17th ICCRTS

"Operationalizing C2 Agility"

Co-Design: Course of Action Integration Through Common Conceptual Model Building

Topic 4: Collaboration, Shared Awareness, and Decision Making

Topic 1: Concepts, Theory, and Policy

Topic 2: Approaches and Organizations

Thomas I. Saltysiak [STUDENT] and Alexander H. Levis

Point of Contact:

Thomas I. Saltysiak

System Architectures Laboratory,

George Mason University,

Fairfax, VA, 22030, USA

703-473-7561

thomas.saltysiak@us.army.mil

tsaltysi@gmu.edu

Co-Design: Course of Action Integration Through Common Conceptual Model Building

Thomas I. Saltysiak[a] and Alexander H. Levis[a]

[a]*System Architectures Laboratory, George Mason University, Fairfax, VA, 22030, USA*

Abstract

Integrating and synchronizing the effects of functional components in military organizations has long been an important principle in all types of military operations. Current approaches to planning integration have largely focused on increasing information and knowledge sharing between parallel planning processes. The proposed approach to integrated planning is focused on common conceptual model creation early in the process. Current planning and operational design activities can be augmented with few coordination activities required to enable common conceptual model agreement. Courses of action developed using a common conceptual model are shown to have a much greater level of integration. The feasibility of this approach is demonstrated through a combination of planning process modeling and course of action performance modeling. The proposed approach provides a viable alternative for consideration in the development of command and control architectures.

1. Introduction

Military commanders always seek to maximize the effects of their organization's components by properly arranging them in time and space to achieve integration. The speed and complexity of modern warfare have only magnified the difficulty in achieving integration[1][2]. This challenge is well documented and variously referred to as the need for: synchronization, synergy, unified action, coordination, and/or collaboration in military planning and military command and control (C2) in general. Many recent military policy and strategy documents make reference to the necessity of integration and related concept as a method to mitigate rising complexity and the challenge of diverse mission requirements [3][4][5]. Reports and critiques of shortcomings in modern military operations also point to integration as a concern that has yet to be fully addressed [6][7]. A great deal of research and development emphasis has been placed on integration. These efforts have focused on increasing information sharing and enabling knowledge sharing between organization components[8][9][10]. Even as knowledge sharing barriers diminish, the challenge of efficiently building common knowledge in time constrained military planning remains[11]. New approaches to military planning and the supporting command and control architectures will be necessary to maximize the benefit provided by new capabilities of knowledge sharing.

The objective of this paper is to describe an approach to military planning which will increase integration between cooperating organizational components, which are termed domains, and will result in better integrated courses of action (COAs). The approach involves investment of additional time early in the planning process to develop a common conceptual model of the operational environment between domains. This approach is contrasted with traditional approaches of separate domain COA development and subsequent de-confliction (iterative adjustment of domain COAs to remove activities that have severe negative impact on the other domains' effectiveness). To demonstrate the feasibility of the proposed approach, a modeling methodology was developed which relates the modified planning process to the performance of the resulting developed COAs. Section 2 describes the concepts of conceptual models, planning, and design, as they related to this effort. Section 3 introduces the new approach for increasing integration through common conceptual model building. Section 4 illustrates the modeling methodology that is used to demonstrate the feasibility of the proposed approach. Section 5 presents the results, while section 6 summarizes the work and suggests areas for continued research.

2. Conceptual Models, Planning, and Design

In order to explore inter-organizational integration, several cooperating domains were considered. These domains are separate functional components of an organization or coalition cooperating towards a common goal(s). Complete integration of the domains' COAs is then defined as follows: ***COAs in which all participating entities act as one organization in pursuit of common goal(s); A set of COAs in which no higher performance can be obtained by changing the actions taken and action timing in any involved domain COA.*** During military planning, the domains are in the process of creating and evaluating COAs. For COA integration, how and when to share information must be considered.

A great deal of research has been done on information sharing between organizations. This research area is extremely broad, potentially covering the fields of management, organizational communication, knowledge management (KM), information technology, and others. One theme which is common to a majority of research in these fields is the delineation of data/information and knowledge [12][13][14]. Related to this is the idea of an individual's or organization's conceptualization of the situation at hand, or the operational environment. Data and information are used to produce organizational knowledge of a situation. Through organizational processes, this knowledge is used to create a conceptual model of the operational environment for which military planning is taking place. [14] This relationship is shown in Figure 1. Sharing of data/information is a requirement before sharing of knowledge can be considered. Likewise, knowledge sharing is necessary but not sufficient for conceptual model sharing. The generic term "elements" is used for information/data, knowledge, and conceptual models components.

During military planning each domain is building a conceptual model of the operational environment. Organization information, knowledge, and conceptual models are evolving during the planning process until decisions are made by the commander to approve specific aspects at certain points. Based on this understanding of how the operational environment works, each domain will choose a COA which best meets the commander's and/or higher authorities' specified criteria.

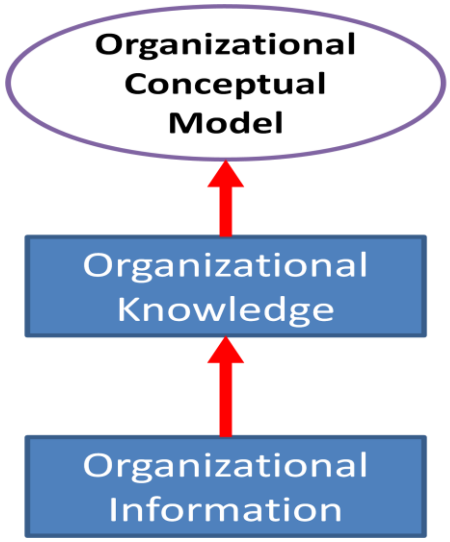

Fig. 1: Organization Information, Knowledge, and Conceptual Models

There are two primary considerations in developing processes to increase inter-domain COA integration: what is shared, i.e., conceptual models, knowledge, or information, and when in the process this sharing is attempted, as shown in Figure 2. The choice of when in the process to share elements affects whether or not the specific element has been approved by the domain commander. In addition, for conceptual models and knowledge, there is the choice of whether or not and when to attempt inter-domain agreement on a specific element.

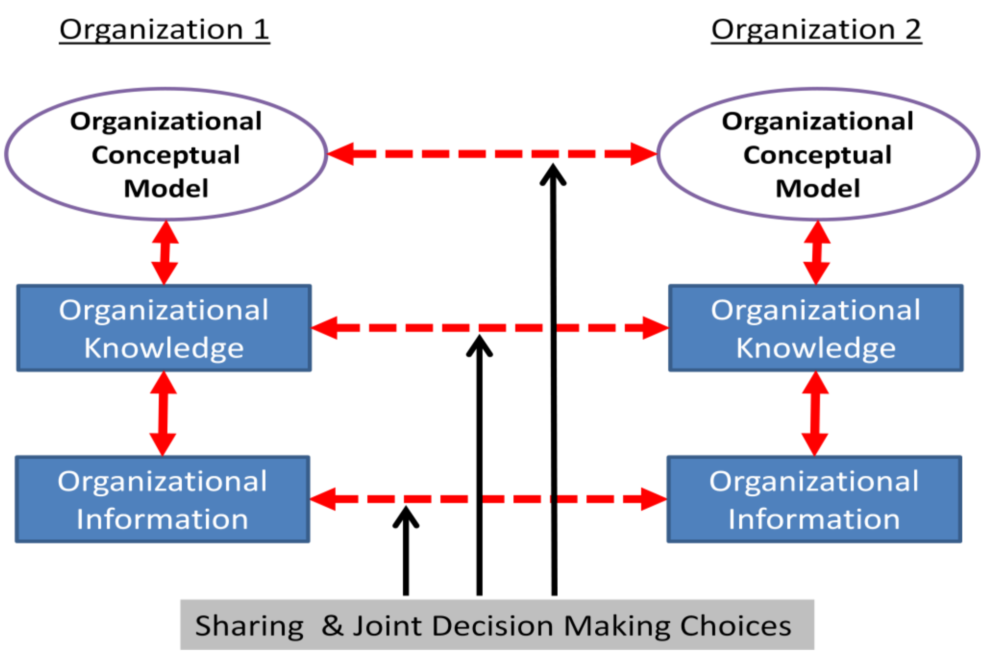

Fig. 2: Element Sharing and Joint Decision Options

Current military planning approaches were explored to understand the potential points for element sharing. During military planning, two complementary activities proceed concurrently, planning and design. Design (also called operational design) involves problem setting and framing and is normally associated with the commander. Organization staff usually conduct planning which is a procedural problem solving process. The United States doctrinal planning processes differ slightly between levels of war and organization/service but are generally similar; examples include the Joint Operations Planning and Execution System (JOPES) and the Military Decision Making Process (MDMP). Most NATO and Western military organizations use similar prescriptive process models. There have been suggestions to include more aspects of Naturalistic Decision Making theory in military planning processes, which would more explicitly integrate planning and design[15][16][17]. These suggestion are still under debate and there have been few significant changes to the process since World War II [18]. United States military descriptions of design focus not on procedure steps but on the results of design which frame the staff planning effort. The design framework in United States military joint planning documents is Center-of-Gravity (COG) analysis[5]. Alternative frameworks include: Effects-Based Operations [19][20][21], Operational Net Assessment [22], and Systemic Operational Design [23][24][25].

In many military planning situations time is a critical factor. In time sensitive planning situations, a trade-off must always be considered between planning time and plan quality/integration. This is summarized well in the United States Army's new field manual on operations: *"Taking more time to plan often results in greater synchronization; however, any delay in execution risks yielding the initiative—with more time to prepare and act—to the enemy."*[26] In planning situations where time is less important, time inefficient processes of inter-domain adjustment can be used. In the more rigorous time constrained environment, full inter-domain de-confliction may not be possible within the time allowed for planning. For a new approach to be considered for use in time sensitive planning, it must not significantly increase the required time for planning. Whether explicit or not, the processes of planning and design are creating an organizational conceptual model of the operational environment. In current military doctrine, this occurs mainly in the first stage of the planning process, Mission Analysis, and the concurrent design activities. The organization conceptual models may be modified during COA development, comparison, and analysis but formulation of the model has largely already occurred. As each domain creates a unique conceptual model of the environment, the stage is set for difficulty in resolving conflicts between domain courses of action later in the process. During conflict resolution, also called de-confliction, domains will try to resolve selected actions which cause negative effects on other domains. The understanding of cross-domain effects will be based on the differing organizational conceptual models making mutual adjustment difficult. United States military planning doctrine does not explicitly define a methodology for inter-domain planning integration[26][27][28]. The importance of planning integration is articulated but no specific approach is suggested.[1] The traditional method for producing an integrated COA is to develop and approve domain COAs and then begin the time consuming process of mutual adjustment coordination[2] to obtain the best performing (criteria determined by the commander) integrated COA. Domains do share information during the planning process but the usefulness can be limited because of information ageing and concurrency issues. This process clearly breaks down in a time constrained environment where the integration level of the COAs is ultimately

[1] United States military planning doctrine does not ignore potential inter-domain interactions during COA development but there is no formal method for identifying inter-domain effects.
[2] Mutual adjustment coordination is the most resource intensive of the standard coordination methods described by Thompson [29].

determined by the time available for mutual adjustment coordination. This is the reality of current United States military planning processes shown in Fig. 3. The process block entitled "Informal design coordination" represents the process of coming to some level of common agreement on a conceptual model of the operational environment. This must take place to have a meaningful dialog on COA changes that increase overall inter-domain effectiveness.

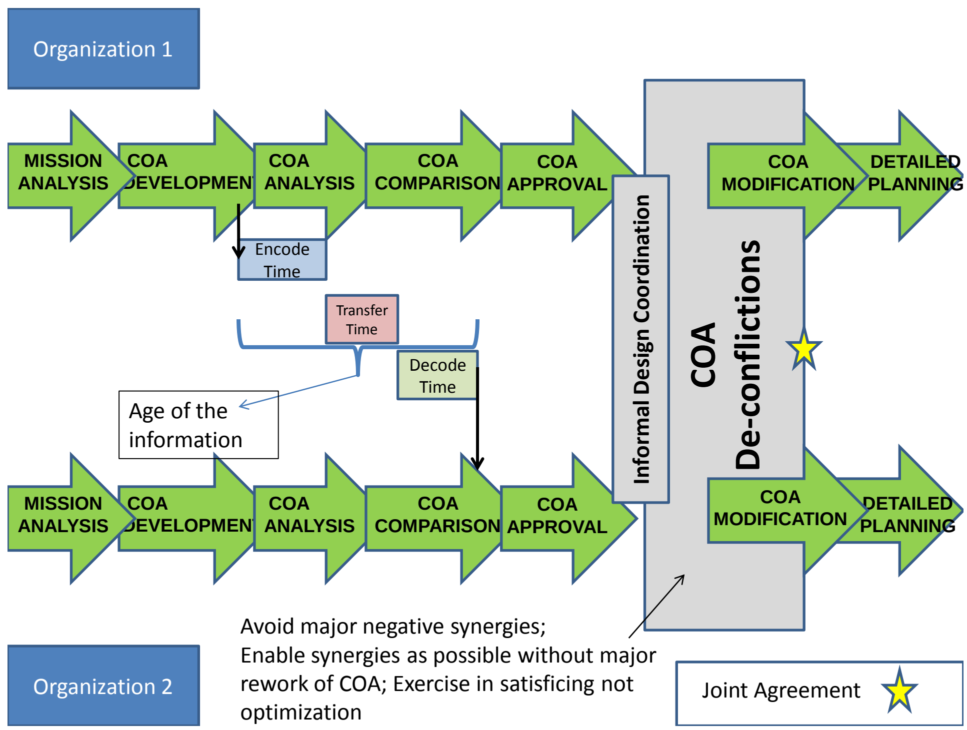

Fig. 3: Current Military De-confliction Approach

Attempts to solve the integration challenge in military planning have been largely focused on increasing information sharing and enabling knowledge sharing. Significant resources have been applied to increase the number and interoperability of information systems to allow greater information flow between domains[30][31][32]. Many efforts are underway to enable and streamline knowledge sharing through creation of common ontologies and related capabilities[33][34][35]. Other efforts have focused on enforcing joint conceptual frameworks through use of common decision support systems among domains[36][37]. Another approach has been to reduce the partitions between domains[38]. These various approaches will contribute to an eventual solution but continued emphasis indicates that challenges remain. Once the capability to share knowledge efficiently has been realized, there will still be the requirement for inter-organizational processes (when and what knowledge to share) to encourage integration.

If we consider military planning in a generic sense, it is a problem solving and design process. Inter-organization military planning is then related to group problem solving , cooperative work, and concurrent/distributed design processes. Research in these non-military fields then provides some insight into approaches for integration. Emerging research in these areas indicates there is a connection between agreeing on a common conceptual model and the integration level of the resulting product [39][40][41].

In their research COAction, Klein et al. demonstrated that for experts in tactical decision making having a common conceptual model enables joint option awareness [42]. Joint option awareness is the understanding of how well a COA meets the commander's criteria and the underlying aspects which affect how well a COA meets the criteria. In the Collaboration Evaluation Framework (CEF) research, Aldeman et al. [43] demonstrate through experimentation Thompson's concept of collaboration methods becoming more resource intensive as they progress from standardized to planned to mutual adjustment. In experiments with tactical level military planning scenarios, it was shown that changing collaboration tasks from mutual adjustment to planned or standardized coordination methods lowered the communication and cognitive resource costs [43]. This would indicate that building a common conceptual model lowers the resource cost of integrating COAs.

3. An Approach to Integrated Planning.

Separate domain conceptual models make integration very difficult and a common model increases integration[44]; therefore the goal is clear: a process that will facilitate common conceptual model creation during military planning without significantly increasing the time required. The proposed approach is based on creating a common conceptual model of the operational environment among all domains prior to developing COAs. Important to the overall concept is the acknowledgement that the domains seek to establish a common conceptual model. Although information and knowledge sharing is required, this is the means and not the end. Current approaches toward integration are based on increasing knowledge sharing: Commanders are sharing knowledge with other commanders, Commanders are communicating knowledge to their staff, and Staffs are sharing knowledge with other staffs. The exchange of knowledge implicitly and slowly adjusts domain conceptual models, but COAs that are initially based on domain conceptual models and then de-conflicted create the burden of changing domain conceptual models after they have been formed. In contrast, the proposed approach is based on integrating the necessary components of domain conceptual models before beginning to develop courses of action.

The proposed approach is centered on consensus building between domains during the operational design process and related planning activities. This approach is therefore termed "Co-design" as it describes a cooperative operational design process among domain participants. Five stages were developed to build incrementally the common conceptual model during mission analysis. This allows domains to agree on essential conceptual model elements one increment at a time to simplify consensus building. The five stages and the conceptual model component delineation were chosen to align with existing concepts in operational design. The five steps, termed design coordinations, are: 1. Objective(s) and metric(s), 2. Key Influencers of objective(s), 3. Adversary and environment potential actions, 4. Organizations' (Domains') potential actions, and 5. System structure (interactions, constraints, synergies). These five steps are envisioned as enabling joint conceptual model creation. To these, three more design coordinations are added to facilitate the overall integrated COA development process: Step 0. Agreement on Coordination Approaches (if not specified by previous agreement), Step 6. Develop Integrated COA Actions, and Step 7. Establish COA Action Timings. The entire process between two domains is shown in Figure 4. Higher headquarters guidance and its potential effect on any point in the process are explicitly shown.

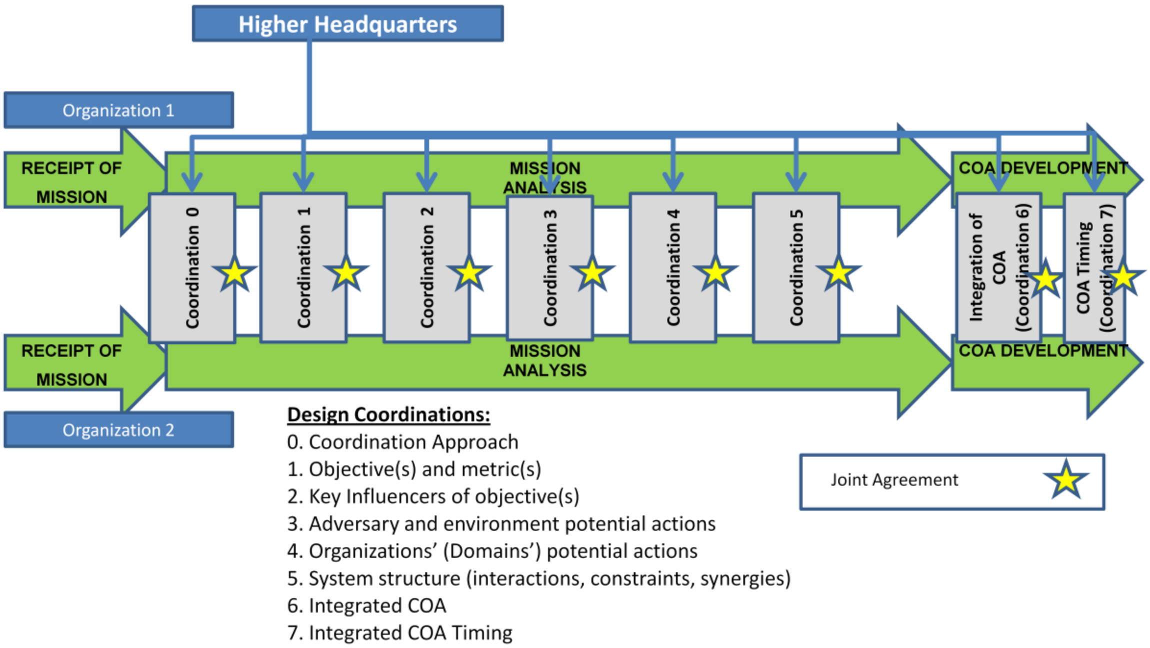

Fig. 4: Proposed Co-design Approach

An attempt was made to lower the potential implementation burden of the new approach through use of existing planning and design processes as much as possible. First the necessary components of a common conceptual model to allow integrated COA creation were identified. These components were then related to the conceptual model components which are commonly created by commanders during operational design. In turn, the necessary inputs for each component of the commanders' design from standard military planning process activities were determined. An example of this information/knowledge relationship is shown in Table 1 for step 2 of Design Coordination. This example specifically uses the Joint Operation Planning and Execution System (JOPES) planning model and the Center-of-Gravity approach to operational design, but equivalent concepts could be used from alternative prescriptive models.

Using process activities from the current approach in the new approach to the extent possible also lowers the potential impact on total process time. The staff planning activities and commander design activities occur in the current approach. The additional activities of the proposed approach are the coordinations between commanders, or their designees, which occur concurrently with current approach activities. Although some additional process time is required to reach consensus on design coordinations, since the new activities are mainly concurrent with existing activities, the overall impact is less than traditional de-confliction activities. Traditional de-confliction activities take place after domain COA approval and are therefore not concurrent with other planning process activities. As a result, all the time required for de-confliction extends the overall process time required by an equal amount.

Table 1: Relationships Between Planning Activity, Design Coordination, and Operational Design Elements

JOPES Activity	JOPES Output/Input to Design Coordination	Design Coordination	Output	Equivalent Doctrinal Design Concept
Determine Own & Enemy's Centers of Gravity and Critical Factors	Enemy Center of Gravity and Critical Factors	2. Key Influencers of objective(s)	Joint Key Influencers of Objectives	Critical Factors that Affect the Enemy Center of Gravity

4. Modeling the Planning Process

Inter-domain coordination was modeled as iterative consensus building between domain decision makers. The five-stage interacting decision maker model was used as the basis for the iterative consensus building model[45]. The five stage interacting decision maker model builds upon classic decision making theory model of two stages, situation assessment and response selection[46][47], by considering the additional stages for interacting with other decision makers and design support systems. In the situation assessment (SA) stage, decision makers create their assessment based on input from the environment or other decision makers. This assessment can be shared with other decision makers. Decision makers that receive shared information can fuse it during the information fusion (IF) stage. The fused information can be used in the task processing (TP) stage to select an approach to response selection (RS). The command interpretation (CI) stage accounts for restrictions to response selection place on decision makers by superior decision makers. In the final stage a response is selected which can be an organizational output or an input to another decision maker[45]. This model is shown in Figure 6.

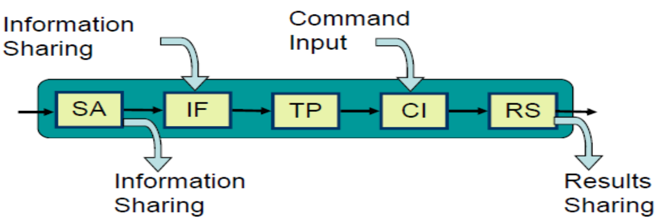

Fig. 6: The Five-stage Decision Maker Model

The five stage interacting decision maker model was extended to model iterative consensus building. Successive iterations were modeled by replicating the decision making organizations. These successive decision making organizations receive as input the results from that domain's previous decision and then during the information fusion stage gain understanding of the other domain's decisions and willingness to continue consensus building. In the response selection stage decision makers not only make a selection for the decision at hand but also determine whether they are willing to begin/continue consensus building. If any decision maker elects not to continue then the decisions will become final regardless of whether consensus has been obtained. Figure 7 demonstrates this process with two organizations and one iteration of consensus building. The coordination process structure is the same for all modeled coordination activity. The only exception is that the command interpretation stage is only used if there is appropriate command guidance. The number of iterations required to achieve full consensus for each type of coordination is a parameter examined in the subsequent analysis and can be deterministic or stochastic.

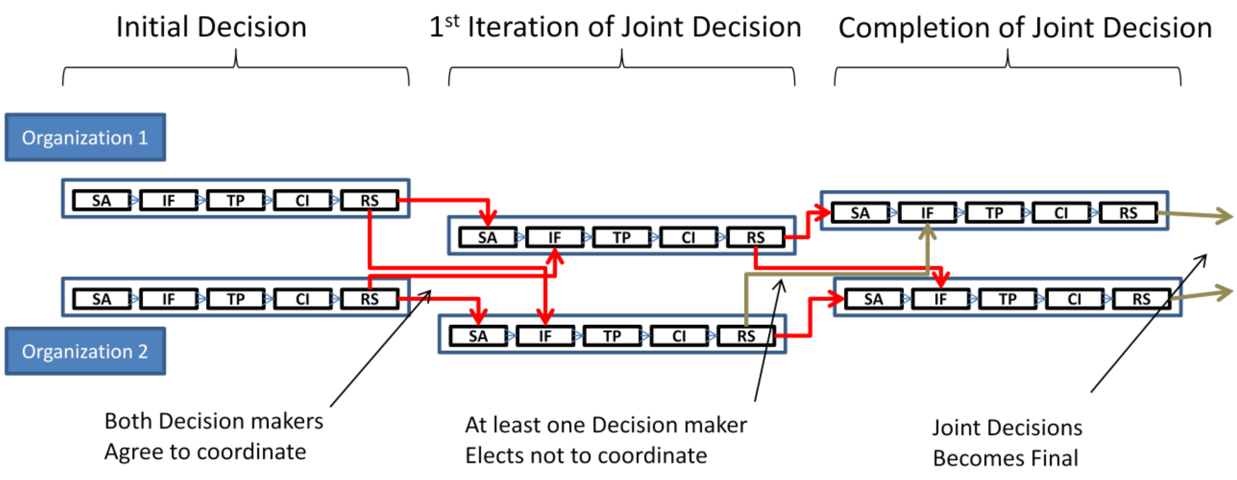

Fig. 7: The Iterative Consensus Building Modeling Approach

Conceptual modeling was accomplished using Timed Influence Nets (TINs) [48]. TINs were used to model both domain conceptual models and courses of action with performance estimates. The Pythia software tool was used to implement the TIN models used in this effort. Influence nets and timed influence nets are probabilistic belief networks with similarities to Bayesian Networks (BN). Unlike BN, TINs assume independence between casual influences which greatly simplifies the process of parameter elicitation by avoiding the requirement for eliciting extensive tables of conditional probability. The tables are instead constructed through the Causal Strengths (CAST) algorithm [49]. In situations where probability estimates are subjective, such as in strategic/operational course of action development, this assumption is appropriate. Previous research has demonstrated the effectiveness of TINs in operational and strategic level course of action development and modeling [50] .

Based on a chosen scenario, one TIN was developed which represents the complete model of the operational environment. An example is shown in Figure 8. The performance of combined COAs will be measured using this complete model regardless of the approach used. COAs are chosen based on domain conceptual models, but the performance is based on applying those actions in the complete model. This complete model is the goal of conceptual model integration, representing a complete understanding of each domain's potential actions and their effects. Each domain will have this conceptual model on which to base COA selection if they conduct the proposed approach to build a common conceptual model. This complete model can be divided into eight types of nodes: actions for each of the three domains; goal node; key influencers of the goal node; standard enemy/environment effects; strong negative cross-domain effects; and strong positive cross-domain effects. The strong cross-domain effect nodes are designed to model the significant but non-obvious interactions that are not routinely discovered with the current approach.[3] The strong positive cross-domain effects are only discovered by creating a common conceptual model. Strong negative cross-domain effects can be identified through a common conceptual model or the more thorough level 2 de-confliction. During level 1 de-confliction, the domains expand their domain-centric conceptual models to incorporate other domains' actions and effects. After successful completion of level 1 de-confliction, all domains have the same conceptual model encompassing all domain actions, goal node, key influencers of the goal node, and standard enemy/environment effects. At that point the domains can proceed to level 2 de-confliction, if they have chosen that approach.

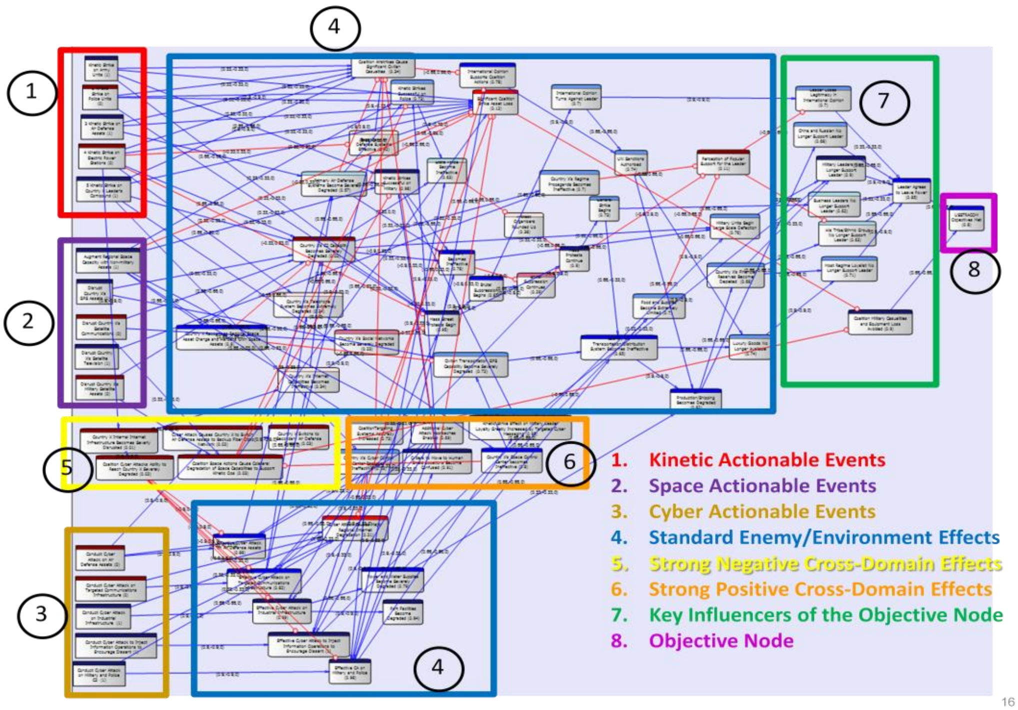

Fig. 8: The Complete Integrated Conceptual Model

Traditional domain centric conceptual models are also represented in a TIN. These domain models have the same goal node but are a subset of the complete TIN. These subsets are intended to model the knowledge of only the effects in the specific domain (and adversaries and neutral actors) without knowledge of the actions of adjacent domains; an example is shown in Figure 9 for the kinetic domain. If no coordination is conducted, domains will choose COA based on respective domain model without any knowledge of the chosen actions of (or effects on) other domains.

[3] The absence of discovery of these types of effects is evident in the continued emphasis on improved integration.

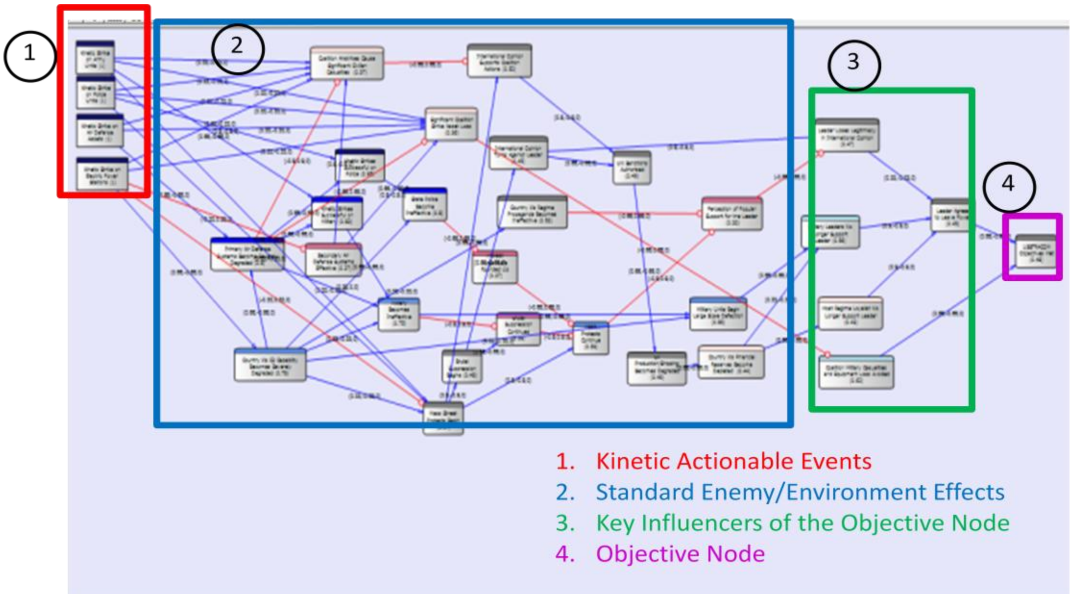

Fig. 9: An Example Domain Conceptual Model

5. Experiment Results

The process model was limited to the military planning phases from receipt of mission to COA approval. The scenario chosen was a 48-hour time line for approval of an operational level COA. In the scenario, coalition forces have the goal of encouraging a brutal dictator to step down from power after he has lost international legitimacy. There is an equally weighted additional goal of preventing significant loss of coalition capability. Parameters considered during results analysis included: expected times for all planning activities, expected times for coordination activities, and expected number of coordination iterations to complete consensus building. In addition to the expected values for those parameters, each was also assigned a variance, zero for the deterministic case up to significant variance for different stochastic settings. The expected values were based on subject matter expert opinions from a current United States military command which conducts strategic and operational level planning. It would seem counter-intuitive that based on the planning activity time estimates the current approach including de-confliction can take longer than 48 hours when the time estimates are based on a 48 hour process. In other words, the apportionment of time from the 48 hours period for de-confliction is less than that required for full de-confliction. This is purposeful based on the feedback that, under current processes, full de-confliction is rarely achieved and time constraints often result in partially de-conflicted COAs. Another parameter examined was that of increasing time efficiency in subsequent consensus building iterations. As the leaders involved become increasingly familiar with the joint decision for which consensus is sought, it is possible that later iterations will take less time. This was modeled with two parameters: a percentage decrease by iteration in the original expected activity time and a minimum activity time.

Table 2 shows the deterministic results and Table 3 shows the stochastic results with significant variance on activity times and coordination iterations required. These results are based on the use of subject matter experts' opinions for parameter settings and computational experimentation with the described modeling methods. An exploration of the sensitivity of the various parameters has shown that these results are not particularly sensitive to any specific parameter value. Increasing the variability of the process times and iteration numbers increases the mean planning time (as would be expected in parallel processes) but the relative difference between the approaches remains fairly constant.

Table 2: Deterministic Model Results

Approach Used	Combined COA Type	Process Times (Without Iteration Efficiency) (CPN Model)		Process Times (With Iteration Efficiency) (CPN Model)		COA Performance (Probability of Goal Node Being True) (Pythia Model)		
		Minutes	Hours	Minutes	Hours	Coalition OBJs Met	Coalition Losses Avoided	Leader Agrees to Leave Power
New Approach	**Integrated COA**	**3105**	**51.75**	**3007**	**50.11**	**0.802**	**0.9**	**0.85**
Current Approach Level 2	**De-conflicted Level 2**	**3385**	**56.42**	**2968**	**49.46**	**0.56**	**0.67**	**0.59**
Current Approach	**De-conflicted**	**3260**	**54.33**	**2860**	**47.66**	**0.394**	**0.45**	**0.43**
No Coordination	**Combined Domain COAs**	**2610**	**43.5**	**2610**	**43.5**	**0.28**	**0.32**	**0.295**

6. Conclusions

Based on estimates of realistic parameters for operational level COA development, the proposed approach provides significantly better integrated performance with at most a marginal increase (up to 5% depending on parameters) in the mean time required for the planning process. These results indicate the potential feasibility of the Co-design approach. However, there are several limitations in this approach to be addressed in further research described below. The approach articulates a framework for logical and efficient construction of a joint understanding of the operational environment between disparate domains. This work also demonstrates a new approach to the C2 planning process which emphasizes integrated planning and development of a common conceptual model. This is in contrast to most current approaches which simply increase sharing information with the expectation that integration will ensue without a specific supporting process. As a feasible alternative to current military planning approaches, Co-design offers an important design alternative for consideration in military command and control architectures.

Table 3: Stochastic Model Results

Approach Used	Combined COA Type	Process Times (Without Iteration Efficiency) (CPN Model)		Process Times (With Iteration Efficiency) (CPN Model)		COA Performance (Probability of Goal Node Being True) (Pythia Model)		
		Hours (Mean)	Hours (Std Dev)	Hours (Mean)	Hours (Std Dev)	Coalition OBJs Met	Coalition Losses Avoided	Leader Agrees to Leave Power
New Approach	**Integrated COA**	**52.6**	**2.3**	**51.2**	**1.8**	**0.802**	**0.9**	**0.85**
Current Approach Level 2	**De-conflicted Level 2**	**57.4**	**1.3**	**50.2**	**1.1**	**0.56**	**0.67**	**0.59**
Current Approach	**De-conflicted**	**55**	**1.5**	**48.5**	**1.2**	**0.394**	**0.45**	**0.43**
No Coordination	**Combined Domain COAs**	**44**	**1.2**	**44**	**1.2**	**0.28**	**0.32**	**0.295**

A key assumption for the model approaches used is domain decision makers are properly motivated to come to consensus and will make choices which increase the likelihood of joint objective accomplishment. Research in many fields have shown the boundedness of rational decision making under various conditions[51]. It is also likely that in real military planning situations, domain leaders may have to balance competing domain objectives with common inter-domain objective(s). It is therefore important that experimentation with the Co-design approach be conducted with human decision makers with and without competing objectives. In addition, the focus of this effort has been on horizontal integration between domains; further research must be done on the application of Co-design within multiple levels of command. Another aspect to be explored is the effect on COA performance of compressing the time allowed for coordination processes in order to meet a strict planning timeline.

References

[1] J. K. DeRosa and M. D. Woodall, "Evolution To Integrated Command and Control," *NASA*, 1998.

[2] D. S. Alberts and R. Hayes, *Power to the Edge: Command and Control in the Information Age*. 2003.

[3] Chief of the Defence Staff, "Canadian Forces Joint Publication 5.0." Apr-2008.

[4] Department of Defense, "Command and Control Joint Integrating Concept." 01-Sep-2005.

[5] Chairman of the Joint Chiefs of Staff, "Joint Operations." 2010.

[6] Department of Defense, "Quadrennial Defense Review Report," Feb. 2010.

[7] J. A. St Laurent, "Military Operations. Actions Needed to Improve DOD's Stability Operations Approach and Enhance Interagency Planning," DTIC Document, 2007.

[8] P. Louvieris, N. Mashanovich, C. Collins, G. White, M. Faulkner, J. Levine, S. Henderson, and D. T. C. Surrey, "Exploring Joint Usability and Decision Effectiveness using a Networked-Enabled Virtual Collaborative Working and Visualisation Environment for Military Planning," 2008.

[9] D. A. Gilmour, “Real-Time Course of Action Analysis,” Information Directorate, Air Force Research Lab, Rome, 2006.
[10] Q. Huang, J. Haallmats, K. Wallenius, and J. Brynielsson, “Simulation-based decision support for command and control in joint operations,” in *Proceedings of the 2003 European Simulation Interoperability Workshop*, p. 091.
[11] T. Clark and T. Moon, “Interoperability for Joint and Coalition Operations,” *Australian Defence Force Journal*, vol. 151, no. November/December, pp. 23–36, 2001.
[12] C. Zins, “Conceptual approaches for defining data, information, and knowledge,” *J. Am. Soc. Inf. Sci.*, vol. 58, no. 4, pp. 479–493, Feb. 2007.
[13] S. G. McIntyre, M. Gauvin, and B. Waruszynski, “Knowledge management in the military context,” *Canadian Military Journal*, vol. 4, no. 1, pp. 35–40, 2003.
[14] W. Perry, *Information Sharing Among Military Headquarters: The Effects on Decisionmaking*. 2004.
[15] D. J. Bryant, “Can We Streamline Operational Planning?,” *Canadian Military Journal*, vol. 7, no. 4, pp. 2006–2007, 2007.
[16] J. Vowell, “Between Discipline and Intuition: The Military Decision Making Process in the Army’s Future Force,” US Army School for Advanced Military Studies,250 Gibbon Ave,Fort Leavenworth,KS,66027, May 2004.
[17] N. R. McCown, “Developing Intuitive Decision-Making In Modern Military Leadership,” Operations Department, Naval War College, Newport, RI, 2010.
[18] C. R. Paparone, “US Army Decision Making: Past, Present and Future,” *Military Review*, Aug. 2001.
[19] M. Vego, “Effects-Based Warfare: A Critical View.”
[20] Z. Jobbagy, “Literature Survey on Effects-Based Operations,” Aug. 2003.
[21] E. A. Smith, *Effects Based Operations: Applying Network Centric Warfare in Peace, Crisis, and War*. .
[22] M. J. Hannan, “Operational Net Assessment: A Framework for Social Network Analysis,” *IO Sphere*.
[23] C. H. Canon, “Systemic Operational Design: An Alternative to Estimate Planning,” Operations Department, Naval War College, Newport, RI, 2009.
[24] C. D. Dalton, “Systemic Operational Design: Epistemological Bumpf or the Way Ahead for Operational Design?,” 2006.
[25] W. T. Sorrells, G. R. Downing, P. J. Blakesley, D. W. Pendall, J. K. Walk, and R. D. Wallwork, “Systemic Operational Design: An Introduction,” School of Advanced Military Studies United States Army Command and General Staff College Fort Leavenworth, Kansas, 2005.
[26] Headquarters Department of the Army, *The Operations Process (FM 5-0)*. Headquarters Department of the Army, 2010.
[27] Chairman of the Joint Chiefs of Staff, “Joint Operation Planning.” 26-Dec-2006.
[28] Chairman of the Joint Chiefs of Staff, “Joint Operation Planning and Execution System (JOPES) Volume I (Planning Policies and Procedures).” Joint Staff Washington, D.C. 20318, 2001.
[29] J. D. Thompson, *Organizations in Action*. McGraw-Hill, 1967.
[30] M. Mullen, “The National Military Strategy of the United States.” Joint Chiefs of Staff, 2011.

[31] “Organizational Transformation: Military Departments Can Improve Their Enterprise Architecture Programs.” Government Accountability Office, 2011.
[32] T. F. Jenkins, A. D. Hewitt, C. L. Grant, S. Thiboutot, G. Ampleman, M. E. Walsh, T. A. Ranney, C. A. Ramsey, A. J. Palazzo, and J. C. Pennington, “Description and Analysis of Military Planning Systems,” 2006.
[33] S. Liu, Duffy, A.H.B., and Whitfield, R.I, “Towards the Realisation of an Integratated Decision Support Environment for Organisational Decision Making,” *International Journal of the Decision Support System Technology*, vol. 1, no. 4, pp. 35–58, 2009.
[34] M. Chmielewski, “Ontology Applications for Achieving Situation Awareness in Military Decision Support Systems,” *Computational Collective Intelligence. Semantic Web, Social Networks and Multiagent Systems*, pp. 528–539, 2009.
[35] J. Hanna, “Course of Action Simulation Analysis,” Science Applications International Corp (SAIC) Beavercreek Ohio, 2005.
[36] G. E. Seymour and M. B. Cowen, “A Review of Team Collaboration Tools Used In the Military and Government,” 2007.
[37] P. Louvieris, A. Gregoriades, and W. Garn, “Assessing critical success factors for military decision support,” *Expert Systems with Applications*, vol. 37, no. 12, pp. 8229–8241, 2010.
[38] “Defense Acquisitions: Steps Needed to Ensure Interoperability of Systems That Process Intelligence Data.” United States General Accounting Office, 2003.
[39] S. C.-Y. Lu and J. Cai, “A Collaborative Design Process Model in the Sociotechnical Engineering Design Framework,” *Artif. Intell. Eng. Des. Anal. Manuf.*, vol. 15, no. 1, pp. 3–20, Jan. 2001.
[40] K. Schmidt, “Modes and Mechanisms of Interaction in Cooperative Work,” *RisU00F8 National Laboratory, Roskilde, Denmark*, 1994.
[41] H.-Z. Huang, H.-W. Xu, and Xu Zu, “Petri Net-based Coordination Component for Collaborative Design,” *Concurrent Engineering*, vol. 18, no. 3, pp. 199–205, Sep. 2010.
[42] G. L. Klein, J. L. Drury, M. Pfaff, and L. More, “COA Action: Enabling Collaborative Option Awareness,” 2010.
[43] G. L. Klein and L. Adelman, “A Collaboration Evaluation Framework,” in *Proceedings of the 2005 International Conference on Intelligence Analysis*, 2005.
[44] T. Saltysiak, “On Approaches for Integrated Course of Action Development,” George Mason University, Fairfax, VA, 2012.
[45] A. H. Levis, “A Colored Petri Net Model of Command and Control Nodes,” in *Toward a Science of Command Control and Communications*, Carl R. Jones., Washington, DC: AIAA Press, 1993.
[46] J. G. March and H. A. Simon, *Organizations*. Oxford, England: Wiley, 1958.
[47] H. Mintzberg, D. Raisinghani, and A. Théorêt, “The Structure of ‘Unstructured’ Decision Processes,” *Administrative Science Quarterly*, vol. 21, no. 2, pp. 246–275, Jun. 1976.
[48] L. W. Wagenhals, I. Shin, and A. H. Levis, “Creating Executable Models of Influence Nets with Colored Petri Nets,” *International Journal on Software Tools for Technology Transfer (STTT)*, vol. 2, no. 2, pp. 168–181, Dec. 1998.
[49] K. C. Chang, P. E. Lehner, A. H. Levis, A. K. Zaidi, and Z. Xinhai, “On Causal Influence Logic,” George Mason University, Center of Excellence for C3I, 1994.
[50] L. W. Wagenhals, T. Reid, R. J. Smillie, and A. H. Levis, “Course of Action Analysis for Coalition Operations.” Jun-2001.

[51] H. A. Simon, G. B. Dantzig, R. Hogarth, C. R. Plott, H. Raiffa, T. C. Schelling, K. A. Shepsle, R. Thaler, A. Tversky, and S. Winter, “Decision making and problem solving,” *Interfaces*, pp. 11–31, 1987.