

Achieving a Decision Paradigm for Distributed Warfare Resource Management

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Abstract – The ability to optimally manage distributed warfare assets for collaborative operation significantly increases our military advantage. The primary results include enhanced situational awareness and improvements in fire control, engagement support, operational planning, combat reaction times, threat prioritization, and the list continues. Bettering the use of sensors and weapons in concert with one another—effectively creating a system of distributed systems—provides major payoffs.

The effectiveness of managing distributed resources depends on the ability to make complex decisions. The complexity is due in part to the circuitous nature of fusing data from multiple sensor sources to provide a representation of the operational environment from which to redirect sensors for further information optimization and from which to base military operations. The “goodness” of such complex decisions depends on the “goodness” of the information available and the understanding of the situation from a “big picture” perspective.

This paper explores distributed resource management from a decision-based perspective. With an objective of enabling a collaborative system of systems (SoS), a systems approach is proposed to implement a decision paradigm that extends from system conception to operations.

Keywords—*Distributed warfare resources, collaborative systems-of-systems, decision paradigm, resource management, operational effectiveness, measures of effectiveness, decision confidence*

I. INTRODUCTION

Obtaining sufficient situational awareness in military theaters of operation is an enduring goal. The growing presence of sensors coupled with ever-improving sensor capabilities, presents an increased opportunity for enhanced awareness. The key lies in optimizing the management of the distributed sensors and making the best use of the collected data. Improvements in communications, networks, interoperability, and open architectures provide a foundation and framework for achieving enhanced awareness by enabling a system of systems (SoS) approach for managing distributed sensors. The intent is to view (and manage) distributed sensors with a collaborative focus—and enable them to function collectively as a system.

The act of managing sensors in military operations is a form of command and control (C2). Sensors are controlled primarily to improve situational awareness and support military

operations. Assuming a complex operational environment, it may be the case that particular sensors have competing task priorities or multiple missions occurring at the same time; or it may be the case that a choice of multiple sensors could be selected from to address a single mission. Or it may be the case that the set of overlapping sensor missions is large and complex and changing and is therefore best served by a C2 system capability that can support the optimal management of the distributed sensor SoS. Figure 1 illustrates this decision complexity.

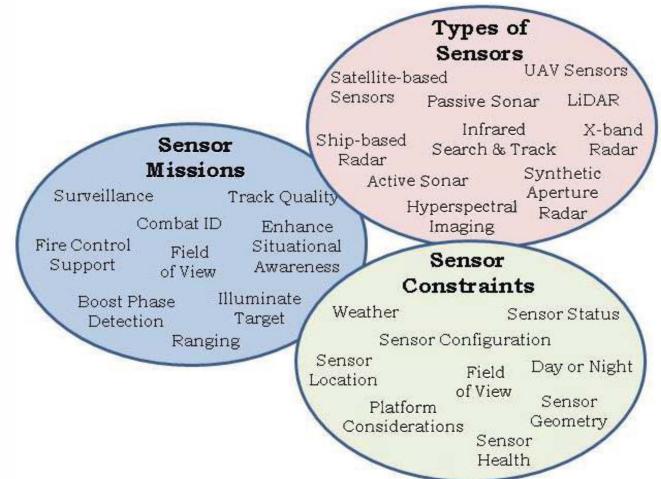


Figure 1. Complex Decision Basis for Managing Distributed Sensors

To take this C2 complexity a step further, the decision process to optimally manage distributed sensors must also include other relevant warfare assets that are interdependent and can afford enhancements to military operations through their cooperation and collaboration. Thus, the sensors must be managed in conjunction with weapons, platforms (ships, aircraft, satellites, land-based vehicles, submarines, etc.), communications, and C2 systems, themselves. If optimal operation involves deciding whether a sensor is best directed to search an area vice support an engagement, it follows that both sensor and weapon resources must be considered together in C2 tasking.

This paper explores the decision complexity involved in managing distributed sensor and warfare resources as collaborative systems of systems. It examines future decision strategies and capabilities that support the attainment of a

distributed C2 SoS for managing distributed sensor and warfare resources. First the fundamental concepts for decision-based command and control of warfare resources are discussed. Second, a concept is explored for a decision “engine” (or method) that is based on managing warfare resources to optimize the achievement of overall measures of operational effectiveness. Next, concepts for the decision-confidence engine are discussed. Finally, the paper discusses the benefits of incorporating the decision paradigm into the design and development phase of systems that have potential to participate in future systems of systems (SoS).

II. DECISION-BASED PARADIGM

Effective command and control of warfare resources will depend on the achievement of: collaborative systems of systems (through agility, interoperability and a suitable SoS architecture); a foundation of data fusion capabilities; and ultimately a shift to a decision-based paradigm. Decision-making must take the center stage for future complex military endeavors—it must be the focus for designing and developing the constituent systems that will comprise SoS; and it must be the focus for envisioning how SoS will operate most effectively to address the complex mission space.

A widely accepted foundational framework that describes military command and control is the Joint Directors of Laboratories’ (JDL) model of data fusion. The JDL model (illustrated in Figure 2) has a data-centric focus, identifying levels of data fusion starting with the fusion of raw data, assessing signals and features (level 0), assessing entities (level 1), assessing the situation (level 2), assessing impacts (level 3), and assessing the process (level 4). The model also contains the human/computer interface and resource management. In a sense, the JDL data fusion model takes a bottom-up approach by starting with the available data and determining all that can be gleaned from it as it rises through the levels and is fused with other data to assess the real world situation. The primary focus of the JDL data fusion model is to achieve and maintain situational awareness through data processing, human interaction, and a feedback control loop which monitors and refines the processes and manages sensor resources to optimize data collection based on the situational knowledge being attained.

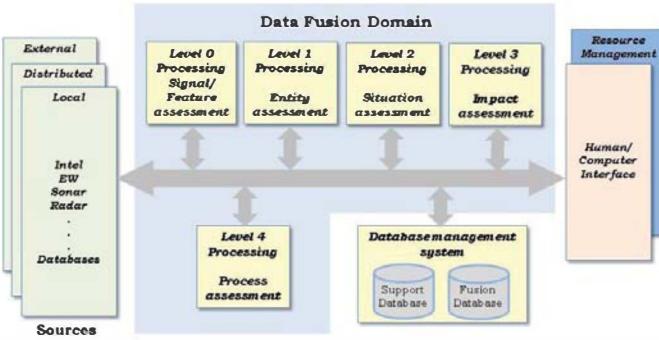


Figure 2. Data-Centric C2 Framework (JDL Data Fusion Model, 2004)

Similarly, there has been much focus on interoperability and open architectures with levels of interoperability defined and much work done on defining architectures that are “open”

for modularity and emphasis on interfaces between systems. Achieving this provides the necessary foundation for enabling collaborative SoS. However, the focus here has been on the architecture and mechanics of the interfaces and information flow among systems; rather than on the operational C2 decisions that must be made to manage warfare resources.

Approaching C2 from a decision-centric viewpoint offers a new perspective with Resource Management (RM) as its focus. This conceptual RM capability (or simply “RM”) could use the data fusion products (situational awareness) as input to determine the operational missions and what resource tasking decisions need to be made. The RM would assess all possible resource tasking options within the SoS and make C2 decision recommendations for directing warfare resources. Improving the knowledge of the operational environment is a necessity to military effectiveness, but to be truly effective, RM must take a more holistic (big picture) perspective and consider all mission areas (not just battlespace awareness) and all resources (weapons, platforms, and communications, in addition to sensors) when making the most effective decisions about how to command and control distributed forces and systems. Figure 3 illustrates the shift in emphasis from the data fusion domain to the decision domain, or RM, within the JDL data fusion framework.

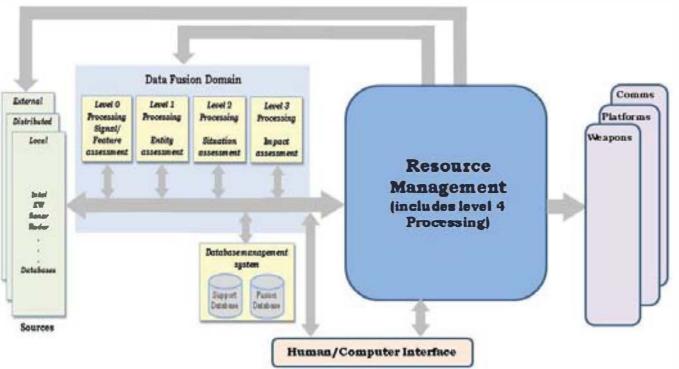


Figure 3. Decision-Centric C2 Framework

Another change to the framework is the merging of the level 4 data fusion (process assessment) into resource management. Process refinement is a form of resource management focused on controlling sensors and the data fusion process to further enhance situational awareness. However, enhancing SA is one of potentially many operations contributing to the achievement of overall mission objectives. Thus, process refinement should not be performed in isolation. If each of the various warfare resources is managed individually, it defeats the objective of force-level collaboration. Likewise, if the various operational missions are managed individually, it diminishes the ability of the force or system of systems to optimize its resources across all the mission areas. The data fusion processes must be viewed as warfare resources alongside the sensors, weapons, communications, and platforms.

Recent efforts have been made to study RM and level 4 of the data fusion model in greater detail. It's been noted that “...resource management...is lagging data fusion development by more than 10 years [10].” In order to fully realize the

collaborative potential of future warfare SoS, a top-down systems approach must be adopted and based on a decision-centric paradigm, that takes advantage of the data fusion products. A systems approach starts with the operational missions and determines what decisions need to be made; and then uses the products of the first three levels of data fusion as inputs to provide decision alternatives.

III. A CONCEPT FOR RESOURCE MANAGEMENT

Conceptual top-level functionality for a systems approach to RM is illustrated in Figure 4. The RM should provide a decision space that includes all the information and decision methods available. Decisions need to be made from top-down. Rather than just focusing on what data and fused information products are available, decisions need to be based in systems thinking and consider the operational mission and flow down from there to best determine how to task assets. The other aspect of making effective decisions is to have an understanding of the “goodness” of the data and information upon which the decisions are based.

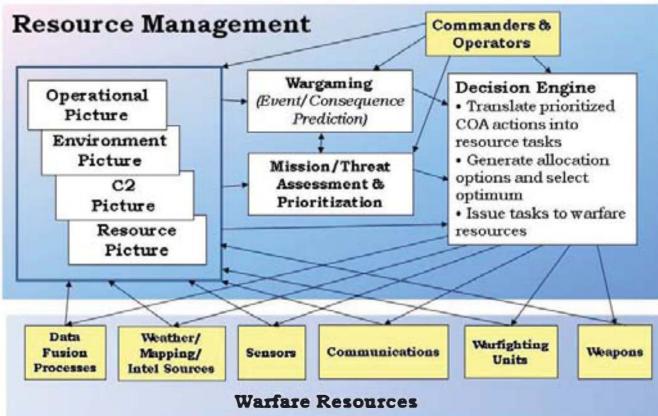


Figure 4. Resource Management Functionality

The RM could use information from the operational picture of the battlespace (situational awareness) to understand the mission space and from this, derive a set of resource tasks, tailored to optimally address the operational missions. Information that could support real-time SoS decision-making includes: knowledge of the threat/mission space; a “resource picture” that includes the health, status, configuration, and capabilities of the warfare resources; and an “environment picture” that includes pertinent and available information about the weather, time of day, temperature, humidity, sea state, etc. From this information, a list of resource tasks is derivable, that is prioritized to address the mission objectives.

The conceptual RM capability depends on the ability of each warfare resource (as shown in Figure 4) to communicate its health, status, location, configuration, capabilities, and constraints to the “resource picture” (information database). This information would be critical to assess how well individual resources or groups of resources might perform against mission objectives. This information would need to be continually updated as the warfare resource information changes during the operations.

Another potential capability that could enhance RM is a wargaming capability (as shown in Figure 4) to assess the current operational situation and make predictions about future operational situations. This capability could generate hypothetical situations based on possible SoS courses of action (COA) and the possible enemy responses. The likelihood and consequences of possible outcomes could be assessed. And the results of this wargaming analysis could be used by the decision engine to help shape both far-term planning and near-term resource tasking.

Mission/threat assessment is another capability that would be required to implement and effective RM. In order to effectively task warfare resources, threats must be identified, evaluated, and prioritized. Threats identified in the operational picture can be evaluated. This capability could use policy guidance (i.e., rules of engagement) from the C2 picture, already-established mission objectives, and outputs from the wargaming function to assess and prioritize missions and threats. This prioritized list could then be translated into SoS tasks by the decision engine.

Finally, a conceptual decision engine is identified that could translate the prioritized COA and threat list into a set of prioritized task lists that the distributed resources could perform to address the mission objectives. Once the list of tasks is generated, the decision engine could generate possible SoS design alternatives (based on groups of collaborative distributed resource systems). The decision engine could then assess each SoS design alternative to determine their relative effectiveness to meet mission objectives and address the prioritized task list. The decision engine output would consist of the tasks or operational actions for the warfare resources to perform.

The RM concept is a system of automated decision aids in the form of information processing and assessment methods to support human decision-makers (commanders and operators) in military situations involving distributed warfare resources and complex operational environments. Ultimately the commanders make the resource tasking decisions; but the cognitive role of human operators to make decision-aid assessments is important to the operation and role of the RM capability. Figure 4 illustrates the automated portion of RM with “commanders and operators” shown as part of the system. Human C2 decision-makers must be able to manipulate the information in the pictures, provide input to wargaming strategies, alter threat prioritizations, and ultimately negate or modify warfare tasking.

The discussion so far has been C2 architecture-neutral. The RM decision-aid concept could support a centralized, de-centralized or hybrid configuration for the C2 architecture. The major difference for RM between the various C2 architectures is whether there is a single RM instance or multiple RM instances. In a purely centralized architecture with one central C2 processing node, the single RM decision-aid system would reside at the central node along with the data fusion processes. Data from the distributed sensors and data sources would all flow to the central location; and tasks would be directed outwardly to the resources. In a de-centralized architecture, each distributed warfare platform may contain a C2 node; thus

each platform may contain a RM instance and data fusion processes. Data would be shared among participating platforms, and the multiple data fusion/RM instances would each develop situational awareness and assess possible SoS resource configuration decisions. An added synchronization capability would be required to ensure consistency among operational picture databases and decision recommendations (or resource tasking decisions). A hybrid architecture would reduce the number of C2 nodes (and thus data fusion/RM instances); by having some platforms with C2 nodes and others as “dummy” platforms. The de-centralized or hybrid C2 architectures would require more sophisticated capability, but would also empower each distributed warfare platform with C2 capability within the operational theater.

An important characteristic of the conceptual RM capability is the fluid nature of the mission space and thus, decision space. As the operational situation changes, the missions and threats will change—they may exist or disappear or change in priority. The RM capability must be constantly changing its decision assessments (and thus resource tasking recommendations) in response to the changing mission needs. Thus, the conceptual RM capability is one characterized as an on-going process rather than a single decision assessment.

IV. SE ASSESSMENT APPLICATIONS FOR RM

An analogy can be made between the systems engineering design phase and the real-time management of distributed warfare resources. Both processes are based on decision-making. During the systems engineering phase, analysis is performed to support design decisions. The systems engineering analysis involves the assessment of the performance, risk, and cost of the design alternatives. This analysis methodology can be applied to the decision process of managing distributed resources in a complex operational environment.

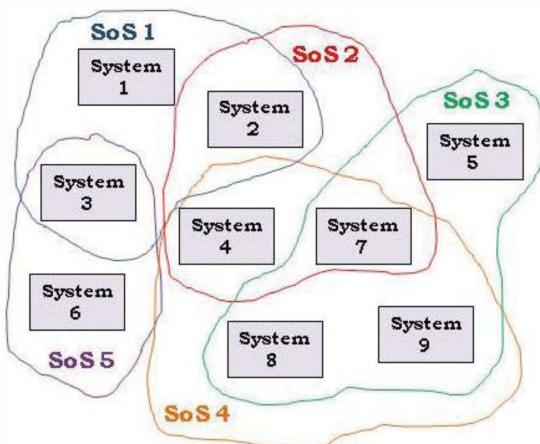


Figure 5. SoS Design Alternatives

The systems engineering design assessment methodology is a top-down systems approach that is based on operational effectiveness. The assessed performance of design alternatives is based on how effective each is projected to be in the operational environment to support mission objectives. As this methodology is applied to real-time C2 operations, the system

design alternatives are replaced by SoS configurations of distributed resources. Each possible configuration of warfare resources can be considered a different SoS design alternative. Figure 5 shows a simple example of how a set of distributed warfare resource systems can be grouped into different combinations of resources, each group constituting a different SoS configuration.

The best choice of SoS configuration should be based on the one that is assessed as most operationally effective, cost effective and risk averse (as shown in Figure 6). These are the three categories of assessments made to determine the optimum systems design in good systems engineering practices. For real-time operations involving systems of systems, these three types of assessments can be modified to support resource management decisions. Operational effectiveness can be applied in a very similar manner using modeling-based decision-aids to evaluate both the operational situation and expected performance of each SoS configuration based on the situation. A concept for applying such system performance assessment methods to decision-making for real-time operations is discussed in Section V.



Figure 6. Three Types of RM Assessments

Cost assessment as applied to operational decision-making is treated differently, as the systems (or warfare resources) being managed during operations are already designed and presumably operational. Cost considerations can be factored in for cases where there is a significant cost associated with the use of a resource. Perhaps for certain threats, a less expensive interceptor (or defense option) may be desirable, as an example. Other cost considerations may include significant fuel or energy costs associated with some kinds of warfare resources; or significant maintenance or repair costs. Another related consideration in determining the most optimum resource tasking configuration is safety. Perhaps some options may only be considered if the threat is critical and no other options are viable. Decision-aid methods for incorporating “cost” factors into the assessment of resource tasking options is discussed further in Section VI.

Risk is also applied differently to the conceptual RM capability than for system engineering design assessments. In the case of real-time operations, presumably the systems (or warfare resources) are operable and technically mature and have successfully moved beyond the risks associated with the design, development, and test phases of systems engineering. For the conceptual RM capability, the focus of risk analysis is

the risk or uncertainty involved with each decision option. A confidence level can be associated with each decision alternative based on the “goodness” of the data and information upon which each decision is based. A concept for determining the confidence level of decision options is discussed in Section VII.

V. OMOE DECISION ENGINE

The Overall Measure of Effectiveness (OMOE) is a parameter used in systems engineering to evaluate the expected performance of a system based on an evaluation of its design’s overall operational effectiveness. The OMOE depends on the system design’s ability to meet all of its measures of effectiveness (MOEs), which sum up to result in the OMOE value. The measures of a system’s effectiveness are based on the operational missions being addressed. Thus, by using OMOEs and MOEs to make system design decisions, system engineers are ensuring that the design process follows a top-down systems approach in which systems are optimized for user needs.

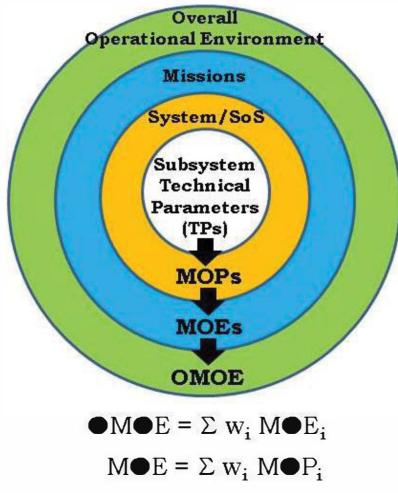


Figure 7. Measures of Merit Hierarchy

Figure 7 illustrates a system (or SoS) measure of merit hierarchy with the OMOE at the outermost level with MOEs, measures of performance (MOPs), and technical parameters (TPs) as inner layers of the model. Presented as a hierarchy, the values at each level can be summed up to derive the next higher level’s value; thus the levels contribute to the OMOE score. Systems engineers can use this hierarchical model to observe how changes in measures of merit values will affect the OMOE score; indicating how different design options will ultimately meet operational mission objectives.

An example of an objective hierarchy model for a sensor system is provided in Figure 8. The overall objective (or OMOE) is to provide situational awareness. This is shown at the highest level of the hierarchy. The next level of the hierarchy contains MOEs which are also based on the operational effectiveness of the system to achieve the ultimate goal (the OMOE). Each MOE is then decomposed into a set of MOPs that relate to a function or performance characteristic that the system can provide to achieve the MOE. If each “box” in the objective hierarchy is represented by a numerical value,

the lower tiers of MOPs (that represent how well the system can perform a given function) can be summed to give quantitative values for the MOEs, which can then be summed to provide an OMOE score.

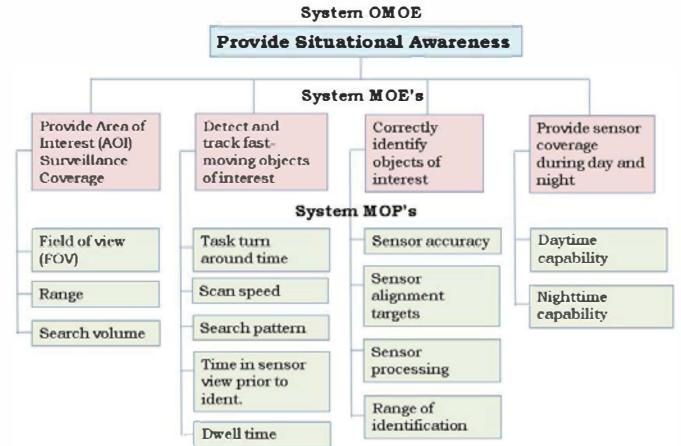
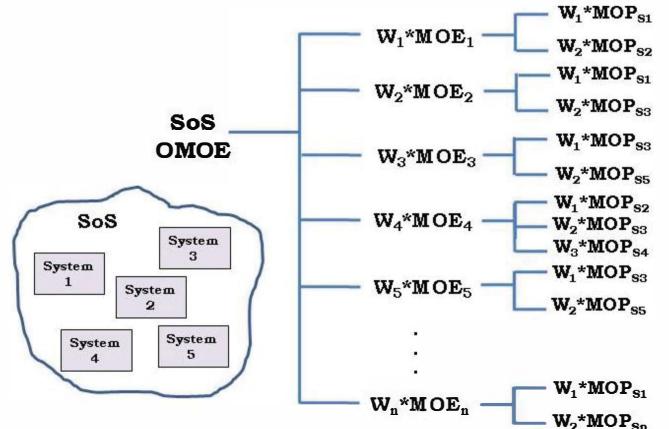


Figure 8. Example of an Objective Hierarchy Model

A notable characteristic of the objective hierarchy model is that it is system-neutral. In other words, a variety of systems (with differing designs) could be “applied” to the model; and based on how well they perform against each of the measures of performance, the MOEs and OMOE can be determined. Furthermore, a collaborative SoS can be applied to the model, and a SoS OMOE can be determined. For example, the illustration in Figure 8 could represent an objective hierarchy model of a system of sensor systems, rather than a single sensor system. This system-neutral characteristic is what makes this analysis method applicable to real-time distributed resource management operations.



$$\text{SoS OMOE} = \sum w_i \text{ MOE}_i \text{ (Note - these are SoS MOEs)}$$

$$\text{SoS MOE} = \sum w_i \text{ MOP}_i \text{ (Note - these are System MOPs)}$$

Figure 9. Quantitative Objective Hierarchy Model

Figure 9 illustrates the objective hierarchy model from a quantitative perspective. Weighting factors can be included which provide relative priority among the MOPs and MOEs.

The concept for applying this systems engineering assessment methodology to real-time resource management,

lies in the use of OMOEs and the objective hierarchy model. Once the hierarchical framework representing the operational missions is developed, simulation involving possible permutations of SoS alternatives can be run through the model to assign OMOE scores for each alternative. The process is referred to as the “OMOE decision engine” to denote that it is conceived to be a model-based computational system with inputs of information, missions, and prioritizations; and an output of a recommended resource tasking decision alternative.

The actual operational environment at any given time can be characterized as a complex set of missions of varying priority. Examples include possible threats that need immediate defensive responses; targets that require offensive actions; objects that need to be identified and tracked; areas that require surveillance; etc. These missions can be generated from the results of the data fusion processes and wargaming capability or manually entered by operators. The importance and criticality of the missions can be captured in the model through prioritizations in the weighting factors (shown as “W’s” in Figure 9. These parameters can be adjusted to reflect the changing and complex missions.

The applicability of the distributed warfare resources to addressing mission objectives is determined through a process of matching the MOPs with the most applicable resources. This can be accomplished by matching required performance capabilities with known information about the resources that can be captured and continually updated in the “resource picture” with up-to-the-moment status of resources. The most important MOPs to be accomplished at any given moment would be identified through the process of weighting MOEs to best represent the operational missions.

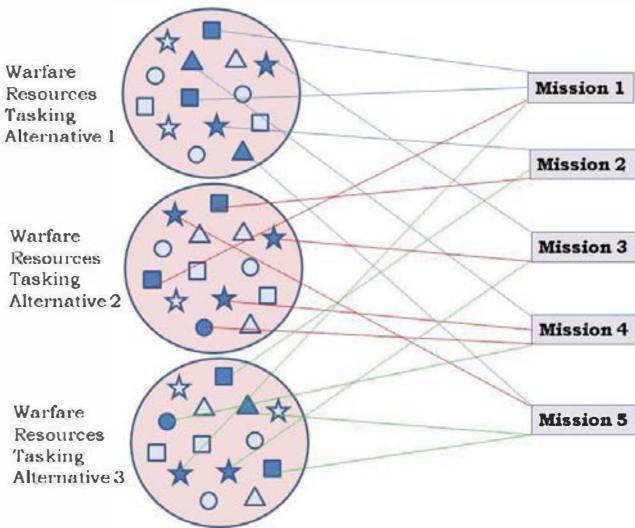


Figure 10. Generation of Resource Tasking Alternatives

Figure 10 illustrates the resource tasking alternatives that are being assessed against the set of operational missions at a point in time. Each of the three circles represents the set of available warfare resources. The top circle and its connections to the five missions represent the first possible alternative. The second circle and its connections represent the second possible tasking alternatives. And a third is shown. There would be

many more possible resource-to-mission tasking alternatives that could be assessed.

In summary, the conceptual OMOE decision engine is an Operational Effectiveness Model that can support distributed resource management by generating decision recommendations for optimally tasking resources. The objective hierarchy model could represent the operational missions through weighted measures of merit and be used to assess the possible SoS resource tasking alternatives. This assessment methodology could compute an OMOE score for each alternative and provide a tasking recommendation based on projected operational effectiveness to decision-makers.

VI. DECISION COST ENGINE

For the SE design process, cost assessment is an important part of determining which design alternative will provide the most performance for the best cost. The focus of SE cost assessment is the determination of the most accurate estimate of what the total lifecycle cost of the system design alternatives will be. For the distributed resource management application, the constituent systems (or warfare resources) are already operational and “paid for”. Thus, the assessment would not be focused on estimations of the projected costs of competing alternatives.

However, there are still possible “cost” considerations for RM, as shown in Figure 11. There may be cost factors that affect the optimum choice of SoS resource tasking decisions. As mentioned earlier in Section IV, costs may take the form of resources whose expenditure is expensive (i.e., interceptors, torpedoes), that require significant fuel or energy to operate (i.e., aircraft, ships, etc.), that require costly maintenance upon their use (i.e. helicopters), or have a higher risk of posing danger to humans (i.e. manned vs. unmanned vehicles).



Figure 11. RM Cost Considerations

The conceptualized decision cost engine would provide methods to quantitatively represent the cost associated with the use of each warfare resource. The quantitative representation would provide relative levels or values for each resource based on high/medium/low or a more well-defined score. These values could then be used to further refine the overall relative ranking of resource tasking decision alternatives. Three possible methods for folding cost assessments into the overall decision recommendation are posed.

1. The relative cost levels could be applied in an “after-the-fact” manner by bumping OMOE scores up or down (quantitatively) based on whether more or less “cost” is

associated with a particular decision option. This method would be most applicable for when only one cost factor is being considered. For example, if a significantly cheaper interceptor can be fired and still have equivalent projected operational effectiveness, this alternative's OMOE score would increase relative to the alternative with the more expensive interceptor.

2. A second method for handling the management of very costly warfare resources would be to associate a "red flag" or identifier within the RM system that would flag (or highlight) decision alternatives that utilize the cost resources. This would send an indicator to the human operator to decision-maker to request closer attention and possibly manual assessment of such decision alternatives.

3. A third method is applicable when more than one "cost" factor needs to be considered. Cost ranking values for all the resources in each decision alternative could be combined to develop a single cost score. Then each decision alternative's cost score could be plotted against their OMOE scores and a Pareto approach could be used to determine the best option for the best "cost". This would involve a decision-aid that calculates "cost" scores using similar methods with weightings and quantitative values for each resource that is part of the decision option. Once plotted, as illustrated in Figure 12, the decision alternative with the position closest to the ideal point (with the highest OMOE score and lowest cost value) would be the recommended resource tasking option. In Figure 12, three resource tasking options are illustrated—"A", "B", and "C". The ideal point is shown in the upper left-hand corner of the graph. Although alternative "B" has a higher OMOE score than alternative "A", it has a higher cost associated with it. Thus "A" would be the most desirable alternative in this situation. Alternative "C" has a higher cost and lower OMOE score than the other two, placing it as the least desirable option.

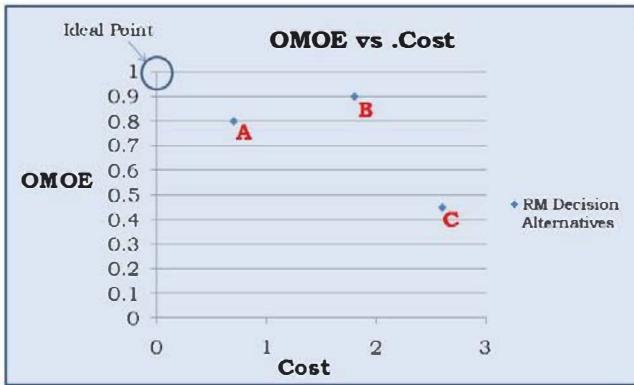


Figure 12. Assessment of OMOE vs. Cost

VII. DECISION CONFIDENCE ENGINE

For the system design process, risks are related to designs that might not meet schedule, cost, or technical requirements. Designs are assessed in terms of how risky (or likely to not meet requirements) they are and in terms of the severity of consequences when requirements are not met. The causes of risk at this stage in the SE process include technical immaturity (unproven/untested technologies), cost overruns, management

issues, and external factors (i.e. budget cuts, program cancellations, etc.)

These types of risk do not apply to the operational RM situation. At this point, the resource systems have presumably met requirements and passed test and evaluation. And since the systems are operational, for the uses in which they are intended, the risk should be minimal or at least known/predictable. Thus, risk involved in systems not being able to perform as intended or needed is taken into consideration in the OMOE decision engine.

Therefore the focus of risk for the conceptual RM process is uncertainty in the decision alternative's assessments. Basically, the decision-makers need to know the level of confidence they can have in the resource tasking decision. They may have questions about the reliability (or "goodness"), of the information upon which alternatives are assessed. Or how accurate the data fusion processes were at fusing, assessing, and developing the operational picture and mission/threat situation. Error can be introduced during sensing, data fusion, communications, and from delays in data observations and fusion that can cause the process to get out of sync. Error and incorrect computations/processes can result in mis-associations, incorrect identifications, dropped tracks, and poor track quality, to name a few.

The confidence level is probabilistic in nature and depends on a number of contributing factors such as those listed in Figure 13. Each source of possible error can be represented as a probability of correctly occurring. For example, a probability of correctly detecting an object by a sensor is a value that is dependent on the sensor health, status, and proximity to the object at the time of detection. The probability of detection can also depend on factors such as the environmental situation, the speed of the object if it is moving, and the object's brightness.

Sources of Decision Error

- Sensor Observations (SO)
- Communications (C)
- Data Fusion Processing (DFP)
- Association (A)
- Attribution (At)
- Identification (Id)
- Threat Prioritization (TP)
- Mission Identification/Prioritization (MP)
- Resource Information (Health, Status, Configuration, Location, etc.) (RI)

Notional Decision Confidence Level:

$$P_{\text{Decision Accuracy}} = P_{\text{SO}} * P_{\text{C}} * P_{\text{DFP}} * P_{\text{A}} * P_{\text{At}} * P_{\text{Id}} * P_{\text{TP}} * P_{\text{MP}} * P_{\text{RI}}$$

Figure 13. Sources of Error that Affect the Decision Confidence Level

The determination of a confidence level for a resource tasking alternative could be based on a hierarchical probability model that includes all the possible sources of error. As the operational situation changes, the model is populated with best estimates of probability factors at the lowest level of the hierarchy. These are summed to calculate an overall confidence level for each alternative. If there is a significantly

low confidence level for a particular alternative, this choice may be avoided even if a high OMOE and low cost are indicated.

The confidence level for each decision alternative can be plotted against the OMOE scores and cost scores—either individually in 2-D or against both at once on a 3-D plot. The alternative with the highest OMOE, lowest cost, and highest confidence level will be the optimum choice. However, a confidence level threshold can also be identified, so that decision alternatives that don't meet the minimum confidence level will automatically be eliminated as viable options.

VIII. CONCLUSIONS

Future command and control stands to benefit from adopting a decision paradigm in addition to the traditional data-focused perspective. The decision framework for distributed resource management, based on a systems approach, can use decision assessment methodologies from systems engineering design. These specific SE applications provide methods for operational performance, cost, and risk assessments of resource tasking alternatives.

| Decision Assessment for System Design | Decision Assessment for RM Operations |
|---|---|
| System is in design phase | Systems are in operation |
| To select the most operationally effective design | To select the most operationally effective SoS/resource tasking |
| Single decision | Continuum of decisions |
| Projected performance against operational mission requirements | Projected performance against actual operational missions/threats |
| Cost in terms of estimated \$ for acquisition and total lifecycle | Cost in terms of known cost to operate & maintain; safety |
| Risk in terms of ability to meet requirements | Risk in terms of decision uncertainty or level of confidence |

Figure 14. A Comparison of Decision Assessment for Systems Engineering Design and Resource Management Operations

Figure 14 summarizes the differences between the decision assessment methodologies as applied to system design and resource management operations. Differences include the single decision for system design versus a continuum of decisions for RM operations that would need to be made as the operational environment changes to continually redirect resources. Another major difference is that for system design, decisions are based on more estimations and projections of system capabilities against requirements that address future operational missions; whereas for RM operations, there is less projections or predictions, and more known information upon which decisions are based. Costs are no longer estimated, they are known; and operational missions are eminent and real and resource capabilities and performance are better known.

Another consideration for implementing the decision paradigm is to improve the design and engineering of warfare resource systems to become more collaborative and more

conducive to being “directable” or “taskable” for multiple missions in future operations. Systems could be designed and developed (or re-designed/upgraded) to be more agile and collaborative. Much emphasis has been placed on interoperability, modularity, interfaces, and open architectures. In addition to these characteristics, future study should be on designing systems to have multiple uses/applications. This is only possible by understanding the operational missions from a SoS/force-level perspective. Future warfare resource systems should also be designed so that they operate independently of platforms, other resource systems, and from the local C2 systems.

Achieving a decision paradigm for distributed resource management largely rests on taking a systems approach to emphasize the real-time operational decision process and all that can be possible in the future. Enabling a conceptual framework such as the decision assessment methods proposed in this paper is a first step. Further areas of study include: wargaming, threat/mission prioritization, resource picture development, objective hierarchy modeling, techniques for generating resource tasking alternatives, and the development of the OMOE decision engine, cost decision engine, and decision confidence engine.

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