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TECHNICAL REPORT NO. TR-737

THE NEXUS OF MILITARY MISSIONS AND MEANS

JUNE 2004

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U.S. ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY
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In support of Defense Transformation, it has become vital that military planners, operators, and analysts not merely concentrate on “doing things right” but also focus on “doing the right things.” The Cold War era “right thing” of winning the heavy-armor battles in Europe has given way to multiple and diverse “right things” of unconventional warfare, homeland defense, peacekeeping operations, etc. To address these complex objectives, what is needed is a robust means to rigorously specify operational purposes and goals, then explicitly relate, map, and allocate them to the proposed means for accomplishment. Accordingly, this report describes a framework for representing the synthesis of military operations and the employment of materiel/forces to accomplish missions. It also formalizes the mission space, details how framework components need to be linked and instantiated, and discusses ways in which this approach is being exercised.

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PREFACE

This report is being published to formally record the state of the Missions and Means Framework (MMF) circa 2002. However, since that time, the MMF has continued to evolve and has been presented in updated forms at various conferences. See, for example, the "Military Missions and Means Framework" paper published in the Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), December 2003 (downloadable from http://www.arl.army.mil/slad/Overview/1257_v05_final.pdf).

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THE NEXUS OF MILITARY MISSIONS AND MEANS

1. INTRODUCTION

The military today faces operational challenges unlike any it has ever seen before. Through the first half of the 20th century, the U.S. military's planning and posture was largely dependent upon the "safety barrier" that two vast oceans provided from foreign threats. Enemies were confronted and wars prosecuted primarily on someone else's soil. In the second half of the century, however, the paradigm changed. The World Wars gave way to the Cold War, and it became clear that geography could not preclude emerging technologies such as nuclear submarines, intercontinental ballistic missiles, nuclear and long-range bombers from threatening the American mainland. The threat was clearly the Soviet Union, and national defense policy and military strategy increasingly focused on threat deterrence rather than on threat defeat.

But the 21st century has brought with it yet another paradigm. The fall of the Iron Curtain and the rise of the Information Age have uncovered a host of new threats no longer restricted to the traditional, anti-democratic "isms" of fascism, nazism, socialism, and communism. Today's rapidly developing global crises demand strategic mobility in hours, and days instead of weeks and months. The battle "fields" of the past now comprise the populated streets of towns and cities. And "mission success" has become highly abstract as the age-old scenario of mass force-on-force conflicts between "blue" and "red" is replaced by more asymmetrical operations—such as terrorism prevention and peacekeeping efforts—where goals are primarily political, moral, and economic; threats and battles are often ill-defined; and finality is seldom achieved. Fortunately for military planners, operators, and analysts, although the types of military operations have changed, the basic composition has not. Despite all of today's added complexities, military operations can still be viewed in terms of two fundamental elements: ***missions***, the actions that must be accomplished to meet objectives, and ***means***, the physical components that must execute those actions. In effect, the missions are the outcomes and the means (which includes both materiel and forces) are the resources in successful military prosecution. (Note that *strategies/doctrine*—which are the methods or ways in which the means accomplish missions—are sometimes considered a third element in the composition; however, for the purposes of this paper, strategies/doctrine are generally included as part of the mission.)

Not surprisingly, missions and means are highly dependent on each other. Missions, as defined by the warfighter/operator, supply the necessary *requirements and tasks* for the means, and the means, as determined by the scientist/engineer, provide the necessary *capabilities* for the mission.

Although this nexus, or linkage, appears to be simple enough at first, the process of comprehensively identifying, decomposing, and instantiating these principal parts has not been easy to accomplish. One problem is the potentially large number of connections involved, which gives the process a kind of "one-over-the-world" aspect. Another is the lack of richness in the way we measure effectiveness (e.g., the loss-exchange ratio [LER] is often not applicable for today's operations). Yet another is the way in which we have tended to treat issues of weapon system requirements, effectiveness, capabilities, and materiel as a series of independent "black boxes" that can somehow be wired together without necessarily accounting for what is inside of them or addressing the synergism that results from linking them.

But as the military continues to transform itself from a forces-based, materiel-centric (i.e., "player"-focused) posture to a capabilities-based, mission-centric (i.e., "playbook"-focused) posture—where distributed, networked systems-of-systems (SoS) must work in concert over a sustained period and with continuously changing components—the missions-means linkage becomes vitally important for a wide range of military efforts, including weapon system development and acquisition, war planning, operational and developmental test planning, modeling and simulation, analysis of alternatives (AoA), readiness evaluation, cost estimation, mission rehearsal, and soldier training.

In the end, what is needed is a conceptual tool that the Defense community can use to rigorously specify operational purposes, objectives, goals, and then explicitly relate, map, and allocate them to the proposed means for accomplishment, both extant and conjectured. The purpose of this paper, therefore, is to (a) describe a framework for representing the synthesis of military operations and the employment of materiel/forces to accomplish missions, (b) describe a mission space formalism, (c) discuss how these components need to be linked and instantiated, and (d) present ways in which this approach is being exercised.

2. FOUNDATIONS FOR THE FRAMEWORK

2.1 The Need. Choices have consequences. And the conventional corollary is that for every intended consequence, there are 10 unintended consequences. In the extraordinary complexity of the political, military, civil, and physical environment of contemporary military operations, each choice/decision has hundreds and perhaps thousands of consequences—most of which are unintended (or unwanted) and too many of which are negative. So, in the spirit of the builder's dictum to "measure twice and cut once," the way forward is to systematically identify and evaluate (hopefully, before the fact) how the consequences of choices and decisions made now will enable or constrain subsequent choices and decisions in the march to fundamental objectives and desired outcomes.

Conventional methodologies are widely available for a priori selection of an operating point along an existing cost/capability trade-off curve, but present transformation efforts call for something stronger. The need is for a framework and a methodology that will enable the creation and employment of operational concepts and supporting technologies that shift the trade-off curves to improved capability at each cost and to reduced time-to-deployment and effective engagement at each capability.

To make a difference, this framework must have the credibility to make hard decisions (and have them stay made), the timeliness to support dynamic human interaction, and the capacity to provide the community with a "look-before-you-leap" capability that, hopefully, will lead to faster, better, and cheaper materials and methodologies. The manifest inability to efficiently transfer local content and expert insight across the boundaries of "stove-piped" products and perspective, life-cycle stage and focus, domain principles and expertise, warfare area and technology bases, Service roles, and Joint missions is a fundamental barrier to these credibility, timeliness, and affordability demands. The framework needs to capture in one place the disparate perspectives and end uses of warfighting and combat operations, training and readiness, basic research and fundamental experimentation, operations research and systems analysis, material acquisition and force development, logistical support and life-cycle sustainment.

2.2 Underlying Principles. The desire for such a framework has been akin to a search for the Holy Grail of knowledge formation. To succeed requires a heretofore-unattained level of composability of pieces and parts, scalability in construction and execution, and correctness in meaning and content. For this framework to achieve what others have sought and not yet obtained, the following underlying principles have been incorporated:

- Explicitly state purpose and abstraction
- Employ the same canonical representation to capture purpose and abstraction
- Separate the specification of missions and means
- Separate the specification of capability and interaction and employ them as interface components to link missions and means
- Separate synthesis from employment
- Separate cognitive from physical, reality from perception, and tangible from intangible

- Separate transparent-box, skin-in representation components from opaque-box, skin-out representation components
- Employ a layered decomposition with well-defined interfaces enforced between layers
- Separate human-consumable language and machine-consumable language with opaque-box interfaces.

2.2.1 Explicitly State Purpose and Abstraction. As shown in Figure 1, all representations (and the models, tests, simulations, and evaluations that employ them) are ultimately created with the same objective: knowledge formation to support decision making. Decisions are effective exactly when they achieve a desired purpose (i.e., goals, desired outcomes, and "success"). Purpose is the most crucial element in the entire equation. "Why" should drive "what, who, and how," not the other way around.

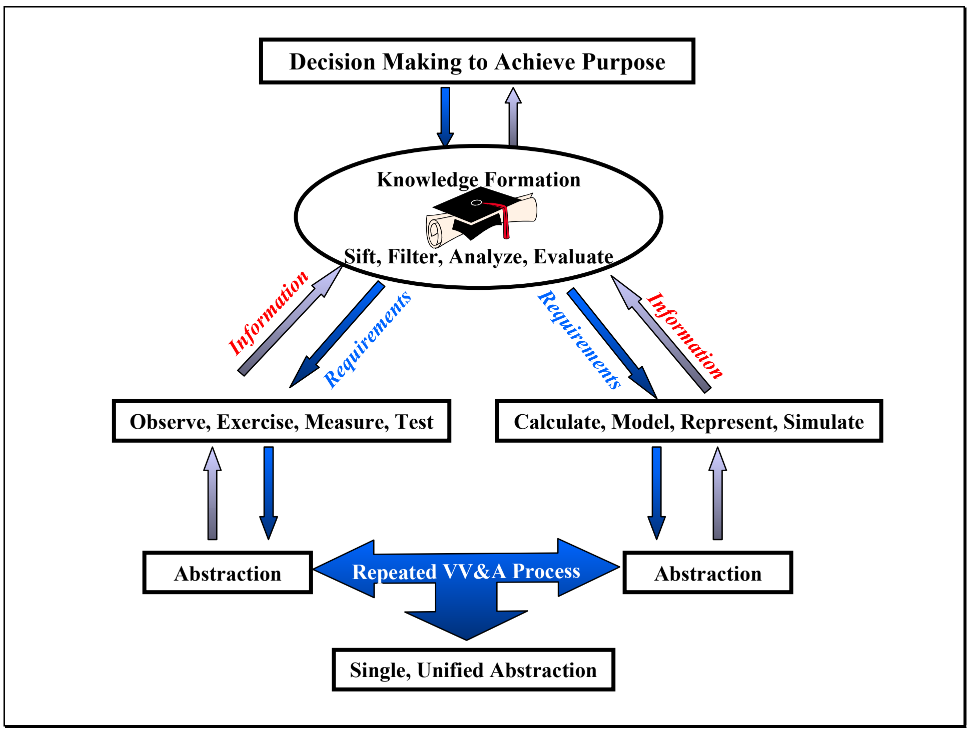

Figure 1. The Path to Decision Making.

Unfortunately, purpose is usually understood only as implicit tribal knowledge by a few key stakeholders. So, a rigorous and explicit statement of the purpose is the single most important factor in achieving desired outcomes. The simple transition from internal knowledge to text is a first but essential step.

As shown in Figure 2, a central tenet of our approach is that the utility of stating purpose increases as that statement transitions from natural language narrative to fully structured and ultimately canonical representations. This amounts to explicitly stating the abstractions used to formulate and express the explicit statement of purpose.

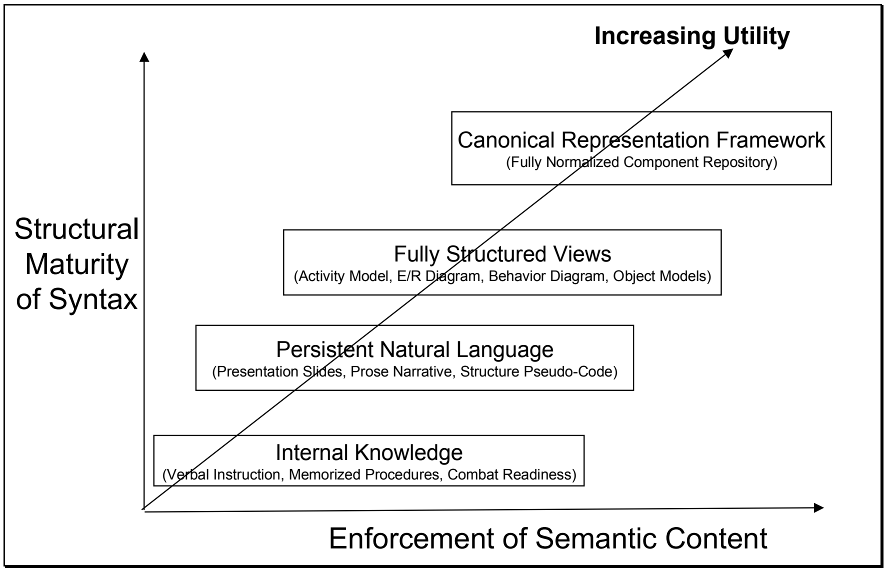

Figure 2. Representation Dimensions.

Abstraction is a mental facility that permits humans to view real-world problems with varying degrees of detail depending on the current context of the problem. Indeed, the use of abstraction may be the most "human" of all homo sapien activities. Representations are the embodiment of such abstractions whether employed in a mental concept, a computer calculation, a field measurement, or an order in a military operation. Clearly stating the abstraction employed enables the stakeholders to provide an informed judgment—based on objective theory and professional expertise—on the degree to which the abstraction implemented in a particular model, test, simulation, or evaluation is suitable for the purpose. Of course, an abstraction that is entirely suitable for one purpose may be manifestly unsuitable for another.

2.2.2 Employ the Same Canonical Representation to Capture Purpose and Abstraction. The explicit statement of purpose and abstraction is the lever by which we intend for Atlas to move the world. However, in the words of Clemens Szyperski [1998], "As long as all solutions to problems must be constructed from scratch, growth can be at best linear."

To meet timeliness and affordability requirements, it must be genuinely more efficient and effective to take existing statements of explicit purpose and abstraction at lower levels of syntactic maturity and semantic content and move them to higher (ultimately canonical) levels than it is to start from scratch. This framework must have features that make the composability and re-use implied by Figure 3 a reality rather than just "technological happy talk." To enable this objective, we require the canonical representation framework in Figure 2 to be a regular expression grammar that can be transformed into unambiguously parsable acyclic graphs that, in turn, can be compiled into computer-executable mission content.

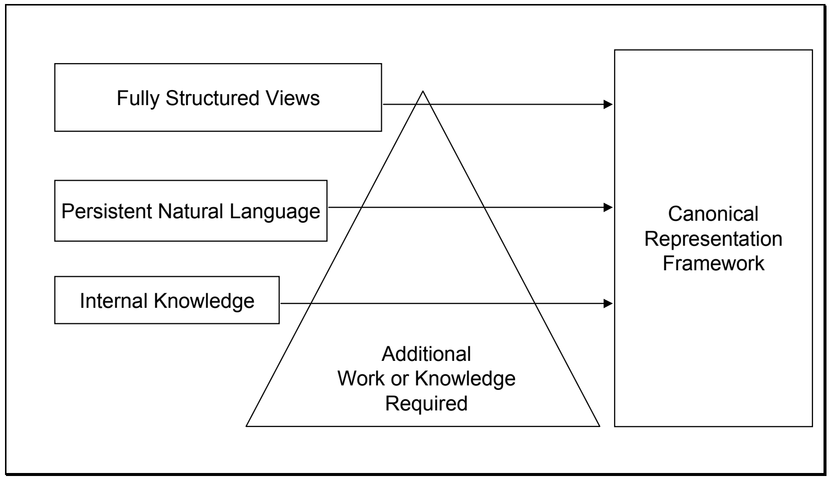

Figure 3. Migrating Representations at Multiple Levels of Structural Maturity and Semantic Enforcement.

The elicitation from internal knowledge to persistent natural language makes the content persistent and (manually) portable. Investment to move from narrative text to structured views follows the proverb, "a picture is worth a thousand words."

The additional investment to move to the desired (canonical) regular expression grammar has two benefits. First, parsable acyclic graphs can be transformed from one fully structured view to any number of alternative fully structured views (if, of course, the required content for the alternative view is in fact contained in the original view; otherwise, additional content must be added). This enables different stakeholders, with disparate concerns and distinct professional expertise, to reconstitute the available content in fully structured views that are suitable for their distinct purposes. This translates roughly to "one size need not fit all." Second, the further investment to move from unambiguously parsable to compiled executable content scales the proverb from "a picture is worth a thousand words" to "a dynamic animation is worth a thousand pictures."

The theoretical ideal for a canonical representation framework is a mathematical basis set: a collection of framework elements that are orthogonal and complete (mutually exclusive and exhaustive). Roughly speaking, this means that the elements of the regular expression grammar have no overlapping content (orthogonal, mutually exclusive) and scaled combinations of these elements can represent any content of interest (complete, exhaustive).

In the framework presented here, we have striven for completeness but have not attempted to obtain orthogonal elements. Rather, we have adapted the database management system (DBMS) technology heuristic of normal forms. Approximately speaking, DBMS 1st through 5th normal forms indicate the degree to which "one fact" is known, stored, and maintained "in one place." Decomposition is a crucial enabler for this framework. For reasons of practicality, we softened the rigor of orthogonal decomposition and the higher normal forms in favor of a more pragmatic systems engineering notion of "separation of concerns," which permits some degree of overlap and de-normalization.

To obtain a framework that is a feasible balance between the competing advantages of pragmatic utility and scientific rigor, we employ the additional principles that follow.

2.2.3 Separate the Specification of Missions and Means. Missions translate purpose into required operations and tasks, organized by strategy. Forces and materiel (in the form of SoS) are useful precisely to the extent that they provide a means (who and how) for accomplishing the mission. Note in this formulation, the SoS includes the complete force: the units (organizations), warfighters (personnel), and networked materiel.

Within our approach, missions are specified using process-centric abstractions (usually named with verbs). Means are specified using entity-centric abstractions (usually named with nouns). To the extent practical, these specifications (both missions and means) are stated with "catholic agnosticism"—catholic (meaning universal) so that specific means can be employed in any mission that requires that capability and agnostic (literally meaning unknowing but here more nearly connoting unbiased and implementation independent) so that specific missions can employ any means that can deliver the required capability.

Missions and means are separately represented and then joined only at the moment of employment. Metaphorically, collections of verbs and nouns are held in reserve and are combined into complete sentences only as actually required. This amounts to separating the players (i.e., forces and materiel) from the playbook (missions, operations, tasks) for maximum flexibility and composability of game plans, situation substitution, and play calling.

This is a major departure from some conventional practices where historical precedent hardwires warfighting roles to specific Services and platforms and contemporary object-oriented programming, which hard-codes behaviors into objects embedded in deeply nested class hierarchies. It is, however, a direct emulation of how operational forces task-organize to execute combat missions.

2.2.4 Separate the Specification of Capability and Interaction and Employ them as Interface Components to Link Missions and Means. By deriving the capability specification as a standalone component of the representation (rather than embedding in the specification of the SoS), a cause-and-effect interface is created between the cause (employment of means) which provides capability and the effect (enable or constrain the completion of missions). Similarly, by deriving the specification of interactions as a standalone component of the representation (rather than embedding in the specification of the operations and tasks), a cause-and-effect interface is created between the cause (execution of tasks) which generate the interactions and the effect (change in the state of the SoS). In the sports analogy, this principle provides one interface for expressing how player actions contribute to the completion of plays and another interface for expressing how the execution of plays affect the state of players.

This is a departure from conventional representation methodologies. However, making the software interfaces themselves standalone components between application components is a fundamental enabling composability technology in the emerging component-based software engineering industry. In the present context, it is a fundamental enabler for the catholic agnosticism discussed previously.

2.2.5 Separate Synthesis from Employment. Synthesis is the top-down planning and decision-making process that conceives, designs, and fashions missions and that creates, selects, and task-organizes means to achieve a stated purpose within real and perceived constraints imposed by the military, civil, and physical environment. Synthesis begins with purpose, resources, and constraints and hierarchically flows down to implementation. This planning and decision-making process considers everything that practically could matter, considers alternative solutions, and iteratively defines implementation increments. Synthesis representations require a rich warehouse of composable building materials and a library of loosely coupled how-to books. This is the art of representation.

Employment is the bottom-up execution and adjudication process that determines whether the actual implementation achieves the stated purpose and provides the desired outcomes. Employment begins with the implementation, establishes which factors actually matter, and generates results. Employment representations require a parsimonious, formal grammar for adjudicating the effect in a post-state from the cause in a prior state. This is the science of representation.

A central tenet of our approach is that the synthesis is not complete until employment is supported. In a modeling and simulation application, this requires that the specification of the solution be machine executable.

2.2.6 Separate Cognitive from Physical, Reality from Perception, Tangible from Intangible. These separations are compatible with the separation of mission and means, synthesis and employment. The mission perspective and process-centric abstractions shown on the left side of Figure 4 are heavily cognitive, largely intangible where the perception of situation drives the “Thinking” component of synthesis as represented in Figure 5. Conversely, the means perspective and entity-centric abstractions depicted on the right side of Figure 4 are heavily physical and largely tangible, where the actual situation drives the “Doing” component of employment as depicted in Figure 5. Note this principle requires a symmetric representation of own and opposing forces even when the own and opposing missions and means are decidedly asymmetric. For the purposes of this framework, cognitive includes fully automated, computer-executed algorithms and rule sets, and physical includes changing the values stored in digital registers.

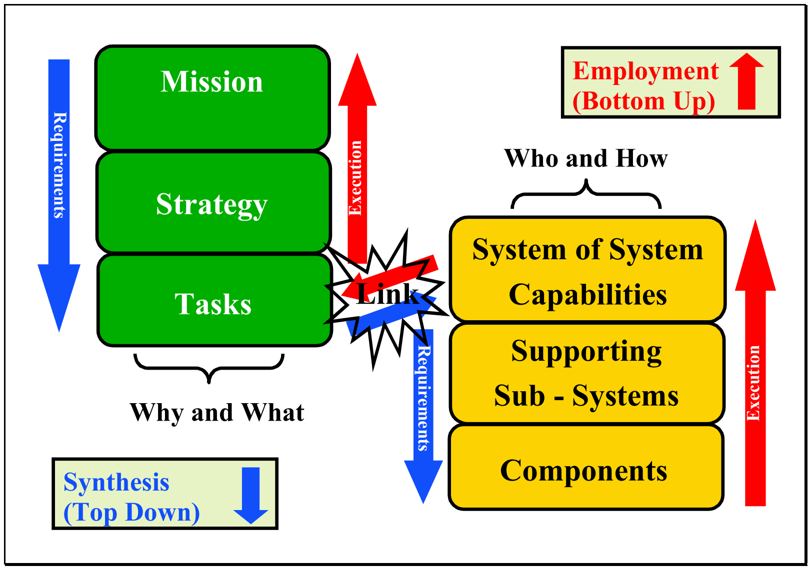

Figure 4. Separating Mission and Means.

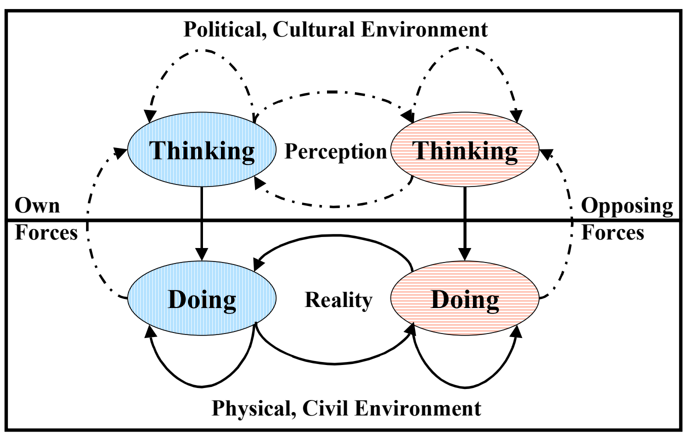

Figure 5. Cognitive and Physical Connections.

2.2.7 Separate Transparent-Box, Skin-In Representation Components from Opaque-Box, Skin-Out Representation Components. Transparent-box (sometimes called "clear-box") and opaque-box (sometimes called "black-box") is common testing terminology adopted from the electronics and software industries. Transparent-box indicates the tester has knowledge of the internal design of the device under test and the ability to directly stimulate and observe responses from those internal components. Opaque-box indicates that the tester has limited (or no) knowledge of the internal design of the device and can only stimulate and observe responses from external input/output interfaces.

As employed here, the representation of missions and means are transparent-box (the internals are available for inspection and redesign) to the decision maker responsible for the mission and in charge of the means. The representation of capability and interaction provide opaque-box interface components between missions and means both between cooperating own forces and across non-cooperating opposing forces.

2.2.8 Employ a Layered Decomposition with Well-Defined Interfaces Enforced Between Layers. Hierarchical decomposition is a fundamental component of both military planning and of systems engineering. The issue is depth of direct connection. Deeply nested class hierarchies in object-oriented software are notoriously difficult to integrate with other class decompositions. Layering separates an otherwise deeply nested decomposition into a number of regions with shallow or moderate decomposition depth in each region. Within each region or layer, direct transparent-box, skin-in connections are made between components. Between differing layers, opaque-box, skin-out interfaces encapsulate the layers. Components in differing layers communicate only through the encapsulating interfaces. The eight-layer OSI communication architecture is a well-known example in systems engineering. The overall layering of strategic national, strategic theater, operational, and tactical levels of war is an analogous concept from military planning.

2.2.9 Separate Human-Consumable Language and Machine-Consumable Language with Opaque Box Interfaces. In the end, one cannot truly think about a subject without a language for expressing the concept. In the 18th century words of Antoine Lavoisier, the father of modern chemistry [Bartlett and Kaplan 1992]:

> "It is impossible to dissociate language from science or science from language, because every natural science always involves three things: the sequence of phenomena on which the science is based; the abstract concepts which call these phenomena to mind; and the words in which the concepts are expressed. To call forth a concept, a word is needed; to portray a phenomenon, a concept is needed. All three mirror one and the same reality."

The rigor of a regular expression grammar is required to meet the composability and re-usability, parsability and executability goals. However efficient and effective this grammar may be for machine intelligibility, such grammars are nearly unintelligible to all but its creators. It is necessary to create one language that is crisp and efficient for human communication and another language that meets computer-to-computer requirements and then to construct two sets of interfaces: human-to-computer and computer-to-human.

3. DEVELOPING THE FRAMEWORK

3.1 Background. Based on the aforementioned principles, we can now begin to develop an abstraction to better conceptualize the mission-means connection. To do this, we start with the Vulnerability/Lethality (V/L) Taxonomy, which was first formalized in the mid-1980s to construct the direct-fire vulnerability model SQuASH in support of the Army Abrams Live-Fire program [Deitz and Ozolins, 1989; Deitz et al., 1990; Klopcic et al., 1992; Deitz, 1996; Deitz and Starks, 1999; Klopcic, 1999] and was later revised and adapted to generate a new vulnerability environment for ground and air targets [Hanes et al., 1991; Juarascio et al., 1998; Juarascio and Keithley, 2000; Mergler and Steelman, 1999], to improve estimation of personnel casualties and operational effectiveness [Frew and Killion, 1996], and to form the foundation for the V/L portion of the Tri-Service Advanced Joint Effectiveness Model (AJEM) [Wasmund, 2000; AJEM Development Team, 2001].

Using the taxonomy as a point of departure, we integrate key concepts from the Strategy-Mission-Task (S-M-T) methodology (see Section 4), the C4ISR Architecture Framework, the Functional Descriptions of the Mission Space (FDMS), and the Unit Order of Battle project. We then extend the taxonomy to explicitly represent evolution through time (either time stepped or event stepped), to retain a history of prior states and events, to include intangible cognitive states (including units and personnel) and to distinguish actual from perceived state.

3.2 Overview of the Levels and Operators. Basically, the taxonomy is a set of multi-tiered, logically connected state vectors. As illustrated in Figure 6, the main structure consists of four levels (shown as ellipses) that represent static data states. These levels are connected by three operators (shown as ascending arrows), which represent the action or linkage between the states.

In mathematical terms, the operators can be said to map a vector at one level (n) to a vector at the next level (n+1). So, each point in the Level 1 ellipse represents a vector that can be mapped up through Levels 2, 3, and 4. In physical terms, the operators can represent a set of physical processes or tests that begin with component state changes and end with evaluation in utility or mission space. This end-to-end mapping supports the Simulation and Modeling for Acquisition, Requirements, and Training (SMART) analysis process.

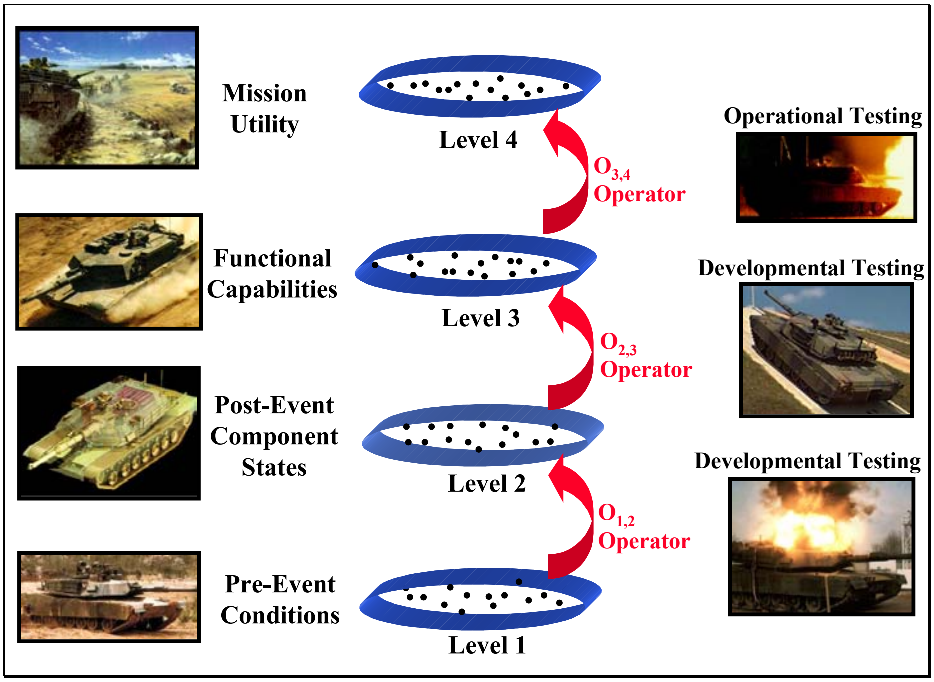

Figure 6. The Basic Framework in a Ballistic Live Fire Context.

Level 1, referred to as ***Pre-Event Conditions***, is the state of all system/SoS[1] components (including units and personnel) and environmental conditions before an interaction or state change. In the case of a threat-target interaction (which is tangible, physical), this would include the geometry and material of both the striking munition and the target vehicle as well as encounter information such as hit location, kinematics, (e.g., the kinetic energy delivered), etc. In the case of intangible cognitive information, this would include the prior track history of the perceived location of a threat given prior sensor reports.

The ***$O_{1,2}$ operator*** represents the dynamics between the "before" interaction conditions at Level 1 and the "after" component state at Level 2. In the ballistic penetration example, this operator represents various phenomenologies such as blast, shock, heat, entry hole size, depth of penetration, spall, and the concomitant component damage. Other examples of this operator (which are discussed later) include permanent and temporary nonballistic degradation mechanisms and even component restoration and improvement. For the intangible cognitive information event, the $O_{1,2}$ operator receives the new sensor report and estimates the new location.

Level 2, referred to as ***Post-Event Component States,*** is the operational state of all the SoS components (working and nonworking) after the action has occurred. In the penetration example, this would be the post-hit assessment of component damage to the target or platform. In the cognitive situation awareness example, the new perceived location of the threat is reported.

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[1] *SoS* as employed here is scaleable and represents a wide range of materiel aggregation including subsystems, systems, platforms, personnel, and units within the SoS.

The ***$O_{2,3}$* operator** represents the aggregation/integration of all component operational conditions (Level 2) into the resulting capability of the SoS (Level 3). In the penetration example, it might be the component linkages and interdependence often represented in fault-tree diagrams/analysis, including redundancy and graceful degradation designs. In the cognitive example, the receipt of a new (perceived) threat location sample provides sufficient track quality to enable the capability to shift from search to engagement mode.

Level 3, referred to as ***Functional Capabilities***, is the state of SoS functionality as a consequence of the post-event component states of Level 2. In the penetration example, this would be the target's ability to move, sense, communicate, engage, etc., while it prosecutes the mission.[2] In the cognitive example, the change might be that a track mode needed for threat engagement is now available to weapon systems operator.

The ***$O_{3,4}$* operator** represents the current (aggregate) SoS capability (Level 3) to perform the overall mission requirements (Level 4). The importance of a change in capability, *in terms of mission utility*, depends on the specific mission being prosecuted. For example, engine damage incurred by a fighting vehicle that results in some loss of ability to move (e.g., top speed, agility, etc.) will generally have greater loss of effectiveness in an assault role than in an overwatch role. In the cognitive example, $O_{3,4}$ operator determines that there is a greater range of mission options in having the capability to engage a threat rather than to simply report its location.

Level 4, referred to as, ***Mission Utility***, is the state of force effectiveness as a consequence of a system's changed capabilities at Level 3 to meet mission requirements. It is the level that addresses the overall "So what?" of the component conditions and SoS functionality. In the penetration example, this might be the effectiveness of a combined arms task force or team given the damage to, or capability loss of, one of its fighting vehicles. In the cognitive example, if there are no suitable munitions available to engage the threat, the increased capability to engage (over the lesser capability to report location) does not contribute to an improved mission outcome.

3.3 Bottom-Up and Top-Down Approaches. Thus far, we have discussed the framework in a bottom-up, causal fashion. This makes sense from the standpoint of *mission execution*. In a time-forward sequence, each action starting at Level 1 and propagating up to Level 4 represents a snapshot in time, and a series of these varied actions culminates in a mission outcome. It is also important to note here that Level 2 is *primary* and Levels 3 and 4 are *derivative*. That is to say, all state changes initiate between Levels 1 and 2, and Levels 3 and 4 are related expressions (with additional context information) of the function and utility of the Level 2 post-event component states.

Obviously, operational reality dictates the mission requirements (top-down) process precede mission execution. As is discussed in Section 5, from the top-down synthesis perspective, Level 4 is primary and all other levels and operators are derivative, which differs

[2] Although the terms *capabilities* and *performance* are sometimes used interchangeably, they are not actually synonymous. Capability is the potential to deliver performance. A sports car sitting idle in a parking lot is not employing the acceleration that it has the capability to deliver. Performance is only present when a system is actually employing the capability.

from the subsequent bottom-up employment perspective of Level 2 being primary and all other levels and operators being derivative.

In terms of the mission-means linkage, Figure 4 illustrates how the levels decompose or build, depending on one's approach (i.e., execution vs. requirements). On the left, the mission piece decomposes down into levels of effectiveness and tasks, and on the right the materiel piece builds up from individual component conditions to the capabilities of subsystems, systems, platforms, and—most recently— the SoS. The all-important link, then, between mission and means occurs as SoS capabilities satisfy task standards. This decomposition and end-to-end linkage are discussed in more detail later in Section 5.

3.4 Broadening the Framework.

3.4.1 Adding the Military Operations Context. Obviously, the previously discussed levels and operators do not exist in a vacuum. So also added into the framework is a mechanism for representing the external factors and context data that feed input data into the framework. We call this mechanism the Military Operations Context (MOC), and it is a vital part of the mission-means connection.

In the baseline V/L Taxonomy, the MOC in Level 4 was usually limited to a number of entity-centric measures of effectiveness (MoE) (e.g., loss exchange ratio, number of targets prosecuted, etc.). A full elaboration of the MOC is required in the proposed framework. Section 4 describes how the S-M-T methodology is employed to organize Level 4. This subsection connects that extension to the Doctrine, Training, Leadership, Organization, Materiel, and Soldier (DTLOMS) paradigm.

As shown in Figure 7, the MOC starts with the DTLOMS structure, which is the underlying context for all Army operations, planning, development, execution, and analysis [U.S. Army Training and Doctrine Command, 1996]. In a sense, DTLOMS is like the education, experience, training, and skill set that an employee possesses when undertaking a job. The MOC then injects mission-specific information such as tactics, scenario, terrain, weather, and other global variables that can be used as input data (in the form of context, risk factors, and mission requirements). In the end, it is this input that customizes the entire structure to fit a given mission.

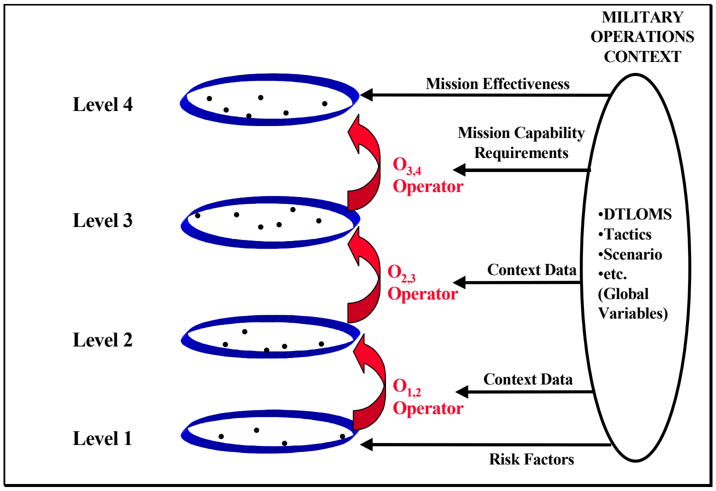


Figure 7. The Military Operations Context.

3.4.2 Decomposing Missions and Means. Not only does DTLOMS provide the underlying context for Army planning and operations, but it also provides the starting point for linking mission requirements (which ultimately take the form of tasks) to forces. DTLOMS is often viewed as a single unit because of the strong interdependencies among its elements; however, for our purposes, the structure can be broken into two pieces (see Figure 8). One piece (which contains the first three letters: Doctrine, Training, and Leadership Development) is primarily mission dominant, and the other piece (which contains the last three letters: Organization, Materiel, and Soldier Structure) is primarily forces dominant.

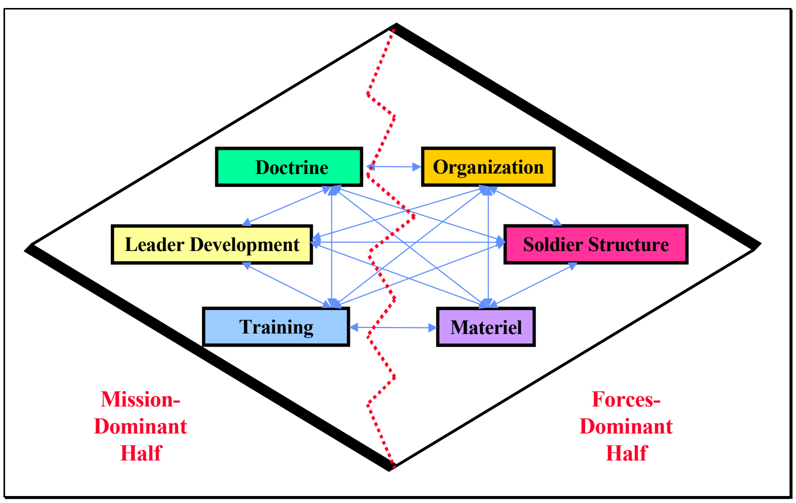


Figure 8. The DTLOMS Structure.

Furthermore, as shown in Figure 9, the specific mission goals, strategies, etc., included in the MOC serve to focus the DTLOMS structure into appropriate measures of effectiveness (MoEs) at the top of Level 4 and then into corresponding tasks (e.g., UJTLs [which are discussed in the next section]) at the bottom of Level 4. The MoEs can, if applicable, originate at the Strategic National level and decompose down through the Strategic Theater, Operational, Tactical-Aggregate, and Tactical-Atomic levels until they eventually end with elemental tasks. Of course, higher-level tasks can sometimes skip intermediate levels altogether and directly spawn elemental tasks (e.g., the national-level decision to launch or reposition a space satellite, which occurs at a national level). This spawning is illustrated by the dotted arrows in Figure 9.

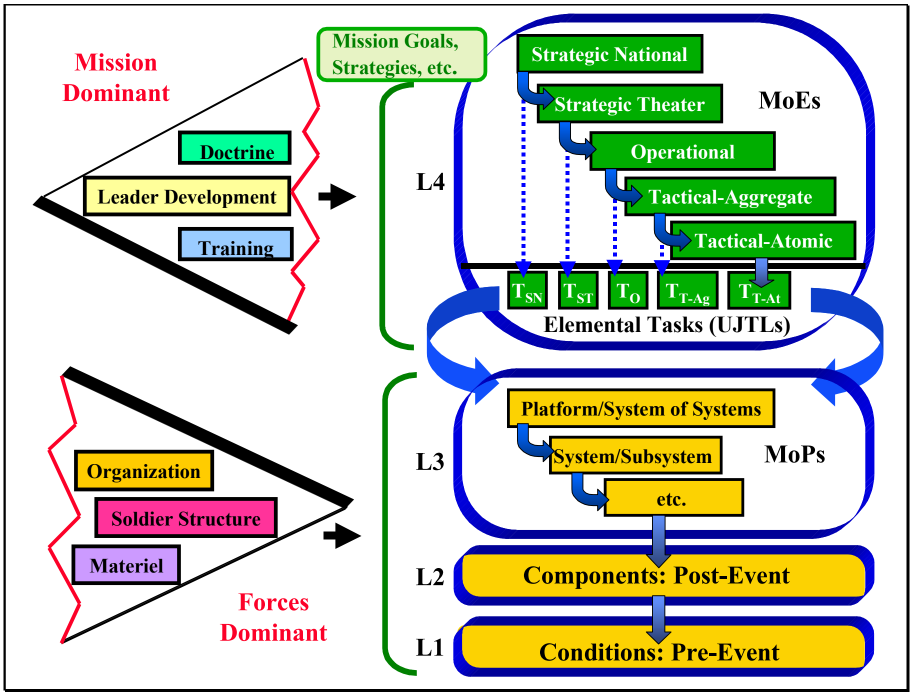


Figure 9. The Decompositional Linkage of Requirements to Tasks to Materiel.

Proceeding down further, we move away from mission-dominant metrics and toward forces-dominant metrics (as derived from the second piece of the DTLOMS structure and focused through the mission context). We can link the elemental mission tasks at the bottom of Level 4 with the aggregate platform (or SoS) capabilities at the top of Level 3. For a single platform, this corresponds to the aggregate capability of the platform. For an SoS, this is the aggregate set of capabilities in which the performance of all networked components is properly accounted.

It is important to note that, at this "height" in the framework, the Level 3 capabilities required to achieve success at Level 4 should still be largely *forces-independent*. In other words, mission requirements, as defined by their elemental tasks, care only about being serviced by capabilities, not about the source of those capabilities (i.e., force). This kind of top-level "agnosticism" in mission planning and forces acquisition is critical to ensuring the proper match-up of fielded systems (e.g., special operations soldiers teaming with B-52s in Afghanistan) and the appropriate development and selection of new technologies for future missions.

However, as we continue to decompose capabilities and measures of performance (MoPs) down through systems, subsystems, and sub-subsystems at Level 3, force composition dependencies become stronger until, eventually, the capabilities terminate at Level 2, the component "atomic" element (or leaf node) level.

We should also note that there is no set resolution to which all components should be represented. If the SoS is not divided and subdivided far enough, important phenomena can be overlooked. On the other hand, unnecessary complexity (i.e., resolution beyond what will be measured or evaluated) can waste time and money. In short, it is the *purpose* that must determine the "appropriate" level of granularity at all stages of the model.

3.4.3 Considering Complex Mappings and Multi-Situational State Changes. Now that the linkage has been established between mission-based MoEs, the tasks and capabilities that support them, and the units, personnel, and materiel that forms the basis for that support, it is appropriate to consider more complex ways in which materiel can change as it prosecutes the mission.

For instance, as shown by the arrows ascending up through the levels in Figure 10, multiple mappings can occur with multiple events. That is, identical pre-event conditions at Level 1 can map to different outcomes at Level 2, and yet achieve the same Level 3 system capability and thus the same mission outcome at Level 4. Also, outcomes at Level 2 can map to entirely different Level 3 capabilities and Level 4 mission outcomes.

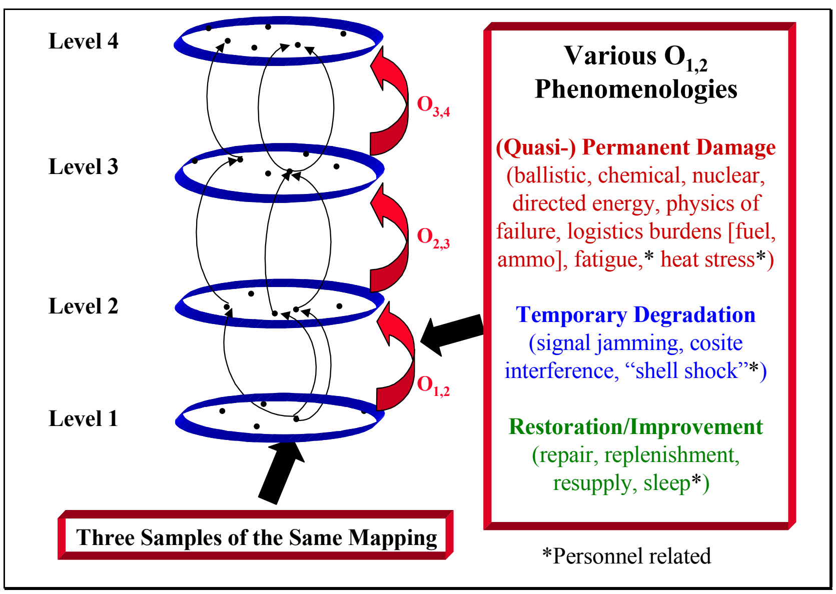


Figure 10. Some Possibilities for Multiple-Event Mappings and the $O_{1,2}$ State Change.

Consider this *stochasticism* in the previously discussed materiel-centric live-fire example. We know that a single vector (represented by a point) in the space of Level 1 represents a specific test condition (such as the, warhead, target, or kinematics condition). But due to the complexity of ballistic processes (such as penetrator overmatch, spall generation, and shotline variability), repeated identical shots result in variations of component kills. This explains the Level 1–2 mapping of three repeated shots, where each outcome is different (e.g., engine damage vs. track damage vs. radio damage). Furthermore, in the case of the Level 2–3 mapping, the first two different damage states (the degraded engine and track) are shown to map to the same capability state (e.g., the loss in system mobility), whereas the third damage state (the degraded radio) maps to a different capability state (e.g., the loss in communications). Of course, the impact on Level 4 mission utility is always a direct translation of the Level 3 capability states regardless of which components contributed to the degradation.

Also shown in Figure 10 are multiple types of operations that can change Level 2 component states. We've discussed several ballistic mechanisms, but there are also chemical, nuclear, biological, directed-energy, and other nonballistic mechanisms that cause permanent (or quasi-permanent) damage. We tend to think of these types of damage as being enemy-induced, but they could just as well be "self-induced," involving such mechanisms as logistic burdens, physics of failure, and reliability.

There is also temporary damage (e.g., electronic jamming) and even "positive" types of state changes that can cause restoration or even improvement to components (e.g., repair, replenishment, re-supply, etc.). Personnel are a good example of this. As "components," people may be degraded or incapable of working due to fatigue or injury; however, they can experience a change of state (caused by sleep, fluid replenishment, medical treatment, etc.) that may put them at a restored or enhanced condition [Hughes, 1995].

3.4.4 Categorizing Mission Utility. Because success is the goal of every mission, as we map to Level 4 it is a logical step to group the vectors according to the value of their possible outcomes: successful, unsuccessful, or ambiguous. In Figure 11, the successful vectors are enclosed in a circle, the unsuccessful are enclosed in a diamond, and the ambiguous are left unenclosed. Through backward inferencing, we can identify the capabilities at Level 3 that lead to successful outcomes and, equally important, those that do not. We can then derive the corresponding individual component states Level 2.

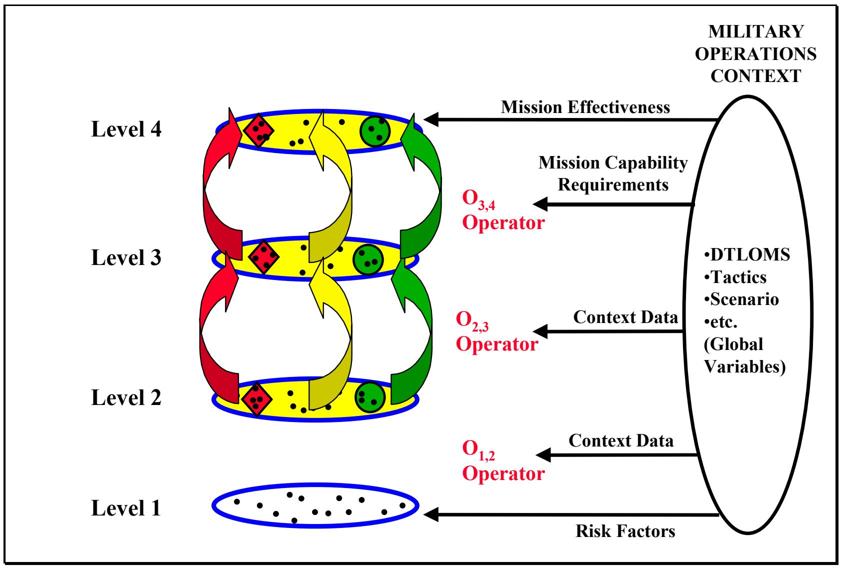


Figure 11. Mission-Based Utility.

Of course, this brings up a critical question: What is "success" in the first place? Although loss-exchange ratios (LER) have traditionally been the primary figure of merit for measuring effectiveness in various types of models, many missions today have requirements much different than those of D-Day, Iwo Jima, or even Desert Storm. As mentioned previously, the current trend is toward asymmetrical warfare, where success is increasingly “in the eye of the beholder.” And how does one measure success in nonlethal missions, such as terrorism prevention and peacekeeping/humanitarian relief efforts?

Obviously, this issue brings with it many unanswered questions. Perhaps this is why Level 4 has presented, and will continue to present, the most difficult challenges for the military community. But one thing is certain—close coordination is required between the scientist/engineer and the warfighter/operator to establish MoEs that are strongly tied to the objectives of the mission. See Section 4 for details of how the S-M-T approach is employed to capture the MOC.

3.4.5 Considering Costs and Benefits. Closely related to the idea of success is the idea of cost and benefit. After all, what purpose does a clear, valid, and specific MoE actually serve if the price to achieve success is too great or if the benefit from it is too small? These are vital concerns, especially in the current era of budgetary reallocation and organizational realignment.

Accordingly, the V/L Taxonomy is beginning to be explored in cost-benefit (C/B), cost as an independent variable (CAIV), analysis of alternatives (AoA), and other related studies [Krondak and Works, 2002]. We first capture benefits in Level 4 metrics and then use the top-down approach to go through “successful” capabilities at Level 3 and cost trade-off analyses of competing materiel costs at Level 2 [Nelson, 2000].

3.4.6 Extending to a System-of-Systems. Finally, we have thus far examined the abstraction primarily in terms of the states and transformations of independent systems and components. However, maybe the most important extension that the V/L Taxonomy can make (especially with regard to profound transformation such as FCS) involves the representation of an interconnected SoS.

Figure 12 shows that Level 2 can actually represent an aggregated set of component groupings from multiple systems (note the stack of “cards” on the left side). In effect, while each card (i.e., system) has its own four-level framework, the networked linkage occurs at Level 2. This Combined Level 2 can then map to Combined Level 3 capabilities and Combined Level 4 utility. And, once again, the success categories can be backward-inferred to Combined Level 3 capabilities and Combined Level 2 components. This construct means that one can take all of the components in all of the systems and network them together among all of the platforms in the SoS.

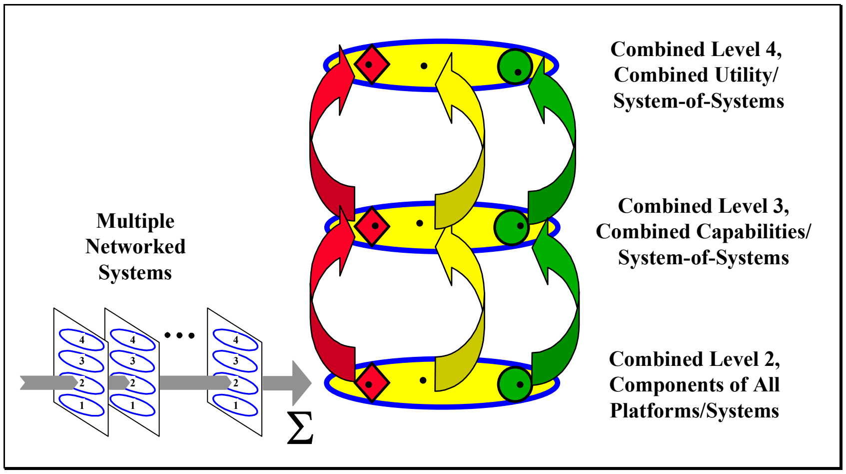


Figure 12. The Framework Applied to a System-of-Systems.

As mentioned previously, it is important to remember that the combination of utilities (MoEs), capabilities (MoPs), and components has a synergistic effect. This means that networking a group of components/capabilities can potentially multiply the overall effectiveness potential of a force working in concert to prosecute a given mission. Of course, the loss or degradation of networked components/capabilities can likewise increase the overall negative impact on the force. For example, the loss of communication abilities in one system unnecessarily degrades the communication abilities of other systems as well (i.e., a single two-way radio has little utility if it has no other radio with which to communicate).

Note also that in speaking about a future interconnected SoS, we often do so in terms of *platforms* and *vehicles* not too different from those that presently exist. In light of the expressed Defense Transformation, however, it is important for the community to be prepared to represent systems and interactions unlike any we know of today.

4. FORMALIZING LEVEL 4

4.1 It's All About the Mission. Now that we have presented the overall framework for discussing the mission-means linkage, it is appropriate to focus more closely at one particular part, perhaps the most important part, of the framework—the mission. In the end, combatant commanders, their component commanders, joint task force commanders, and all leaders responsible for military organizations know that their *raison d'etre* is to accomplish missions. These assigned missions may originate in the Joint Strategic Capabilities Plan (JSCP), National Command Authority (NCA) taskings, or treaty obligations in accordance with the principles and procedures found in the Unified Command Plan (UCP) or the Unified Action Armed Forces (UNAAF). At lower levels higher headquarters will assign tasks that then become the mission of that unit. As shown in Figure 13, for each assigned mission, one or more commands will be in a supported role while others will be in a supporting role.

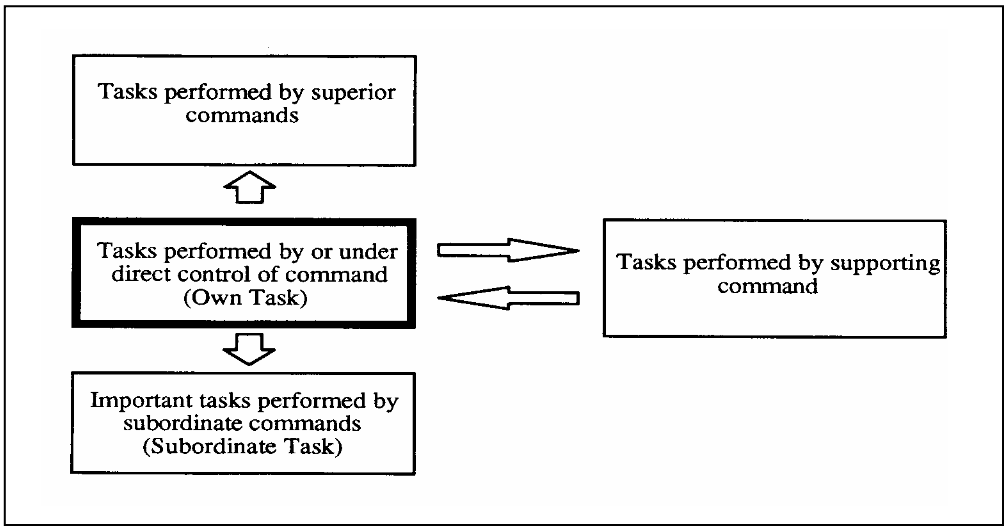


Figure 13. Task Relationships.

To understand "mission utility" as described previously, one needs to understand that *missions* are assigned to commanders and that the mission will include a number of *operations*. Operations are comprised of multiple *tasks*. Finally, operations and tasks are the fundamental building blocks of missions and are executed by specific units or organizations. It follows that mission utility is about one's ability to complete a task to a standard under a given set of conditions. The good news is that both the Joint community and the military Services have developed and structured a comprehensive, hierarchical listing of the tasks that can be performed by a military force. For joint forces this is the Universal Joint Task List (UJTL) and for the military Services these are their respective Service Task Lists (STLs). The following paragraphs focus on the UJTL but apply equally to the STLs. We now extend the V/L Taxonomy to employ this S-M-T methodology as the fundamental organizing principle for Level 4 Mission Utility representation.

The UJTL uses the levels of war (strategic, operational (OP), and tactical (TA)) as the hierarchy for task placement. The strategic level is further divided into strategic national (SN) and strategic theater (ST) due to the uniqueness of certain task categories (i.e., mobilization is only done at the national level). The UJTL also contains a common language of conditions that are used to describe the operational context in which tasks are performed. Lastly, the UJTL contains a menu of measures of performance (MOPs) for each task and these MOPs are used to develop standards of performance to meet mission requirements. The tasks contained in the UJTL, when associated with mission based conditions and standards, describe a required capability. And, this required capability can be directly linked to a materiel solution.

4.2 Types of Operations Templates. The UJTL is contained in CJCSM 3500.04C, 1 July 2002. This memorandum is " . . . designed as an interoperability tool for use by joint force commanders to communicate mission requirements." In addition to the 815 tasks, 352 conditions, and approximately 7,500 measures of performance in the UJTL, the memorandum describes the concept of "operations templates."

Operations templates provide a graphical depiction of the activities performed as part of a military operation. They depict activities and interactions among them. The activities represented in an operations template can include tasks performed by the commander and staff, tasks performed by other combatant commands or agencies (e.g., command-linked tasks), and tasks performed by subordinate commands or organizations (e.g., supporting tasks).

In general, operations templates represent operations and tasks at a single level of war. By extension, however, operations templates can be developed *across* levels of war (e.g., OP to TA or OP to ST to SN). The CJCSM recognizes three basic types of task characteristics and interactions among tasks that can be depicted in operational templates: temporal, spatial and informational. [Note: Kill chains involve/depend on each of these; however, the real organizing principle is cause/effect.]

Temporal templates depict whether a task occurs once, more than once, or continuously. Temporal views are actually sequential views wherein one task must be completed before another can start, one task might start at the same time as another task, or one task may have to be completed at the same time as another task. It is also possible to further amplify the sequential view by adding information on task duration as well as initiation, termination, and interrupt cues. Figure 14 is an example of a temporal operations template at the tactical level of war for key asset protection operations in Bosnia.

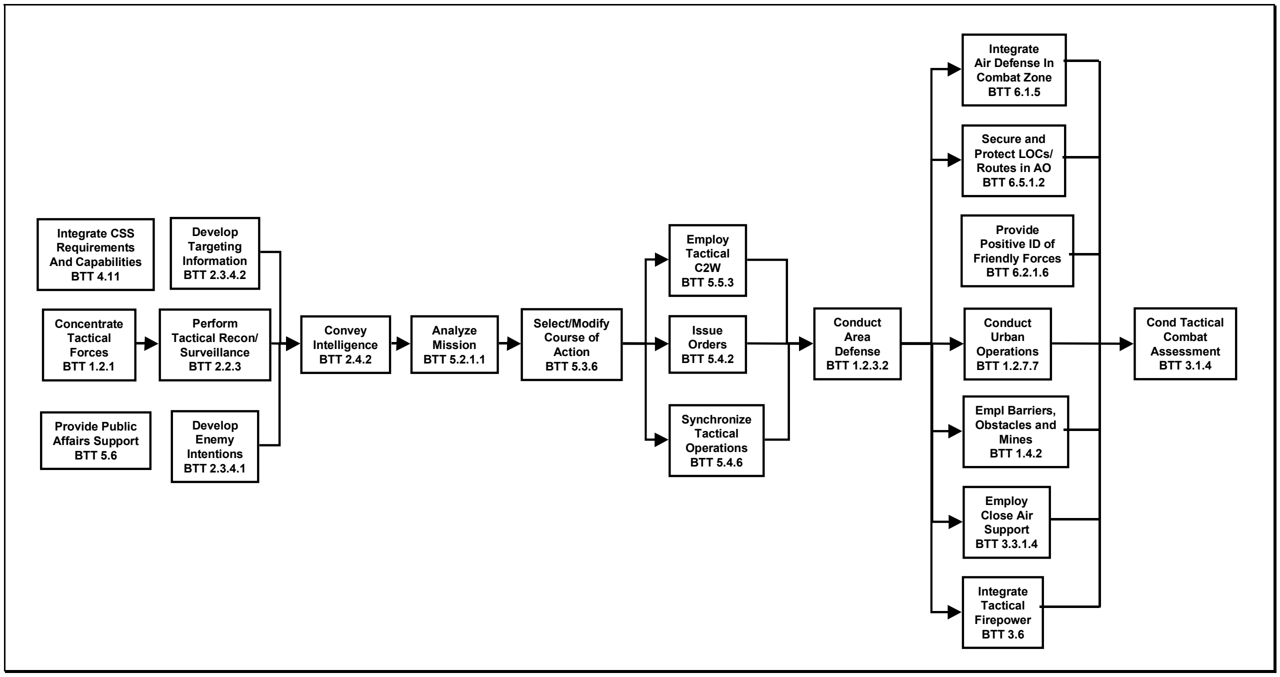


Figure 14. Temporal Operations Template (Bosnia).

Spatial templates essentially depict the location of task performance in geographical terms. This is especially important in support activities (i.e., communications, engineers, intelligence, logistics) where spatial considerations often determine the allocation of organizational resources. Spatial tasks may begin or be completed at a specific location or a task may be performed at multiple locations. Spatial interactions among tasks could include the need to perform a task in the same area as another task is being performed. Spatial task characteristics include multiple locations, point/route/area of performance, and changes in location over time. Continuing with Bosnia as an example, Figure 15 is a spatial template for key asset protection.

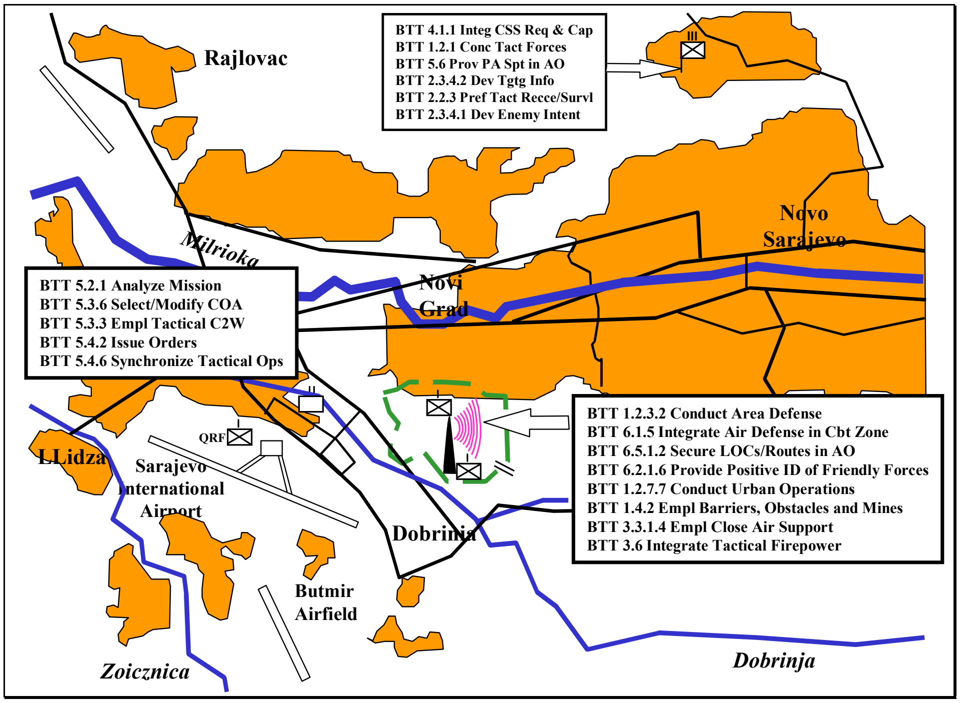


Figure 15. Spatial Operations Template (Bosnia).

Informational templates depict the need for information in order to perform tasks (e.g., task of selecting targets to attack requires intelligence input), the transformation of one type of information into other types during task performance, and the output of information after a task is performed (e.g., production of an Air Tasking Order). Informational interactions among tasks concern the input and output relationships among various tasks in an operation. Some tasks feed other tasks while other tasks receive information. By using an IDEF-like structure, one can depict these tasks and task relationships. Figure 16 is an example of an information template following once again a Bosnia key asset protection operation.

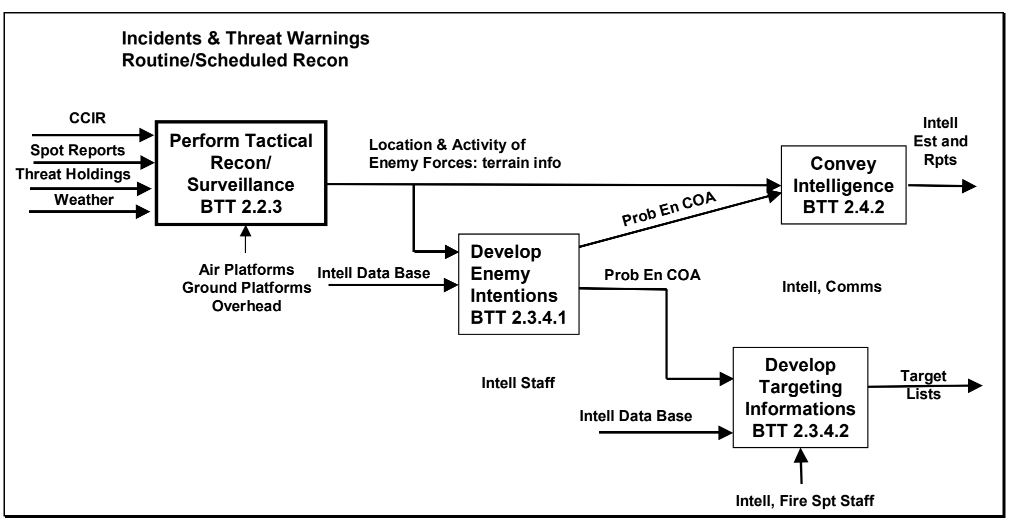


Figure 16. Informational Operations Template (Bosnia).

While CJCSM 3500.04C specifically addresses the previously described operations template types, a fourth type is a logical extension. This is a causal template. Here the focus is on task interactions in terms of constraints (e.g., how the performance of one task enables or constrains another task). This depiction allows for more analysis of direct or more complex relationships. Causal task characteristics focus on the dimensions of performance—performance measures—that affect other tasks. An example of a simple causal template for joint interdiction operations is at Figure 17.

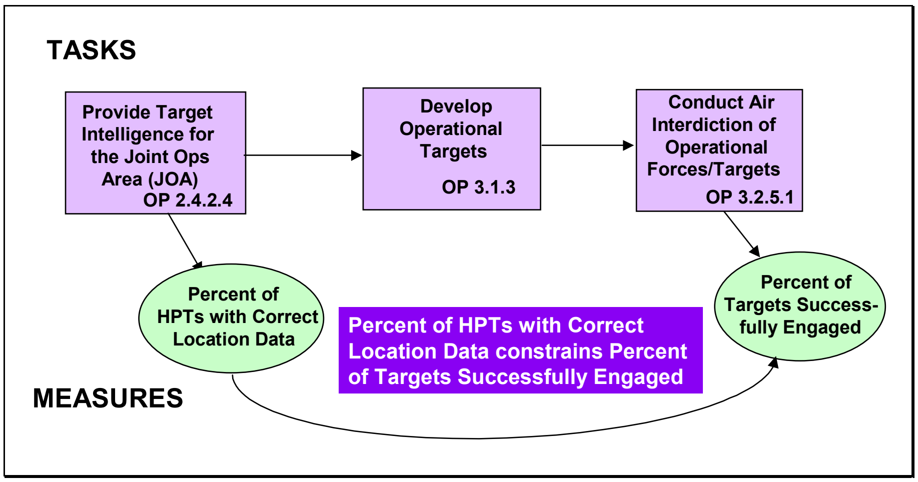


Figure 17. Causal Operations Template (Joint Interdiction).

4.3 Developing Operational Templates. Operations templates, regardless of type, are generally developed using a three-step process as follows:

- **Step 1: Conduct Mission Analysis**
  - Begin Estimate Process
  - Identify Type Mission/Operation

- **Step 2: Conduct Doctrine Analysis**
  - Review Applicable Doctrine
  - Identify Complementary Operations
  - Analyze Key Doctrine Planning Considerations

- **Step 3: Identify Joint Tasks**
  - Conduct Doctrine to Task Analysis
  - Divide Operations Templates/Group Major Tasks
  - Conduct Preliminary Sequencing
  - Refine Tasks and Sequences
  - Produce Generic Template
  - Adjust Template to Meet Special Requirements

The methodology used to build operations templates is very similar to that used in the Joint Operations and Planning System. Regardless of whether a commander is working within a deliberate planning cycle or in the crisis action system, all planning begins with receipt of a mission. For developing operations templates, the source of the mission tasking (Joint Strategic Capabilities Plan, NCA-directed, OPLAN, OPORDS, or treaties) is only a starting point. The key first step in the development process is Mission Analysis.

4.3.1 Step 1: Conduct Mission Analysis. Begin Estimate Process. Upon receipt of a mission, a commander and his staff begin the Estimate Process (see Joint Pub 3-0, Appendix B). The purpose of the process is to analyze and then restate the mission, examine the situation and courses of action, analyze opposing courses of action, compare own courses of action, and then decide. The decision translates the course of action selected into a concise statement of what the force, as a whole, is to do and explains, as appropriate, the when, where, how, and why. The resultant plan establishes the commander's intent, the concept of operations, and the initial tasks to the components of the force. These tasks in turn become the missions of the subordinate commands who likewise begin their own estimate.

*Identify Type Mission/Operation***.** Operations templates begin with type missions requiring type operations. Joint Publication 3-0, Doctrine for Joint Operations, and Joint Publication 3-07, Joint Doctrine for Military Operations Other Than War, provide examples of missions and operations. A commander must select a type operation that is best suited to the accomplishment of his assigned mission. An estimate can be conducted of this type operation to describe the "how" the operation is to be conducted. Nevertheless, the estimate must be complemented by a detailed analysis of doctrine that is the next step in the process.

4.3.2 Step 2: Conduct Doctrine Analysis. Review Applicable Doctrine. Military doctrine presents fundamental principles that guide the employment of forces. It represents authoritative guidance but is not intended to restrict the authority of joint force commanders or Service component commanders from organizing a force and executing a mission in a manner that the commander deems most appropriate to ensure unity of effort in the accomplishment of the overall mission. Joint Publication 1-01.1, Compendium of Joint Publications, provides a description of approved joint doctrinal publications, those under development and those proposed for development. The Joint Electronic Library (JEL) at http://www.dtic.mil/doctrine/jel/ is an on-line listing of approved joint publications, selected Service publications, and research papers addressing joint warfighting issues. However, joint doctrine does not yet exist for many areas and Service doctrine fills this void in the interim. In developing an operations template, joint doctrine should be the first resource used to understand the objectives and key concepts related to a specific operation.

Identify Complementary Operations. A military operation (e.g., joint interdiction) does not typically take place in isolation. Rather, different elements of the force will conduct operations at the same time designed to achieve military and political objectives. Doctrine will often address these complementary operations; e.g., those operations that impact on and are in turn impacted by the operation that is being templated. For example, for a joint interdiction operation, the key doctrinal publication is Joint Pub 3-03, *Doctrine for Joint Interdiction Operations.* This doctrine specifically provides guidance for "joint action to divert, disrupt, delay, or destroy the enemy's surface military potential before it can be used effectively against friendly forces" (underlining added). The highlighted words are in fact those objectives of interdiction operations that guide the commander's concept of the operation. The publication also identifies Counter Air, Special Operations, Psychological Operations (PSYOPS), Intelligence Collection and Reporting, Reconnaissance, Surveillance, and Target Acquisition (RSTA), Anti-surface Warfare, Anti-submarine Warfare, Command and Control Warfare (C2W), and Suppression of Enemy Air Defenses (SEAD) as complementary operations (see Figure 18).

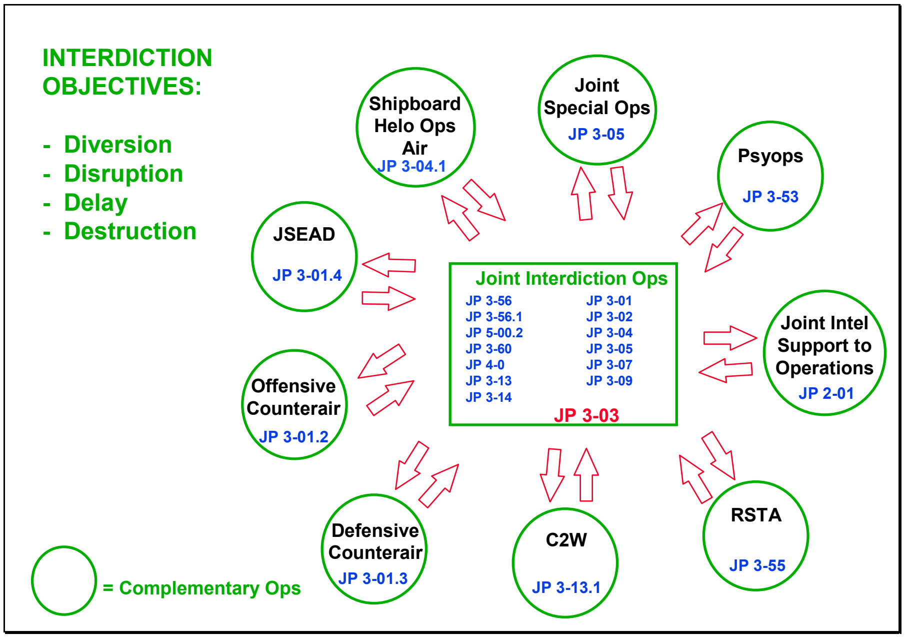


Figure 18. Joint Interdiction Operations.

Analyze Key Doctrine Planning Considerations. Doctrine provides guidance as to the steps in conducting a specific type of operation. In the interdiction example, doctrine describes the process for determining joint force interdiction objectives and level of effort. A doctrinal review of the process of target selection, prioritization, planning and coordination; apportionment and allocation of air assets; and how interdiction operations are conducted to support land and sea control operations supports the analysis of courses of action. It then becomes a matter of examining alternative courses of action to determine the most adequate, suitable and feasible. With a selected course of action, it is possible to turn to the next step in the methodology and identify the applicable joint tasks.

4.3.3 Step 3: Identify Joint Tasks. Conduct Doctrine to Task Analysis. The UJTL provides a menu of capabilities (mission-derived tasks with associated conditions and standards) that may be used by a joint force commander to accomplish an assigned mission. Thus, operators and planners can use the UJTL for understanding and integrating joint operations. The UJTL is organized by level of war, so that when examining joint operations, choosing a level of war is a first decision. Each level of war contains the full breadth of activities performed by a military force (e.g., operational level: Conduct Operational Movement and Maneuver, OP 1, Develop Operational Intelligence, Surveillance, and Reconnaissance, OP 2, Employ Operational

Firepower, OP 3, Provide Operational Logistics and Personnel Support, OP 4, Provide Operational Command and Control, OP 5, Provide Operational Force Protection, OP 6, Counter CBRNE Weapons in the Joint Operations Area, OP 7). While the level of war chosen will drive the key or critical tasks necessary for an operation, consideration must be given to tasks at the other levels of war, which should be considered as "linking" tasks. However, just identifying the tasks involved in an operation without specifying the interactions among them is not sufficient to support template development. Therefore, there is a need to develop ways to capture and represent the identity of tasks involved in conducting types of military operations and the interactions among the identified tasks. Using a Doctrine to Task Worksheet is a useful way to narrow the total potential tasks down to a more manageable number.

Having conducted a doctrine analysis in Step 2, it is possible to extract from the doctrine specific language related to the "how" of conducting operations. Likewise, it is possible to match doctrine phrasing with UJTL task descriptions. Often a key word or phrase (e.g., "support operations," "develop intelligence," "employ firepower") as it appears in doctrine will have a direct link into one or more UJTL tasks. Using joint interdiction as an example, Table 1 contains four instances in which doctrinal guidance is related to what needs to be done, who does it, and what planning considerations must be employed. At the operational level of war, one can focus on OP tasks in the UJTL under broad categories of OP 1 through OP 7. In the example, the first two doctrine extracts address "execution planning." The general UJTL category dealing with this subject is Exercise Operational Command and Control, OP 5. Using the key phrase, OP 5.3 and OP 5.8 appear relevant. The third doctrine extract also addresses "execution planning" but here, the doctrine shifts focus to a specific "means" toward implementing a process. This is a case where there is no specific cross walk to the UJTL but a generic task, *Integrate Joint Force Staff Augmentees,* OP 5.5.3, does apply. Note also that the keystone doctrine (JT Pub 3-03 refers to another publication (JP 5-00.2) which provides even more specific guidance on how to set up a joint targeting board. The last doctrine excerpt focuses on joint interdiction and fire support. There is a direct correlation to *Synchronize Operational Firepower*, OP 3.2.7.

The Doctrine to Task Worksheet may contain 40, 50, or more UJTL tasks. Thus, the next step is to further narrow the tasks.

Table 1. Doctrine to Task Worksheet.

Doctrinal Task (Ref)	UJTL Task	Performed By
"Detailed joint interdiction planning is based upon the JFC's joint campaign planning objectives." (JP 3-03, Chap. IV, Para. 3a)	"Restate the mission (includes assigned strategic military objectives), develop the concept of operations (operational movement and firepower), give clear statement of commander's initial intent (aim of entire campaign or major operation), and identify subordinates' tasks and objectives." Issue Commander's Estimate (OP 5.3.8)	Joint Force Commander
"JFCs typically conduct joint interdiction through component commanders." (JP 3-03, Chap. III, Para. 3-1(b))	"Make detailed plans, staff estimates, and decisions for implementing the geographic combatant commander's theater strategy." Prepare Plans and Orders (OP 5.3)	Joint Force Commander, Joint Operations Component Commander
"Typically, JFCs organize JTCBs . . . the JTCB reviews target organization and develops targeting guidance and priority recommendations for the JFC's approval." (JP 3-03, Chap. III, Para. 3-1(b))	"Transfer designated staff officers to the operational control of the joint force commander during execution of an operation." Integrate Joint Force Staff Augmentees (OP 5.5.3)	Components
"The JFC ultimately approves the integration of joint interdiction operations with execution of other joint force ops." (JP 3-03, Chap. II, Para. 2d)	"To synchronize operational firepower and integrate as necessary operational attacks on single or multiple operational targets at the decisive time and place." Synchronize Operational Firepower (OP 3.2.7)	Joint Force Air Comp Commander, Joint Targeting Coord. Board

Divide Operations Templates/Group Major Tasks. Operations typically take place in "stages" that represent "planning" and "execution." This allows a preliminary grouping of tasks -- based upon the Doctrine to Task Worksheet—to one or two digit level of resolution related to the planning functions (e.g., Provide Operational Intelligence, Surveillance, and reconnaissance, OP 2, Prepare Plans and Orders, OP 5.3, Command Subordinate Operational Forces, OP 5.4) and execution functions (e.g., Attack Operational Targets, OP 3.2, Provide Operational Force Protection, OP 6).

Conduct Preliminary Sequencing. The high-level grouping and a general sequence of tasks by stage can then be depicted along with some basic, temporal relationships (Figure 19).

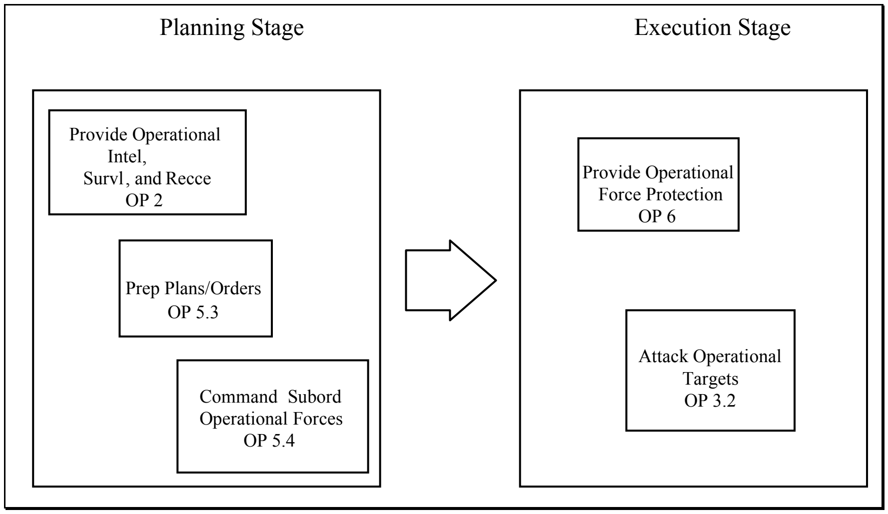


Figure 19. Preliminary Sequencing of Tasks for Interdiction Example.

Refine Tasks and Sequences. Selected tasks within stages can be taken to the three and four digit level and more precisely aligned with the concept of operation and doctrine. Again, in the example of joint interdiction, a major task (Direct and Lead Operational Forces, OP 5.4.1) has been assessed as critical by a commander and thus is further broken down into its sub-tasks (e.g., Approve Plans and Orders, OP 5.4.1, Issue Plans and Orders, OP 5.4.2, Issue Rules of Engagement, OP 5.4.3, and Synchronize and Integrate Operations, OP 5.4.4, and Coordinate/ Integrate Components, Theater, and Other Support, OP 5.4.5). In this case, a commander may feel that current rules of engagement contained in standing instructions provide sufficient latitude for the forces and may choose not to include this task in the operations template. The resulting portion of the template dealing with OP 5.4.1 could be as displayed in Figure 20.

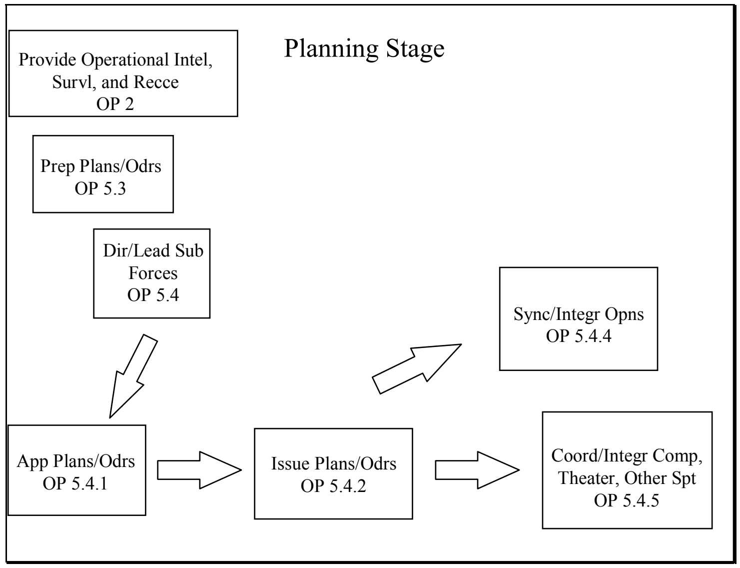


Figure 20. Task Refinement and Sequencing for Interdiction Example.

Produce Generic Template. The process of building the template continues until both the planning and execution stages accurately represent the notional commander's concept of the operation. A completed template for joint interdiction is shown in Figure 21. Note that in the execution stage all possible subordinate unit tasking contained in the notional concept of operations are included.

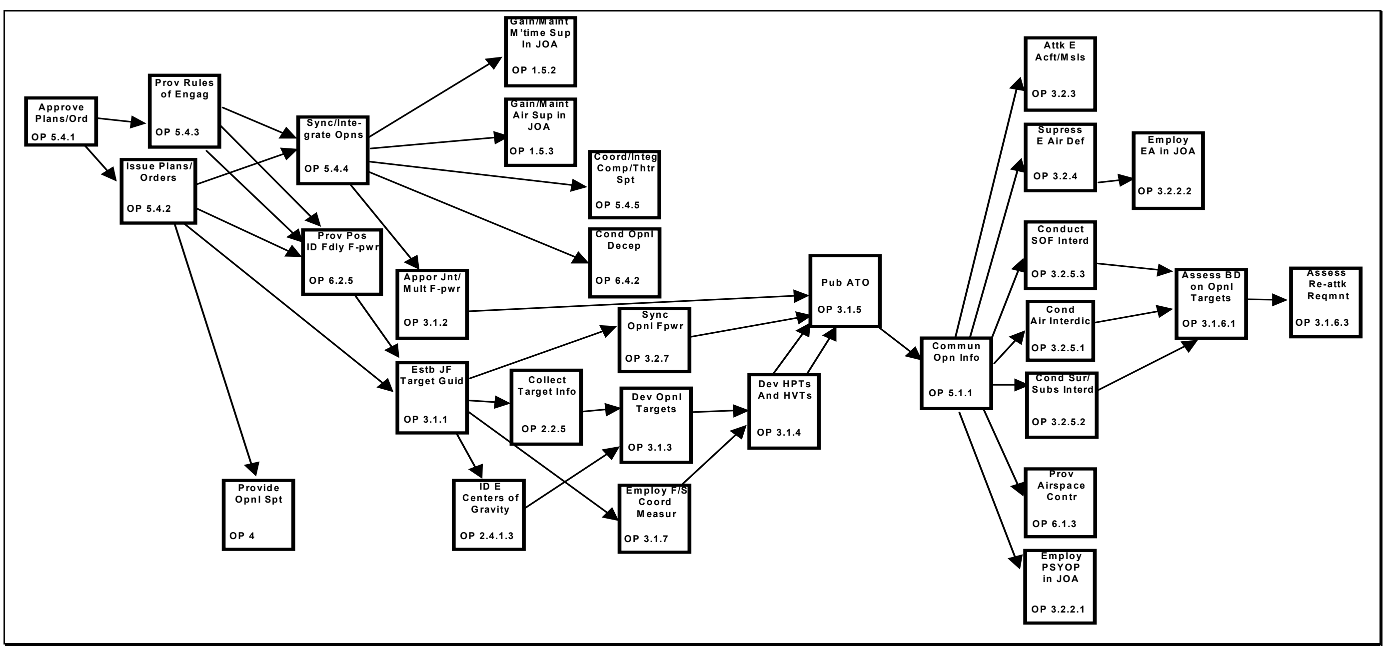
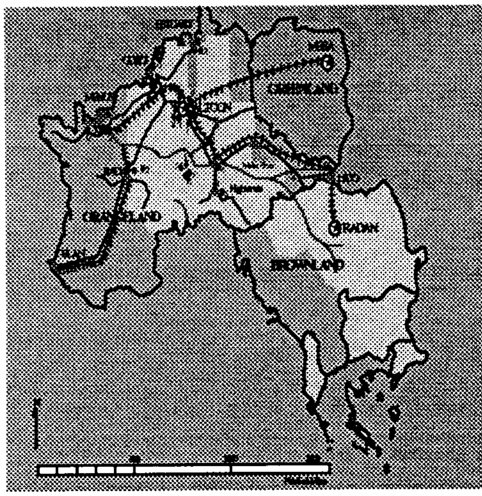


Figure 21. Joint Interdiction Operations Template.

Adjust Template to Meet Special Requirements. An operator or planner may wish to examine an individual task in a template more closely. This may require the specification of the means employed to perform the task in question. For example, in examining *Attack Operational Targets, OP 3.2,* a sample map and target matrix can be developed to define the who, what, and when of the operation (see Figure 22). In the target matrix Special Operations Forces are given the mission to attack the MENUS command and control center in Phase 1 of the overall operation. The template can be adjusted to show just those tasks related to his mission (e.g., delete *Conduct Air Interdiction of Operational Forces/Targets, OP 3.2.5.1, Attack Aircraft and Missiles (Offensive Counterair) (OCA), OP 3.2.3,* etc.).



Mission	Unit	Means of Attack	Time	Place of Attack
1	TBD	Sub-surface missile	Phase 1	Altoon South
2	TBD	Sub-surface missile	Phase 1	Altoon West
3	TBD	SOF	Phase 1	Menus
4	TBD	Fighter/Attack AC	Phase 1	Highland South
5	TBD	Fighter/Attack AC	Phase 2	Lido West
6	TBD	Fighter/Attack AC	Phase 2	Mder Bridge 1
7	TBD	Bombers	Phase 2	Mder Bridge 2
8	TBD	Sub-surface missile	Phase 1	Altoon South
9	TBD	Bombers	Phase 1	Altoon North
10	TBD	Bombers	Phase 1	Highland South
11	TBD	Fighter/Attack AC	Phase 2	Menus
12	TBD	Surface to Surface Msl	Phase 2	Mder Bridge 1
13	TBD	Surface to Surface Msl	Phase 2	Lido
14	TBD	Bombers	Phase 2	Reda East
15	TBD	Bombers	Phase 2	Menus

Figure 22. Map and Target Matrix to Support *Attack Operational Targets*, OP 3.2.

At this point one could shift to developing a spatial, informational or causal view. A *task decomposition* would essentially follow the same development sequence except Service doctrine, MTPs and TTPs would supplement joint doctrine in determining the sequencing of the tasks. Significantly, the latest UJTL includes Appendix A to Enclosure E, Suggested Operational Templates by UJTL Task, that identifies 60 operations types with candidate tasks identified for building complete operational templates. The U.S. Navy has developed complete operational templates for carrier battle group (CVBG) operations and the U.S. Army has sponsored the development of 12 reference mission sets for the FCS program.

4.4 Task Decomposition Example. As noted in the first section of this report and referenced as Level 4 in Figure 9, MoEs can, if applicable, originate at the Strategic National level and decompose down through the Strategic Theater, Operational, Tactical-Aggregate, and Tactical-Atomic levels until they eventually end with elemental tasks. Figure 23 is an example of a temporal operations template at the Tactical-Atomic level. A platoon leader is reacting to an ambush while conducting a mounted screening operation. The individual tasks are based upon MTPs, ARTEPs, and soldier tasks. Each task would have associated conditions and measures of performance (standards).

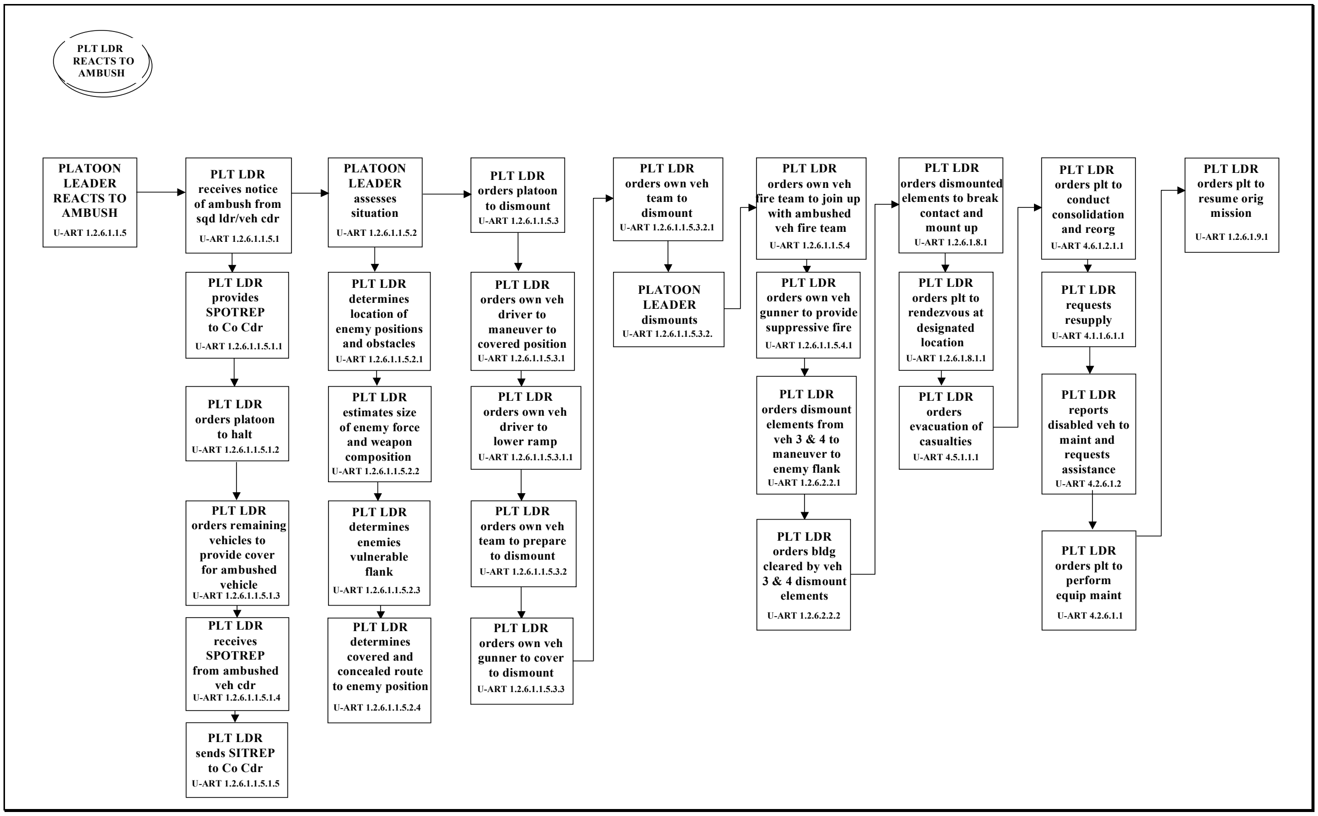


Figure 23. React to Ambush Decomposition (Platoon Leader).

One could further examine the linkage to materiel by examining whether the tasks to be performed are either enabled or constrained by the system or SoS providing support to the platoon leader accomplishing his mission. In this example, the platoon leader has four Bradley Fighting Vehicles (BFVs). If we select five tasks beginning with the “Platoon Leader assesses situation” and ending with the “Platoon Leader determines covered and concealed route to enemy position” and array them against his C4ISR means on board the BFV, then it is possible to evaluate whether the platoon leader can or cannot do his mission in terms of equipment capability (Figure 24).

	Command	Control	Communications	Computers	Intelligence	Surveillance	Recon
Platoon Leader Assesses Situation							
Platoon Leader Determines Enemy's Vulnerable Flank							
Platoon Leader Determines Covered and Concealed Route to Enemy Position							
Plt Ldr Orders Own Veh Drvr To Maneuver To Covered Position							
Plt Ldr Orders Platoon to Conduct Consolidation and Reorganization							

Figure 24. BFV C4ISR Matrix (Platoon Leader).

Figure 25 is an example of the equipment on the BFV that is considered “Intelligence.” Thus, as the platoon leader attempts to “ . . . determine Enemy’s vulnerable flank,” he would employ these on-board systems.

	Command	Control	Communications	Computers	Intelligence	Surveillance	Recon
Platoon Leader Assesses Situation		X	X	X	X	X	X
Platoon Leader Determines Enemy's Vulnerable Flank			X	X	X		X
Platoon Leader Determines Covered and Concealed R Enemy Posit							
Plt Ldr Ord Drvr To Ma Covered Pos							
Plt Ldr Orders Platoon to Conduct Consolidation and Reorganization	X	X	X				

- ENHANCED POSITION LOCATION REPORTING SYSTEM (EPLRS)
- POS/NAV WITH INERTIAL GPS (PLGR) SYSTEMS
- INTEGRATED COMBAT COMMAND AND CONTROL VIA FBCB2 SOFTWARE RUNNING IN AN APPLIQUE+ CPU
- COMMANDER’S TACTICAL DISPLAY WITH MAPS/GRAPHICS
- SQUAD TACTICAL DISPLAY/FLIR MONITOR
- MASS STORAGE PROVIDED IN THE APPLIQUE+ CPU

Figure 25. BFV Intelligence Equipment Matrix.

The platoon leader would further identify criteria and measures to assess his capability to use each system to do his task (Figure 26). As discussed previously, battlefield damage could degrade (cause a state change in) his equipment, thus impacting his ability to meet the standards set by his commander.

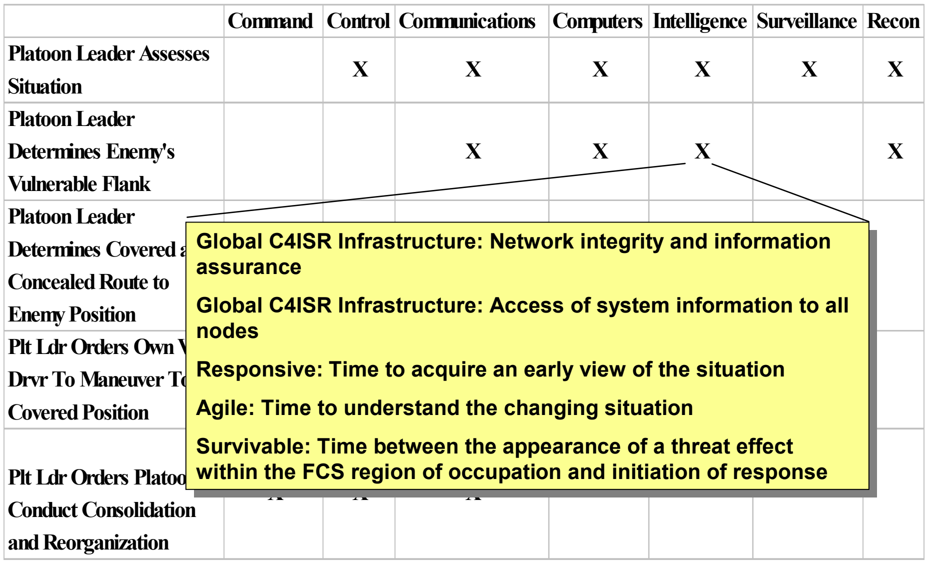


Figure 26. BFV Intelligence Measures of Effectiveness Matrix.

The process of decomposition could be iterated for the vehicle driver, gunner, and individual squad members. The whole of this approach should produce a more accurate representation of the real mission utility. The use of operations templates in their various forms as well as task decomposition techniques leverage the common semantics and syntax of the UJTL and the Service Tasks Lists and offer insights into the Level 3 to Level 4 transformations.

5. THE FRAMEWORK BUILD-DOWN

The framework is applied by a build-down ***synthesis*** process from top to bottom in Figure 27 followed by a bottom-up ***employment*** when executing the representation. As shown in Figure 28, the synthesis build-down is the planning and decision-making component of the framework, and the employment of the resulting decisions and plans is the execution and adjudication component of the framework.

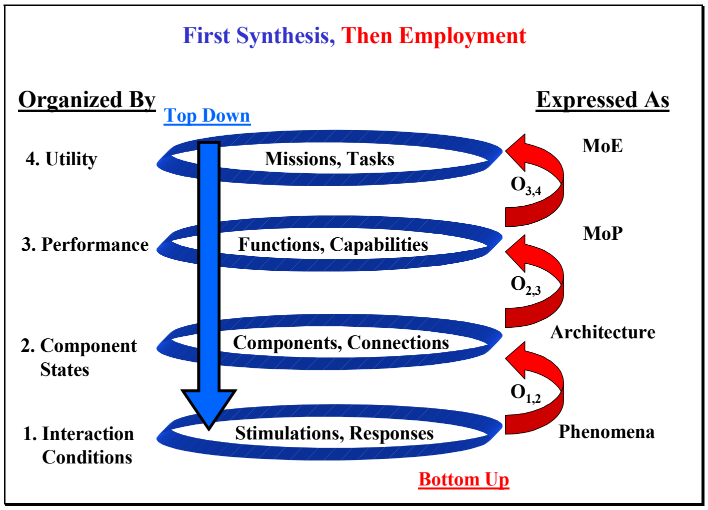


Figure 27. The Synthesis and Employment Processes.

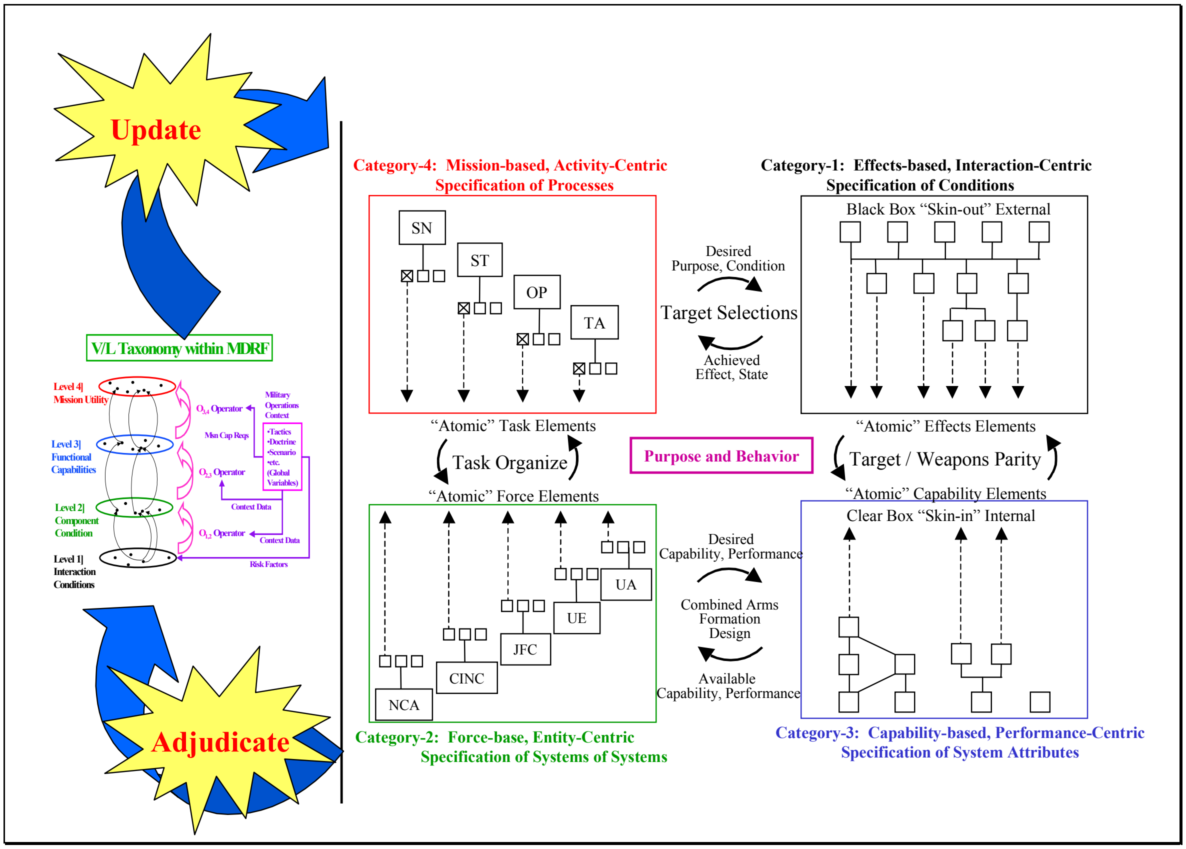


Figure 28. Build-Down Planning and Decision-Making Representation.

The execution and adjudication component is composed of the four levels and three operators previously discussed. The corresponding elements of the planning and decision-making component are Purpose, four Categories, and Behavior, which are defined as follows:

- **Purpose:** the explicitly stated purpose of the mission; the desired outcomes and end-states.

- **Category-I:** the effects-based, interaction-centric specification of conditions (under which activities affect entities), which the military operations is intended to achieve.

- **Category-II:** the forces-based, entity-centric specification of the SoS. Category II captures the description, entity relationships, organization, and hierarchical decomposition of physical environment, materiel, units, and personnel.

- **Category-III:** the capability-based, performance-centric specification of systems attributes (of entities conducting activities).

- **Category-IV:** the mission-based, activity-centric specification of processes. Category-IV captures the description, functional relationships, organization, and hierarchical decomposition of missions, operations, tasks, and processes.

- **Behavior:** the context-based, behavior-centered specification of the tactics, techniques, and procedures (TTPs) and physical phenomena that constitute how the entities perform the interacting activities.

The build-down process is iterative and recursive. In each iteration, the planner and decision maker at each layer of the decomposition receive a purpose for the mission, resources to achieve the purpose, and constraints on the means and outcomes from a superior in the layer above, plans and executes operations with peer organizations in the same layer, and delegates remaining purpose as tasks and means to the next subordinate layer.

Again, quoting Antoine Lavoisier [Bartlett and Kaplan 1992]:

> "I shall therefore content myself with saying that if, by the term elements, we mean to express the simple and indivisible molecules that compose bodies, it is probable that we know nothing about them; but if, on the contrary, we express by the term elements or principles of bodies the idea of the last point reached by analysis, all substances that we have not yet been able to decompose by any means are elements to us."

When "atomic" task-elements, force-elements, capability-elements, and interaction-elements are task-organized to achieve a portion of the purpose, behavior is selected, the synthesis process is complete for that portion of the purpose, and an instance of the planned operations (represented by four categories, purpose, and behavior) is mapped onto the employment component to be executed and adjudicated using the four levels and three operators of the extended V/L Taxonomy.

5.1 Illustration of the Process. The critical first step in the process is to establish the operational context that is to be represented by the scenario. For illustration purposes, we selected a vignette from an actual scenario describing a strategic situation that ultimately drives the need to plan and conduct a deep attack at the tactical level (Figure 29).

Situation

- **Legitimate, pro-Western Government of Country of Interest is overthrown by radical elements and forced into exile.**
- **Radical elements, supported by a neighboring Hostile Country, form a new government, seek to force recognition by UN as legitimate government.**
- **Majority of Country of Interest conventional military forces are loyal to new government.**
- **The United States and its coalition partners believe national interests and regional stability are threatened. They take military action to deter Hostile Country involvement in Country of Interest, to remove radical elements from power, restore legitimate, pro-western government, and to stabilize region and protect US and coalition vital interests.**
- **Coalition forces have commenced offensive ground operations in Country of Interest to defeat conventional forces loyal to radical government and isolate radical government leadership inside Capital of Country of Interest.**
- **Conventional forces from Hostile Country to the south, have begun massing on the border with Country of Interest.**
- **The Joint Force Land Component Commander intends to prevent Hostile Country from reaching Capital of Country of Interest by blocking access to the main north/south road into Capital. He anticipates need to delay movement of Hostile Country forces north long enough for the Heavy Division to occupy defensive positions astride main north/south road.**

Figure 29. Situational Vignette.

Figure 30 illustrates the use of the synthesis component of the framework to perform the top-down analysis for each of the four categories. Starting with **Category-I Effects**, we identify a set of desired effects at each level from Strategic National to Tactical. We know that the strategic effect desired is to set the conditions to restore the legitimate government to power. The responsibility of achieving this effect is given to the combatant commander responsible for the geographic area depicted in this vignette (**Category-II Forces**). The combatant command headquarters provides the strategic-level capabilities (**Category-III Capability**) to develop the strategy and perform the detailed planning necessary to implement the strategy in order to achieve the desired strategic effect. Category-III includes a sample of some of the broad categories of capabilities at each level, such as maneuver, fires, and intelligence that are needed to achieve the desired effects for that level. The desired effects can be captured in the "why" portion of the mission statement, which leads to **Category-IV Activities** for conduct of the strategy-to-mission-to-task decomposition process discussed earlier in the paper. In this example, Category-IV depicts a sample of some of the key tasks that must be performed at each level in order to achieve the desired effects that contribute to mission accomplishment at the highest level.

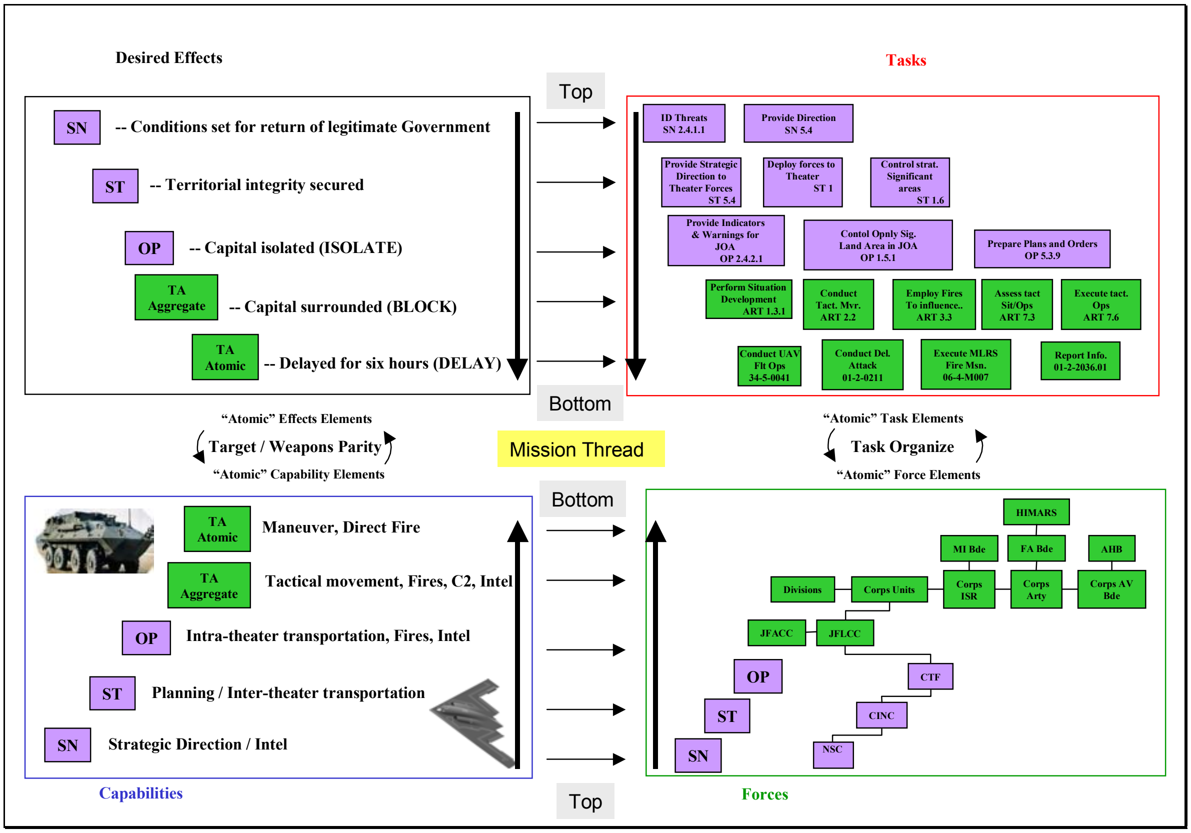


Figure 30. Illustration of the Synthesis Component.

We begin with an explicit statement of Purpose. Then by using the four main categories of the framework provided by the planning and decision-making representation, we can **derive** the Behavior in Figure 31**.** In operational terms, this specification of Behavior begins with the mission statement, containing the top-level description of **who**, **what** type of action (attack, defend, etc.), **when** will the action begin, and—most importantly—**why** the action is being undertaken (i.e., the purpose).

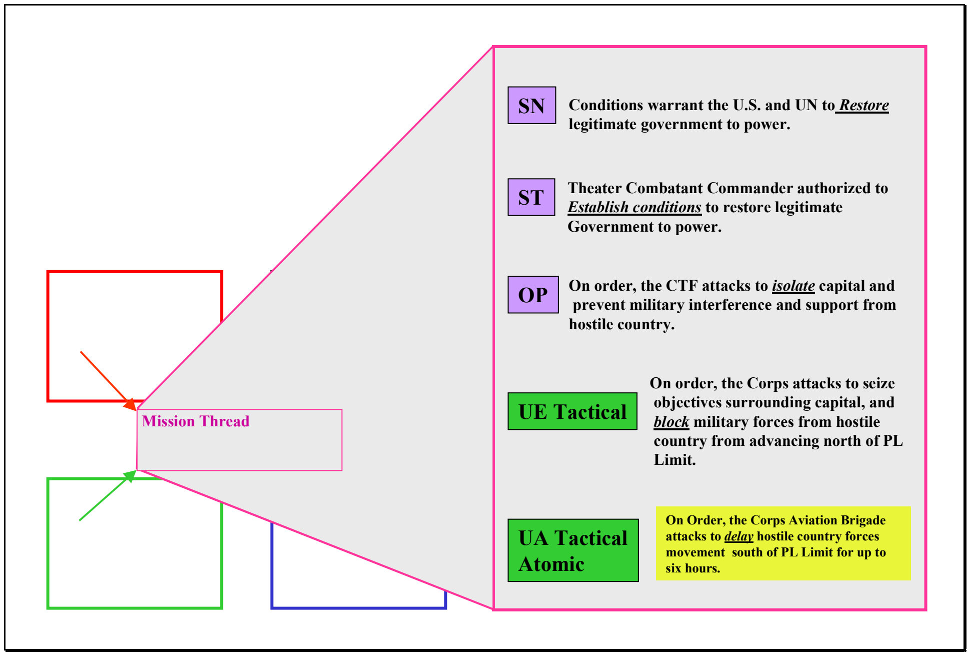


Figure 31. Illustration of Purpose.

"How" the mission is executed can be described by depicting the complex combination of operations and individual tasks, which must be performed in a logical and doctrinally correct sequence. One of the challenges inherent in this process is the management of the proliferation of tasks that are generated during task decomposition. When these tasks are strung together to replicate behavior as represented previously, the number and complex relationship of the tasks to each other and time can be overwhelming. For example, Figure 32 represents an early attempt to graphically represent the string of tasks required to conduct the deep attack in this example.

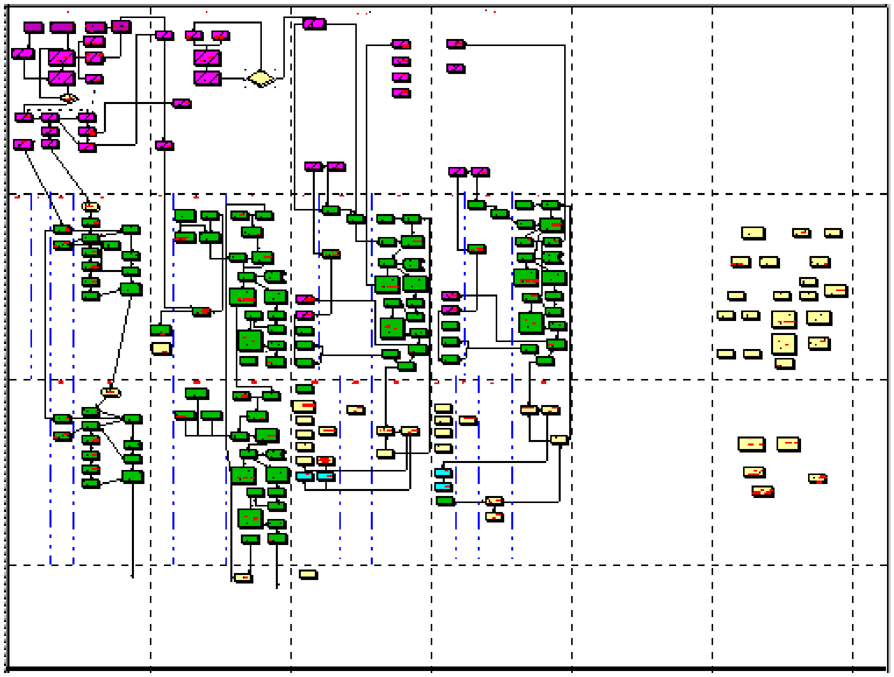


Figure 32. Mission Thread of Tasks.

To help resolve this issue in situations where individual tasks are habitually performed in sequence as part of a process, we have formalized the sequence in the form of a process group (Figure 33) [Haddix 2002]. Some tasks (passage of lines, for example) may stand alone and be represented as a process because they are not habitually connected to other individual tasks. Process groups facilitate the ability to model the derived behavior without having to resort to complex wiring charts of individual tasks such as the one in Figure 32. In fact, the entire derived specification can be modeled as one larger process group that fits into the larger scenario. The modularity of process groups facilitates editing the model and depicting processes that are performed continuously or iteratively.

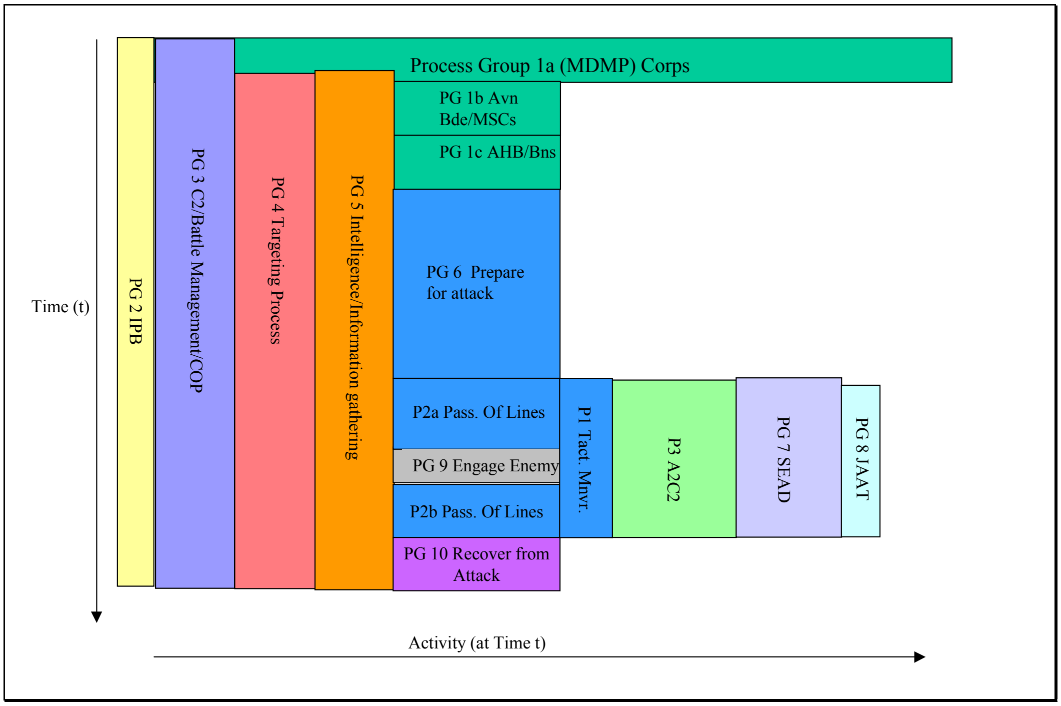


Figure 33. Deep Attack Process Group.

Another advantage of the process group construct is the ability to save process groups in the form of Formalized Data Products containing the process group description, tasks included in the process group, and a detailed description of their event or time-driven relationship to each other. These saved process groups now become modular data packets that can be used as building blocks in the rapid development of "machine-parsable" scenarios or vignettes.

As shown in Figure 34, the process group construct allows us to illustrate the major components (depicted as subordinate processes or process groups) of the specification of behavior at a glance as well as the relationship of the major components to each other over time and to the desired effect—or MoE (the why)—for the top-level mission statement.

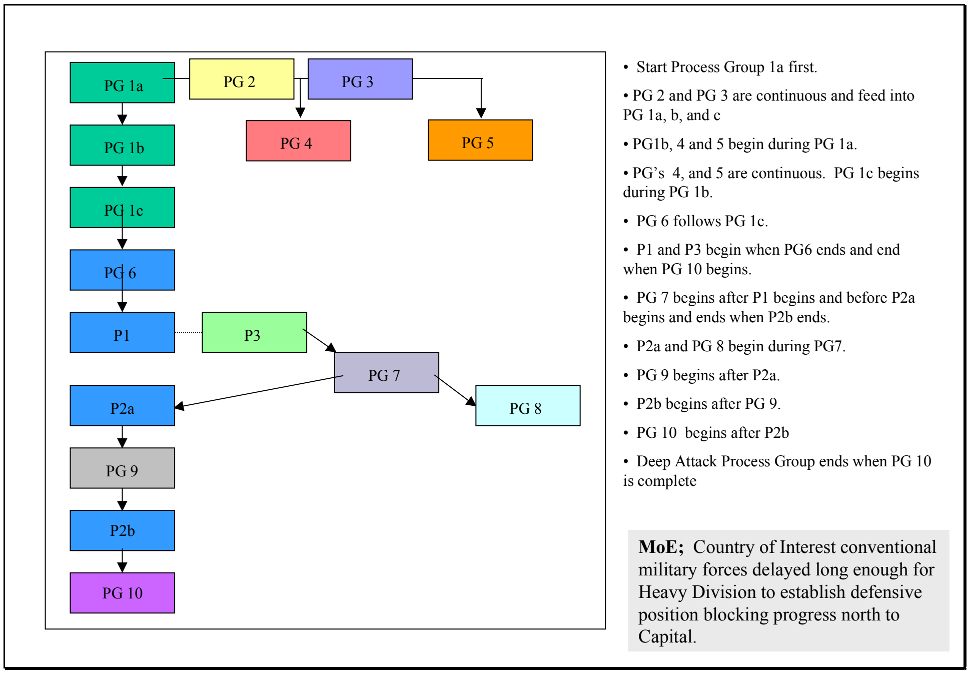


Figure 34. Process Group Relationship.

As seen in Figure 35, further breaking down each process group of the overall process group into their component tasks facilitates the construction of task-based fault trees that are essential to achieving the stated aim of relating performance to effectiveness by mapping MoPs to MoEs. By measuring the execution of each task and subordinate process group against their associated MoPs, we ultimately reach the point where we can trace the performance of each subordinate process group to the overall deep attack mission process group's success or failure in achieving its associated MoE.

Process Group 3 (C2/Battle Management)

MoP: Deep Attack planning, coordination and execution is not adversely affected by inaccurate or outdated information concerning environmental conditions, friendly unit location and status or reported enemy activity, location, strength and intentio (Y/N)				
Sequence #	Task #	Task Title	**MoP**	Unit
3.8	ART 7.3.2.3	Conduct Risk Management	1) No offensive tasks executed that exceed maximum residual risk established by commander. 2) No casualties as a result of failure to manage risk.	DOCC, C/S, CG, AVN Bde, AHB
3.9	ART 7.6.3	Make adjustments to resources, concept of ops or mission	Adjustments are made to exploit opportunities or resolve problems occurring during execution effectively. (Y/N)	DOCC, CG
3.10a	ART 7.5.4	Revise and refine the plan	Revision and refinements to the plan enhance accomplishment of the mission (Y/N)	DOCC, Current Ops, Avn Bde, AHB
3.10b	ART 7.6.1.2	Adjust Graphic Control Measures	1) Adjustment of graphic control measures reflected changes in METT-TC and was timely and effective (Y/N). 2) Lag time between operations and adjustment of graphic control measures. (< 5 minutes)	DOCC, Current Ops, Avn Bde, AHB, FSE

Figure 35. Subordinate Process Group.

The synthesis component of the framework supports the process of mapping MoPs to MoEs for the process group representing the derived specification of behavior by mapping the process group from the synthesis component of the framework to the execution component. Figure 36 provides a graphic description of this mapping. Level 1 represents the beginning conditions of the forces (units, personnel, and material) needed to execute the required tasks. For this thread, the key systems represented are attack helicopters and High-Mobility Artillery Rocket Systems (HIMARS). Level 2 represents the state of the units and equipment following interactions with friendly units, enemy units, and the environment. This state would be reflected in the reported Common Operational Picture (COP) for blue and red forces. Level 3 represents the assessed capability of the selected units by Battlefield Operating System (BOS). This level is derived from commander assessments based on the reported COPs. Level 4 represents the effects achieved as a result of executing the mission thread. Effects achieved are compared to effects desired as represented in the MoE and are derived from factors such as enemy reaction to the actions taken, risk assessment results that may have led to mission abort, and finally task performance as measured by the associated MoP.

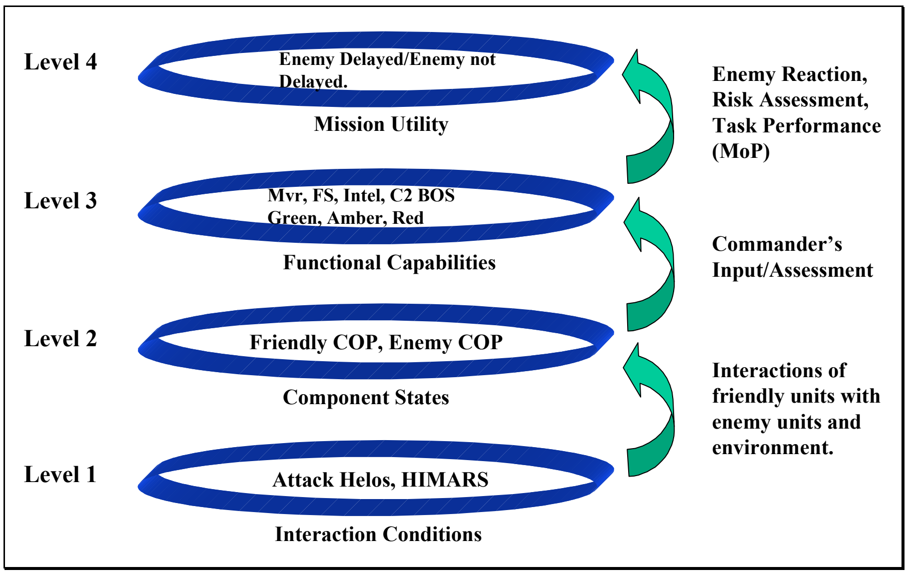


Figure 36. Mapping Behavior to the V/L Taxonomy.

The deep attack process group that was just described and tracked through the framework represents one piece in the larger puzzle of the overall scenario. By assessing the results of execution of the deep attack against the specified MoE, we can determine the contribution that this particular instance of the deep attack makes to overall mission utility. To further illustrate the point, we begin this example with Figure 37 at the lowest level by seeing how the successful performance (as measured by a MoP) of a lower-level task of the Suppression of Enemy Air Defense (SEAD) process group contributed to the ability to achieve the deep attack MoE.

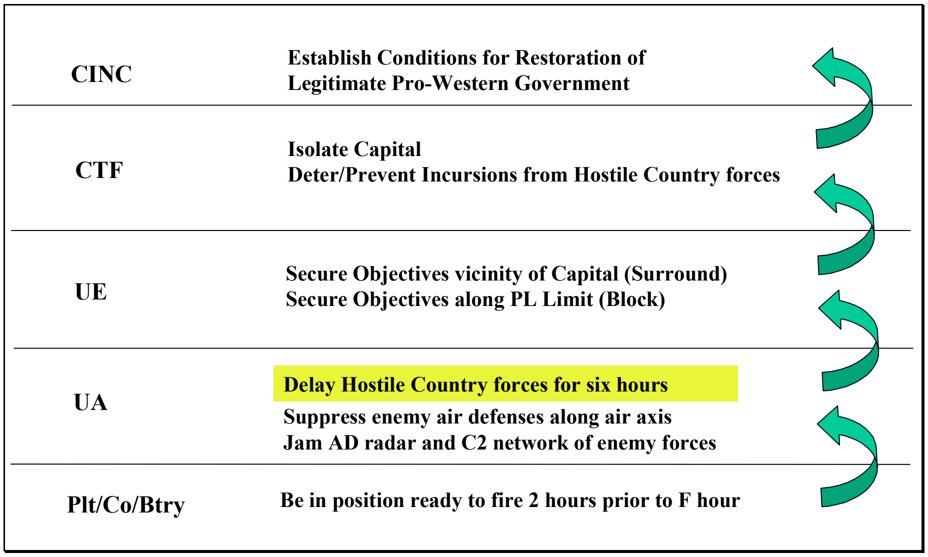


Figure 37. Mapping Effects to Utility.

Because the HIMARS Battery was in position and ready to fire 2 hours prior to F hour, it was able to fire on and suppress enemy air defenses along the deep attack ingress and egress routes. As a result, the attack helicopters were not disrupted or prevented from reaching the engagement area and engaging the hostile country forces, forcing them to stop, recover, and regroup before attempting to continue moving toward the capital.

The delay in their movement allowed enough time for ground maneuver forces to secure objectives along PL Limit and effectively block hostile country forces from reaching the capital. This in turn allowed other forces to surround the capital, contributing to the ability of the CTF to isolate the capital, which is one of the key conditions required by the combatant commander to restore the legitimate government to power.

As Figure 38 illustrates, the impact of failure can also be traced. Failure to achieve the desired effect results in an undesirable set of conditions that can potentially start a chain of events leading to mission failure unless the situation is recognized and action is taken in the form of a new course of action to establish more favorable conditions.

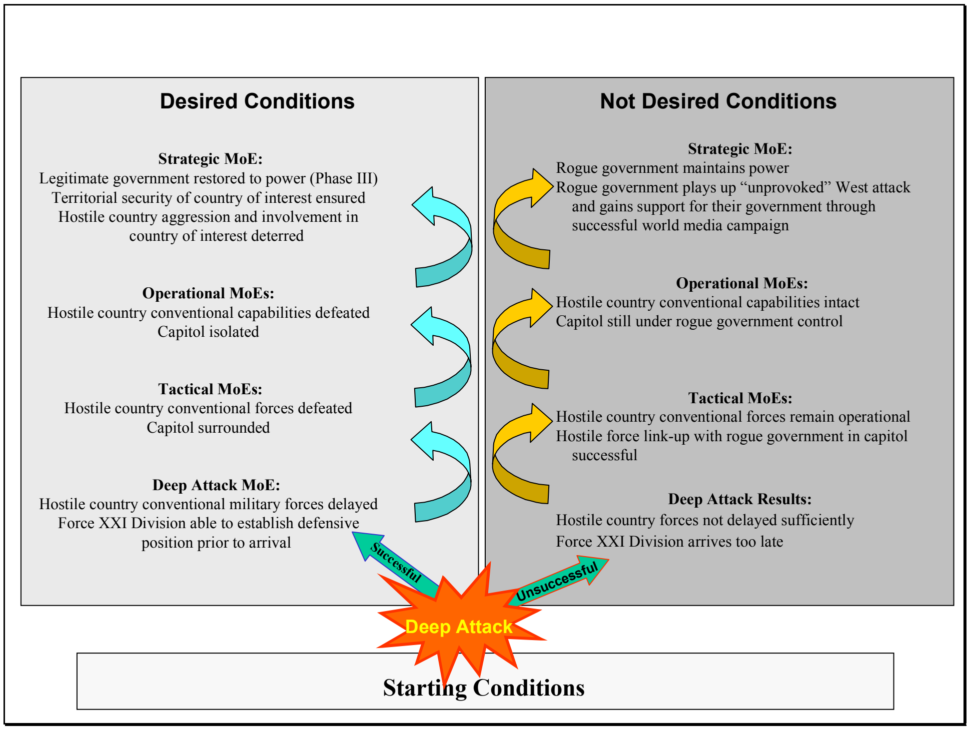


Figure 38. Relating MoPs to MoEs.

In summary, the extended taxonomy provides the necessary rigor to ensure the ability to successfully define and execute a **process** that can be used in the production and maintenance of multiple scenarios that exercise the range of operations, forces, and environments relevant to the Army. Scenarios developed using this process will ultimately support the full range of Advanced Concepts and Requirements (ACR); Research, Development, and Acquisition (RDA); and Training, Exercises, and Military Operations (TEMO) requirements for simulation by providing operational customers and simulation developers with man-readable and machine-parsable scenario products in much less time than is currently required. Just as importantly, the scenarios developed using this methodology will facilitate the ability to conduct effects-based analysis by mapping MoPs to MoEs and relating them to overall mission utility.

6. OTHER RELATED EFFORTS

The framework presented here has also been presented at numerous symposia and has received wide interest in its application. At the 5th Annual Testing and Training Symposium and Exhibition held in Orlando, FL, on August 19–22, 2002, a session entitled "Modeling and Simulation: Connecting the Dots Between the Testing and Training Communities" pulled together the five "Concepts in Practice" from across the Services. Presentations included:

- "Future Concept Systems: An Application of the Weapon System Analysis Framework," by Ellen M. Purdy, SMART Strategic Planning Future Combat Systems Program Management Office.
- "The Joint Training System (JTS)," by Harry Rothmann, Dynamics Research Corporation.
- "Task Force Excel (TFE) Quadrant 1 Process: Defining Performance Requirements and Standards," by Dennis Duke, NAVAIR.
- "Mission-Based Test and Evaluation with Focus on C3 Test Driver," by William J. Krondak, TRADOC Analysis Center.
- "Air Operation Center (AOC) Integrated/Executable Architecture Model," by LTC Emily Andrew, Electronic Systems Center, U.S. Air Force Research Laboratory.

7. SUMMARY

In the current state-of-the-practice, there are five critical deficiencies that the proposed representation framework seeks to address:

- **The lack of effective communication between the warfighter and the systems engineer is a key barrier to transformation.** The *lingua franca* of the warfighter is mission-based measures of combat utility in the execution of military operations and tasks, whereas the *lingua franca* of the systems engineer is component-based measures of physical capability when employed in an operational environment. The representation framework presented here provides a disciplined procedure for explicitly deriving the transformations and mappings from required activity to resulting interactions, force state changes produced by interaction, performance available given force state, capability of available performance to support activity outcome – all arising from the Behavior associated with specific Task-Organized Mission.

- **The current requirements elicitation procedures generate voluminous wish lists that no mortal could consume in a single lifetime, that has limited or no internal consistency and completeness enforcement, and that is either too vague to specify the requirement or so detailed that it obscures the fundamental need.** This framework makes the statement of the transformation concept executable. Executability ensures that sufficient detail, consistency, and completeness have been captured. Interaction rapidly and effectively communicates what the concept is (and is not) to stakeholders both within and across domains.

- **The mission-based operational concepts and task details are implicit information often known only to the individual participating in the wargame or the analysts that actually generate the simulation script.** In the emerging M&S state-of-the-art, the mission-based operational concepts and task details are embedded as (often hard-coded) behaviors in force-based class hierarchies. These emerging M&S capabilities can readily represent and compare new or alternative "players" capabilities (by substituting individual players) but cannot readily adapt to new or alternative "playbooks" (which cut across all players). This framework explicitly **separates** means-centric content (the "players") and mission-centric content (the "playbook"), **selects** (rather than embeds) behavior when forces and activities are task-organized within a mission, and then represents interaction and performance as **dynamic results** of task-organized behavior.

- **Traditional developmental testing and operational testing record physically observable parameters (meters, kilograms, seconds) as measures of system performance.** In most cases, there is no objective, unambiguous connection between the objective measures of performance and the more subjective warfighting measures of success. In most cases, the MoPs are loosely related to attrition-centric MoEs, such as loss exchange ratios. The framework presented here addresses this deficiency by providing disciplined procedure for quantitatively linking observed performance to task-based measures of mission success under realistic combat conditions.

- **Traditional logistics and sustainment studies do not sufficiently address battle damage repair and thus cannot address the full logistics/sustainment requirements in support of missions.** One of the major tenets of Defense Transformation is reducing the logistics footprint. The framework, by defining Level 2 component states, provides a mechanism to address battle damage effects in addition to the traditional reliability failures to generate a complete logistics/sustainment footprint.

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