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# Integrated Battle Command Program: Decision Support Tools for Planning and Conducting Unified Action Campaigns in Complex Contingencies


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## Abstract

The Defense Advanced Research Projects Agency and the U.S. Joint Forces Command are developing transformational technologies to enhance the capability of military commanders and their civilian counterparts to plan and conduct effects-based campaigns. It is expected that, in future conflicts, Commanders and non-military leaders will need to simultaneously apply all means of National power, both military and non-military, to achieve a coherent set of military and non-military effects against the adversary. The commander and leaders will need to act in multiple domains concurrently and conduct integrated and interdependent actions.

The campaign plan may cover several years of effort and will consist of the objectives and actions necessary along multiple lines of effort; it will be characterized by extensive, complex interdependencies. This program is developing a tool to help construct and manage such plans and manage the large array of interdependencies.

Commanders and leaders must also understand the adversary's various political, military (air, land and sea; regular or irregular), economic, social, information distribution, infrastructure, etc. systems and the complex interactions amongst these systems. The program is developing an analytical tool to help evaluate the benefits and consequences of alternative actions. Collectively, the tools will aid commanders in collaboratively visualizing the complex interdependencies in plans and the connectivity between alternative actions and effects.

Two contractor teams led by BAE Systems and Lockheed Martin have developed the first version of these tools and have conducted experiments to verify and quantify the contribution of the tools when employed by command center personnel (military and civilian) in realistic (albeit simulated) environments.

# 1. Introduction

The Defense Advanced Research Projects Agency (DARPA) and the U.S. Joint Forces Command (JFCOM) are embarked on a project to develop decision aids to support commanders and non-military leaders in conducting future coalition-oriented, multi-agency, effects-based campaigns through superior planning and management of integrated and interdependent multiple lines of effort. The focus of the effort is on unified action planning in complex contingencies. In other words, the focus is on tools for military personnel to support the entire coalition of military commanders and civilian leaders in employing the resources of their Nations in order to achieve a unified set of goals.

In the program, JFCOM provides:

- Concepts for campaigning and tool usage
- Subject matter expertise for domains and processes
- Experimentation facilities and personnel

while DARPA provides:

- User oriented tools that support decision making
- Baseline knowledge bases and models
- Drop-in software that fit current environments

Together we conduct periodic experimentation to guide technology development and influence development of concepts.

Military campaigns in the future will not be focused on major military operations alone. These campaigns will involve attempts at conflict avoidance, and if this fails, possibly major combat operations followed by a period of various security, stability, transition and reconstruction operations. Future campaigns will be characterized by an increased demand for commanders and leaders to employ the most appropriate unified actions (diplomatic, information operations, military, economic, etc. or DIME) against the adversary's various political, military (air, land and sea; regular or irregular), economic, social, information distribution, infrastructure, etc. (PMESII) systems.

Together, DARPA and JFCOM have identified the need for computer based decision aids to assist commanders, civilian leaders, and their staffs in:

- Constructing and managing <u>plans</u> that enable the commander to synchronize and integrate, interdependent effects over a long period of time; plans must employ the best sequence of unified DIME actions against the adversary's various PMESII systems
- Generating and exploring <u>options</u> and courses of action to understand the range of outcomes and appreciate the side effects that may occur

Both tools include advanced technology to assist humans in interacting with the tools and in visualizing the interdependencies in the plan, the relations between actions and effects. They also support visual collaborating among all US and coalition leaders (military and civilian), staffs, government agencies and non-government agencies.

It should be noted that the decision aids do not make decisions; they enhance the human's ability to make decisions.

As an "architecture, the tools are being developed as a tool box of web based capabilities that can be employed in existing command center infrastructures, particularly the environments at the US Regional Combatant Commands. To this end, the DARPA tool box includes a set of software interface tools to enable the DARPA tools to be integrated with existing tools and decision aids as well as with data, information and knowledge bases available at the various command centers.

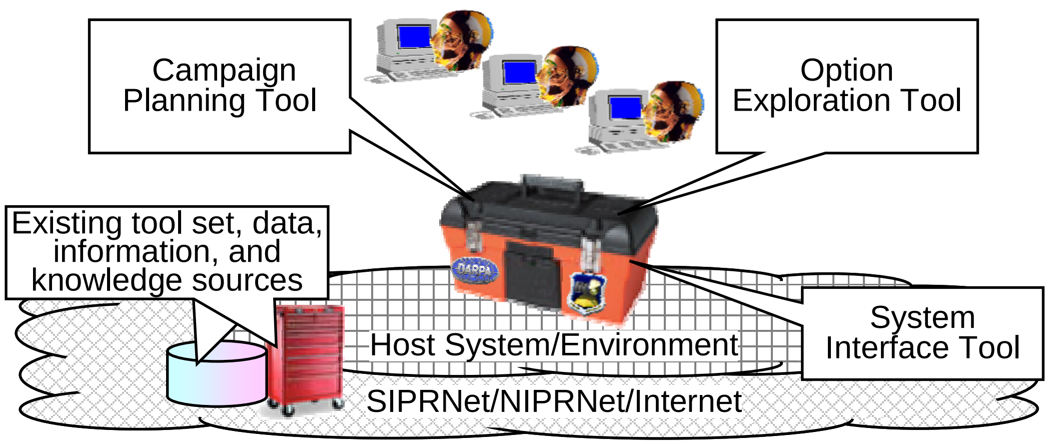


**Figure 1-1: IBC Tool Box**

The development of the technologies involves extensive interaction with subject matter experts from JFCOM, as well as from other agencies, and the use of human in the loop experiments. The latter are being conducted using the physical infrastructure and personnel available at JFCOM.

## 2. The Problem and the Framework

Today, and in the future, commanders and civilian leaders will operate in an environment where:

- Knowledge of the adversary, its tactics and procedures, strengths and weaknesses, may be incomplete (or non-existent)
- The military commander may be working for a civilian Head-of-Mission (e.g., the U.S. ambassador) in the period after Major Combat Operations are complete
- The adversary's adaptation cycle (i.e., the interval from our new action until they have successfully adapted new tactics to defeat or obviate our actions) is measured in days.

Given the complexity of the interactions between the various unified or National actions that can be taken and the systems against which they act, today's planning cycle takes too long and does not adequately account for non-military action or non-military effects. More responsive, iterative, and comprehensive planning cycles are needed. The IBC program is developing tools to support a planning cycle based on a continuous loop process, in which one is continuously adjusting one's tactics and strategy, probing and evaluating the reactions of the enemy, and emphasizing continuous learning in an effort to discover "what works". In such an environment, the ability to visualize the full scope of the operational environment, in all the PMESII dimensions, is critical to the leader's ability to successfully complete the missions assigned.

JFCOM is developing, testing and delivering transformational concepts for conducting future campaigns to the Regional Combatant Commanders. These concepts include Operational Net Assessment, Effects Based Operations/Planning, the Joint Interagency Coordination Group, the Joint Fires Initiative, etc. The organizational structure for employing these concepts is being formalized by JFCOM in the form of the Standing Joint Force Headquarters (SJFHQ). In parallel, the functional capabilities needed by the SJFHQ are being developed as the Collaborative Information Environment. Finally, the physical capability to implement the package is being developed as the Deployable Joint Command and Control (DJC2) System. (See http://www.dtic.mil/doctrine/education/jwfc_pam4.pdf)

Thus, the next generation "system" for joint force command and control is on its way to reality. What is lacking is a comprehensive suite of decision support tools that can automate and greatly facilitate the human actions performed in this "system." The DARPA technology will provide decision aids that will execute in the evolving system and support the evolving command and control process. JFCOM will deliver a transformation in the form of the command and control <u>concepts, processes and facilities</u>; DARPA will deliver a transformation in command and control <u>decision support tools</u>.

### 2.1. Campaign Objectives

The objective of a campaign in the future may not be one of totally defeating a Nation-State or Alliance. It is expected that future campaigns will be more about transferring power from a hostile regime to a friendly and democratic regime or from an obstructionist regime to legitimate institutions, as we have found in recent campaigns in Bosnia, Kosovo, Afghanistan and Iraq, (See *The Quest for Viable Peace, International Intervention and Strategies for Conflict Transformation*, Edited by J. Covey, M. J. Dziedzic and L. R. Hawley, US Institute of Peace Press, 2005.) These types of campaigns require the application of all forms of national power available (diplomatic, information operations, military, economic, etc.) and will require the minimization of undesired consequences and effects.

In the figure below we illustrate the concept of Nation Transformation as espoused in the reference above. When a cross over occurs and the legitimate institutions begin to have more power than the obstructionist, one may say that peace is now viable.

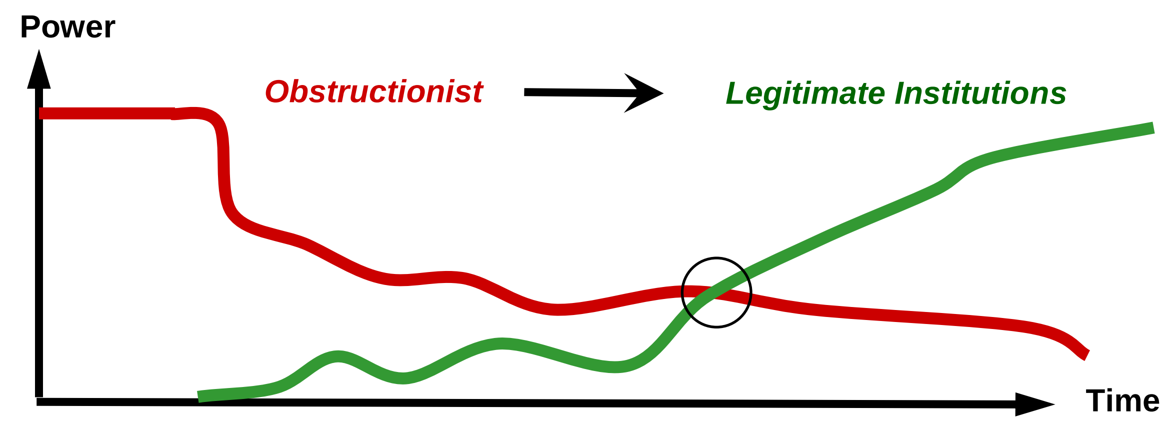


**Figure 2-1: Power Transformation**

## 2.2. Effects Based Planning/Operations

As noted, future conflicts will be characterized by the increased dimensionality of actions and the corresponding increased dimensionality of effects that need to be achieved. This is illustrated below. At the expense of violating "doctrine" in this paper we will use DIME and PMESII as symbols and not as acronyms. This is to highlight that the range of actions and effects are not limited to fitting within these categorical bounds.


**Figure 2-2: Effects Based Operations**

JFCOM has formalized the concept of effects based operations and described it in several publications to include: "Doctrinal Implications of Operational Net Assessment (ONA)" which may be found at http://www.dtic.mil/doctrine/education/jwfc_pam4.pdf. The key concept is that an effect is the physical and/or behavioral state of a system that results from a military or non-military action or set of actions. It is achieved by generating a specific action or activity directly at a specific node. A node in return is a person, place, or physical thing that is a fundamental component or junction of a system. An action conducted against a node should cause the primary effect but may also produce desirable or undesirable effects. Any primary, secondary or third order effects may also result in an action against other nodes that then causes other effects.

In current practice, the adversary's PMESII systems are subjected to a "system of systems analysis" in order to identify the critical nodes and what effects can be achieved. Then an Operational Net Assessment is performed resulting in a set of possible and recommended packages comprised of: 1) an effect, 2) a specific node and 3) an appropriate action that will achieve the effect if employed against the node. It produces a data base of Effect<Node<Action triplets which is essentially a "model" of the adversary's PMESII systems and their reaction to DIME activities.

The commander needs to know the interaction between actions and effects so that an action does not cause an undesirable effect or cause a cascading effect creating other undesirable effects. Conversely, the commander needs to know all of the alternative actions that can be employed in order to achieve an effect. For example, a desired military effect might be achieved by a non-military action. Consequently, the commander needs to understand the complete set of interactions between actions and effects.

An effects based operations plan would consist of the normal temporal-spatial sequence of objectives and/or missions but the details would be decomposed into the effects desired, the "target" nodes and the most desired actions to take (Effect<Node<Action).

### 2.3. Multiple Lines of Effort

Another evolving concept is the notion of an integrated campaign plan comprised of multiple lines of effort. This is presented in the Joint Chief of Staff's *Capstone Concept for Joint Operations*, Version 2.0, dated August 2005. Here there is recognition of the need for interagency and multinational involvement to include: policy coordination, resources, security operations, infrastructure development, economic development, governance, and rule of law. The Capstone describes the need for a planning framework that considers the use of very integrated and interdependent activities, organized into simultaneous lines of effort which by a series of objectives are able to reach a common end state. Thus, separate lines of effort would be conducted in the military, rule of law etc. domains as depicted in Figure 2-3.

Lastly, the lower right illustration of a plan, in Figure 2-3, is shown comprised of sequences of objectives or goal states that need to be reached by Blue (or Dark), Red (or Dark with double lines) and Neutrals (White) such as non-government agencies. The plan must account for not only the desires of the Blue side but also for those of the adversary and neutrals.

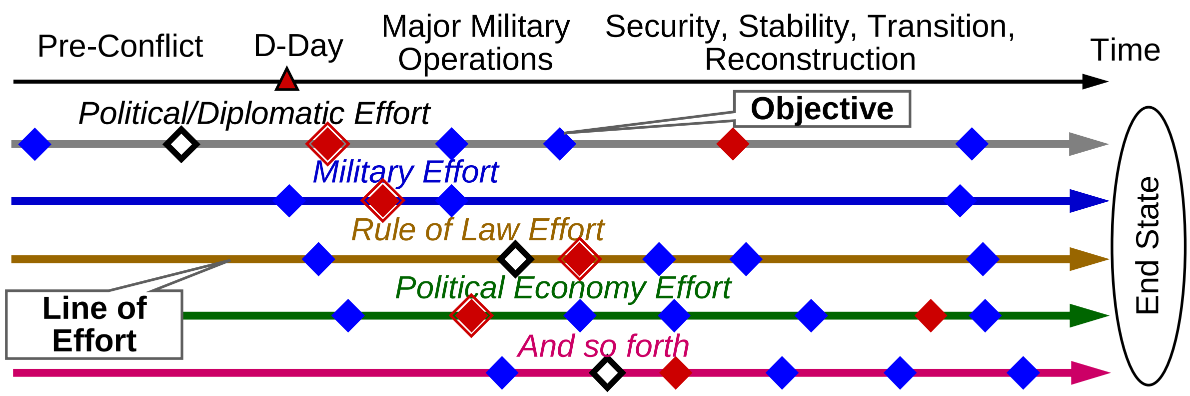


**Figure 2-3: Campaign Plan Framework**

## 2.4. The Uncertainty of Future Conflicts

The nature and location of the next campaign the U.S. will conduct is unknown. The general decision support capabilities that are needed can be inferred from the JFCOM war fighting concepts, the SJFHQ structure and the desired functionality of the Collaborative Information Environment. However, the substantive content needed for these tools is difficult to predict, such as the specific threats (military and non-military) and their behavior. This is the kind of knowledge that forms the “brains” of a decision support tool. We do not know enough details of the future to construct tools that will exhibit the specificity and detail necessary to support human decision making in unknown campaigns.

One option to this predicament is to simply generate a suite of tools for every potential scenario. Another approach is to develop a capability to integrate various tools on-the-fly, as needed for a campaign. A third approach is providing tool-making-tools to allow command personnel to implement tools on their own, as needed, tailored to the campaign. DARPA has adopted the latter two approaches. In this way, decision support tools can be provided which are relevant to the campaign and are acceptable to the user.

The Microsoft product, Excel, is an example of a “tool-making-tool.” Users employ Excel to construct “tools” relevant to their own application or problem. No special computer programming skills are necessary to employ Excel. Users employ Excel and the knowledge of their personal problem domain to create a tool customized to their needs.

Lots of specific decision support tools and models of the adversary do exist or are being developed, although most are specialized to a limited problem domain, and it’s usually one from the past. Various agencies and organizations will continue to develop and refine these tools and models, and it is likely that in the next campaign, a number of decision support tools and models will be available that are relevant. Thus, we need a capability to find and integrate such existing tools and models into an ad hoc system that can be tailored to the campaign and continuously updated and modified to match the evolving campaign.

# 3. Technical Approach

## 3.1. Planning Tool

As noted, a campaign plan is a set of parallel sub-plans or lines-of-effort, for achieving different goals: political/diplomatic, military, etc as illustrated above in Figure 2-4. Each line-of-effort will consist of a sequence of objectives (shown as diamonds in Figure 3-1) and activities (bars in the figure). The activities may consist of Effect<Node<Action triplets that are intended to result in achievement of the objectives by use of effects based operations. Other activities may not be effects based. Multiple activities may be needed to reach any one objective and there will most certainly be alternatives included in the plan or what the military term “branches and sequels.” The plan must also include the assumed courses of action the adversary (Red) may follow as well as those by Neutrals (White) such as non-government agencies.

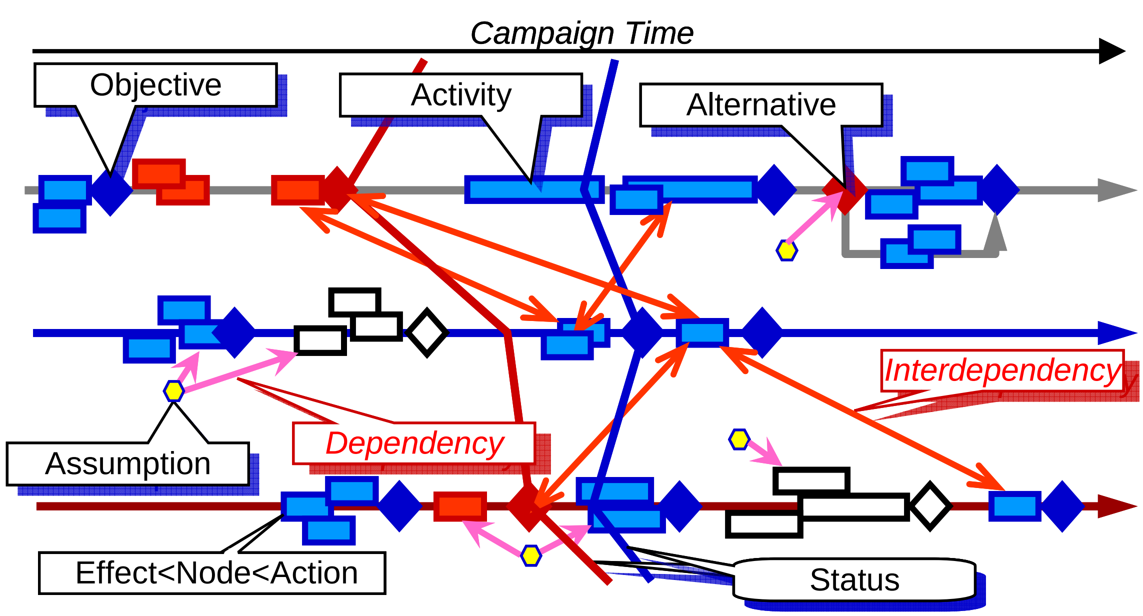


**Figure 3-1: Campaign Plan Elements**

Of critical importance is the relationships that exist between the activities. Each assumption creates a dependency on that assumption and various activities can be highly interdependent. Figure 3-1 illustrates a few of these relationships but a realistic and comprehensive plan would most likely include thousands of these relationships – many more that a human can comprehend and manage. If the plan has n Objectives that require m Activities, there can be on the order of (n•m factorial) Interdependencies. If we include all of the Assumptions and Alternatives, the number of Interdependencies grows even more.

The planning tool being developed aids humans in constructing the sequence of synchronized actions, necessary to support interdependent lines of effort. It provides the following capabilities:

- Supports users in authoring the plan and capturing assumptions and dependencies
- Allows humans to “cut and paste” plan elements and rapidly repair plans
- Automatically detects and manages interdependencies
- Provides capabilities to visualize the plan with all of the dependencies and interdependencies
- Supports humans in monitoring the status of the plan and measuring success.

The last capability, “Success,” refers the need to aid humans in determining the status of a campaign in terms of objectives reached, effects achieved etc. and whether or not the plan is still balanced.

### 3.2. Option Exploration Tool

In constructing a campaign, each activity (Effect<Node<Action triplet or other scheme) will need to be investigated to determine if it produces undesired effects and to determine how it influences other the activities in the plan. Exploring optional effects or actions requires a “model” of the conflict environment, with its military, social, economic, political, etc. systems.

One point that needs to be made strongly and emphasized is that we are not attempting to construct models which predict the most likely outcomes. Rather we are attempting to construct models which generate the distribution of all plausible outcomes. They generate suggestions, not predictions. The objective is to enhance the human’s ability to make decisions by providing and describing all of the possibilities.

The tool must allow the user to explore actions or effects in a bi-directional manner. It must generate the actions that can be employed to achieve a desired effect or generate the effects that could result from an action. Models must be provided for the behavior of the adversary, or the adversary nation-state alliance, as well as for the friendly coalition (which may or may not be led by the US).

As to creating models, no known implemented model or modeling technology is capable of describing the full range of interactions that occur within a nation-state or alliance of nation-states. A multitude of models is required in order to completely span the environment defined by all of the DIME and PMESII dimensions; a family of models is needed as illustrated in Figure 3-2.

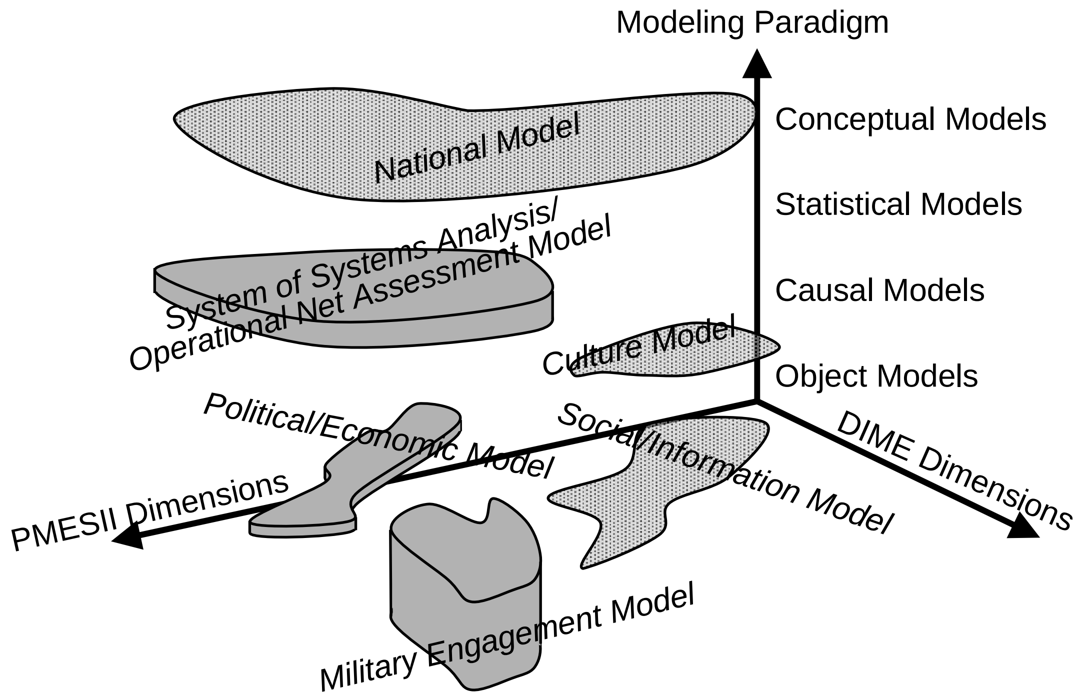


**Figure 3-2: Family of Models**

Each model in the family may represent its portion of the domain in a manner and level of fidelity quite different from other models; this is illustrated by the "modeling paradigm" dimension. The various Modeling Paradigms that are used include techniques such as: concept maps, social networks, influence diagrams, differential equations, causal models, Bayes networks, Petri nets, dynamic system models, event-based simulation, and agent based simulation. These models use disparate mechanisms and a variety of indices, parameters and metrics for their input and output. Some models are broad in scope but thin in depth while others are thick in depth and narrow in scope.

The need for a variety of modeling paradigms is due to several factors. One is that none of the paradigms is truly applicable to the entire domain. They are incapably of modeling the entire domain spanned by the DIME and PMESII dimensions. The different domains of knowledge simply do not lend themselves to being represented by one universal paradigm such as an agent based simulation. Another factor is that human subject matter experts have preferences in the use of different paradigms; different paradigms fit different styles of thought.

A family of interacting models has the potential to produce surprisingly unanticipated results due to the effects of cascading. An analyst may investigate the impact of an action and a model may suggest a primary outcome. However, that outcome may stimulate another model that suggests an outcome that stimulates another model and in a cascade reaction, the family of models, in a symbiotic manner, may suggest many another potential outcomes. Such cascading can produce astonishing results because, while a human may grasp and master a single model, it is unlikely that a human can comprehend the potential, complex interactions between lots of models!

Using a family of models can cause problems which can only be resolved by experimentation. The main tradeoffs, which are themselves interdependent, are:

- Overlap and inconsistency
- Tight interaction vs. no interaction
- Generic models vs. specific, detailed models.

The family of models can produce a large number of overlapping and possibly inconsistent results. The superiority of one suggested outcome over another (or the "goodness" of one model over another) will be difficult to determine and will need to be left to human judgment.

A tightly interacting family of models can be used to analyze the entire environment as a single "system" as opposed to bits and pieces. It will require technology that can link together many disparate models of the adversary's political, military, economic, social, information, infrastructure, etc. systems. Alternatively, the environment can be partitioned and individual models can be employed independently to study the partitions one at a time. If a large number of models is tightly coupled together, it may produce a very large set of outcomes but they may be difficult to interpret because of their volume, the overlap and the inconsistencies. On the other hand, if the environment is decomposed into partitions and these are examined independently with a sub set of models or with a single model, then the distribution of suggested outcomes may be more easily examined and understood by a human – the divide and conquer strategy.

The mechanism to enable diverse models to interact – <u>without human intervention</u> - is a great technical challenge. One approach, the traditional one, is to first develop a single common ontology or modeling language to describe the entire domain and then force each model developer to employ this language in its model interface. This can be overly constraining to model developers and human experts and prohibits the flexibility of being able to easily acquire and integrate additional models as the details of future conflicts become apparent. Another approach is to create a software mechanism that enables applications modules (the individual models and executive software) to autonomously develop data structures and ontologies to connect themselves on-the-fly. Both approaches are being pursued by the DARPA contractors.

The last trade off is whether generic models or specific, detailed models provide the most useful results. Models of specific instances of people, places, organizations, etc. will produce specific results that may be easier to understand in the context of the actual environment. If the user has a good knowledge of the environment (a familiarity with the people, places, organizations, etc.) then it is easier to judge the validity of outcomes suggested by detailed models. On the other hand, if the user has only a general knowledge of the environment, generic models may be of more utility, precisely because of their lack of specificity and the probability that they are unlikely to suggest any unusual or complex outcomes.

The interdependence of the above trade offs suggests the hypothesis that a hierarchy of models will be needed to support different users and different phases of analysis and planning. Broad, generic models of the entire environment may be more useful for some users at certain times. In other times, very detailed, specific groups of models may be needed. Consequently, the Option Exploration Tool needs to have the flexibility to support these alternatives.

In summary, the option exploration tool being developed includes:

- A family of models that span the whole domain
- The capability to select and employ particular models applicable to a particular campaign or phase of the campaign
- A mechanism to enable diverse models to automatically interact so as to suggest the full distribution of plausible activities and outcomes
- Models that can adapt and expand to future conflicts, prior to, during and after the actual campaign
- Mechanisms for users to describe options and visualize outcomes as well as the reasons and the interplay of the models
- The capability to reason from cause to effect or from effect to cause
- The capability to model both sides of the conflict – the friendly as well as the adversary coalition.

### 3.3. Tool Box Architecture

In any command and control system there will exist an underlying computer and communications infrastructure with a suite of decision aid tools and appropriate access to data, information, and knowledge sources or data bases. The DARPA decision support tools can be easily added to this environment as illustrated in Figure 3-4.

The DARPA tool box includes a set of system interface tools and the Software Confederation Web. The Confederation Web is a radically new class of software integration technology to enable the ad hoc, on-the-fly confederation of large ensembles of software components, when and as they are needed. (See Confederation-Web-Net-Centric-Data-Service.doc which may be found at http://www.activecomputing.org/papers)

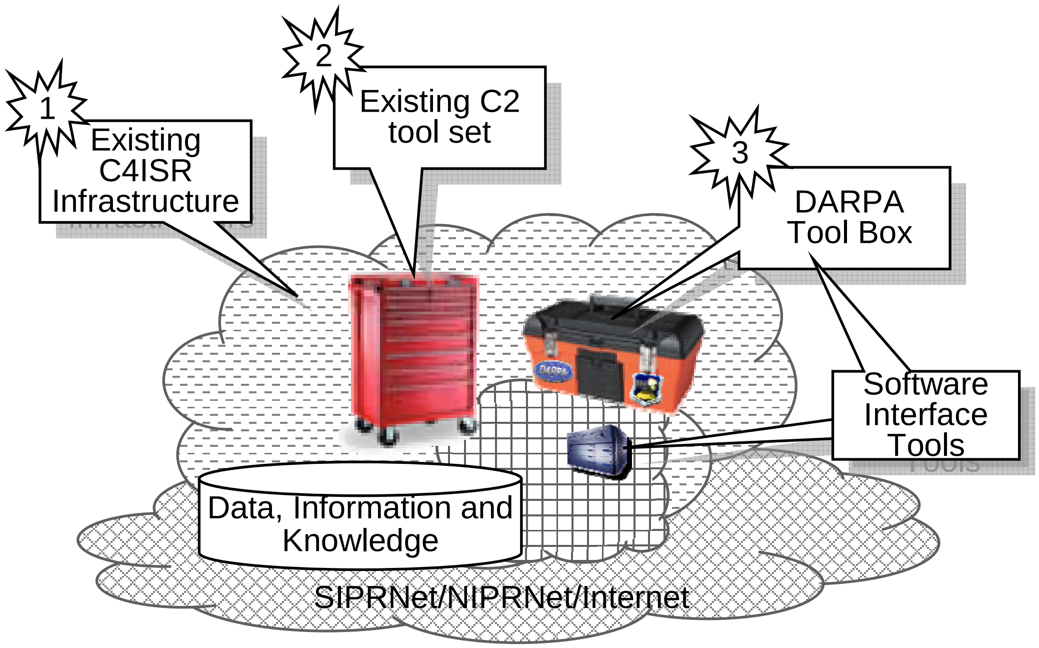


**Figure 3-4: Architecture**

To recapitulate, the toolbox contains:

> **Campaign Plan Construction and Management Tool** for aiding command center personnel in generating plans employing integrated, interdependent parallel levels of effort for pre-conflict, major military operations and for subsequent security, stability, transition and reconstruction operations. The tools aid in detecting and managing the mirage of interdependencies.
>
> **Option Exploration Tool** that enables command center personnel to generate and evaluate the range of effects that might result from an action or the range of actions that could be employed to get an effect. These tools do not predict exactly what will happen; they suggest what might happen; they generate the distribution or range of all plausible outcomes.

### 3.4. Performance Metrics and Goals

In order to manage this technology program, we have developed a set of metrics which quantify or qualify the performance of the various tools. The primary metrics are:

- Net Number of Favorable Outcomes Achieved
- Number of Predicted Unfavorable Outcomes.

Specifically, we are interested in the increase in the value of these metrics due to employing the tools in contrast to not employing them.

Estimating the value of these metrics requires the use of human-in-the-loop experiments. These experiments are conducted using multiple teams of players operating in parallel; some teams are advantaged with the new decision support tools while the control team employs the existing tool set.

The Number of Predicted Unfavorable Outcomes is a measure of the political, military, economic, social, information and infrastructure effects or other events that were predicted as possibilities and considered prior to the decision. The Net Number of Favorable Outcomes Achieved is a measure of the results that were achieved in the political, military, economic, social, information and infrastructure domains – based on a plan/COA that was developed based on consideration of a number of potentially unfavorable outcomes. The net number is the number of favorable effects minus the number of unfavorable effects. Thus, for each decision/plan in an experiment, there will be a pair of values for the Number of Predicted Unfavorable Outcomes (identified and accounted for in making the decision), and the corresponding Net Number of Favorable Outcomes Achieve (that occurred as a result of the decision).

DARPA has established the goals of achieving the performance shown in Table 3-1. They provide the Go/No-Go gates for determining technical achievement.

**Table 3-1: Metrics and Go/No-Go Performance Goals**

| **Metric** | **Phase 1** | **Phase 2** |
|---|---|---|
| **Number of Predicted Unfavorable Outcomes** | **10:1** | **100:1** |
| **Net Number of Favorable Outcomes Achieved** | **10:1** | **100:1** |

In addition, JFCOM is interested in a different set of metrics and performance goals which are discussed in the CCRTS-06 paper: *Integrated Battle Command Experimentation: Evaluating Transformational Concepts and Cutting Edge Technology in an Operational Environment*, Peter S. Corpac, Lt Col Kevin Frisbie, and John R. Gingrich.

## 4. Program Structure

The program is being conducted sequentially as shown in Figure 4-1.

Phase 1: Basal Capability Development which resulted in an initial, rudimentary version of the tool box that exhibits all of the essential functionality desired in the option exploration tool as well as a very basic version of the planning tool; this was conducted by two teams in competition.

Phase 2: Comprehensive Capability Development that will expand on the Phase 1 capabilities and complete their development for transition to JFCOM; this phase is being conducted by a single contractor team.

The Phase 1 prototype was limited in functionality and in the depth and breadth of competence in order to determine the feasibility of accomplishing the technical goals. Phase 2 will enhance and greatly expand the competence (in depth and breadth) of the tools.

DARPA and JFCOM will continue to develop and evolve the campaigning framework, discussed in Section 2, within which the decision aid technologies are employed. This is being performed by a group of senior experts drawn from the military as well as from diplomatic, political, economic and other domains.

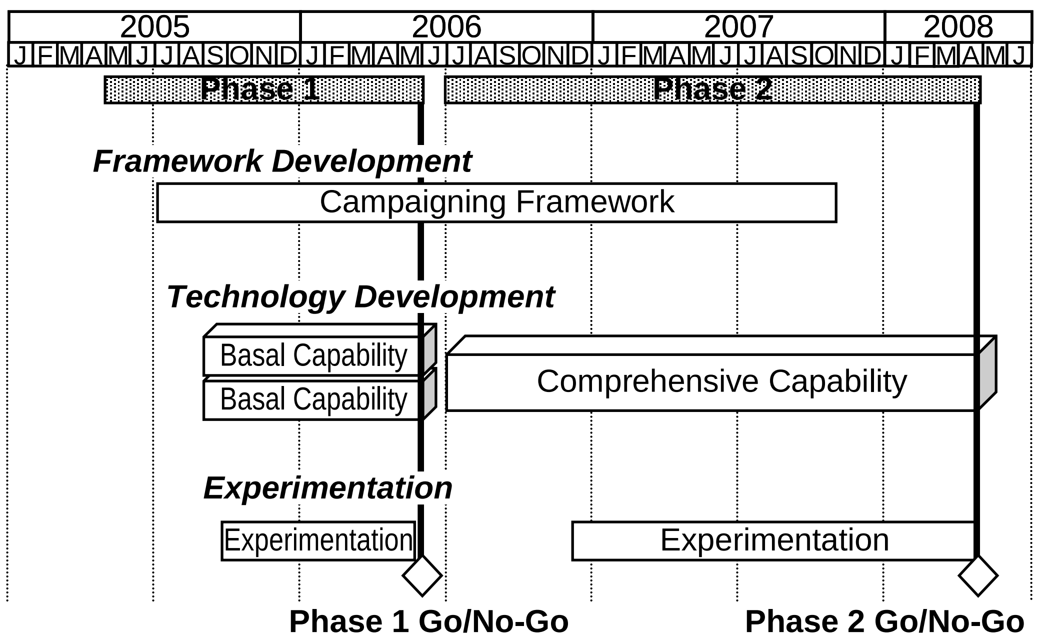


**Figure 4-1: Schedule**

As noted, experiments using humans in the loop are conducted to measure the contribution of the decision support tools. The approach is to employ trained and experienced command center personnel in simulated exercises. Different groups of players separately conduct war game exercises. Some groups employ the advanced decision support tools while others only have available the extant tools provided by the JFCOM Collaboration Information Environment. The decisions and plans generated by the various groups are then compared to determine the efficacy of the advanced decision aids.

## 5. Conclusions and the Way Ahead

Phase 1 of the program was completed in June 2006 and the results of the experiments are reported in the CCRTS-06 paper: *Integrated Battle Command Experimentation:*

*Evaluating Transformational Concepts and Cutting Edge Technology in an Operational Environment*, Peter S. Corpac, Lt Col Kevin Frisbie, and John R. Gingrich.

The Phase 1 effort focused mostly on the Option Exploration Tool and the experiments to date have led to several conclusions about designing such tools:

- Human-machine interfaces, particularly the visualization capabilities, must be able to be tailored to the role of the user be he/she a commander/leader, analyst or planner
  - Staffs prefer an approach that most closely mirrors their planning methodology -- a bottom-up approach to uncover alternatives
  - Commanders prefer a more top-down approach – gaining a sense of the operational environment, or “playing field”
- Extant technologies for modeling PMESII systems are abundant and more than sufficient to describe the known types of PMESII systems
- A hierarchy of models is in fact needed to support different styles of user as well as support different phases of planning and analysis
- Generic models provide users with insight into trends but do not offer specific guidance in planning
- Detailed, in-depth models, instantiated to portray real people, places, organizations etc., are preferred over the use of generic models, because they generate believable, understandable results that can be employed to develop plans
- A family of interacting models can produce large numbers of suggested, plausible outcomes; however, this distribution of plausible outcomes is often difficult to understand because of the variety of indices, parameters and metrics that the different models employ and because of the overlap, redundancy and inconsistencies
- A suite of loosely coupled models is difficult to employ because of the variety of control parameters (inputs) and the variety of indices, parameters and metrics that they generate. When the environment is partitioned, the interactions between partitions are difficult for the human to determine
- Visualization techniques which reduce the dimensionality of data are essential for understanding the complexity of the outcomes that can be generated by models.

These lesions will be incorporated into the tool box and carried forward into Phase 2. DARPA and JFCOM will continue to work closely together on this program and will attempt to rapidly transition the technologies to the combatant commands.