A Decision Analytic Approach for Measuring the Value of Counter-IED Solutions at the Joint Improvised Explosive Device Defeat Organization §

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Abstract - The Joint Improvised Explosive Device Defeat Organization (JIEDDO) focuses on rapidly identifying, developing, testing, and fielding counter-IED solutions. These solutions cover a broad range of functions and potential impacts. A relatively new organization within the Department of Defense, JIEDDO seeks to mature its decision processes. In addition, JIEDDO has faced increasing scrutiny from oversight organizations both within and without the Department of Defense. In this paper we present Discounted Expected Potential Counter-IED Value, a prototype decision analytic model for valuating counter-IED solutions intended to capture JIEDDO's preferences. JIEDDO wants solutions that address counter-IED needs, that can be fielded quickly, and that are likely to transition to the permanent defense inventory. The methodology combines multi-attribute measures of value with the likelihood of success and the value of time. The goal of the research is to provide decision makers with a common basis for assessing both the value of the individual solutions and the overall value of the counter-IED portfolio.

I. Introduction

During the conflicts in Iraq and Afghanistan the most lethal tool of the insurgent has been the Improvised Explosive Device (IED). Created by act of Congress in January 2006, the Joint Improvised Explosive Device Defeat Organization (JIEDDO) has the mission of leading, advocating, and coordinating U. S. defense actions aimed at defeating the IED as a weapon of strategic influence. JIEDDO places particular emphasis on seeking to rapidly deliver solutions to rapidly meet counter-IED needs of U.S. forces in the areas of conflict.

Counter-IED solutions cover a broad range of both military functions and forms. Functions include intelligence, surveillance, electronic warfare, maneuver, targeting, fire support, force protection, and information operations. Forms include software, airborne sensors, ground sensors, vehicle systems, armor recipes, jammers, spoofers, scanners, robots, and a gamut of contracted services.

To help manage these efforts, JIEDDO partitions the counter-IED solution space into three *Lines of Operation*: Attack the Network (AtN), Defeat the Device (DtD), and Train the Force (TtF).

AtN is focused on preventing IEDs from reaching the intended place and time of employment on the battlefield. AtN targets insurgent activities to include financial, recruiting, training, logistical, manufacturing, planning, command and control (C2), and operational functions.

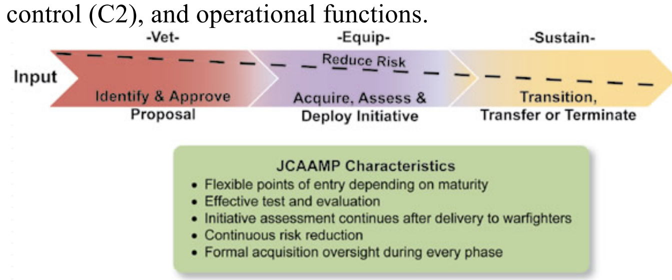

Fig. 1. The Joint IED Defeat Capability Approval and Acquisition Process

DtD focuses on solutions that defeat the IED once it has reached its intended place of employment. DtD attempts to detect, neutralize, or mitigate all aspects of the IED itself, to include the trigger systems, arming systems, firing systems, means of concealment, its means of delivery, and its means of lethality. TtF addresses the means to gain and maintain force readiness for the counter-IED fight, primarily the gaps in the Services' ability to prepare their forces for the latest IED threats and counters.

JIEDDO ties this all together via the Joint IED Defeat Capabilities Approval and Acquisition Process (JCAAMP) [3]. A still evolving process, JCAAMP is designed to rapidly usher promising solutions through a series of phases culminating in transition of the successful solutions to one or more of the Armed Services. JCAAMP's goal is to compress standard defense procedures in order to deliver solutions to the warfighter field in months instead of years. To maximize its responsiveness to the warfighter's needs, JIEDDO considers initiatives sequentially as they arrive. Because the Services are the ultimate customers in this process, the Services, the Joint Chiefs of Staff, and the Office of the Secretary of Defense are active participants in all JCAAMP decision points.

As shown in Fig.1, JIEDDO continuously seeks proposed solutions and rapidly vets these as they are found. An approved solution that has sufficient maturity and suitability becomes an "initiative". Accelerated development is conducted to ensure, among other things, that the initiative has a suitable concept of employment, will be adequately sustained, and has been safety tested. Ultimately, a suitable quantity of the initiative is acquired and deployed to theater for use by the appropriate units in order to assess the initiative's combat effectiveness.

If an initiative has been successful demonstrated in combat as a counter-IED solution, JIEDDO has two years during the sustainment phase to arrange for the solution's turnover to one of the Services. This time period coincides with the length of the defense budgeting cycle, allowing the Services the time required to budget for assuming ownership of a new solution. Every effort is made to identify the likely transition Service as early as possible.

Since 2006, JIEDDO has received $12.4B in appropriations. Congress has been concerned about the efficacy of JIEDDO in employing these funds and has directed several assessments of JIEDDO by the GAO, to examine, among other things, JIEDDO's management practices, performance measures, and metrics [12]. GAO's studies have provided a variety of recommendations, in particular with developing metrics for the selection of initiatives and tracking the performance of initiatives [13].

Our George Mason team has been researching how improve the quality, transparency, and defensibility of JIEDDO's counter-IED initiative assessment and selection process. This paper focuses on a specific aspect of George Mason's work for JIEDDO: how to rapidly measure the value of initiatives in order to inform decisions seeking the best collection of counter-IED solutions. Another aspect of George Mason's work for JIEDDO is the rapid probabilistic modeling of initiative effectiveness. We will not delve into this aspect of our work but it is related to the effort described herein, as the output of the probabilistic modeling of initiative effectiveness is one of the possible inputs to the measure of an initiative's value.

II. Literature

Profit is traditionally used to measure value in business applications. However, a military organization is not a profit-making enterprise. Military investment demands can range from new weapon systems, the means to move them, the means to target for them, the means to maintain these systems, to the manpower to operate them, to include the facilities to house the manpower's families. None of these lead to a profit. Measuring military value requires a way to quantify the degree of accomplishment of military goals and objectives.

Military requirements such as firepower, mobility, or targeting capability can be treated as constraints to satisfy while minimizing costs, an approach taken by Dell and Tarantino in [2]. However, when the problem is maximize military capability subject to constraint, a method is needed to measure this capability that encompasses the many ways this may be manifested: intelligence, logistics, fire support, maneuver, to name a few.

A common approach for assessing the strategic value of investment decisions is multiobjective decision analysis (MODA) [6]. MODA is a valuable technique for complex problems with multiple stakeholders, complex value trade-offs, significant outcomes, and major uncertainties. Most MODA applications will consist of a hierarchy of goals and objectives, evaluative measures aligned with the goals and objectives, value functions to translate evaluative measure levels to a common scale, and weights.

In [11] Parnell describes specific approaches in the practice and application of MODA in military decision-making. The use of MODA for military budget optimization is described by Brown, Dell, Loerch, and Newman [1].

Specific MODA applications in a military budgetary context include [7], [8], and [10]. In [7] Loerch, Koury, and Maxwell describe how they employed value added analysis to optimize U.S. Army long-range budgets. This methodology blends large-scale campaign simulations in various theaters, experimental design to isolate system contributions, multiobjective decision analysis to judge trade-offs between theaters and time frames, and mixed-integer optimization to identify optimal budgetary solutions.

In [8] Parnell et al employed future value analysis to support National Reconnaissance Office resource allocation. This approach employed structured interviews to identify futures challenges and opportunities, a multiobjective decision analysis using value-focused thinking, and integer programming for optimal resource allocation.

In [10] Parnell et al employed a similar approach but the value model and risk measuring approaches are enhanced. The portfolio value model, vice a weighted linear combination of scores, employs a weighted sum of the maximum scores achieved on each value function, since the portfolio value was measured by the maximum level of capability achieved by any one alternative within each capability area. The risk approaches required the assignment of subjective probabilities for different outcomes to be associated with every project. This allowed for the conduct of a Monte Carlo-based risk analysis of any chosen portfolio.

Parnell [11] describes various practice approaches to the application of MODA. For JIEDDO's case, we have been following a combination of Parnell's gold and silver standards. In the gold standard approach, the MODA model builds on an approved vision, strategy, policy, or other high-level guidance. The silver approach is based upon data obtained from the decision-makers representatives. In both approaches, the resulting model must be presented to decision makers for refinement and validation. Our combined approach employed a thorough review of JIEDDO's strategy, interviews with intermediate level personnel, and careful observation of JCAAMP over a period of a year.

III. Strategic Goals and Considerations

A wartime defense program must have as its principle aim the most effective collection of solutions relative to the war effort. JIEDDO's mission is to enable the defeat the IED as a weapon of strategic influence. JIEDDO is not a military service and thus does not actually fight. Rather, it seeks to enable the Services and theater commanders by gaining for them the means to reduce the effects of the IED.

A key criterion for selecting a solution is its potential to contribute to the counter-IED campaign. Thus, our model first seeks to measure the initiative's ability to contribute to these efforts. From our research we have identified two additional goals.

JIEDDO wants initiatives that can be developed and deployed to the theater of war as quickly as possible. A perfect approach that is not ready until after the war is concluded is of little use.

JIEDDO also wants initiatives that are likely to transition to another service. Many factors influence this. Clearly a proven solution is more likely to transition than one not proven effective. The likelihood to transition will be lower for items with higher Total Ownership Cost (cradle to grave cost). Also to be considered is the facility with which the enemy may counter a JIEDDO solution. Something easily countered may have immediate impact but no long-term value. However, a strong short-term impact may still be worth the investment.

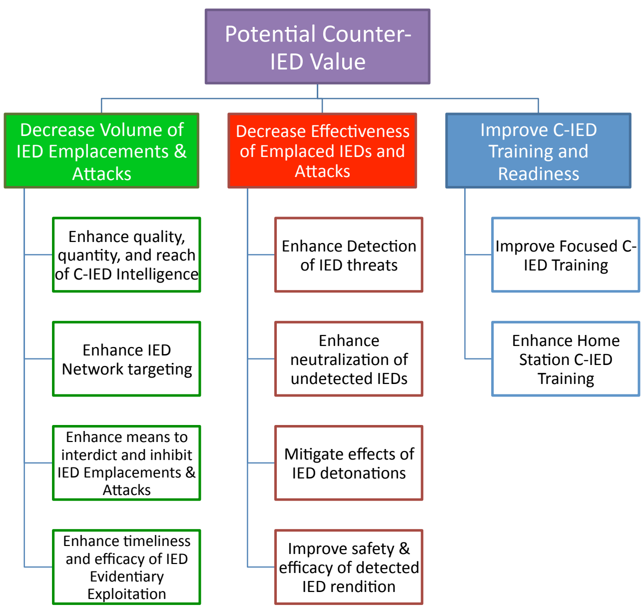

Fig. 2. Value hierarchy for measuring potential counter-IED value of JIEDDO initiatives

IV. Quantifying Counter-IED Value

To assist in its search for solutions, JIEDDO partitions its efforts to identify, develop, demonstrate, and sustain counter-IED solutions into the three previously-described lines of operation: AtN, DtD, and TtF. Through our interviews of personnel, review of documentation, and a year's worth of observation, we have developed a prototype multi-objective decision model of an initiative's Potential Counter-IED Value (PCV) in alignment with the lines of operation. Fig. 2 depicts the value hierarchy supporting the PCV Model.

Each branch of the value tree measures the value of initiatives from their contribution to a specific line of operation: AtN, DtD, and TtF. We have chosen words to describe the desired effects from this function, versus the function itself.

For each leaf of the value tree, we postulate a corresponding evaluative measure. As described by Parnell [11] each evaluative measure will require a least preferable level and a most preferable, or ideal, level. Determining the level of the current Force against the least and ideal levels for each measure provides the portfolio context for determining the value of an initiative.

These measures provide a basis with which to explore the utility of this approach in our future work with JIEDDO. We fully anticipate these measures to evolve as the prototype matures.

A. Attack the Network Value

We model the AtN aspect of the campaign as having four domains: counter-IED intelligence domains, IED network targeting domain, interdiction/inhibition of attackers domain, and IED evidence exploitation domain. As depicted in Fig. 3, these domains come from a conceptual model we developed to depict how AtN functions relative to the enemy. Generally AtN initiatives will contribute to only one of these domains.

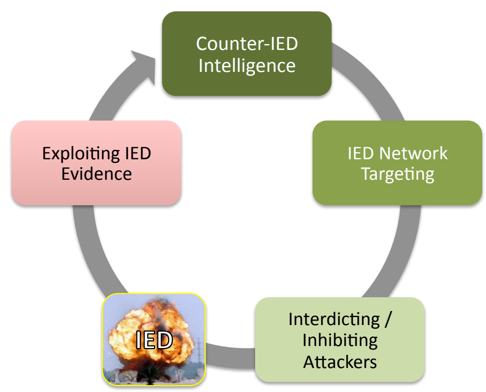

Fig. 3. Attack the Network Cyclical Model

The first aspect of attacking the network is to maximize the intelligence available to those that need it. We postulate that a potential high-level measure of JIEDDO's contribution in this domain is the quality, quantity, and reach of counter-IED intelligence. Our proxy measure for intelligence quality is the average age of products – the inverse of the intelligence refresh rate. Quantity is total size of the available data. Reach is the amount of readership or consumers to whom the counter-IED intelligence is accessible. An initiative can show value in this domain by improving capability in or more of these measures.

The next domain is to improve warfighter's means to target IED cells and functions. Our approach here is to consider a vector of different IED network activities and functions and assess the warfighter's ability to target each of these. Initiatives are measured as the ability to percent improvement in the measures of this vector.

An important part of any defensive battle is hand-off between the screening forces, which are employing an offensive defense to delay and channelize enemy forces, and the stationary defensive forces. The interdiction/inhibition domain covers this conceptual battle hand-off between AtN and DtD. It specifically aims to interdict or inhibit the IED in its final leg towards its intended destination. Our approach for measuring this domain is to consider the vector of attack rates by IED type, in particular the most lethal types. Initiatives in this domain demonstrate value by their expected ability to interdict or inhibit emplacements and suicide attacks.

The last domain is the technical ability of the Force to exploit the information gathered from each encounter with the enemy, which includes forensic methods. There are many means of exploitation, with corresponding rates and throughput capacity. Our approach is to view this as a process and to measure an initiative's value by its expected improvement to this process's rate. This domain provides a natural feedback loop to the first step of enhance C-IED Intelligence.

B. Defeat the Device Value

DtD sub-goals stem from a conceptual event tree that depicts a defense-in-depth. IEDs must first be detected. Detected IEDs must be cleared, typically by Explosive Ordnance Disposal (EOD) teams. Undetected IEDs might be neutralized by some technology. Undetected and un-neutralized IEDs are free to detonate against the Force so these must be mitigated. Fig. 4 depicts this *event tree* - not to be confused with a value tree.

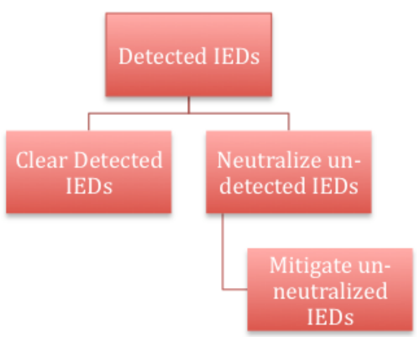

Fig. 4. DtD Event Tree

The first line of defense is to successfully detect the IED before the friendly entity (commonly, a vehicle) enters the IED's effective range. We measure this by again employing a vector, this time of the found-and-cleared rate of friendly forces against each type of IED, particularly the most lethal ones. For the detection domain, JIEDDO seeks the solutions that can best impact this vector.

If not detected, the next line of defense lies in technologies that can neutralize the device: prevent it temporarily or permanently from operating as intended. The difficulty of measuring these impacts operationally – friendly forces have little way of confirming the neutralization of an undetected IED – we would measure this by the demonstrated effectiveness against realistic test threats.

If neither detected nor neutralized, the IED is free to detonate. The last line of defense is a system's ability to mitigate the IED's lethal effects. Against the same list of lethal IEDs as before, we would measure an initiative's ability to reduce the expected number of casualties per IED attack by IED type.

The last goal relates to the sticky issue of how to safely, rapidly, and effectively dispose of the detected IEDs, particularly since they are valuable source of intelligence. We envision a similar vector approach with the average time to reduce each IED type. The initiative should demonstrate an improvement in this vector.

C. Train the Force Value

TtF is subdivided into two basic training needs: the need to train specialized personnel and units at specialized events (National Training Center, schools, etc.), and the training of units at their home stations prior to deployment into theater. For both of these we assume that an overall requirement for all of these activities has been identified. In a similar model to intelligence, we measure quality, quantity, and volume. Quality is measured by both currency of the material and instructor/student ration. Quantity is the number of hours in the training. Volume is the number of personnel processed per year. Initiatives should show measurable improvement one or more of these attributes.

D. Measuring Potential Counter-IED Value

As described above, we align with each of these goals an evaluative measure (or potentially, more layers of goals and measures). The table shows the postulated measures we described above.

Relative to tactical-level actions and effects, each goal is at a very high level and subsumes a large number of operational functions and activities. For each goal, we have described a model for measuring goal attainment. In keeping with our desire to measure net value improvement of the overall capability set, it is critical to measure the current capability level of the Force on each measure. Then, the impact of any initiative would be its improvement over the current capability. Our parallel research effort is investigating the rapid probabilistic modeling of initiatives. This approach has the potential to yield the tactical-level information needed to populate the evaluative measures.

As described by Parnell [11], each measure m needs a least and most preferable level. Between these endpoints, the level on this measure attained by the i^{th} initiative, x_{mi}, requires a mapping, or value function $v_m(x_{mi})$, from the measure space to a level of the value space; e.g., a point on interval [0, 1]. These levels should be elicited from decision makers. It should be kept in mind that since these measures are trying to estimate the net improvement in the capability set by each measure, most initiatives are likely to generate small % improvements.

TABLE I

EVALUATIVE MEASURES

Goal	Model	Measure
Enhance Quantity, Quality, & Reach (QQR) of C-IED Intelligence	QQR := Intel Volume (Tbyte) * Readership / Avg Product Age (days)	% Improvement in QQR
Enhance IED Cell Targeting	Target Service Rates Vector (TSRV) := $\{V_f$: *f* is the set of IED cell functions$\}$	Sum of Estimated % Improvements in TSRV
Enhance Means to Interdict & Inhibit	High Threat Attack Rates Vector (HTARV) := $\{Ar_i$: *i* is the set of high threat IEDs$\}$	Sum of Estimated % Decrease in HTARV
Enhance IED Evidentiary Exploitation	Exploitation Volume Rate (EVR) := Incident Intel Volume (TB) / Weighted Processing Time (days)	% Improvement in EVR
Enhance Means of IED Detection	Found & Cleared Rate Vector (FCRV) := $\{FCr_i$: *i* is the set of high threat IEDs$\}$	Sum of Estimated % Improvements in FCRV
Enhance Means of IED Neutralization	Probability of Neutralization Vector (PNV) := $\{PN_i$: *i* is the set of high threat IEDs$\}$	Sum of Estimated % Improvements in PNV
Enhance Mitigation of IED Effects	IED Casualties Rate Vector (ICRV) := $\{Cr_i$: *i* is the set of high threat IEDs$\}$	Sum of Estimated % Improvements in ICRV
Improve Means of IED Reduction	IED Reduction Rate Vector (IRRV) := $\{Rr_i$: *i* is the set of high threat IEDs$\}$	Sum of Estimated % Improvements in IRRV
Improve Focused C-IED Training	Quantity Quality Volume := Hours * Throughput / Class Size / Content Age	Estimated % Improvement
Improve Home Station Training	Quantity Quality Volume := Hours * Throughput / Class Size / Content Age	Estimated % Improvement

We should not expect that the maximum possible contribution of each measure to the total accrual of C-IED value to all be equal. If they were, we need only take the average of the values. Accordingly, we wish to assign to each $v_m()$ a weight w_m. Parnell describes these as swing weights, which reflect not just importance but the change in overall value within an evaluative measure when swung from its least preferred level to its most preferred level. He describes some approaches for eliciting these from decision makers.

We obtain the resulting mathematical model for measuring the C-IED value of an initiative *I*, which is merely the weighted average of all of normalized measure levels.

$$PCV(i) = \sum_m w_m v_m(x_{m,i}) \qquad (1)$$

$$\sum_m w_m = 1$$

One issue to address is that values may not be strictly additive. For portfolios of financial instruments, Markowitz [8] showed how optimal portfolios could be modeled by looking at both the expected return of the portfolio and its covariance, thereby addressing interdependencies among assets in the portfolio.

We do not have this luxury in dealing with military items but one analogue is that the value of an item is highly dependent upon what else may have been acquired. Loerch et al [7] showed how the contribution of individual systems was frequently not additive. They addressed this by looking at the benefits of combinations of candidate systems. Given the large number of systems, they limited themselves to 2-way combinations.

To avoid this complication, we assume that the design of the evaluation of initiatives is able to obtain their net contribution to the overall value of the counter-IED collection of systems. This requirement forces the evaluation to account for any interactions between the initiative and the current capability set. One fashion might be to score the initiative on each evaluative measure as the maximum of the initiative's score or the current capability. An equivalent fashion is to score the initiative as the % improvement in each evaluative measure over the current capability.

By focusing measures on the marginal contributions of initiative we are able to retain additive values. For each initiative, we are attempting to measure the value of the entire portfolio should the initiative be included. Thus, every initiative must be considered not in terms of its raw performance, but how it might enhance the capability of the current capability set.

The interactions that we might miss by this process are those among initiatives being considered simultaneously. Recall that JIEDDO's solutions are considered sequentially as they arrive. One approach might be to ignore these interactions, since only a few initiatives are ever considered at the same time, and it's unlikely any two might interact.

A more rigorous approach is to require that potentially interacting initiatives being evaluated both separately and as combinations. This complicates the issue, adding potentially many more "initiatives" to evaluate. However, the overall numbers we have seen to date are overall still small and the interactions have proven rare in observation.

E. Likelihood of Transition

Whatever their potential value, not all solutions will prove successful. Many will fail during development. Some prove ineffective when tested in realistic environments, which may include limited evaluations on the battlefield. Others prove effective but will be simply too expensive to buy or operate.

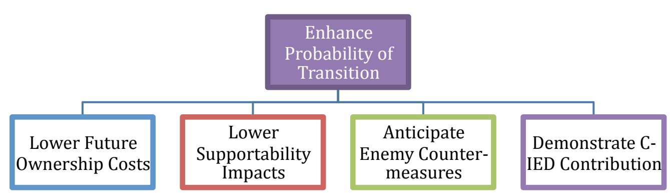

Fig. 5. Factors for Assessing Likelihood of Transition

Proving successful in providing some level of contribution to the counter-IED fight is still not enough to guarantee a program's transition. An initiative being too expensive, with excessively onerous logistical requirements, too easy to defeat in the long term, has had difficulty demonstrating its potential are all reasons to reduce its likelihood of transiting to a Service. Clearly the likelihood of transition is a subjective probability. In future research, we would seek to investigate the history of past initiatives and what factors may have influenced their transition outcome.

Fig. 5 shows the initial set of factors we have identified as possibly being useful in the assessment of this subjective probability.

F. The Value of Time

Meeting the demands of the warfighter requires that solutions being fielded as fast as possible. However, developing new solutions takes time. Discounting is a means of estimating the value today of something valuable but not available until some time into the future. In finance, usually a benchmark is used, such as a current or projecting lending rate, which may or may not be adjusted for inflation. This is the basis for such methods as Net Present Value.

A military solution available now is clearly preferable to one not available for some time in the future. Thus, it makes sense that, when forced to compare the value of two such investment choices, that the value of the one not immediately available be discounted. The extent to discount is a measure of the willingness of the warfighter to wait for a solution. Some factors that might influence the warfighter's willingness to wait include whether a solution is fulfilling a specified Joint Urgent Operational Need (JUON), or if it is anticipating a future need via a tool such as a technology roadmap plan.

G. Discounted, Expected Potential Counter-IED Value (DE-PCV)

Upon arriving an initiative is assessed for its potential to provide an enduring contribution to the counter IED fight. This potential needs realization. To become an enduring contribution, an initiative must transition to a Service. An example of this is the now ubiquitous Counter-IED Radio-controlled Electronic Warfare (CREW) jamming technology, the development of which was funded by JIEDDO (HASC Report 2007).

If the realization of its potential is uncertain, as we should expect, then we will employ the expected potential counter-IED value. At this stage in the model's development, we are considering only two possible outcomes: transition and termination. Treated this as a simple Bernoulli variable, we take the expectation of the potential counter-IED value using the probability of transition P_T.

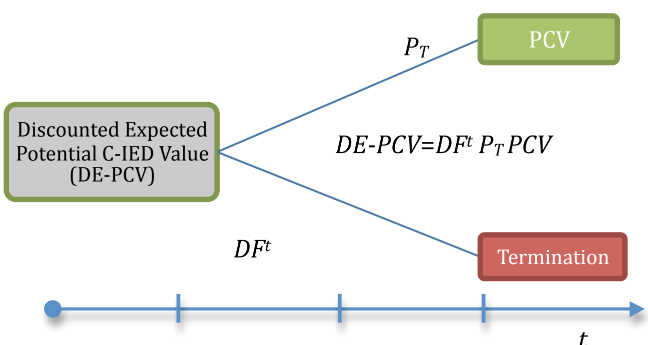

Fig. 6. Discounted Expected Potential Counter-IED Value

Using only the expected potential counter-IED value assumes that the time until the potential value is achieved is insignificant. The realities of conflict dictate a strong preference by the warfighter for solutions that work sooner rather than later. To account for the cost of waiting we employ a discount factor DF, increasing as an exponent of t, where t is the delay until the solution can be deployed to the theater of conflict.

We envision the value of DF as being dependent on the class of initiatives for which theater might be more willing to wait. Initiatives specifically requested by the Combatant Commander might have the highest discount factor. Initiatives lacking a formal requirement will have a lower DF.

We put together these concepts, to include accounting for net contribution of an initiative using the percent improvement offered by the initiative over the current capability. Let y_m be the current measure of capability in evaluative measure m. Then we calculate *DE-PCV* as follows.

$$DE-PCV(i) = \sum_m w_m v_m((1 + P_T DF^t x_{m,i}) y_m)) - \sum_m w_m v_m(y_m) \qquad (2)$$

For each evaluative measure, *DE-PCV* multiplies the current capability times the sum of 100% and the discounted expected evaluative measure improvements and puts this result into the value function. The weighted sum-product is the discounted expected value of the portfolio with initiative i inserted. Subtracting the current value arrives at the net contribution of the initiative i.

V. Illustrative Example

We demonstrate how this process might be employed as part of JCAAMP. JIEDDO has adopted the *DE-PCV* approach as the means to measure the value of initiatives. On a periodic basis, JIEDDO evaluates the collective counter-IED capability levels across the lines of operation, and reassesses the vector of swing weights w_m. The assessment of the current level of capability versus the desired ideal level is depicted in the chart below.

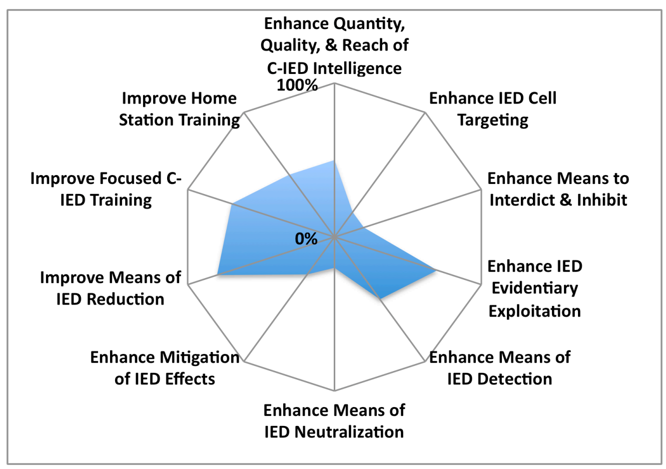

Fig. 7. Illustrative Example: Assessed Capability Levels vs. Desired

Based on this, JIEDDO's leadership assessed the swing weights to assign to each of the enterprise level attributes. These weight reflect not just the importance of each attribute but the amount of swing available between the current level and the desired ideal.

TABLE II
RECENT SWING WEIGHTS – ILLUSTRATIVE EXAMPLE

Evaluative Measure	Current Level (% of Max Preferred)	Rank	Raw Swing Wt	Normalized Swing Wt
C-IED Intelligence	50%	5	40	0.115
IED Cell Targeting	20%	1	60	0.172
Interdict & Inhibit	20%	2	50	0.143
Evidentiary Exploitation	70%	7	30	0.086
IED Detection	40%	3	45	0.129
IED Neutralization	20%	4	41	0.117
IED Effect Mitigation	30%	6	35	0.100
IED Reduction	80%	10	10	0.029
Focused Training	70%	9	15	0.043
Home Station Training	50%	8	23	0.066

The following week, three initiatives arrive: Ground Sensor A, Intelligence Analyst Software B, and Training System C. JIEDDO's Planning Board for Development (PB4D) has convened to examine these.

Ground Sensor A detects a lethal class of IEDs 60% of the time. This is a three-fold improvement in U.S. forces current ability to detect these (20% detection rate). This class of IEDs causes 40% of all IED casualties. Thus, in terms of coalition forces' total ability to detect all types of IEDs, as weighted by the casualties these IED's types cause, Ground Sensor A represents a 20% improvement. The PB4D is informed that this system has been successfully employed in similar conflicts by an ally and requires minimal levels of sustainment support. The Service reps find that its overall costs are affordable. Thus, its probability of transition is set at the highest level – 0.9. Ground Sensor A is addressed by a JUON and is thus assigned the highest DF of 0.99. It can reach theater in the next quarter – the unit of time used for planning and for modifying the discount factor.

The PB4D is informed that the Intelligence Analyst Software B significantly increases the productivity of a large swath of intelligence analysts. It is estimated that it will enhance overall C-IED intelligence by 33.3%. However, it has high sustainment costs, particular in the forecasted number of developers and help desks staff requirements. It has yet not fully matured. Its probability of transition is set at 0.7, indicating some concern for this program. Additionally, it will not be able operational for another 9 months and has no JUON or other supporting requirement. By the business rules the board has established in our fictional example, a lower DF of 0.9 is used.

Training System C provides a 10% improvement in home station training throughput and cuts in half the lag time in inserting the latest battlefield lessons-learned into the training: a 50% improvement in home station training overall. It has been demonstrated at one National Guard site, but the Army and Marine Corps will need JIEDDO to help fund a full roll out of the system, which will take about 12 months. There is much concern about recent environmental issues with its employment that may or may not be resolvable. Despite its modest sustainment requirements, this last issue caused the board to assign this initiative a 0.5 probability of transition. It is addressed in the TtF technology road map so its DF is an intermediate value of 0.95.

The results from the board's evaluation are shown in the table below. Ground Sensor A scored highest, but in large part because its maturity, high likelihood of transition and readiness to be deployed. In fact, the act of computing the discounted expectation reversed the rank ordering of the initiatives. This highlights that resolving some of the issues – getting the theater commander to provide a JUON for System B, resolving the environmental issues with System C – could have dramatic effects on their scores.

The following tables show the progression from evaluative measure results to *DE-PCV*.

TABLE III
EVALUATIVE MEASURE SCORES: DISCOUNTING AND EXPECTATION

$x_{i,m}$

Evaluative Measure	Sys A	Sys B	Sys C
C-IED Intelligence	0%	**33%**	0%
IED Cell Targeting	0%	0%	0%
Interdict & Inhibit	0%	0%	0%
Evidentiary Exploitation	0%	0%	0%
IED Detection	**25%**	0%	0%
IED Neutralization	0%	0%	0%
IED Effect Mitigation	0%	0%	0%
IED Reduction	0%	0%	0%
Focused Training	0%	0%	0%
Home Station Training	0%	0%	50%
t - Time to Deploy (qtrs)	**1**	**3**	**4**
DF	**0.99**	**0.90**	**0.95**
DF^t	**0.99**	**0.73**	**0.81**
P_T	**0.90**	**0.70**	**0.50**

$P_T DF^t x_{i,m}$

Evaluative Measure	Sys A	Sys B	Sys C
C-IED Intelligence	0%	**17%**	0%
IED Cell Targeting	0%	0%	0%
Interdict & Inhibit	0%	0%	0%
Evidentiary Exploitation	0%	0%	0%
IED Detection	**22%**	0%	0%
IED Neutralization	0%	0%	0%
IED Effect Mitigation	0%	0%	0%
IED Reduction	0%	0%	0%
Focused Training	0%	0%	0%
Home Station Training	0%	0%	**20%**

TABLE IV
ARRIVING AT *DE-PCV*

Evaluative Measure	Current Capability Level	With System A	With System B	With System C
C-IED Intelligence	50%	50%	**58%**	50%
IED Cell Targeting	20%	20%	20%	20%
Interdict & Inhibit	20%	20%	20%	20%
Evidentiary Exploitation	70%	70%	70%	70%
IED Detection	40%	**49%**	40%	40%
IED Neutralization	20%	20%	20%	20%
IED Effect Mitigation	30%	30%	30%	30%
IED Reduction	80%	80%	80%	80%
Focused Training	70%	70%	70%	70%
Home Station Training	50%	50%	50%	**60%**
Overall Value	**37.2%**	**38.3%**	**38.1%**	**37.8%**
DE-PCV(i)	**na**	**3.1%**	**2.6%**	**1.8%**

The result of accounting the value of time and for the likelihood of transition resulted in a rank reversal. System A's impact was the lowest ranked in terms of its evaluative measure contribution but the highest ranked after applying discounting, expectation resulting from the probability of transition, and the inner-product of these measures with the swing weights. The chart provides an unweighted view of the impact of the discounted expected measures.

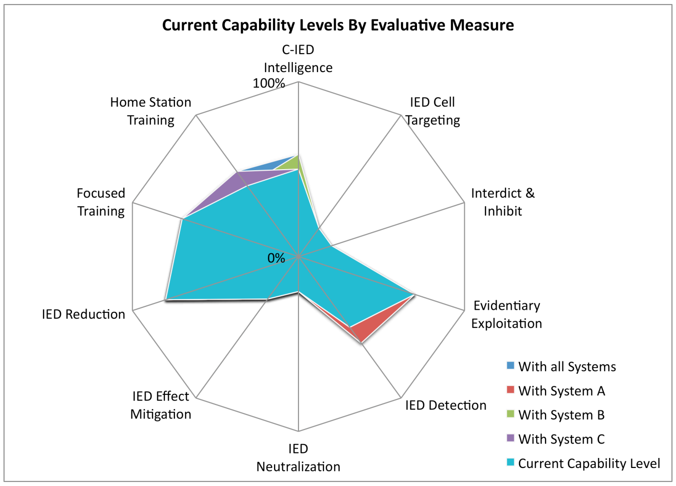

Fig. 8. Changes in Evaluative Measures from the Initiatives under Consideration

As systems progress through JCAAMP, the intent would be to update these measures as information becomes more current; i.e., JUONS are signed, transition likelihood factors are resolved, additional performance data is obtained.

DE-PCV also provides the critical objective function data necessary for any constrained optimization approach.

VII. Future Steps

For successful implementation of the *DE-PCV* model, we will have work with JCAAMP decision makers, stakeholders, and their supporting staffs to validate our approach, the value hierarchy, and the evaluative measures. We fully anticipate that the model will have to evolve to address decision makers concerns, especially since the model is intended for weekly application in order to assist in the evaluation of initiatives as they enter the system and as they proceed through succeeding transition points in JCAAMP.

In parallel we are exploring how to anticipate the impact of future initiatives in order to support the optimal selection of initiatives as these arrive.

It is our sincere hope that this interaction will lead not merely to implementation, but that by doing so the decision makers will gain better insight into the critical choices they must make.

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