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A Practical Approach to Effects-Based Operational Assessment

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Preface

This paper was developed to provide in-depth documentation of a proposed methodology for Effects-Based Operational Assessments. Varying degrees of this method have already been successfully implemented within 1st AF, 3rd AF, 7th AF, 8th AF, 9th AF, 12th AF, 13th AF, and 14th AF. The goal is to eventually establish a standard, baseline approach for assessments that can be applied across all Joint Air Operations Centers (JAOC). Portions of this approach have made their way into Air Force Operational Tactics Techniques and Procedures (AFOTTP). However, as of the writing of this paper, no in-depth, formal documentation exists within the Air Force for an Effects-Based Operational Assessment model. Establishing a baseline will facilitate development and implementation of an assessment training regimen for both analysts and their commanders, opening the door for continual process improvements as people arrive on the job with basic job knowledge. Additionally, a standard baseline will aide in the development of Command, Control, Communication, and Computer (C4) system requirements as the JAOC is continually upgraded.

WARNING: This paper is *not* to be taken as a requirements document, but should aide in the development of a requirements document.

The methodology detailed in this paper is the result of applied lessons learned from numerous exercises and day-to-day real world operations. Operations Research analysts, operational planners, and senior mentors all contributed to its development. Additionally, meticulous attention was paid to ensuring that the final product would be acceptable in the joint and coalition community. Joint doctrine is the foundation for the model and several soldiers, sailors, marines, and coalition partners guided, critiqued, and advised the authors. We believe this document will be useful to all whose work is related to the operational command and control of forces.

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1 – Introduction

Operational Assessment is the hardest job in the AOC. – Lt Gen Garry R. Trexler, 7AF/CC

The world witnessed the incredible clout of American airpower in 1991 during Operation Desert Storm. Modern telecommunications enabled television viewers to experience live broadcasts of the battle unfolding in downtown Baghdad. The cameras rolled as bombs exploded and anti-aircraft artillery tracers littered the night sky suggesting mass confusion to the casual observer. However, the American strategists knew that each target struck was actually a small piece of a precisely planned, 'effects-based,' airpower strategy. Directing the execution of this intricate plan was Lt Gen Charles Horner, Air Force Central Command (CENTAF) Commander.[1] Effects-based military strategy is not a new concept. Military strategists such as Sun Tzu and Carl von Clausewitz detail effects-centered philosophies in their writings. However, the strategy executed by Lt Gen Horner is considered by many to be the genesis of the modern view of Effects-Based Operations. But what are 'Effects-Based Operations'?

"Effects-Based Operations (EBO) are actions taken against enemy systems designed to achieve specific effects that contribute directly to desired military and political outcomes."[2] Huh? EBO, to be clear, is simply a "way of thinking" about military operations.[3] An effects-based approach to operations (EBAO) is a "better way of expressing what EBO really is,"[4] and Air Force doctrine has adopted the term EBAO to add clarity to these concepts.[5] The crux of EBAO is the explicit linkage of tactical actions to operational and strategic military effects. Its goals are ultimately the efficient and effective use of scarce resources to achieve the commander's desired effects.

Commanders at all levels are responsible for the planning and execution of EBO – the Joint Force Air Component Commander (JFACC) is primarily responsible at the operational level of war. The JFACC and Air Component staff derive specified and implied tasks from Joint Force Commander (JFC) guidance. These tasks are translated into the Air Component's mission and are the basis for determining the JFACC's operational objectives and effects. The weapon system the JFACC utilizes to command and control the planning, execution, and assessment of Air Component operations designed to accomplish Air Component objectives is the joint air and space operations center (JAOC). Within the JAOC, the strategy division (SRD) is responsible for developing, refining, disseminating, and assessing the JFACC's air and space strategy.[6] The operational assessment team (OAT) supports the SRD throughout the strategy development process, however, its main focus is on "evaluating the effectiveness and efficiency" of joint air operations.[7] In other words, the OAT provides joint air *operational level* assessments to the JFACC.

The counterinsurgency efforts in Iraq and Afghanistan have highlighted the importance of an accurate assessment of progress. Senior leaders throughout government, including members of congress, now realize that an accurate assessment of the 'situation on the ground' consists of more than reports of tactical successes and failures. An accurate assessment will also include how those tactical successes and failures have influenced progress toward higher level effects and eventually the strategic end-state. This high level interest has resulted in a push to develop and refine assessment methodologies and tools for all levels. This paper details an assessment methodology advancement at the operational level that is the result of a survey of existing OA techniques, an in-depth review of joint and Air Force doctrine, and consultation and collaboration with numerous strategists and warfighters. Chapter 2 provides a brief overview of the evolution of OA techniques, addressing both the positive and negative aspects of each. Chapter 3 proposes a refined model for OA, focused on evaluating the performance of tasks and the achievement of effects. Chapter 4 provides a demonstration of the new technique using a notional scenario. Finally, Chapter 5 provides a summary and way ahead for OA methodology refinement.

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[1] Reynolds, Chapter 7.
[2] AFDD-1, 98.
[3] Deptula.
[4] Hunerwadel.
[5] AFDD-2, 13
[6] AFI 13-1AOC, 14.
[7] Ibid, 19.

2 – The Origins and Evolution of Operational Assessments

Things are to you such as they appear to you and to me such as they appear to me – Protagoras

The JFACC is responsible for achieving multiple operational objectives – objectives that compete for scarce air, space, and cyber power resources. To accomplish these objectives, resource allocation decisions must be made for each air tasking order (ATO) based on an assessment of the operation. Consequently, the OAT exists to help the JFACC make informed resource allocation decisions. OA, then, is fundamentally about decision-making. Good decision-making can be complicated and confusing, but it need not rely exclusively on "gut feel."[8] There exists a large body of decision-making techniques, which have been successfully implemented across "a wide variety of situations,"[9] that the JAOC can leverage to refine its OA methodologies. An effective decision-making process fulfills these six criteria[10]:

1. Focuses on what is important
2. Logical and consistent
3. Acknowledges both qualitative and quantitative factors and blends analytical with intuitive thinking
4. Requires only as much information and analysis as is necessary to resolve a particular dilemma
5. Encourages and guides the gathering of relevant information and informed opinion
6. Is straightforward, reliable, easy to use, and flexible

The OA techniques in use across the JAOCs through early 2006 all violated two or more of the criteria presented above. This section briefly reviews the evolution of OA and the most common legacy OA practices.

Tasks, Effects, and Causal Links

Before embarking on a review of OA methodologies, we must first provide some context and basic definitions. Joint Publication 3-0 (JP 3-0), *Joint Operations* defines an effect:

> **effect**. 1. The physical or behavioral state of a system that results from an action, a set of actions, or another effect. 2. The result, outcome, or consequence of an action. 3. A change to a condition, behavior, or degree of freedom.[11]

The doctrinal definition of an effect is very broad and needs clarification to place it in the context of OA. As implied in the above definition, the term "effect" cuts across all levels of war, but can mean something different for each level. The JFACC is primarily responsible for tactical level effects and operational level effects. The manifestation of effects at the tactical level and effects at the operational level are fundamentally different; however, they are very closely linked. A fundamental premise to this paper is that tactical effects contribute to the creation of operational effects.

The tactical level effects are the direct or first-order effects. These are the immediate result of a weapon system's application (*tactical action*) and can be either kinetic or non-kinetic. The JFACC has a great degree of influence over tactical level effects as these are achieved through successful execution of tactics – the science of war. As an example, when an aviator successfully puts 'bombs-on-target,' a tactical effect has been created – the target blew up. The JFACC can task tactical commanders with the responsibility to create tactical effects; henceforth referred to as *tasks* or *tactical tasks*.

Tactical tasks are not assigned arbitrarily. Instead, the JFACC first determines what really needs to be accomplished at the operational level by answering the question: What does success look like? The answers to this question are the operational level effects. *The operational level effects are the indirect or higher-order effects*. These are the result of the aftermath of a weapon system's application – the resultant impact to the battlespace caused by the tactical tasks. In the context of this paper, we refer to operational level effects simply as *effects*. Several external factors mesh with the tactical tasks to contribute to the resulting effect. This is where the operational art comes into play. The JFACC must determine which tactical tasks will contribute the most to the desired effects while taking into consideration the external factors and the potential for adverse effects.

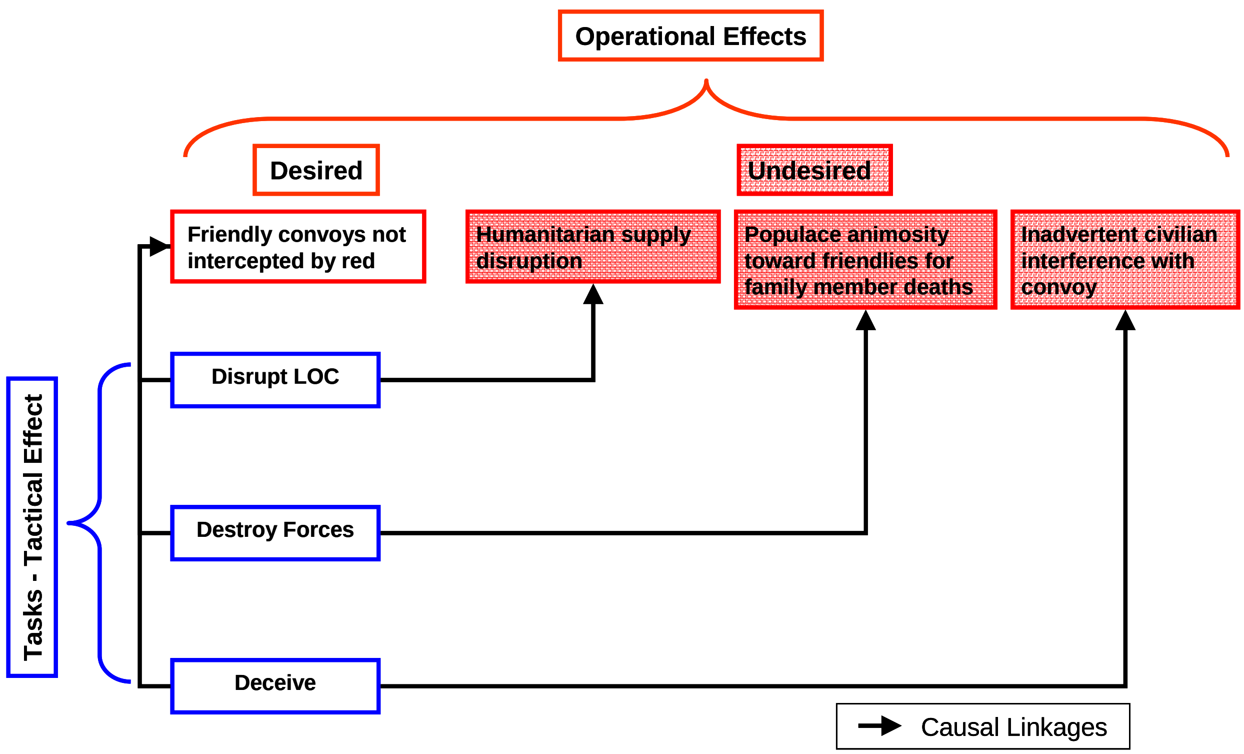

Figure 1: Effects Example

Consider, as an example, a generic counter land objective. A desired effect may be stated as: "Friendly convoys free from Red ground force attack." There are several tactical tasks that may result in accomplishing this effect. For example, the JFACC may choose to disrupt lines of communication (LOC), destroy enemy forces, deceive the enemy with misinformation, or any combination thereof. The JFACC must execute the option he believes will result in the desired effect while taking into consideration external influences (weather, geography, culture, etc.) and weighing potential undesired effects (humanitarian supply disruption, populace animosity toward friendlies for family member deaths, inadvertent civilian interference with convoy, etc.).

Going With Your Gut

Assessing the situation is an integral component to decision-making. Before there was a strategy division and its OA team, commanders relied primarily on their "gut feel" and advice from trusted advisors to guide their assessment. Commanders relied on years of tactical experience to help them process all of the intelligence and mission reports and used their intuition to assess how things were going. While such experience is essential to producing a sound assessment, the absence of an analytic approach for interpreting the data can leave room for bias and ultimately lead to sub-optimum decisions.

Admiral Nimitz demonstrated the shortcomings of this method when assessing the preparatory bombardment of Iwo Jima. He believed that the explosive tonnage dropped on the island was "sufficient to pulverize everything on the island." The Marines, however, would later discover an entirely different set of circumstances. During the bombing campaign, the Japanese actually increased the number of major defensive fortifications from 450 to over 750[12]. By relying exclusively on his experience to interpret the BDA and the tactical reports, Admiral Nimitz reached a conclusion exactly the opposite of reality; namely he believed he had rendered the island indefensible, while in reality the Japanese had nearly doubled their defenses.

Strategy-to-Task

The strategy-to-task framework is a hierarchical structure that establishes a coherent chain linking tactical level tasks all the way up to the national security strategy. The Air Force was introduced to strategy-to-task thinking in 1989 by Lt Gen (ret.) Glenn A. Kent,[13] former Assistant Chief of Staff, Studies and Analysis. Since then, this technique has been widely applied to the planning of joint air operations and is typically documented in a joint air operations plan (JAOP) or an air operations directive (AOD). In general, strategy-to-task hierarchies have focused on targets, using the following structure:

- Operational objective (OO)
  - Tactical objective (TO)
    - Tactical Task (TT)
      - Measure of performance (MOP)

Figure 2 is a notional, and admittedly incomplete, strategy-to-task hierarchy for a single operational objective. In general, a JFACC has multiple operational objectives, each requiring a strategy-to-task hierarchy.

- OO: Gain and Maintain Air Superiority
  - TO: Degrade enemy SAM systems
    - TT: Destroy Enemy SA-2 Systems
      - MOP: Percent of known enemy SA-2 launchers destroyed
      - MOP: Percent of known enemy SA-2 radar vans destroyed
    - TT: Degrade enemy SA-3 systems
      - MOP: Percent of known enemy SA-3 launchers destroyed
      - MOP: Percent of known enemy SA-3 radar vans destroyed
  - TO: Degrade enemy Air Forces
    - TT: Degrade enemy airfields
      - MOP: Percent of enemy airfields non-operational
      - MOP: Percent of enemy airfields with limited operations
    - TT: Destroy enemy aircraft
      - MOP: Percent of enemy fighters destroyed
      - MOP: Percent of enemy bombers destroyed
  - TO: Degrade enemy IAD C3
    - TT: Degrade higher headquarters communication links
      - MOP: Percent of higher headquarters facilities destroyed
    - TT: Degrade operational level communication links
      - MOP: Percent of sector operations centers destroyed

Figure 2: Generic Strategy-to-Task Hierarchy for One Operational Objective

The strategy-to-task hierarchical planning structure was tremendously valuable in the context of force-on-force warfare. In this type of warfare, the defeat of the enemy's military equated to a strategic victory. This led to target based strategies aimed at destroying military forces, resources, and supply chains. The idea was that if we prosecuted enough military targets successfully, we would eventually defeat the enemy. The strategy-to-task planning structure gave planners a methodical approach to break down the enemy's military into distinct target sets that could then be prioritized for execution.

We have since learned that prosecution of targets and defeat of a nation's military does not necessarily lead to a strategic victory. Victory in irregular warfare requires a different approach to planning. Instead of focusing only on target sets, we must now focus on the secondary and tertiary effects of prosecuting target sets.

While the strategy-to-task hierarchy introduced a logical thought process into military planning and assessment activities, it lacked a means by which to accurately determine the resulting effects of military operations.

The "Roll-Up" Model

The first major effort to add quantitative analysis to JAOC OA, pioneered by United States Air Forces in Europe (USAFE), was based on a "roll-up" model of the strategy-to-task hierarchy. The logic and mathematics of a "roll-up" model are quite simple. The logic assumes the completion of a set of activities at one level of the hierarchy implies the completion of a set of activities at the next level. For example, completing all tactical tasks (destroy enemy SA-2 systems, degrade enemy SA-3 systems) implies the achievement of the tactical objective (degrade enemy SAM systems). The achievement of tactical objectives (degrade enemy SAM systems, degrade enemy air forces, degrade enemy IAD C3) implies operational objective (gain and maintain air superiority) is met. To create a mathematical model, weights are assigned to each line in the hierarchy to indicate the relative importance of each measure, tactical task, and tactical objective. A score for each operational objective is then generated by rolling up (weighted averages) the lower level scores beginning with an initial value for each MOP. "Roll-up" models such as this are typically referred to as linear weighted-additive models.

As the first to suggest, and then demonstrate, that linear weighted-additive "roll-up" models could be used to perform OA, USAFE operational assessors deserve much of the credit for the advancement of OA within JAOCs. This approach quickly spread across the OA community; first to Korea, and then elsewhere. Although not perfect, the linear weighted-additive model is logical, straightforward, and easy-to-use.

While the USAFE model made great strides within OA, it had two major shortfalls. First, the logic assumes that our understanding of the enemy system matches reality. In other words, intelligence gaps combined with traditional planning approaches can lead to lower level actions that do not "roll-up" to complete higher level objectives. Second, this model focuses solely on accomplishing tasks in the strategy-to-task hierarchy while disregarding the key elements of the operational plan – the commander's desired effects. While not perfectly suited for assessment of EBAO, this model provided the natural stepping stone to methodologies that combine performance and effects in a mathematically logical, yet straightforward approach.

"Rolling-Up" with Effects

As EBAO spread, the Joint Air Estimate Process (JAEP) evolved to support its concepts. Planners recognized that the strategy-to-task framework could still be utilized for the effects-based approach by adding statements of the desired effect or changing the focus of the Tactical Objectives. A shift in the plan's focus also led to a shift in the assessment. Now, assessors included quantitative measures of effectiveness (MOEs), and/or qualitative success indicators (SIs), along with MOPs, to gain a more complete picture of the battlespace conditions associated with achieved objectives.

In an effort to support the evolution of EBAO-inspired strategy-to-task plans, OA models began providing a "roll-up score" that combined both performance and effects metrics, believing that more information would produce more complete results. Doing so, however, violated the major mathematical assumptions of linear weighted-additive models, and often resulted in meaningless results. Essentially, combining performance and effect metrics in a linear-additive model resulted in one of two cases:

1. If there were correctly assumed causal linkages, the inherent dependency of an effect on performance allowed small successes or failures to drive disproportionate change in the roll up score – the impact would be scored multiple times because the same results would be seen in performance and effect.
2. If there were incorrectly assumed causal linkages, the "roll-up" score would balance out – for example if the effect measures were high and the performance measures were low, the

resulting roll-up would be somewhere in the middle – a confusing result to a commander who believes the objective has been achieved since the desired effects are present.

In either case, the OA team was forced to employ qualitative "override" scoring inputs based on their experience. The bottom-line was that evaluating performance and effects metrics together broke the model, and OA teams regressed to relying on their gut feel to inform the JFACC's assessment.

Look Forward

The methodology presented in this paper is an extension of the models briefly discussed. The proposed methodology overcomes the mathematical limitations and enables the OA team to assess both desired operational effects and the performance of planned tasks simultaneously. Its development is based on experience in the JAOC strategy divisions with the support of many JAOC OA personnel, EBAO experts, and Air Force senior mentors. The approach meets the six requirements for a sound decision-making tool, and thus provides a clear, simple structure for conducting solid operational assessments.

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[8] Kirkwood, 1.
[9] Ibid, 1.
[10] Hammond, *et al*, 4.
[11] JP 3-0, GL-14. This term and its definition modify the existing term and its definition and are approved for inclusion in the next edition of JP 1-02.
[12] Bradley, *et al*, 135
[13] Kent, 1989

3 – A Practical Methodology for Operational Assessment

> *One accurate measurement is worth a thousand expert opinions. – Admiral Grace Hopper*

A tenet of this paper is that OA must support the effective and efficient use of air, space, and cyberspace power. Given this assertion, OA must answer two fundamental questions:

1. Are we doing things right?
2. Are we doing the right things?

The first question addresses the performance of planned air operations by focusing the assessment on the completion of tasks. The second question addresses the efficient use of scarce airpower resources by focusing on the achievement of the JFACC's desired effects. The synergy between the answers resulting from these two questions allows the OA team to provide the commander with actionable information upon which to base decisions about the direction of the strategy. Inherent in this process is the capability to point out areas with greater operational risk – highlighting potential tradeoffs for allocation decisions.

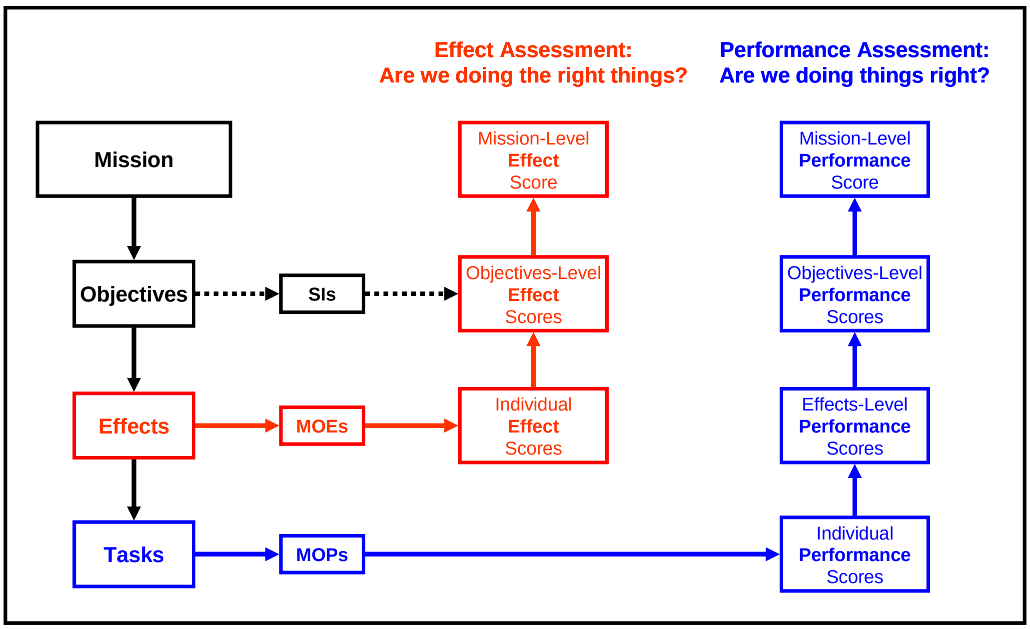

Figure 3: OA Methodology Overview

An overview of the effects-based OA model is shown in Figure 3. This assessment is tied directly to the air operations plan. The "plan" should detail the JFACC's desired operational level effects with corresponding MOEs and Success Indicators (SIs). In addition, it should detail the tasks the JFACC believes must be performed to achieve the Air Component's objectives as well as the corresponding MOPs for these tasks. The operational planning structure (Mission→Objectives→Effects→Tasks) of *JP 5-0 Joint Operation Planning*, 26 Dec 2006, will be assumed for the remainder of this paper; however, the approach is also valid for the traditional strategy-to-task structure (Operational Objective→Tactical Objective→Tactical Task) as long as the Tactical Objective captures the JFACC's desired effect. To assess an air operations plan, two mathematically independent models are built--one model to evaluate the achievement of the

JFACC's desired *effects*, and a second model to evaluate the *performance* of the JFACC's plan. There are "several good reasons" to objectively quantify the subjectively built plan into models.[14] The primary reason is to help clarify the meaning of the effects and "facilitate all aspects of decision-making".[15]

While independently scoring *effects* and *performance*, OA Teams must maintain Task and Effect linkages to make overall assessments. Separating Tasks and Effects may marginalize or overemphasize one or the other and may diminish the linkage between the two. The linkage between Tasks and Effects is the very heart of effects-based thinking. This assessment methodology is designed to explicitly assess these linkages through the juxtaposition of *effect* and *performance* results.

In addition, if attention to causal links is maintained, mathematically independent scoring models for *effect* and *performance* can provide great utility because they help highlight and distinguish "weight of effort" and "achievement of objective" trade-offs. This approach is especially useful during the planning phase because it helps mitigate the danger of assessments becoming too "fuzzy;" however, it must be balanced with the tendency to devolve to an overly quantitative assessment.

Notation

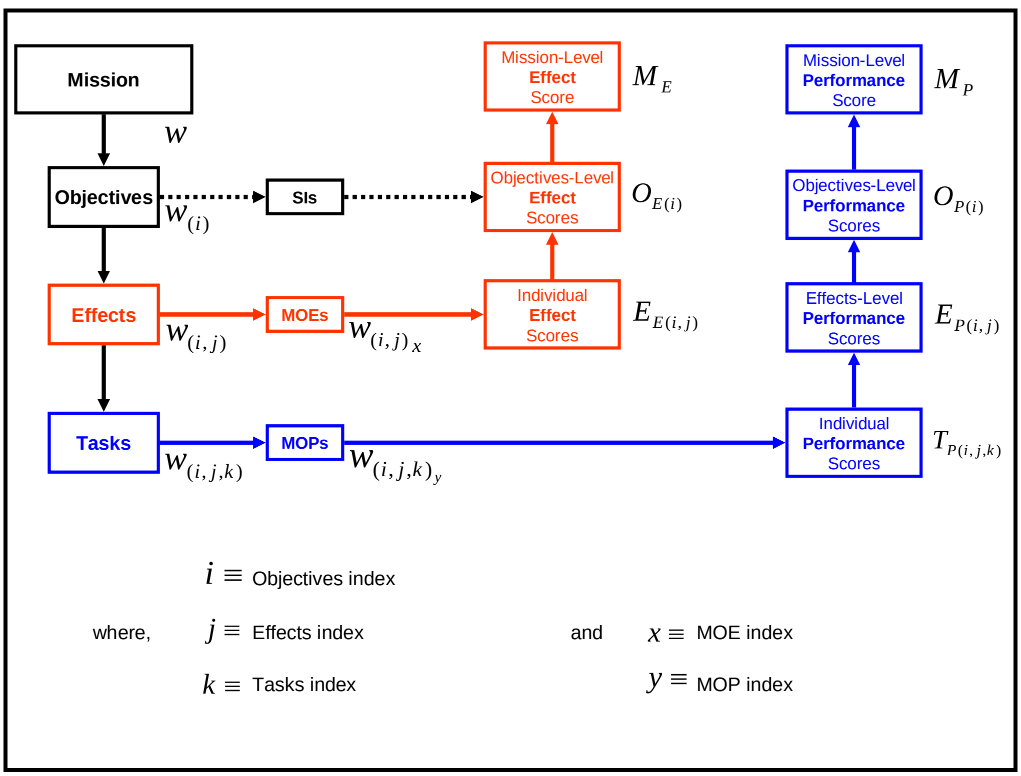

Figure 4: Assessment Structure Notation

Before describing the detailed mathematics in our methodology it is important to introduce the notation that will be used. Figure 4 provides our weighting, scoring, and indexing notation in relation to our assessment methodology overview. A w represents the relative importance weight. For example, $w_{(i)}$, refers to the relative importance weighting of Objective i. M, O, E, and T represent calculated scores for various plan levels: Mission, Objectives, Effects, and Tasks respectively. Subscripts $_E$ and $_P$ indicate *effect* and *performance* scores, respectively. For example, $O_{E(i)}$ refers to the *Objective-Level Effect Score* for Objective i.

Linear Weighted-Additive Model Assumptions

Every mathematical model is actually an approximation of the real-world system. There are simply too many factors involved in any system to account for everything. As such, there are certain assumptions that must be made about the actual system to simplify it and find a mathematically tractable solution. It is important to explicitly state the assumptions of the model so that a user will understand the strengths as well as the limitations of the model. The following are assumptions for the Effects and Performance linear weighted-additive models.

1. Mutually Exclusive – This is the assumption that was critically violated in the models that combined effects and performance scores. Effects are inherently dependent on tasks. Therefore, MOEs are inherently dependent on MOPs which implies that the two are not mutually exclusive. Violating this assumption leads to nonsensical results of marginal value to the commander. Scoring effects and performance separately addresses this problem, leading to interpretable results.
2. Preferential Independence – The change in the value of one measure does not change the importance or value of another measure. There are many instance in military operations in which this assumption could be violated; however, there are methods to handle these situations such that the assumption is not violated and the model remains complete. One such method is creating a two-dimensional metric as demonstrated in Figure 5.
3. Collectively Exhaustive – Each level in the assessment model hierarchy is a complete listing of the components of the superior level. For example, we assume that the effects listed under an objective are a complete listing of the effects that contribute to that objective. Recognize that this assumption will be violated in virtually every implementation of a linear weighted-additive model; however, tremendous insights can still be gained as long as the major pieces are included and the results are analyzed by a skilled OAT – to include both analysts and operators.
4. Additive Value Functions – Each level in the assessment model hierarchy will sum to the value of the superior level. War is not linear; however, this model is designed to provide a linear approximation of progress toward achieving the commander's objectives.

A Brief Discussion of Measures

Measures define the degree to which something is accomplished.[16] For our purposes, *MOEs define the degree to which effects have been achieved*, and *MOPs define the degree to which tasks have been completed*. The use of MOEs and MOPs lets us provide unambiguous evaluations of how well we are achieving effects or performing tasks.[17, 18]

The proposed assessment model is in the form of a linear weighted-additive model – sometimes called an additive utility function.[19] This type of model requires that the units of measurement be uniform. We've all heard the saying, "you can't add apples to oranges." However, we can add the monetary or caloric value of an apple to the corresponding value of an orange. This is done by applying simple mathematical transformations:

f(*apple*) = \$*x* or *x* cal. and,

f(*orange*) = \$*x* or *x* cal.

The transform functions, f(*apple*) and f(*orange*) are called the *individual utility functions*. In the case of MOEs and MOPs, we apply *normalized* individual utility functions. That is, f(*MOE*) and f(*MOP*) will always result in a value between 0 and 1. For simplicity, when describing the mathematical equations, we will refer to f(*MOE*) and f(*MOP*) as MOE and MOP respectively.

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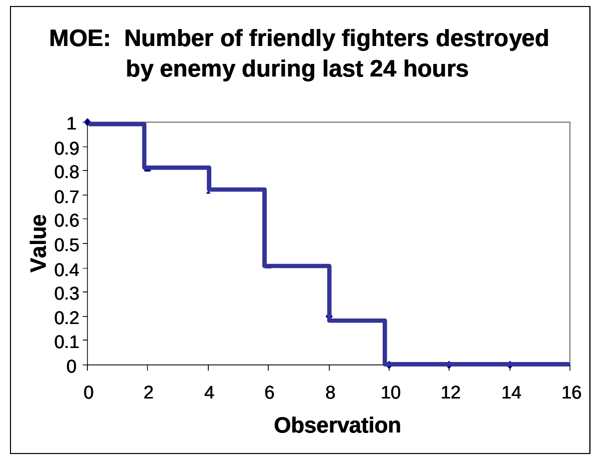


An individual utility function can take on many forms depending on the commander's beliefs. Examples of A – discrete, B – Continuous, and C – multi-dimensional individual utility functions are given in Figure 5 for notional MOPs and MOEs. A detailed discussion of methods to determine the individual utility function can be found in Clemen and Reilly's *Making Hard Decisions with Decision Tools.*[20]

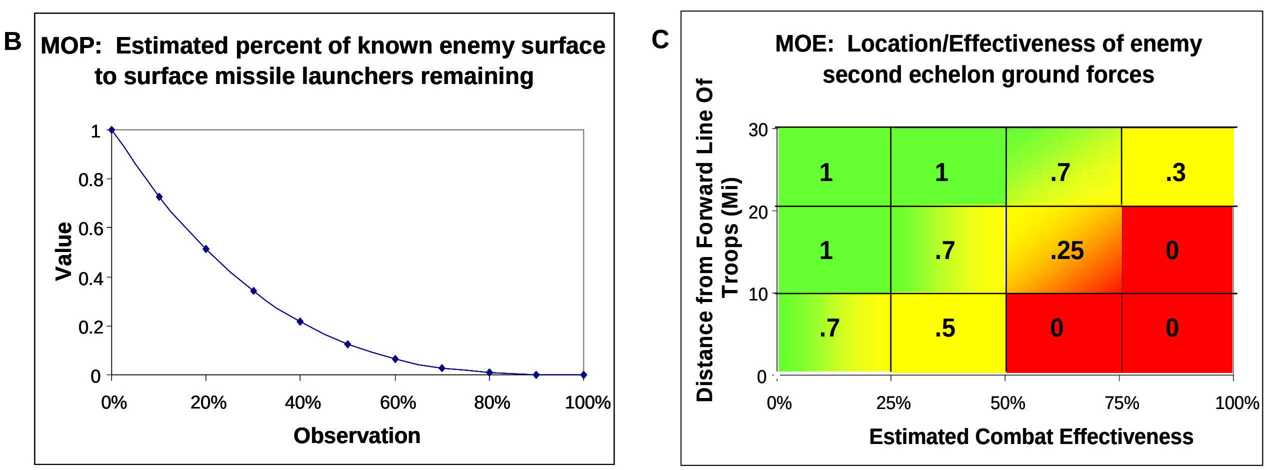


Figure 5: Sample Individual Utility Functions

Writing good measures is an art; there is no set formula. However, there are some general guidelines that, when followed, can aid in developing high quality metrics.

- *The measure should be a measure*. Often, metrics developers are tempted to write a goal or criterion as a measure. The desired measurement can sometimes be deduced from the goal, but often leads to misguided data collection efforts. Instead, the goal will be accounted for in the individual utility function where the commander's risk tolerance and thresholds are captured.

- *Bad Example*: No friendly fighter losses.
- *Good Example*: Number of friendly fighter losses.

- *The measure should be measurable*. The data satisfying a measure should be able to be gathered by observation. The data should either be countable (quantitative) or categorical (qualitative). This minimizes bias and allows for clear data requirements.
  - *Bad Example*: Civilian populace attitude toward stability forces.
  - *Good Example - Quantitative*: Percentage of surveyed civilian population giving "favorable" rating to stability forces.
  - *Bad Example*: Progress towards opening new Air Base.
  - *Good Example - Qualitative*: Phase of Air Base stand-up (secured land, runway operational, 30-day sustainment capability in-place, long-term sustainment capability in-place).

- *The measure should be clear and concise.* A list of measures should be in such plain language that someone with no prior knowledge of the measures can still understand the data requirements.
  - *Bad Example:* Status of enemy fighters.
  - *Good Example:* Number of enemy fighters capable of flying.

- *The measure should measure <u>it</u>.* In other words, the measure should be relevant to the effect or task it is intended to describe. If there are important measures that do not directly relate to a stated task or effect, the plan may be incomplete.

- *Measure the entire plan, but don't overdo it.* This is a simple case of "don't set yourself up for failure." All effects and tasks need to be measured, and there may even be multiple measures required to fully describe the progress toward an effect or task. However, one must consider the value added to the end result before adding too many measures. This is especially important during fast paced operations when data collectors can easily become over-tasked resulting in gaps in the assessment model. Remember, <u>**the assessment model provides insight; it does not produce final decisions.**</u>

Effect Scoring

Implementation of EBAO forces strategic and operational planners to shift their thinking away from strictly targeting and, instead, focus on desired outcomes – effects. Desired effects drive the JFACC's resource allocation decisions and may even influence changes to the overarching strategy. Therefore, rigorous evaluation of effects is crucial to successfully implementing EBAO. Assessing effects answers the question, "Are we doing the right things?" The effects model is summarized in Table 1, followed by an in-depth discussion of the mechanics of the "roll-up" computations. As a reminder, we will refer to f(*MOE*) simply as MOE in the mathematical formulas.

Mission	$M_E = w_{(1)}O_{E(1)} + w_{(2)}O_{E(2)} + ... + w_{(i)}O_{E(i)}$ where, $\sum_{n=1}^{i} w_{(n)} = 1$ **Mission-Level *Effect* Score**
↑ Objective	$O_{E(i)} = w_{(i,1)}E_{E(i,1)} + w_{(i,2)}E_{E(i,2)} + ... + w_{(i,j)}E_{E(i,j)}$ where, $\sum_{n=1}^{j} w_{(i,n)} = 1$ **Objective-Level *Effect* Scores**
↑ Effect	$E_{E(i,j)} = w_{(i,j)_1}MOE_{(i,j)_1} + w_{(i,j)_2}MOE_{(i,j)_2} + ... + w_{(i,j)_x}MOE_{(i,j)_x}$ $\sum_{n=1}^{x} w_{(i,j)_n} = 1$ **Individual *Effect* Scores**

Table 1: Effects ‘Roll-Up Model Summary

We assess the achievement of the JFACC’s desired effects, using a linear weighted-additive model. The mathematical mechanics are an iterative process in which the same steps are repeated for each level (Mission, Objective, and Effect). Starting at the lowest level, each Effect has a number (x) of MOEs associated with it. In addition, each MOE is assigned a relative importance weight. For each assessment period values associated with each MOE are observed and input into the model. Using Equation 1, an *Individual Effect Score* is calculated for each Effect. The score, between 0 and 1, indicates the level that a particular individual Effect has been achieved. A score of 1 indicates the Effect was, at least temporarily, completely achieved.

$$E_{E(i,j)} = w_{(i,j)_1}MOE_{(i,j)_1} + w_{(i,j)_2}MOE_{(i,j)_2} + ... + w_{(i,j)_x}MOE_{(i,j)_x}$$
$$\sum_{n=1}^{x} w_{(i,j)_n} = 1$$

Equation 1: Individual *Effect* Scores

“Rolling-up” the model, we next calculate an *Objective-Level Effect Score* for each Objective. Each Objective in the plan is associated with a number (j) of Effects. In addition, each Effect has been assigned a relative importance weight with respect to the given Objective. Using Equation 2, we calculate each *Objective-Level Effect Score*. The score, between 0 and 1, correlates to level of achievement for a particular Objective. As with the Individual Effect Score, a score of 1 would indicate that a particular Objective was completely achieved.

$$O_{E(i)} = w_{(i,1)}E_{E(i,1)} + w_{(i,2)}E_{E(i,2)} + ... + w_{(i,j)}E_{E(i,j)}$$
$$\text{where, } \sum_{n=1}^{j} w_{(i,n)} = 1$$

Equation 2: Objective-Level *Effect* Scores

Finally, we calculate the *Mission-Level Effect Score*. The Mission has a number of Objectives, with index *i*, that must be accomplished. Similar to the *Effect*- and *Objective-Level* scoring, each Objective is assigned a relative importance weight. Using Equation 3 we calculate the *Mission-Level Effect Score*. The assessment, between 0 and 1, indicates the level of accomplishment of the Mission. An assessment of 1 would indicate that the Air Component's portion of the Mission was, at least temporarily, completely accomplished.

$$M_E = w_{(1)}O_{E(1)} + w_{(2)}O_{E(2)} + \ldots + w_{(i)}O_{E(i)}$$

$$\text{where, } \sum_{n=1}^{i} w_{(n)} = 1$$

Equation 3: Mission-Level *Effect* Score

> **A Note on the Mission-Level *Effect* Score:** *The mission will often encompass more than any component can accomplish alone. In these cases, the mission level score can be interpreted as the Air Component's portion of the mission. The theater strategic level assessment should take these into account in their performance assessment and compare to the theater level effects scores to aide in developing JFC guidance to the components.*

The *effect* scoring methodology just described provides a means to quantitatively assess the qualitative attributes in the JFACC's mission. We realize, however, that not all things important to the JFACC's decision-making will 'fit' in the model. We therefore encourage the use of SIs to support the effects scoring. SIs are subjective metrics used to give structure to a "gut check" of the assessment. In practice, these are a set of business rules that define success and failure at the objective level. It is important to note that these do not simply summarize the MOEs, but paint a picture of what success at the objective level looks like. Essentially, statements are placed into ranges on the chart that describe how the commander envisions the battlespace looking for the given range. The true statements can then be subjectively translated into values. For example, consider the sample SI in Figure 6. If there is neutral press coverage, increased HUMRO traffic, and decreased HUMRO tactical airlift demand, the commander will probably feel that the objective is accomplished and will expect a high effect score.

Figure 6: Example Success Indicator

An SI may be utilized in three ways:

1. When no or insufficient MOE data is available, SIs can be used to make a structured subjective call on the objective level effect score.

2. When sufficient MOE data is available, SIs can be used to check the validity of the model. If there is disparity between the objective-level score and the SI, the culprit may lie in the weights, measures, arithmetic, or the lack of the collective exhaustiveness of effects.
3. SIs can be integrated into the math of the "roll-up." For example, the roll-up may be the average, minimum, or maximum of Equation 2 and the SI score.

Performance Scoring

Tasks are the means we choose to achieve our desired effects. Tasks are developed based on our understanding of the enemy's system-of-systems, and are executed with the intent of creating the JFACC's desired effects. Assessing how well Tasks are performed is key to understanding whether we are "doing things right." In other words, we are attempting to determine if the resources we are expending are leading to the accomplishment of our Tasks. The performance model is summarized in Table 2, followed by an in-depth discussion of the mechanics of the "roll-up" computations. As a reminder, we will refer to f(*MOP*) simply as MOP in the mathematical formulas.

Mission	$M_P = w_{(1)}O_{P(1)} + w_{(2)}O_{P(2)} + \ldots + w_{(i)}O_{P(i)}$ where, $\sum_{n=1}^{i} w_{(n)} = 1$ **Mission-Level *Performance* Score**
↑ Objective	$O_{P(i)} = w_{(i,1)}E_{P(i,1)} + w_{(i,2)}E_{P(i,2)} + \ldots + w_{(i,j)}E_{P(i,j)}$ where, $\sum_{n=1}^{j} w_{(i,n)} = 1$ **Objective-Level *Performance* Scores**
↑ Effect	$E_{P(i,j)} = w_{(i,j,1)}T_{P(i,j,1)} + w_{(i,j,2)}T_{P(i,j,2)} + \ldots + w_{(i,j,k)}T_{P(i,j,k)}$ where, $\sum_{n=1}^{k} w_{(i,j,n)} = 1$ **Effects-Level *Performance* Scores**
↑ Task	$T_{P(i,j,k)} = w_{(i,j,k)_1}MOP_{(i,j,k)_1} + w_{(i,j,k)_2}MOP_{(i,j,k)_2} + \ldots + w_{(i,j,k)_y}MOP_{(i,j,k)_y}$ where, $\sum_{n=1}^{y} w_{(i,j,k)_n} = 1$ **Individual Task *Performance* Scores**

Table 2: Performance Model Summary

We assess the *performance* using a linear weighted-additive model. As with the effects scoring, this is an iterative process in which the same steps are repeated for each level (Mission, Objective, Effect and Task). Starting at the bottom, each Task has a number (y) of MOPs associated with it. In addition, each MOP is assigned a relative importance weight. Similar to the effects scoring, values for the various MOPs are observed and input into the model for each assessment period. Using Equation 4, an *Individual Task Performance Score* is calculated for each Task. The score, between 0 and 1, indicates the level of completion for that particular Task. A score of 1 would indicate that the Task was completed as of the latest assessment period.

$$T_{P(i,j,k)} = w_{(i,j,k)_1} MOP_{(i,j,k)_1} + w_{(i,j,k)_2} MOP_{(i,j,k)_2} + \ldots + w_{(i,j,k)_y} MOP_{(i,j,k)_y}$$
$$\text{where, } \sum_{n=1}^{y} w_{(i,j,k)_n} = 1$$

Equation 4: Individual Task *Performance* Scores

Moving up to the next level in the model, we calculate the *Effects-Level Performance Score* for each Effect. Each Effect in the model has a number (k) of Tasks associated with it, and each Task has a relative importance weight. Using Equation 5, we calculate each *Effect-Level Performance Score*. The score, between 0 and 1, shows the level that Tasks designed to achieve a particular Effect have been completed. A score of 1 would signify that all Tasks, for a particular Effect, were completed.

$$E_{P(i,j)} = w_{(i,j,1)} T_{P(i,j,1)} + w_{(i,j,2)} T_{P(i,j,2)} + \ldots + w_{(i,j,k)} T_{P(i,j,k)}$$
$$\text{where, } \sum_{n=1}^{k} w_{(i,j,n)} = 1$$

Equation 5: Effects-Level *Performance* Scores

Next, we calculate the *Objective-Level Performance Scores* for each Objective. Each Objective is associated with a number (j) of Effects, and each Effect has a relative importance weight. Using Equation 6, we calculate each *Objective-Level Performance Score*. The score, between 0 and 1, indicates the level that all Tasks for a particular Objective have been performed. A score of 1 would indicate that the Tasks, for a particular Objective, were completed.

$$O_{P(i)} = w_{(i,1)} E_{P(i,1)} + w_{(i,2)} E_{P(i,2)} + \ldots + w_{(i,j)} E_{P(i,j)}$$
$$\text{where, } \sum_{n=1}^{j} w_{(i,n)} = 1$$

Equation 6: Objective-Level *Performance* Scores

Finally, we calculate the *Mission-Level Performance Score*. The Mission has a number of Objectives, with index i, that must be accomplished, and each Objective has a relative importance weight. Using Equation 7 we calculate the *Mission-Level Performance Score*. The score, between 0 and 1, indicates the level of completion of the Tasks designed to accomplish the Mission. A score of 1 would indicate that all planned Tasks, associated with the Mission, were completed.

$$M_P = w_{(1)} O_{P(1)} + w_{(2)} O_{P(2)} + \ldots + w_{(i)} O_{P(i)}$$

$$\text{where, } \sum_{n=1}^{i} w_{(n)} = 1$$

Equation 7: Mission-Level *Performance* Score

Operational Assessment

The JFACC allocates resources to perform tasks which contribute to the achievement of effects. The methodology presented provides the OA team with a process to assess our performance of tasks, and determine if these tasks are producing the desired effects. A high *performance* score suggests many of the planned tasks are completed. A high *effect* score suggests many of the JFACC's desired effects are present in the battlespace. Low *performance* and *effect* scores naturally have an opposite interpretation. The most significant step in this methodology is to draw inferences based on the comparison of the resulting *performance* and *effect* scores. Figure 7 provides some generalized interpretations for various combinations of high and low *performance* and *effect* scores.

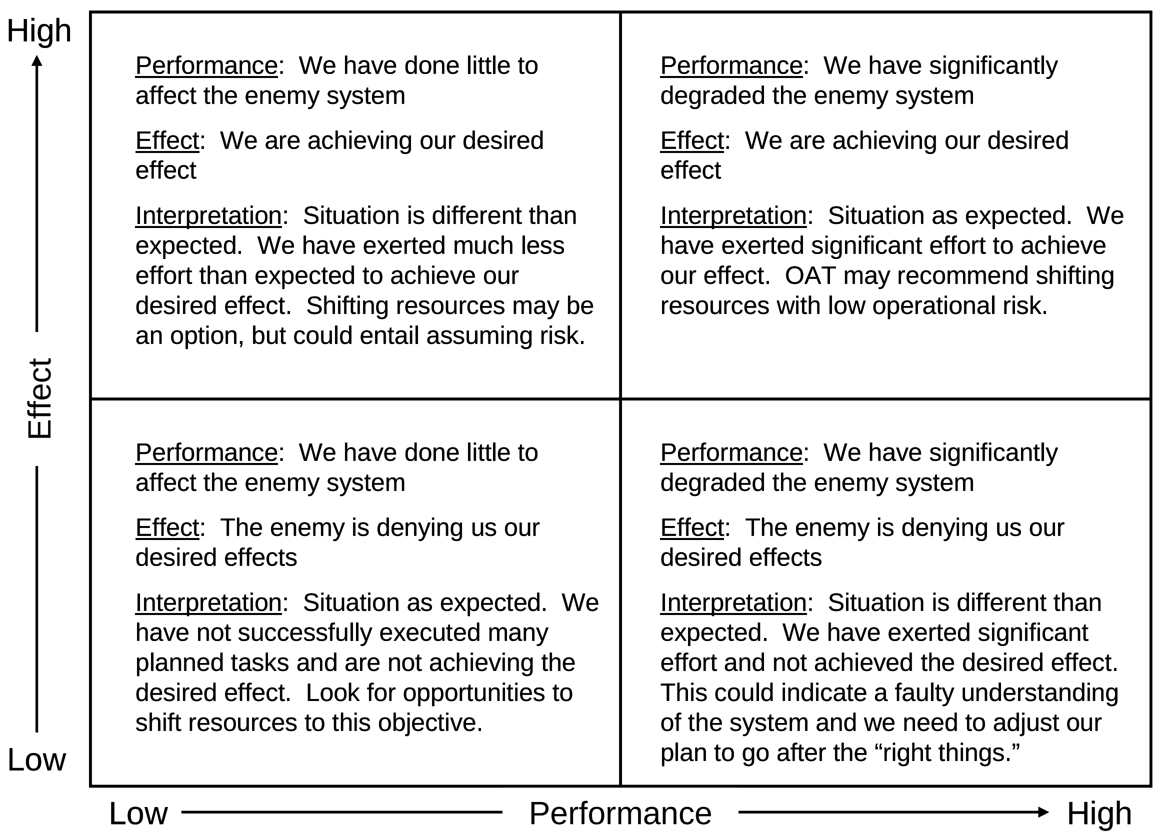
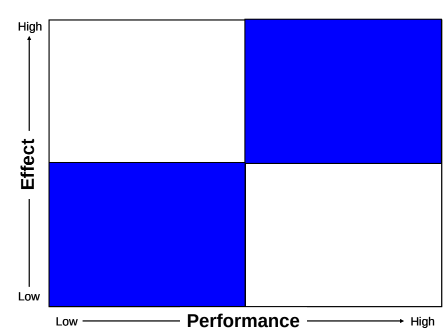
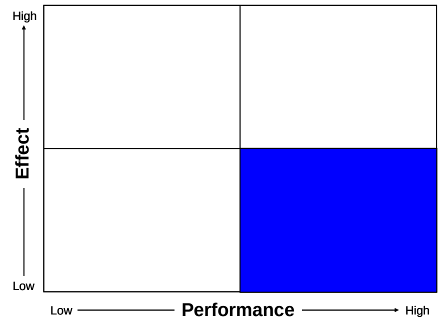


Figure 7: Generalized OA Results Interpretation

The independent scores for *performance* and *effect* can be characterized in three basic ways. The scores may be

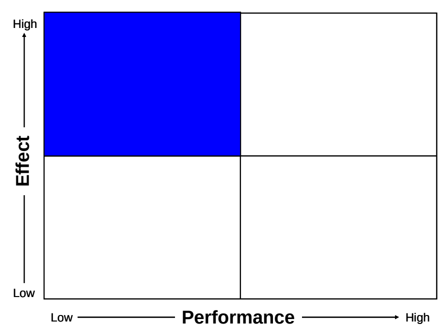


similar; the *performance* score will be higher than the *effect* score; or the *effect* score will be higher than the *performance* score. In the first case, similar *effect* and *performance* scores suggest the operation is proceeding as expected--our understanding of the enemy system and the causal linkages between tasks and effects appear to be correct. This is not to say that the operation is on schedule. However, effects are being achieved in proportion to the level of completion of subordinate tasks.



Disconnects between *effect* and *performance* scores indicate that portions of the plan may require further examination. When *performance* scores are higher than *effect* scores, the completion of tasks are, to this point, not creating the desired effects. Numerous issues, including data latency, delayed effects, or a misunderstanding of the enemy system could be driving the score mismatches. For example, we may have confirmation of successful leaflet drops (*performance*) supporting special operations efforts to turn the local populace against their government (*effect*), but due to "comm-out" conditions we are unable to receive reports of civilian uprisings (MOE). In addition, we may have BDA indicating destruction of all enemy fuel storage (*performance*), but we won't see fuel impacts on enemy operations (*effects*) for two weeks. Finally, we may have destroyed all national power production (*performance*) to limit enemy command and control, but because the enemy employs couriers and hand-held radios as their primary means of communication, enemy C2 remains intact (*effect*).

In other words, our assumptions about the direct links between the achievement of objectives and their prerequisite, lower level, effects and tasks may be flawed. **In fact, the OA process may prove most valuable when the completion of lower level tasks *do not* result in the achievement of higher level effects or the accomplishment of higher level objectives.** At this point, the primary focus of OA should be on quickly identifying and recommending required changes to the plan.



Conversely, when *effect* scores are higher than *performance* scores, desired effects are being achieved without the comparable completion of subordinate tasks. Numerous issues, including data latency, enemy deception, good fortune, and a misunderstanding of the enemy system could lead to these score mismatches. For example, we do not have BDA from our strikes on enemy strategic SAMs (*performance*), however they have not fired during the last five ATOs (*effect*). Further, although we haven't taken any action against enemy fighters (*performance*) they are not flying. This situation may arise simply due to the fact that the enemy fighters are hidden in caves; regardless, our air operations have not been inhibited (*effect*).

In this case, the JFACC may be able to reallocate resources to another objective or effect under the conclusion that the desired effect has been achieved. Identifying these opportunities will allow the JFACC to execute operations more efficiently. However, one cannot assume that an achieved effect will remain so. The low performance score may indicate that much of the enemy's capability to adversely impact the JFACC's desired effect remains. Capturing that remaining capability translates to a picture of the operational risk the JFACC will incur if he chooses to reallocate resources. Situations of high *effect* scores with low *performance* scores can quickly be reversed, for example, if the enemy brings their aircraft out of hiding. If the JFACC decides the risk is acceptable, the OA team should focus on identifying which objectives warrant additional resources.

Where is the Operational Art?

The process of developing an effective strategy requires "significant creativity and hard thinking,"[21] and the entire strategy team consisting of operations, intelligence, logistics, analysis, and sister service personnel must be involved. The development of the plan's structure--the decomposition from Missions to Tasks--is an entirely qualitative process based on the experiences and judgment of strategists. Additionally, assigning relative importance weightings and choices of SIs, MOEs, and MOPs must be based on the knowledge and experiences of the entire strategy team.

Well structured plans provide the basis for the use of quantitative assessment models.[22] Therefore the OA team must play a critical role in developing the air operations plan to ensure the ability to accurately assess the results. The results this quantitative model produces, however, must be viewed in the context of the operation in order to translate into effective strategy recommendations--this is where the strategist's application of operational art becomes critical.

The science of this methodology produces scores, not assessments. Producing operational assessments requires a blend of operational art and mathematical science. The models produce scores that draw attention to areas of interest. The results, however, must be investigated for cause-effect relationships and interpreted through the trained eyes of experienced strategy professionals. Opportunities for recommendations to "stay the course," "change the plan," or "shift weights of effort" will be highlighted by the scores but ultimately made through collaboration with the entire strategy team.

Where is the Data?

Lack of data is a real problem for all analytic OA methodologies, including this one. Data collection and dissemination issues are present in every theater and they must be planned for. Experience and sound judgment, already a necessary ingredient for quality assessments, increase in importance when required information (military intelligence, battle damage assessments, mission reports, etc.) for assessment models is unavailable. The reality of limited data, however, does not obviate the OA Team of its responsibilities to develop a sound assessment structure, identify intelligence and other information requirements, and conduct a sound operational assessment.

Even in the worst data deficient cases, there are great benefits to implementing an assessment methodology such as that described in this paper because this "structuring… results in a deeper and more accurate understanding…of the decision context."[23] Further, by providing a sound analytic framework, the OAT will have a frame of reference when discussing confidence in results. OA results and recommendations can be couched in terms of data availability, providing the JFACC greater insight into the balance of art and science in the current assessment.

Finally, a consistent and methodical approach to OA can counter the inevitable effects of a lack of continuity in the JAOCs. While a lack of data combined with the constant rotation of personnel assigned to the JAOC may seem to provide an impenetrable barrier to sound OA, a method such as the one proposed in this paper can reassure the JFACC that assessments and recommendations are based upon a consistent approach.

Methodology Summary

The OA methodology described in this paper maintains the simplicity and logical consistency of the original "roll-up" model approach while focusing on "what is important"--the JFACC's desired effects. It will enable the OA team to identify situations in which our understanding of the enemy system does not match reality. It also encourages the use of both qualitative and quantitative factors in the assessment. In addition, by using mathematically independent *effect* and *performance* models we have overcome the mathematical limitations that have frequently confounded past OA efforts. The results of these models enable the OAT to provide the JFACC risk considerations, trends in the operation, and a level of confidence in the results. Finally, this straightforward and flexible model can be applied to various planning structures and in various theaters with ease.

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[14] Keeney,129.
[15] Ibid.
[16] Ibid, 100.
[17] Kirkwood, 25.
[18] A thorough discussion of measurement theory is beyond the scope of this paper; however, interested readers are referred to *Theory of Effectiveness Measurement* by Maj Richard K. Bullock.
[19] Clemen, *et al*, 100.
[20] Ibid.
[21] Keeney, 56.
[22] Ibid, 69.
[23] Keeney, 69.

4 – Methodology Demonstration

However beautiful the strategy, you should occasionally look at the results – Winston Churchill

In this section, the OA methodology developed in the previous section is applied to a notional example. A notional plan in the framework of *JP 5-0 Joint Operation Planning* is depicted in Figure 8. The plan is admittedly incomplete; however, it is sufficient as an example to highlight the benefits of effects-based OA. Developing a plan is the responsibility of the strategy division to which the OA team is a critical component. Therefore, the OA team should not undertake this task alone. Conversely, it is critical that the OA team not be excluded while the hierarchy is being developed. Any strategy-to-task hierarchy constructed without assessment in mind from the beginning is likely to contain immeasurable portions which will force assessment back into the realm of exclusively gut feel. For a cogent discussion of the characteristics of well written Objectives, Effects, Tasks, MOEs, MOPs, and SIs refer to *Operational Assessment of Effects Based Strategies—Proposed Approaches to Measurement.*[24]

Mission: Restore Sovereignty of Allied Nation
- Objective$_{(1)}$: Gain and maintain air superiority throughout the joint operations area
  - Effect$_{(1,1)}$: Friendly fighters unaffected by enemy action
    - MOE$_{(1,1)1}$: Number of friendly fighters destroyed by enemy in last 24 hours
    - MOE$_{(1,1)2}$: Number of friendly fighters damaged by enemy in last 24 hours
    - MOE$_{(1,1)3}$: Number of friendly fighter retrogrades due to enemy action in last 24 hours
    - Task$_{(1,1,1)}$: Degrade enemy SAM systems
      - MOP$_{(1,1,1)1}$: Percent of known enemy SAM launchers destroyed
      - MOP$_{(1,1,1)2}$: Percent of known enemy SAM radar vans destroyed
    - Task$_{(1,1,2)}$: Degrade enemy air-to-air capabilities
      - MOP$_{(1,1,2)1}$: Percent of enemy airfields non-operational
      - MOP$_{(1,1,2)2}$: Percent of enemy airfields with limited operations
      - MOP$_{(1,1,2)3}$: Percent of enemy fighters destroyed
  - Effect$_{(1,2)}$: Friendly ground forces have freedom from enemy air action
    - MOE$_{(1,2)1}$: Number of friendly ground casualties due to enemy action in last 24 hours
    - MOE$_{(1,2)2}$: Number of friendly battalion sized units halted prior to objective
    - Task$_{(1,2,1)}$: Destroy enemy air-to-ground capabilities
      - MOP$_{(1,2,1)1}$: Percent of known enemy air-to-ground fighters destroyed
      - MOP$_{(1,2,1)2}$: Percent of known enemy bombers destroyed
      - MOP$_{(1,2,1)3}$: Percent of known enemy attack helictopters destroyed
- Objective$_{(2)}$: Prevent enemy 2nd echelon forces from reinforcing main effort
  - Effect$_{(2,1)}$: Enemy 2nd echelon forces unable to reach main battle area at combat effective strength
    - MOE$_{(2,1)1}$: Status of Red Battalion (miles from friendly troops & estimated combat strength)
    - MOE$_{(2,1)2}$: Status of Purple Battalion (miles from friendly troops & estimated combat strength)
    - Task$_{(2,1,1)}$: Destroy available avenues of approach
      - MOP$_{(2,1,1)1}$: Percent of key river crossings destroyed
    - Task$_{(2,1,2)}$: Destroy 2nd echelon forces
      - MOP$_{(2,1,2)1}$: Estimated combat effectiveness of Red Battalion
      - MOP$_{(2,1,2)2}$: Estimated combat effectiveness of Purple Battalion

Figure 8: Generic JP5-0 Strategy-to-Task Hierarchy

Now that the plan is complete, we can build the *effect* and *performance* models. Figure 9 depicts the effect scoring model for our generic plan including the model structure and relative importance weights for each Objective, Effect, and MOE. Figure 10 provides the performance scoring model structure, with relative importance weights shown for each Objective, Effect, Task, and MOP.

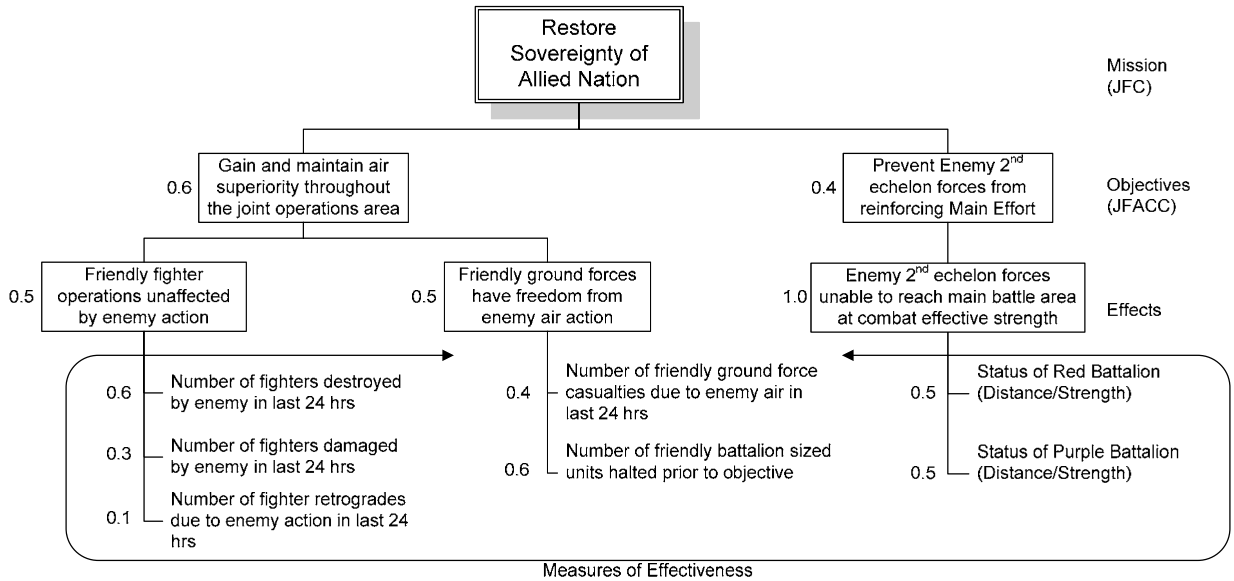

Figure 9: Effect Scoring Model with Weights

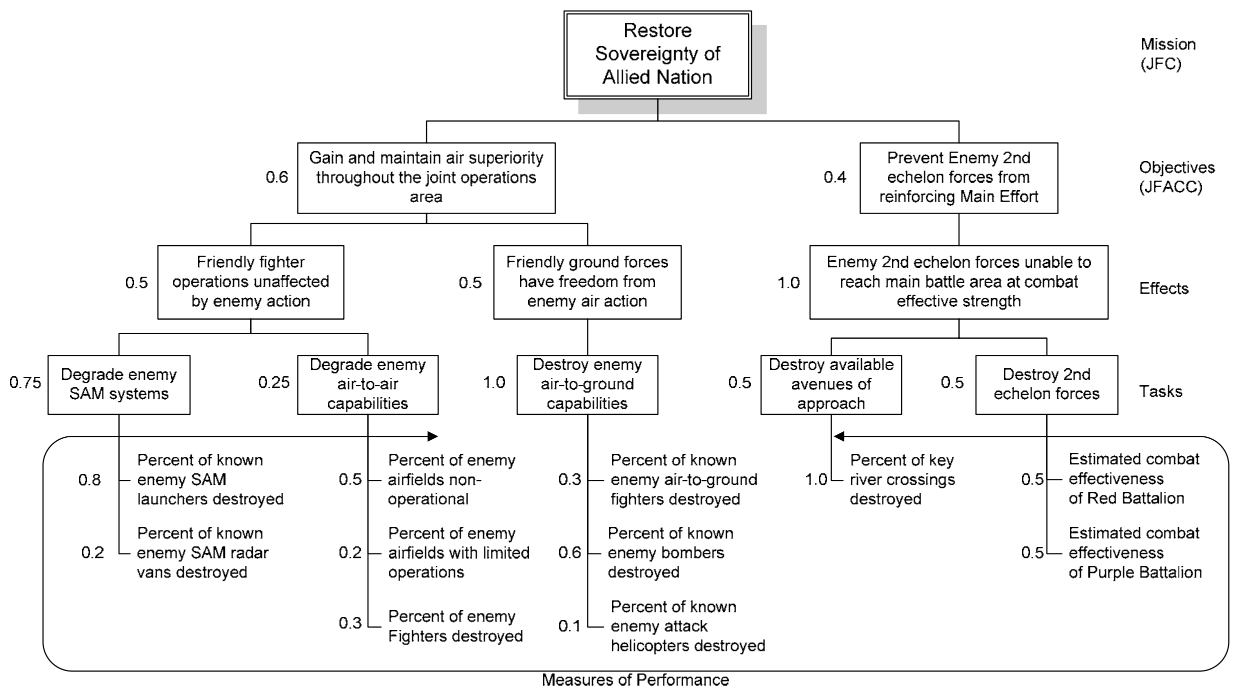

Figure 10: Performance Scoring Model with Weights

Several techniques can be used to derive the hierarchy weights such as “Pricing Out”, “Swing Weighting”, or “Lottery Weights.” Pricing Out consists of determining how much of one objective you would be willing to give up for a unit of increase in another objective; Swing Weighting involves comparison and ranking of hypothetical outcomes; and Lottery Weights are determined by assessing the probability of success on an objective that would make the choice between that objective and a sure thing on another objective indifferent.[25] A detailed discussion of these methods is beyond the scope of this paper; however, it is important to note that the method chosen is dependent on the personality, values, and experience of the decision-maker – not the analyst. The method that is most straightforward to the decision-maker will be most useful in eliciting his or her true belief system.

With the structure defined and weights elicited we can build an assessment tool. The required calculations of this methodology are simple enough to be performed by hand, with a calculator, or in a simple spreadsheet model. The next section highlights the simple mathematics required to produce *effect* and *performance* scores for this notional example.

Model Calculations for "ATO A"

The purpose of this section is to walk through the mathematical mechanics of our methodology for a sample data set. Table 3 and Table 4 provide notional data for one ATO period. The 'Observed' column contains the notional observation, and the 'Value' column contains the transformed value of that observation. That is, the 'Value' column contains the individual utility scores computed using the individual utility functions. Figure 11 illustrates how the values are computed – by identifying the value corresponding to the observed level of the MOE on the graph of the Individual Utility Function. The example shows that the observed MOE of '6 fighter losses' corresponds to a normalized value of 0.4.

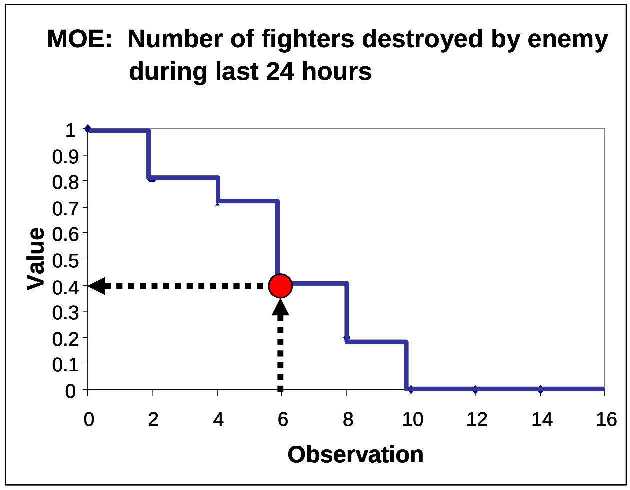

Figure 11: Sample Value Derivation

As a reminder, the higher the value, the better with a maximum value of 1.

Measures of Effectiveness	ATO A	
	Observed	Value
MOE: Number of Fighters destroyed by enemy in last 24 hrs	6	**0.4**
MOE: Number of Fighters damaged by enemy in last 24 hrs	21	**0**
MOE: Number of Fighter retrogrades due to enemy in last 24 hrs	12	**0.1**
MOE: Number of friendly ground force casualties due to enemy air in last 24 hrs	400	**0**
MOE: Number of friendly battalion sized units halted prior to objective	0	**1**
MOE: Status of Red Battalion (miles from friendly troops & estimated combat strength)	65 mi, 95%	**1**
MOE: Status of Purple Battalion (miles from friendly troops & estimated combat strength)	25 mi, 95%	**0.3**

Table 3: Sample MOE Inputs for ATO A

Measures of Performance	ATO A	
	Observed	Value
MOP: Percent of known enemy SAM launchers destroyed	40%	**0.4**
MOP: Percent of known enemy SAM radar vans destroyed	10%	**0.1**
MOP: Percent of enemy airfields non-operational	0%	**0**
MOP: Percent of enemy airfields with limited operations	0%	**0**
MOP: Percent of enemy fighters destroyed	10%	**0.1**
MOP: Percent of known enemy air-to-ground fighters destroyed	5%	**0.05**
MOP: Percent of known enemy bombers destroyed	5%	**0.05**
MOP: Percent of known enemy attack helicopters destroyed	0%	**0**
MOP: Percent of key river crossings destroyed	20%	**0.2**
MOP: Estimated combat strength of Red Battalion	95%	**0.05**
MOP: Estimated combat strength of Purple Battalion	95%	**0.05**

Table 4: Sample MOP Inputs for ATO A

Figure 12 highlights the calculations necessary to determine the *Individual Effect Score* for the notional Effect, "Friendly fighter operations unaffected by enemy action," using Equation 1, the weights from Figure 9, and the values from Table 3. For each MOE, the assigned relative importance weighting is multiplied by its observation value from ATO A. The three MOE scores are then summed to produce the Individual Effect Score of 0.25. Scores, as previously stated, are between 0 and 1; a score of 0.25 would indicate to the OA team that we were quite far from achieving our desired effect.

$$
\begin{aligned}
E_{E(1,1)} &= w_{(1,1)_1} MOE_{(1,1)_1} + w_{(1,1)_2} MOE_{(1,1)_2} + w_{(1,1)_3} MOE_{(1,1)_3} \\
E_{E(1,1)} &= (0.6)(0.4) + (0.3)(0) + (0.1)(0.1) \\
E_{E(1,1)} &= 0.24 + 0 + 0.01 \\
E_{E(1,1)} &= 0.25
\end{aligned}
$$

Figure 12: Calculations for Individual Effect Score

Using inputs from Tables 3&4, the weights from Figures 9&10, and Equations 1 thru 7; we computed the *effect* and *performance* scores for the *Mission*-, *Objective*-, and *Effect-Levels* as well as the *performance* scores for each Task. Figure 13 contains all the calculated *effect* and *performance* scores for ATO A. The next section discusses the interpretation of results.

	Effect Score	Performance Score
Mission: Restore Sovereignty of Allied Nation	***0.52***	***0.14***
Objective$_{(1,1)}$: Gain and maintain air superiority throughout the joint operations area	**0.43**	**0.15**
Effect$_{(1,1,1)}$: Friendly fighters unaffected by enemy action	**0.25**	**0.26**
Task$_{(1,1,1,1)}$: Degrade enemy SAM systems		**0.34**
Task$_{(1,1,1,2)}$: Degrade enemy air-to-air capabilities		**0.03**
Effect$_{(1,1,2)}$: Friendly ground forces have freedom from enemy air action	**0.60**	**0.05**
Task$_{(1,1,2,1)}$: Destroy enemy air-to-ground capabilities		**0.05**
Objective$_{(1,2)}$: Prevent enemy 2nd echelon forces from reinforcing the main effort	**0.65**	**0.13**
Effect$_{(1,2,1)}$: Enemy 2nd echelon forces unable to reach main battle area at combat effective strength	**0.65**	**0.13**
Task$_{(1,2,1,1)}$: Destroy available avenues of approach		**0.20**
Task$_{(1,2,1,2)}$: Destroy 2nd echelon forces		**0.05**

Figure 13: Effect and Performance Scores for Notional Example

Presentation of Assessment Results

The methodology described in this paper and its associated calculations are critical to producing a sound effects-based operational assessment. For the JFACC, however, a picture is often worth a thousand words. Thus, OA results are typically shared with the JFACC via briefings in which a large amount of information <u>must</u> be presented clearly and concisely in a short period of time. Presentation techniques must be tailored to the preferences of each JFACC, however, we offer some sample presentation options here. By no means are the formats we present prescriptive.

For demonstration purposes we present results for a notional subsequent ATO we'll call ATO D. Thresholds for "stop-light charts" were set such that scores less than 0.3 are "red," scores between 0.3 and 0.7 are "yellow," and scores above 0.7 are "green." Actual assessment thresholds would be set through collaboration with the JFACC or a suitable representative.

The first, and perhaps most important, assessment slide presented to the JFACC provides an overall assessment across the JFACC's objectives. The purpose of the slide is to provide a quick status of the operation and to allow the JFACC to swiftly observe the progress of air, space, and cyber activities, identify risk areas, and determine potential resource trade-offs between objectives. Figure 14 provides a notional macro assessment across four JFACC objectives (AS: Air Superiority, CL: Counter Land, CM: Counter Maritime, IS: Information Superiority) on ATO D.

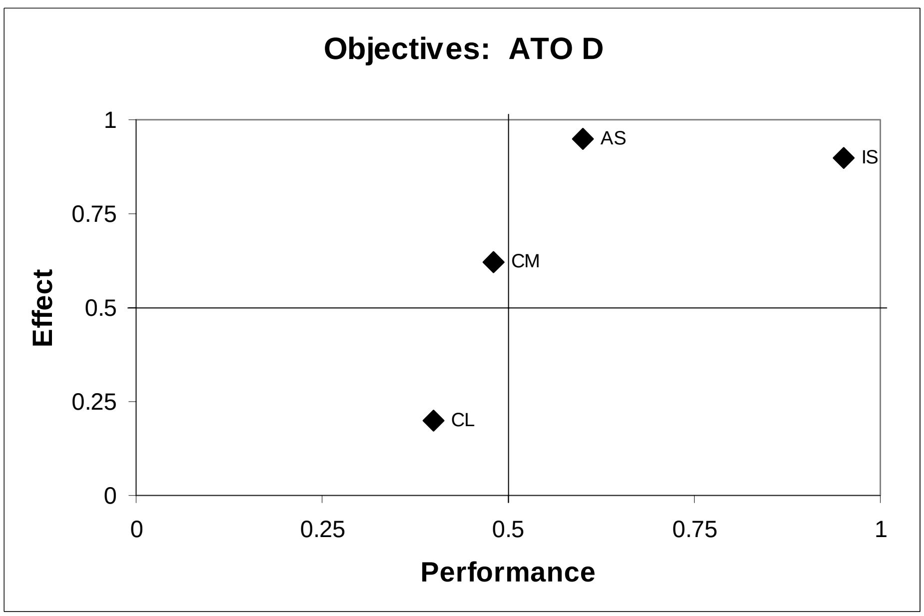

Figure 14: Macro-Level Assessment of JFACC Objectives

It is clear from Figure 14 that, early in the campaign, we are creating our desired Air Superiority effects (effect score: 0.95) significantly more than expected given the level of performance (performance score: 0.59) thus far. Before recommending strategy changes (such as shifting weight of effort to other objectives) the OA team should further investigate these results.

Figure 15 is an alternative display option that provides additional insight into Air Superiority. This graphic, focused on a single objective, provides the JFACC with critical trend information. The JFACC can quickly observe the daily progression of this objective. This graphic again reminds the JFACC that although we are observing our desired effects, the enemy appears to retain a significant capability. Further, it appears we are at or approaching a point of diminishing returns, in which continued effort applied to this objective will produce limited gains in desired effects. This presentation format additionally provides the opportunity to observe the impacts of risk acceptance decisions made across multiple ATOs by observing the daily interaction between *effect* and *performance* results.

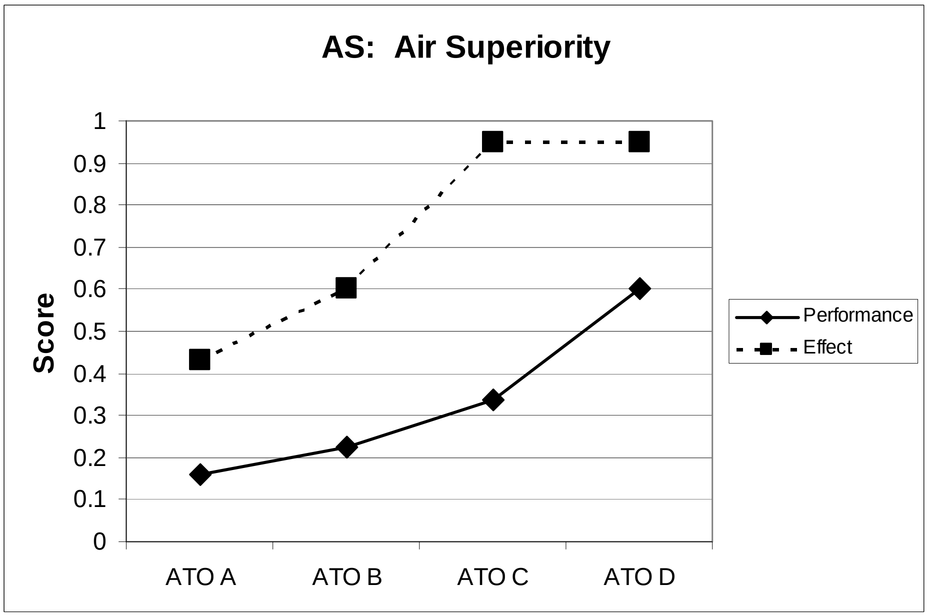

Figure 15: Air Superiority Trend Analysis

To provide even more insight to the JFACC, the OA team could "peel the onion back" an additional layer. Figure 16 provides an in-depth look at a single Air Superiority objective to provide additional insight by examining *effect-performance* discrepancies at the lowest levels. This "stop-light-chart" highlights the cause that is driving the difference in our overall *effect* and *performance* scores for Air Superiority. Friendly fighter aircraft have not been affected by enemy fighters ("Green" *effect* score); however we have done little to degrade their fighter capability ("Red" *performance* score).

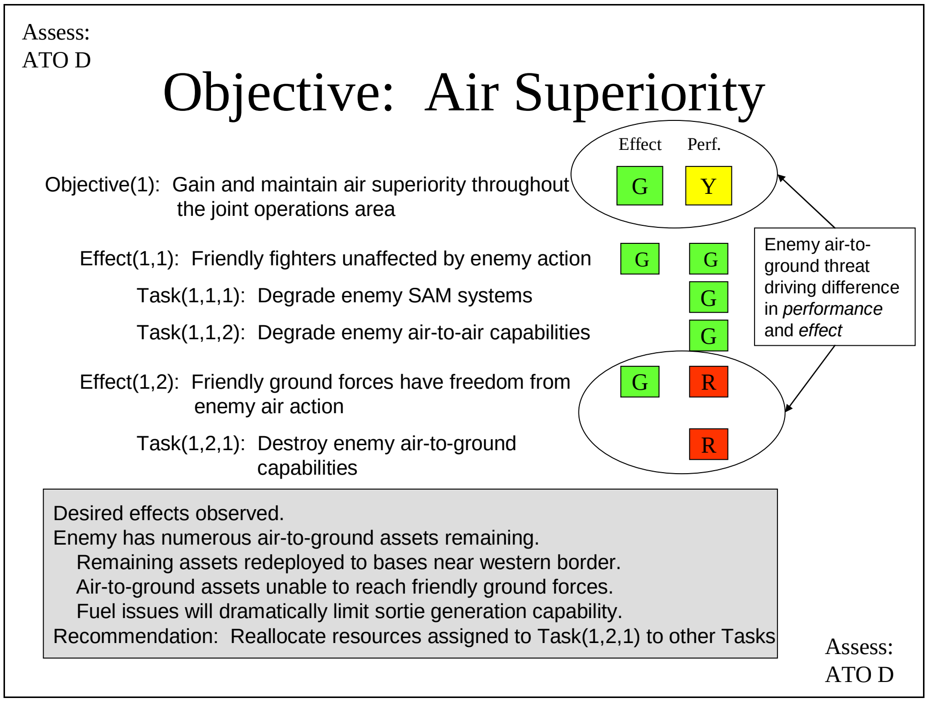

Figure 16: Focused Assessment of Air Superiority

The difference between Air Superiority performance and effect results highlights a potential disconnect in our assumed causal linkage for this task and effect. It also highlights a potential opportunity to reallocate scarce airpower resources. However, there could be numerous explanations for this observation. The enemy may have redeployed his fighters deep within their borders, beyond our reach, but available for use later (high future risk). The enemy may have buried their aircraft in the desert, never to be used again (opportunity to reallocate resources). The enemy may be using his fighter aircraft for reasons we did not anticipate. Subsequently, they are not affecting friendly fighter aircraft. However, enemy aircraft may be significantly impacting the JFC's campaign by posing a viable threat to neighboring nations (misunderstanding the enemy system).

As needed, the OA team could provide greater depth and breadth of assessment using this approach to help the JFACC execute air operations more effectively and efficiently. This assessment methodology is designed to support strategist's recommendations to the JFACC. It does not eliminate the need for operational art; rather it is designed to quickly highlight areas of opportunity and risk for strategists to consider when making recommendations to the JFACC.

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[24] Schaefer, *et al*, 2007
[25] Clemen, *et al*, 614-620

5 – Summary and Recommendations

Count what is countable, measure what is measurable, and what is not measurable, make measurable. – Galileo

OA is useful to the JFACC if and only if it adds to his or her understanding of how the campaign is progressing. The OA methodology described in this paper contributes to that understanding by independently evaluating *performance* and *effect* in order to provide an understanding of the relationship between what friendly forces are doing and the impact on the enemy system. Previous OA methodologies suffered from various limitations which resulted in information that was difficult to interpret when events were not proceeding according to the plan. Comparing *performance* and *effect* enables the JFACC to determine if the Air Component is "doing things right" and "doing the right things." Armed with this knowledge the JFACC can make adjustments to the strategy as required.

Real World Implementations

The assessment methodology in this paper has been shared and implemented, in various forms across numerous JAOCs. 7AF has employed this methodology the most completely and effectively. During Exercise ULCHI FOCUS LENS 2006, the OA team successfully demonstrated the methodology to the SRD Chief and the JFACC. Following UFL, the SRD Chief focused his strategy re-write conference on "planning for assessment," and fully implemented the methodology in support of his strategy development process for 7AF's primary war plan. The value of this methodology was validated during 7AF's Reception, Staging, Onward-Movement & Integration (RSOI) 2007 exercise.

13AF modified this approach to assess steady-state operations. The current pace of operations is such that the commander's decision brief (to include operational assessment reporting) occurs weekly. Due to the relatively low ops tempo, the OAT found that while it was straight forward to assess performance on a weekly basis, it was extremely difficult to discern changes in effects from week to week. To address this, they applied a similar approach to the one described in this article and separated assessment of *effects* and *performance*. Under the new approach, performance is assessed and briefed to the JAOC Director each week. To accurately assess the changes in effects, the OAT examines them over a longer time-span (generally 60-90 days). This approach provides the commander with a longer-term look at each objective every few weeks, while still allowing sufficient time for the changes in effect to become apparent.

Deployed analysts in 9AF implemented a similar approach in late 2005. The OAT assessing Operation IRAQI FREEDOM and Operation ENDURING FREEDOM struggled to provide the commander with an effects-based assessment of his objectives. In that case, the team decided to limit themselves to assessing *performance*, while leaving the assessment of *effects* to the supported command. The supported command's *effects* assessment was briefed to the DCFACC along with a *performance* assessment conducted by the OAT.[26]

The 1AF SRD adopted the methodology during the development of their Defense Support to Civil Authorities (DSCA) Joint Air Operations Plan (JAOP) in 2006. The DSCA JAOP was developed to provide guidance for joint air operations during events such as Hurricane Katrina. The DSCA JAOP was stressed during Exercise ARDENT SENTRY and the OA methodology was successful in supporting JFACC decision-making during the exercise.

This methodology has been applied across multiple theaters for a wide variety of operations. It has been used to support homeland defense scenarios, the development and exercising of strategy for a major theater war, and modified to support steady state operations. However, room for improving this approach remains.

The Way Ahead & Future Research Recommendations

The way ahead for OA is to adopt a standard methodology across the JAOCs. Each JFACC has unique issues that he/she must face; however, a core set of assessment requirements exists. This methodology was developed to support the core OA needs of each JFACC while providing the flexibility needed to address their area-specific issues.

The first practical benefit of adopting a standardized approach would be the development of a standardized OA training program. Each OAT must be augmented during contingency operations. A standard OA methodology would enable the development of initial qualification training for OA augmentees, minimizing the “pick-up game” approach to assessing operations. This would enable the OAT to be more effective from the first day of a contingency and would also lead to further development of OA processes. Time that is now spent learning the basics of OA could be utilized for improving data flow processes or developing better methods to examine causal linkages.

Adopting a standard OA methodology is the first step to establishing standard tools. By developing a standard set of tools we can reduce the workload of each OAT Chief by eliminating the need to develop and maintain his or her own individual tools. Further, a standard set of tools could be linked to the JAOC software backbone, Theater Battle Management Core Systems (TBMCS) or its successors, potentially automating much of the data collection effort. Collection and input of relevant data is currently a very labor intensive process for OATs, reducing the time those teams are able interact with the SRD during Course of Action (COA) development and refinement. This training would certainly incorporate the use of a standardized tool set enabling deployed OA team members to quickly contribute to strategy and assessment during contingency operations.

Future research efforts should initially be methodologically focused. A major issue with any assessment is the problem of missing data. Many statistical approaches exist that address missing data issues. JAOCs can exploit these techniques to enable better assessments. Gaining insight into causal linkages, during both planning and execution, is a growth area for strategy and OA. Strategists often use the term “assumed causal linkages” because they are developed based on our limited, and often biased understanding of the enemy system. If operations are assessed according to the methodology described in this paper, the raw results could be used to develop causal relationships between our *performance* and *effect* results. That is, we could correlate the completion of our tasks with the achievement of our desired effects. Numerous statistical techniques, such as canonical correlation, neural networks, and logistic regression, could be used to add greater understanding to our causal linkages.

[26] Messer, *et al*, 65-68

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