirements based on the identification of a set of Mission Essential Competencies (MECs). 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. Targeting specific training objectives using these broad competency definitions is difficult, therefore the MEC process also involves the identification of Supporting Competencies and more specific Knowledge and Skills.

Research at the Air Force Research Laboratory has developed methods that permit quantitative links to be established between the MECs and specific Knowledge and Skills. These links are a critical step in the definition of mission performance requirements and serve as the drivers for the specification of training objectives and the design of scenarios for distributed training. This report describes the development of these links and will detail how the links have been used to define scenarios and syllabi. In addition, the paper will present data on pilot proficiency improvement resulting from the implementation of competency-focused scenarios and syllabi. Implications for future application of the quantitative links as a means of pinpointing proficiency gaps and performance shortfalls are also discussed.

## PREFACE

This research was conducted for the Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Readiness Research Division (AFRL/HEA), at Mesa Research Site, Mesa AZ, under USAF Contract F33615-97-D-5000, Task Order 17. The workunit number was 1123-AS-03, Tools and Technologies for Combat Training and Rehearsal. The laboratory project scientist was Dr Winston Bennett, Jr, AFRL/HEA.

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The views expressed herein are those of the authors and do not necessarily reflect the views of the Air Force.

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# Linking Knowledge and Skills to Mission Essential Competency-Based Syllabus Development for Distributed Mission Operations

## INTRODUCTION

### *Mission Essential Competencies*

The U.S. Air Force Research Laboratory and Air Combat Command have pioneered the development of a new approach to defining warfighter training and rehearsal requirements based on the identification of a core set of Mission Essential Competencies (MECs). 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 (Colegrove & Alliger, 2002). As the definition suggests, MECs are very broad definitions of competency requirements, which makes targeting specific training objectives difficult. Therefore, the MEC process also involves identification of Supporting Competencies as well as Knowledge and Skills of relevance for mission performance.

### *MEC Construct*

Tables 1 through 3 lists the MECs, Supporting Competencies and Knowledge/Skills defined for the Air-to-Air Mission. These Knowledge/Skills are the cornerstone of subjective and objective performance measurement and are at a suitable granularity to allow for their manipulation in specific syllabi and scenarios based on evaluated deficiencies.

**Table 1. Air-to-Air MECs List**

Organize Forces to Enable Combat Employment
Detects Factor Groups in Area of Responsibility
Intercept and Target Factor Groups
Engage-Employ Ordnance & Deny Enemy Ordnance
Assessment/Reconstitute-Initiate Follow on Actions
Remain Oriented to Force Requirements
Recognize Trigger Events that Require Shift in Phase

**Table 2. Air-to-Air Supporting Competencies List**

Adaptability
Communication
Decision Making
Flight Battle Management
Identification
Information Management
Situational Awareness
Timeline
Weapons Engagement Zone Management

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## Table 3. Air-to-Air Knowledge/Skill List

**KNOWLEDGE**

Comm Standards
Commit Criteria
Engage Criteria
Follow-on Options
Formation
Friendly Capabilities
Mission Objectives
Package Composition
Phase of Mission
ROE
Threat Capabilities
Time Restrictions

**SKILLS**

Adapts to changes in environment
Adapts to friendly changes
Adapts to threat changes
Anticipates problems
Builds picture
Controls Intercept Geometry
Develops new options
Executes merge game plan
Executes short range game plan
Interprets sensor output
Listens
Maintains formation
Makes assessment
Manages mission timing
Manages stress
Multi-tasks
Prioritizes communications
Radar mechanization
Rebuilds picture
Reforms
Selects tactic
Sorts information
Sorts targets
Speaks clearly
Switchology

In addition to these Knowledge/Skills, subject matter experts (SMEs), through a systematic series of surveys, have identified critical Experiences (Table 4) that are developmental events in the training of a warfighter, necessary either to learn or practice a particular Knowledge/Skill under operational-like conditions. Research at the Air Force Research Laboratory has developed methods that permit quantitative links to be established between each MEC and specific Knowledge/Skills. These links are a critical step in the definition of mission performance requirements, and serve as the drivers for specification of training objectives and the design of scenarios, incorporating these Experiences for distributed training and rehearsal.

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## Table 4. Air-to-Air Experiences List

| EXPERIENCES |
| --- |
| Restricted Weapons Load |
| Limited Fuel Remaining |
| Operating Area Restrictions |
| Restrictions to Visibility |
| Visual Illusions |
| Marginal/Minimal Cloud Clearance |
| Daytime Employment |
| Dusk Employment |
| Night Employment |
| Mountainous Terrain |
| G-Induced Physical Limitations |
| Degraded Comm |
| Degraded Nav |
| Degraded Weapons Employment |
| Battle Damage |
| Supersonic Employment |
| Full Range of Adversary Air Threat/Mix |
| Full Range of Adversary Ground Threat/Mix |
| Operations with Friendly IADs |
| Operations with Ownship and Friendly ECM |
| Operations Against Threat with Chaff/Flare |
| Operations with Friendly Use of Chaff/Flare |
| Operations Against Comm Jam/Spoofing |
| Operations Against Adversary ECM |
| Roe Limitations and Restrictions |
| Fatigue/Time on Task |
| Task Saturation |
| Limited Time to Act/React to Situation |
| Radar Search Responsibilities |
| Targeting and Sorting Responsibilities |
| Air Refueling |
| Live Weapons Employment |
| Simulated Weapons Employment |
| Various Initial Conditions |
| Emergency Procedures |
| Formation Responsibilities |
| Lost Mutual Support |
| Dynamic Retasking/Scramble Operations |
| Various Employment Altitudes |
| 1:1 Force Ratio |
| 1:2 Force Ratio |
| 1:3+ Force Ratio |
| OCA Escort Missions |
| OCA Sweep Missions |
| Employment with Various Packages |

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### *Fighter Training Syllabus Background*

Fighter training syllabi have traditionally concentrated on presenting warfighters with repetitive mission scenarios that increase in complexity and/or difficulty over a set training timeframe. These mission scenarios have generally been developed by combining likely threats, including the numbers and the tactics likely to be encountered, with typical mission types and friendly package compositions. By combining different threat presentations with possible mission types, a majority of likely mission scenarios could be rehearsed and used for training. This repetition and rehearsal was intended to facilitate the development of certain skills over this same training timeframe. The warfighter was then subjectively graded by an instructor, and either moved on to the next mandatory event, or required to repeat the same set of scenarios. While this methodology has been successful in training warfighters in the past, it is acknowledged as an inefficient process.

## MECs POTENTIAL IN DMO TRAINING

The development of MECs and their associated Knowledge/Skills and Experiences as quantifiable definitions of warfighter training requirements provides information for the development of more focused training syllabi. These new MEC-focused syllabi, combined with the advent of improved subjective and objective performance measurement systems available in Distributed Mission Operations (DMO), should enable more efficient training opportunities.

### *Current DMO Training*

A result of this process is three competency-based syllabi currently being used at the Air Force Research Laboratory. While not noticeably different to the warfighter from training syllabi of the past, these syllabi are a fusion of past and present methodologies and a reflection of the MEC process. The mission scenarios in these competency-based syllabi incorporate many of the critical Experiences identified in the SME surveys deemed to be imperative for warfighter development. As a result, many of the key Knowledge/Skills and Experiences are being more closely focused and exercised much more rigorously. By capitalizing on improved performance measurement system software in addition to these focused mission scenarios, improvements can be quantified.

### *DMO Training Protocol*

Training research groups at the Air Force Research Laboratory use three syllabi for one week at a time. Their incoming competency of Knowledge/Skills is measured at the beginning of the week with specifically designed “benchmark” mission scenarios. These benchmark mission scenarios, which all have similar complexity and difficulty, were designed to maximize the group’s use of these Knowledge/Skills while incorporating many of the critical Experiences. After completing the benchmark mission scenarios on day one, the syllabi utilizes the “crawl, walk, run” approach throughout the rest of the week by flying focused mission scenarios to facilitate the maximum amount of training. At the end of the week, the group’s competency is again evaluated with a mirror image of the benchmark mission scenarios (Denning, Bennett & Crane, 2002).

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### *DMO Training Results Overview*

The difference in performance of individuals and teams, from the beginning of the week to the end of the week, is quantified by the comparison of both subjective and objective performance measurements. The delta in benchmark mission scenario performance has been summarized in the following manner. "Comparing pre- and post-test benchmark performance, the 19 teams (76 pilots), on average, allowed 63% fewer enemy bombers to reach their target, killed 24% more enemy fighter aircraft, allowed 68% fewer F-16 mortalities, and increased the proportion of F-16 missiles resulting in a kill by 7%. Furthermore, other measures suggest that these improvements were not the result of simply increasing a risk bias. The F-16 pilots launched their radar missiles at 8% longer ranges, they survived more frequently, they spent 63% less time within critical ranges to threat fighter aircraft, and they reduced the proportions of threat missiles resulting in a kill by 62%.". (Schreiber, Watz, & Bennett, 2003) Experienced warfighters made dramatic improvements in their ability to "kill and survive" in just four days, through the focused development of their Knowledge and Skills which was facilitated by a well designed syllabus.

## MEC CONSTRUCT RELATIONSHIPS

These were excellent results, but what had not been established, was a relationship, or quantitative link, between the mission scenarios with their embedded Experiences, the Knowledge/Skills, and the MECs. As previously discussed, MECs are broad in nature and difficult to measure with the hopes of building, adjusting, or modifying scenarios and syllabi. Knowledge/Skills, however, have a more suitable granularity to measure and ultimately make these assessments. If the impact of different Experiences within a mission scenario have on these Knowledge/Skills is known, and the relationship between the Knowledge/Skills and the MECs is understood, competency in the MECs can be determined based on performance measured in the Knowledge/Skills. If, for example, a deficiency is noted in a Knowledge/Skill and therefore a MEC, that Knowledge/Skill can be exercised by creating a mission scenario that includes a critical experience to emphasize this Knowledge/Skill. This will ultimately foster competency in that particular MEC. To perform this analysis these links needed to be established.

### *Original Relationships*

The MEC process, as it quantified warfighter requirements, did establish a relationship between the MECs, Supporting Competencies, and Knowledge/Skills. However, this relationship was only binary. In other words, either a Knowledge/Skill was determined to be related to a MEC, or it was not. Originally relationships were developed between Knowledge/Skills and Supporting Competencies and then between Supporting Competencies and MECs, to determine the relationship between Knowledge/Skills and MECs.

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### *Knowledge/Skill – MEC Relationship*

There is definitely a relationship between Supporting Competencies and MECs and between Supporting Competencies and Knowledge/Skills. However, the overarching nature of the Supporting Competencies limited the ability to meaningfully quantify their relationship to specific Knowledge/Skills and specific MECs. Once this intermediate link between Knowledge/Skills and MECs was removed, the "combined" links between mission scenario and MECs appeared to be much clearer. For example, a mission scenario which obviously emphasized a particular MEC, such as "Organize Forces for Employment," would then clearly have a correspondingly higher "combined" rating. Therefore, the Supporting Competencies were not included in the quantitative links in the MEC construct, but were set aside for further discussion and study as to their relationship in the overall MEC construct.

### *Quantifying Relationships*

As the relationships in the MEC construct were analyzed, it became obvious that in order to provide more focused information on warfighter competencies, the relationships inside the construct would have to be clarified beyond the originally binary relevant/not-relevant ratings. Initial analysis made it apparent that mission scenarios and their Experiences were relevant to Knowledge/Skills and Knowledge/Skills were relevant to MECs in varying degrees. To quantify these relationships, the following survey was developed and given to a number of SMEs in order to determine the quantitative relationships or links. Precise wording for the 0-3 scale was selected from the U.S. Army Research Institute for the Behavioral and Social Sciences Questionnaire Construction Manual in an attempt to ensure validity of surveys through relatively equal distribution of choices. The 0-3 scale was chosen to also provide sufficient differentiation on the survey, avoiding a "middle ground" or default answer, while providing an opportunity to choose extremely strong or direct relevance and basically no relevance. The scale values for possible survey answers and key wording of each answer are in Table 5.

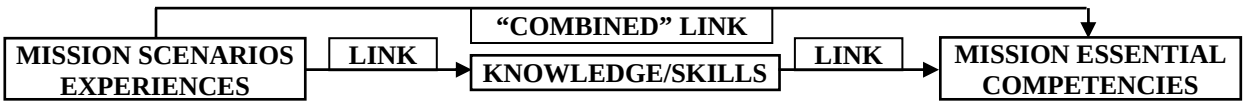


**Figure 1. MEC Construct Relationships – Links and "Combined Link"**

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### *Survey: Mission Scenario-Knowledge/Skill-MEC*

The following survey was designed to determine the quantitative relationships. The survey was designed to be administered to SMEs with general understanding of the MEC construct and in-depth understanding of their particular mission or role.

**THIS MISSION SCENARIO IS _____ TO EVALUATING OR EXERCISING THIS KNOWLEDGE OR SKILL.**

**3 EXTREMELY RELEVANT** – Mission Scenario is **exceptionally applicable** for evaluating execution of or providing experience in this Knowledge/Skill. All or nearly all aspects of Knowledge/Skill may be employed and Knowledge/Skill will be **extremely vital** to successful mission accomplishment.

**2 LARGELY RELEVANT** – Mission Scenario is **considerably applicable** for evaluating execution of or providing experience in this Knowledge/Skill. Many aspects of Knowledge/Skill may be employed and Knowledge/Skill will be **important** to successful mission accomplishment

**1 SOMEWHAT RELEVANT** – Mission Scenario is **fairly applicable** for evaluating execution of or providing experience in this Knowledge/Skill. Some aspects of Knowledge/Skill may be employed, but Knowledge/Skill will only be **moderately** significant to successful mission accomplishment.

**0 NOT RELEVANT** – Mission Scenario is **not applicable** to this Knowledge/Skill. Little or no aspects of Knowledge or Skill will be employed and Knowledge/Skill will be **non-essential** to successful mission accomplishment.

**THIS KNOWLEDGE/SKILL IS _____ TO SUCCESSFULLY ATTAINING THIS MEC.**

**3 EXTREMELY RELEVANT** – Knowledge/Skill is **exceptionally applicable** to this MEC. All or nearly all aspects of Knowledge/Skill may be used and Knowledge/Skill will be **extremely vital** to successfully attaining MEC.

**2 LARGELY RELEVANT** – Knowledge/Skill is **considerably applicable** to this MEC. Many aspects of Knowledge/Skill may be used and Knowledge/Skill will be **important** to successfully attaining MEC.

**1 SOMEWHAT RELEVANT** – Knowledge/Skill is **fairly applicable** to this MEC. Some aspects of Knowledge/Skill may be used, but Knowledge/Skill will only be **moderately** significant to successfully attaining MEC.

**0 NOT RELEVANT** – Knowledge/Skill is **not applicable** to this MEC. Few or no aspects of Knowledge/Skill will be used and Knowledge/Skill will be **non-essential** to successfully attaining MEC.

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**Table 5. Scale Ratings of Key Survey Words**

| Wording | Scale | Diff |
|---|---|---|
| Extremely Relevant | 4.4 | |
| | | 1.5 |
| Largely Relevant | 3.0 | |
| | | 1.5 |
| Somewhat Relevant | 1.4 | |
| | | 1.4 |
| Not Relevant | 0 | |

| Wording | Scale | Diff |
|---|---|---|
| Exceptionally Applicable | 4.4 | |
| | | 1.4 |
| Considerably Applicable | 3.0 | |
| | | 1.2 |
| Fairly Applicable | 1.8 | |
| | | 1.8 |
| Not Applicable | 0 | |

| Wording | Scale | Diff |
|---|---|---|
| Extremely Vital | 8.8 | |
| | | 2.0 |
| Important | 6.8 | |
| | | 1.6 |
| Moderately | 5.2 | |
| | | 2.6 |
| Non-essential | 2.6 | |

### *Use of Ratings to Further Define MEC Construct*

### "Combined" Ratings from Surveys

This relevance scale may be used with only minor wording changes to develop quantitative links anywhere in the MEC construct. Once a quantitative link between two directly related levels of the MEC construct is established, the 0-3 rating assigned to that link may now be "combined" with other direct links. This "combined" link will quantify the relevance of levels related to each other through another level of granularity in the MEC construct. For example, a mission scenario will have a quantitative relationship to Knowledge/Skills on the 0-3 scale from an SME survey. A 0-3 quantitative relationship between the Knowledge/Skills and a MEC can also be developed in the survey. The next step is to develop a "combined" relationship between the mission scenario and a MEC. While the relationship between an entire mission scenario and a MEC is generally too complex to rate subjectively by an SME, the quantitative relationships previously developed may be "combined" in some manner to establish a relationship between a mission scenario and a MEC.

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## Method to "Combine" Ratings

The "combined" relationship between the mission scenario and MECs is postulated to be a product of the two ratings determined directly from SME surveys. This rating of mission scenario – MEC would therefore be a 0-9 scale. For example, if a mission scenario provides excellent training and/or experience in a particular Knowledge/Skill and this Knowledge/Skill is rated high in relevance/importance to a MEC, then the portion of the mission scenario – MEC relationship directly resulting from this Knowledge/Skill should be much higher than if one of the relationships was rated low or very low. In fact, if one of these relationships was rated as barely relevant or non-essential, then the mission scenario – MEC rating resulting from this Knowledge/Skill should also be rated as generally unrelated. Using the product of these two relationships and then adding all of the products resulting from each individual Knowledge/Skill, a more objective rating of the relationship between mission scenario and the MECs may be determined.

## Example: Combined Rating from 3 – 3

For example, a mission scenario with large numbers of groups of adversaries, dispersed widely may be rated "extremely relevant" (3) to the "Radar Mechanization" Skill and the "Radar Mechanization" skill may be rated "extremely relevant" (3) to the "Detect Factor Groups" MEC. In this case, this mission scenario would have a 9 rating for relevance to the "Detect Factor Groups" MEC through the "Radar Mechanization" Skill.

## Example: Combined Rating from 0 – 0

Conversely, a mission scenario involving only a four ship on an Offensive Counter Air mission, with no timing constraints may be rated "barely relevant" (0) to the "Manages Mission Timing" Skill and the "Manages Mission Timing" Skill may be rated "barely relevant" (0) to the "Employ/Deny Ordnance" MEC. In this case the mission scenario would have a 0 rating for relevance to the "Employ/Deny Ordnance" MEC, through the "Manages Mission Timing" Skill. While this mission scenario is obviously relevant on some order to the "Employ/Deny Ordnance" MEC, through the "Manages Mission Timing" Skill, the rating for relevance of this link does not increase and any relevance between this mission scenario and MEC will have to come from other Skills.

## Example: Combined Rating from 3 – 0

A more complex example is when the mission scenario is rated "extremely relevant" (3) to a Knowledge/Skill, but the Knowledge/Skill is rated as "barely relevant" (0) to a MEC. In this case the 3 rating between mission scenario and Knowledge/Skill would be multiplied by the 0 rating between Knowledge/Skill and MEC. This would result in a 0 rating in this mission scenario to MEC link through this Knowledge/Skill. This would appear to be justified as the Knowledge/Skill had basically no relevance to the MEC and the link through this factor would therefore be "short-circuited" to a 0 value.

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## USE AND POTENTIAL OF MEC CONSTRUCT

With this methodology, the relevant link is established and will remain constant between these entities. This allows someone to work backwards from the MECs to see what Knowledge/Skills and Experiences affect their progression and how to manipulate them, or vice versa to see what affect a different mission scenario with associated Experiences has on MEC proficiency. It has also spawned the development of a new, more focused syllabus, based upon these links. By knowing these relationships, mission scenarios can be developed to maximize their affect on competency development. It has even been taken one step further, to make smaller employment exercises, not rehearsals, to focus the development of smaller "muscle groups" or Knowledge/Skills in the hopes of accelerating the proficiency process. An exciting follow on application is the utilization of this concept to aid smart scenario and syllabus generation tools. As performance measurement software is enhanced, more subjective and objective measurements may be processed real time. This real-time performance measurement, utilized with the above established links, will allow for the real time adaptation of competency based scenarios to emphasize measured deficiencies. Or better yet, a custom built syllabus may be developed, specific to one warfighter's needs based on his/her measured performance. This "real-time adaptive" syllabus may greatly enhance the ability to fine tune training for the efficient improvement of individual and team competencies.

## LESSONS LEARNED IN ANALYSIS

Several lessons were learned establishing the quantitative links for the MEC construct. To have a quantitative solution to a very complex problem, it is vital that all of the areas to be measured are of equal magnitude, mutually exclusive, and exhaustive. For instance, some of the Knowledge/Skills appear to be unevenly divided in magnitude and may actually have some overlap, resulting in difficulties deciding relevance to a given MEC. As a result, the MEC construct may be adjusted to address this issue. Another lesson is the care to which relationships are established in a process this complex. For example, the original binary relevance scale did not account for varying degrees of impact certain Knowledge/Skills would have on MEC development.

## CONCLUSION

The results of this work have established a quantitative link between what is incorporated into a mission scenario, and its ultimate impact on warfighter development. This relationship allows for the further refinement of scenarios and syllabi to focus warfighter distributed training and rehearsal requirements, by facilitating the manipulation of any variable in the MEC construct and tracking its impact. The future holds the possibility of being able to diagnose warfighter MEC ailments instantly, through enhanced performance measurement, and ultimately prescribe real-time, adaptive focused mission scenarios and syllabi as the cure.

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