Tracks: #1 Coalition Interoperability; #7 Information Superiority/Information Operations

Course of Action Analysis for Coalition Operations

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Abstract

A prototype Decision Support System for Coalition Operations (DSCCO) is being developed by SPAWAR Systems Center – San Diego to support the Operations Planning Team (OPT) of the Commander in Chief, United States Pacific Command. The goal of DSCCO is to apply and integrate organizational design concepts and decision support technologies in planning and executing multi-national coalition operations. Within DSSCO, there is a module based on CAESAR II[2] focused on the analysis of alternative Courses of Action (COAs). The capabilities of DSSCO and the CAESAR II / COA module were demonstrated in November 2000 at USCINCPAC.

Subject matter expects (SMEs) collaborated in a distributed manner in developing the structure (the relationships between causes and effects) and the data of an Influence Net model representing a key outcome in a hypothetical military operation other than war (MOOTW) in a South Pacific scenario. The influence net was implemented in the CAESAR II / COA module, and sensitivity analysis was used to determine which actions could contribute substantially in achieving the desired effects. Those selected actions formed the basis for the construction of COAs, namely, time-phased sequences of these events. The CAESAR II / COA module was used to illustrate the impact of time-coordinated actions of the coalition partners to the decision-makers.

1 Introduction

US CINCs face the problem of developing and selecting COAs composed of coordinated activities and events carried out by coalition partners supporting small scale contingencies and MOOTW including humanitarian assistance and disaster relief.[3] Given the potential complexity of future situations, as evidenced by the operations in Bosnia and Kosovo, and the many consequences of the responses, an approach was needed that (a) related conventional and information operations of multiple coalition partners to events and events to effects; (b) allowed for the critical time-phasing of actions for maximum effect; and (c) provided in a timely manner the ability to carry out, in near-real-time, trade-off analyses of alternative COAs. A prototype system to assist in developing COAs for Effects-Based Operations (EBO) and evaluating them

[1] This work was supported by SPAWAR Systems Center – San Diego under contract no. N66001-00-M-0724 (GMU) and N66001-99-D-0050 (KAI)

[2] A. H. Levis, Course of Action Development for Information Operations, Phalanx, Vol. 33, No. 4, December 2000

[3] Joint Publication 3-16, *Joint Doctrine for Multinational Operations*, April 2000.

with respect to the effects they are expected to achieve has been developed and is called CAESAR II/COA.

The problem of planning, executing and assessing COAs requires the synthesis of a number of modeling approaches. The CAESAR II/COA prototype system was designed to assist in developing COAs for EBO and evaluating them in terms of the probability of achieving the desired effect. Two of the key components of the system are: (a) an influence net modeler such as CAT, and (b) an executable model generator and simulator based on the software implementation of Colored Petri Nets called Design/CPN. The executable model is used to simulate the COAs and collect data on Measures of Performance. One particular output is the probability of achieving the desired effect as a function of time, called a probability profile. Probability profiles can be compared to determine the more effective COAs. This version of CAESAR II/COA was demonstrated in November 2000 at PACOM Headquarters as part of the DSSCO tool suite. Experiences with building and using the model to support the demonstration are described.

The rest of the paper is organized as follows. Section 2 describes the process for using the CAESAR II/COA tool to develop and evaluate COAs for coalition operations. Section 3 describes the scenario that was used for the demonstration and explains the collaboration that was done to build the influence net model and determine the temporal information. Section 4 presents the sensitivity analysis, and the sequence and timing evaluation using the executable model. Section 5 summarizes the paper with findings and areas for future research.

2 Description of Process: From Commander's Intent to COA development and analysis

The process embodied in CAESAR II/COA consists of four steps. The first step is the determination of the desired effects: the objectives are set by the National Command Authority (NCA) at the strategic level and by the Commander through the Commander's Intent for the operational level (Figure 1).[4] To reach the objectives, certain effects must be achieved. This determination can be accomplished using probabilistic modeling tools (e.g., influence net modeling) such as CAT[5] or SIAM.[6] An influence net model allows the intelligence analyst to build complex models of

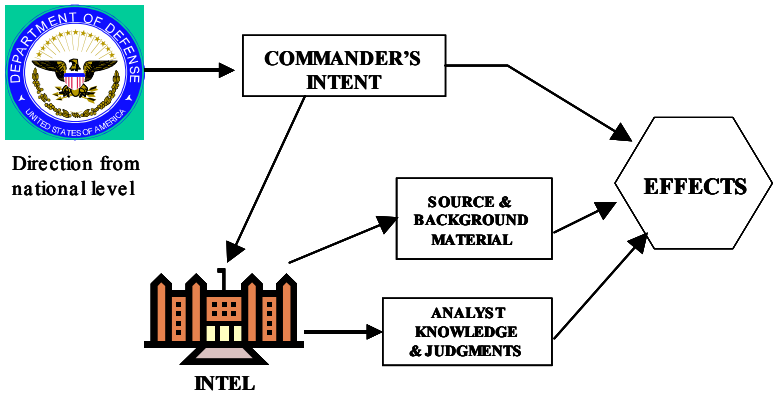

Figure 1: Establishment of desired effects

[4] Joint Publication 3-07, *Joint Doctrine for Military Operations Other Than War*, June 1995, pg. II-1.

[5] CAT is the Effects Based Campaign Planning and Assessment Tool under development at AFRL/IF and is used as a module in the CAESAR II suite of tools.

[6] Rosen, J. A., and Smith, W.L. (1996). "Influence net Modeling with causal Strengths: an Evolutionary Approach," *Proc. Command and Control Research Symposium,* Naval Postgraduate School, Monterey, CA. pp. 699-708. SIAM is a COTS product developed by SAIC to support the intelligence community. It is used as an alternative module in CAESAR II/COA. While version 2.0 supports the export of a file to Design/CPN, version 3.0 does not.

probabilistic influences between causes and effects and between effects and actionable events (Figure 2).

The influence net model is then used to carry out sensitivity analyses to determine which actionable events, alone and in combination, appear to produce the desired effects. It should be noted that influence nets are static probabilistic models; they do not take into account temporal aspects in relating causes and effects. However, they serve an effective role in relating actions to events and in winnowing out the large number of possible combinations. The result of this step is the determination of a number of actionable events that appear to produce the desired effects and an estimate of the extent to which the goal can be achieved.

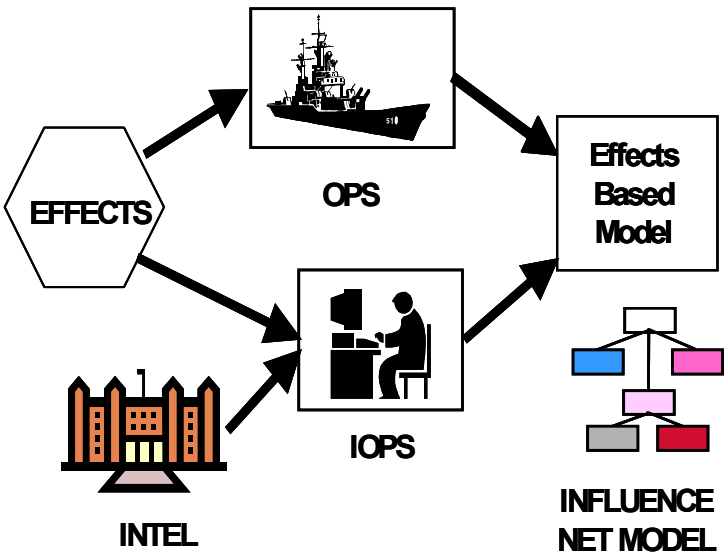

Figure 2. The Effects Based model includes both conventional and information operations as actionable events

Once the influence net of the situation has been developed, the situation analyst uses an automatic algorithm in CAESAR II/COA to convert it into an executable model in the form of a Colored Petri (CP) net that allows the introduction of temporal aspects (Figure 3). These temporal aspects include the time delays associated with the propagation of influences in the influence net and the sequence and timing of the actionable events that comprise candidate COAs. The executable model, when properly initialized with this temporal information, is then used in the simulation mode to determine the effectiveness of the candidate COAs by generating

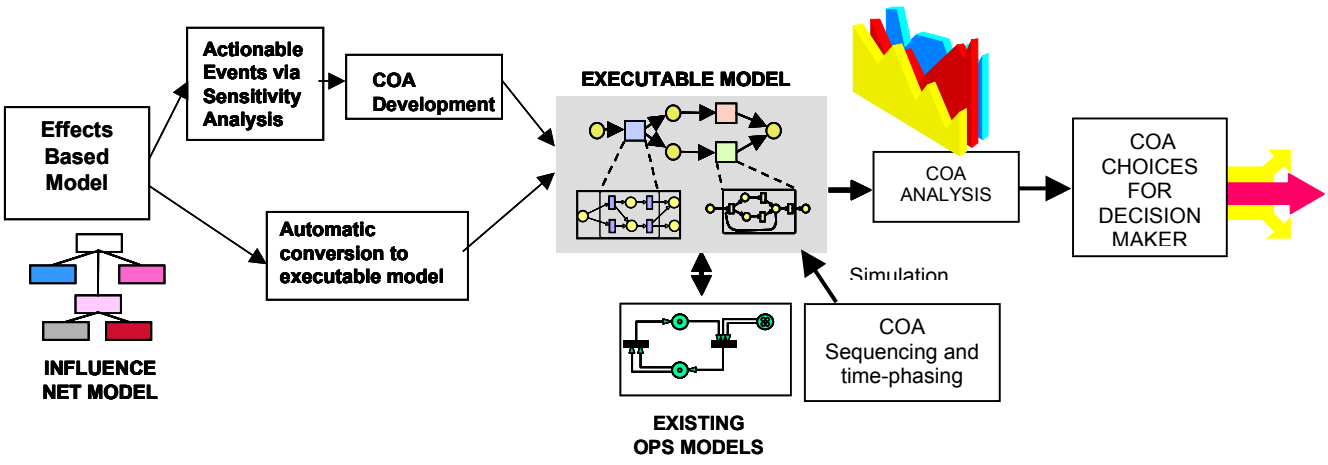

Figure 3. Converting Influence Net to Executable and Evaluation Candidate COAs

the time-related probability profile for each one. A commander can then make an informed choice and direct the planning staff to prepare a detailed plan for the chosen COA.

3 Example of the Process

To prepare for the demonstration, the process described in Section 2 was closely followed. After developing a scenario for the demonstration, the influence net was developed by a team of SMEs. Initially, the SMEs worked without the use of an influence net tool. Instead they developed the model using Excel. The knowledge captured in the Excel model was then converted into the influence net using the CAT tool. Using CAT, sensitivity analysis was conducted to assess the set of actions that should be planned for to achieve the desired effects. After this assessment, the CAT model was imported into the web-based portion of the CAESAR II/COA tool for temporal analysis of candidate COAs.

3.1 Scenario

A scenario that was plausible but fictitious was developed for the purpose of the demonstration. The purpose of using a specific hypothetical scenario was to bound the information with which DSSCO developers "stocked" the DSSCO components and resources (databases, task templates, and a coalition planning guide) and to provide a context for prototype interaction during user testing and any associated demonstration/training. This scenario was designed to enable DSSCO products to be demonstrated in the context of the planning and monitoring processes of a coalition operation.

This scenario involves actual countries and organizations. This helped guide DSSCO product development, as the feasibility of accessing desired information was tested while the scenario was being constructed. Having real information also served as a basis for a user to assess its usefulness within the context of the planning or monitoring processes that are depicted in the scenario.

The scenario involves Indonesia, and a great deal of detailed information about the religious, ethnic, governmental, and non-governmental organizations was assembled. In the scenario, internal political instabilities in Indonesia have deteriorated and ethnic tensions between the multiple groups that comprise Indonesia have increased. Religion has been a major factor in these conflicts. Members of one of the minority (2%) religious groups have banded together to combat disenfranchisement.

These members have formed a rebel militia group. Armed conflict recently occurred between these rebels and the Indonesian military. The rebels fled to eastern Java where they have secured an enclave of land. This has resulted in a large number of Indonesian citizens (estimates of about 10,000) who are within the rebel-secured territory. Many of these people are unsympathetic to the rebels and are considered to be at risk. It is feared that they may be used as hostages if ongoing negotiations break down with the Indonesian government. The food and water supply and sanitation facilities are very limited within the rebel-secured territory.

Several humanitarian assistance (HA) organizations are on the island, having been involved with food distribution and the delivery of public health services to the urban poor for several years. So far, the rebels have not prevented HA personnel from entering the territory to take supplies to the citizens. The U.S. and Australian embassies in Jakarta are closely monitoring the situation for any indications of increasing rebel activity. In addition, Thailand, which has sent several hundred citizens to staff numerous capital investment projects on Java, is known to be closely monitoring the situation.

As the crisis deepens, a US interagency working group (IWG) has been formed to assess the situation and examine the possible ramifications of the crisis and possible US response. Additionally, the Australians indicate that they will participate, but not lead, in any effort to support the HA being provided.

As the theater CINC, USCINCPAC is a member of the IWG[7] and begins planning coalition operations to support the Indonesian government and protect the ongoing HA effort. The USCP OPT forms to assess the situation, using a DSSCO template to guide the assessment. Using collaboration tools, the American embassy in Jakarta and the Australian Theater command join in this assessment effort. Also assisting is the CINCPAC Center of Excellence for Humanitarian Assistance and Disaster Relief, which has extensive information on non-governmental organizations (NGOs) and private volunteer organizations (PVOs) operating in Indonesia.

With the decision by the NCA to take action in response to this crisis, the Planning Phase of Operation RESTORE ORDER commences. COMSEVENTHFLT is designated as the Commander Coalition Task Force (CCTF) to lead the coalition effort, with an Australian deputy commander. Data from the DSSCO Coalition Database provides the CCTF with information on potential coalition partners to assist in planning.

It is apparent from the start that the use of sectors for the mission is the most effective way to divide up the effort. A Joint Operations Area (JOA) is designated and divided into three sectors, one each for the US, the Australians, and the Laotians, who have joined the coalition.[8] US Coalition Support Teams are assigned to the coalition partners to assist in communications and liaison. The Malaysian military wants to participate in the operation and the NCA directs that they be included in the coalition. Because of recent tensions between the Indonesian and Malaysian governments, it is decided that the Malaysians will provide support in the headquarters area, working closely with the US.

In the meantime, the International Committee of the Red Cross reports that they would like to send more resources into the area, via the Red Crescent, if the area is secure. Jakarta is concerned with the Rules of Engagement (ROE) to be employed and with the growing size of the footprint. This prompts the NCA to direct that the CCTF coordinate closely with the Indonesian government.

The Execution Phase of the operation commences when the Indonesian government recognizes that their military forces are unable to maintain peace and that the tide of world opinion has turned against them. The government then asks the US to lead the anticipated coalition operation in an effort to ensure aid is delivered to the population encompassed by the JOA.

Coalition forces begin to arrive in the JOA and CCTF / COMSEVENTHFLT establishes a Civil Military Operations Center (CMOC) to coordinate the ongoing relief operations between coalition military forces and NGOs.[9] The first priority is to secure and provide protection of the Air Ports of Debarkation and Surface Ports of Debarkation to allow all of the coalition forces to arrive quickly. The flow of aid increases dramatically as the operation progresses.

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[7] Joint Publication 3-08, *Interagency Coordination During Joint Operations Vol I*, October 1996, pg. I-3.
[8] Joint Publication 5-00.2, *Joint Task Force Planning Guidance and Procedures*, January 1999, pg. I-2.
[9] Joint Publication 3-07.3, *Joint Tactics, Techniques, and Procedures for Peace Operations*, February 1999, pg. I-15.

Of increasing concern is the threat from rebel leaders that the presence of Malaysians is unacceptable. Rebel leaders warn that, in their view, Malaysia has a poor record towards people of the rebels' faith. The Malaysians are currently assigned to HQ support in the US sector.

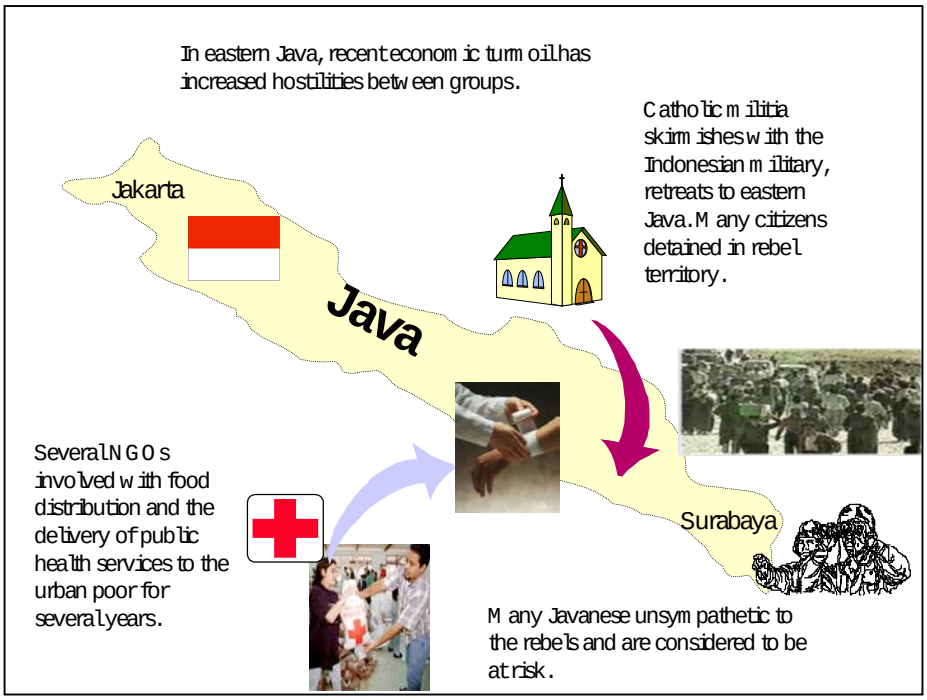

Figure 4. The coalition was asked to provide physical security for NGOs and PVOs supplying HA aid to Indonesia

As the HA effort progresses, the situation continues to destabilize. NGOs in the JOA report incidents of rape of their workers by Indonesian soldiers and the NGOs request security assistance from the CCTF via the CMOC.

The deteriorating conditions within the JOA are not the only problem facing the coalition. NGOs in the JOA also report that regional pirate activity threatens food distribution. Coalition naval forces step up patrols to combat this threat.

Despite the increased emphasis on force protection and protection of NGOs, conditions continue to deteriorate. The Thai government reports that it will conduct a unilateral noncombatant evacuation operation (NEO) of its citizens from eastern Java.

CCTF / COMSEVENTHFLT confers with the CINC, who in turn, confers with the NCA and the IWG to determine the US response to this development. Figure 4 encapsulates some of the key points in the scenario.

3.2 Derivation of Key Effects

Peacetime ROE remain in effect at this point. There are now essentially three threats for the coalition to cope with.

- The original anti-Government of Indonesia (GOI) faction (the rebels in the enclave). Although threatening now to also take on an anti-Malaysian nature, to date, all incidents have been conflict with GOI troops. Rebels may be holed-up in the enclave, which contains 10,000 Indonesian noncombatants who are not rebel sympathizers. Protection of these noncombatants was the reason for the original GOI request for US assistance.
- GOI Army troops (who have reportedly raped NGO workers)
- Pirates (threatening the arrival of goods and, thus, food distribution)

The challenge to the CCTF is to meet physical security objectives, while maintaining neutrality. His objective is to provide physical security for the HA effort until the GOI – rebel peace negotiations are concluded and the GOI can once again guarantee the security of the HA effort. In the interim, the CCTF must:

- Protect all noncombatants from the rebels
- Protect NGO/PVO workers from the GOI army
- Protect HA resupply efforts from piracy (outside of GOI territory)
- As a precaution, he must also be prepared for a NEO

In 1984, then-Secretary of Defense Caspar Weinberger, speaking at the National Press Club, articulated a six-point test for the employment of US forces in combat abroad.[10] (See Figure 5.) That test remains valid. If the CCTF had applied that test to this scenario, it would be clear that these conditions were unlikely to be met to allow the commitment of US forces to a combat role. Given that, the question would be, "How do we prevent this turning into a combat scenario?" The answer leads us to the imperative to deter rebel violence.

1. The United States should not commit forces to combat overseas unless the particular engagement or occasion is deemed vital to our national interest or that of our allies.
2. If we decide it is necessary to put combat troops into a given situation, we should do so wholeheartedly, and with the clear intention of winning.
3. If we do decide to commit forces to combat overseas, we should have clearly defined political and military objectives.
4. The relationship between our objectives and the forces we have committed— their size, composition, and disposition— must be continually reassessed and adjusted if necessary.
5. Before the U.S. commits combat forces abroad, there must be some reasonable assurance we will have the support of the American people and their elected representatives in Congress.
6. The commitment of U.S. forces to combat should be a last resort.

Figure 5. Secretary of Defense Weinberger's six point test for the use of US combat forces abroad

Failing to deter that violence could be a harbinger of mission creep that changes the perception of US troops from welcome peacekeepers to adversaries.[11] The bombing of the Marine Barracks in Lebanon in 1983 and the shootdown of the Army Blackhawk in Somalia in 1993 illustrate the risk of that path.[12] In both cases, US forces were withdrawn after suffering casualties in a situation that was unlike the one they first deployed into.

In developing an influence net for this scenario, then, the effect that was most closely scrutinized was "Can the coalition deter rebel violence long enough for the GOI and rebels to negotiate a settlement?" This could allow the coalition to successfully return the physical security responsibility for the longstanding HA effort to the GOI after a short-term commitment of coalition forces with a non-combat mission. Thus the key effect upon which the COA would be evaluated was expressed as "The rebels decide to avoid violence."

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[10] Caspar W. Weinberger, *Fighting for Peace: Seven Critical Years in the Pentagon*, Warner Books, 1990, pp. 433-445.

[11] Joint Publication 3-07.3, *Joint Tactics, Techniques, and Procedures for Peace Operations*, February 1999, pg. I-9.

[12] Adam B. Siegel, "Mission Creep or Mission Misunderstood?," *Joint Force Quarterly* (Summer 2000), pg. 114.

3.3 Building the net in EXCEL: Knowledge Elicitation from SMEs (nodes, relationships, weights, and timing information)

To that end, we convened a session among SMEs. They represented years of experience in operations, intelligence, and politico-military affairs at all levels from the task force commander's staff, to the CINC's staff, to the Joint Staff and NCA advisors. Some of them had credentials for in-depth understanding of the sensitive cross-cultural issues involved in this scenario. Some were selected because they did not specialize in this theater but understood well the staff work required to support a CCTF.

In trying to identify all possible cause-and-effect relationships relevant to this influence net, they began with examining how the US could influence the rebels. Doctrine teaches us that a nation's grand strategy has four instruments of power that can be brought to bear:[13]

- Economic
- Diplomatic
- Informational
- Military

Each of these instruments of power was explored in depth. Additionally, doctrinal sources for civil affairs[14] and psychological operations[15] were consulted to fully flesh-in the options for the use of military power that remained short of combat operations. 91 cause-and-effect relationships were identified that might influence the ability to deter rebel violence.

Each of the experts then expressed their confidence in these relationships by voting on three things:

- How likely do you think it is that this causal condition is true?
- If true, how likely is it to cause the indicated effect?
- If untrue, how likely to cause the indicated effect not to happen?

Since the influence net was developed without benefit of access to CAT, collaboration was done via e-mail, with ballots cast by filling-in Microsoft Excel worksheets. (All experts had access to IT-21 technology, which includes Excel.) The returned votes were copied into an Excel file (Figure 6[16]) as new worksheets and then a final worksheet was set-up to tabulate them

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[13] Joint Publication 1, *Joint Warfare of the Armed Forces of the United States*, November 2000, pp. I-5 - I-8.
[14] Joint Publication 3-57, *Doctrine for Joint Civil Affairs*, June 1995.
[15] Joint Publication 3-53, *Doctrine for Joint Psychological Operations*, July 1996.
[16] Each row in the spread sheet documents a cause and effect relationship in the influence net. Graphically, each row indicates that there is an influence arc from the causal node to the effect node. Each node has a unique ID number as shown in the first and third columns. The number in the fifth column is used to determine the baseline probability of each causal node. The number, which ranges between –5 and 5, is normalized to a value between 0.0 and 1.0. The numbers in the last two columns correspond to the h and g values used in the CAST Logic algorithm [Rosen and Smith] for estimating the conditional probability values for a node in the influence net. The number in the "confidence in positive effect" column indicates the "strength" of the influence if the cause is true. Negative numbers, indicated by parenthesis, mean that if the cause is true, the effect will be less likely. Positive numbers mean that if the cause is true the effect is more likely. The "confidence in negative effect" (last column) indicates a similar assessment for the condition that the cause is false. For example, the second row indicates that node number 3 is "Rebels believe the coalition will keep peace impartially" and it has a baseline probability of 0.4 (normalized from –1.00). It influences node number 1, "Rebel decide to avoid violence." If node 3 is true, it will have a fairly strong positive influence on node 1. If node 3 is false there will be a fairly strong negative influence on node 1.

Votes were tallied and reviewed. Three general patterns were recognized.

- General group consensus, with some variation in grades assigned. The mean was used to express the group consensus as to numerical strength.
- Bipolar grouping. The issue was identified and revisited to ensure that there was no error in communications due to phraseology employed in describing the cause-and-effect relationship. When the issues were clear but the experts broke into two schools of thought, the "mainstream" mean was captured as a "weak" group consensus, with the item flagged as having a minority position (represented by the mean of the second grouping). This became an ideal candidate for later running a sensitivity analysis.
- A single outlying point (roughly two standard deviations from the mean of the other mass). Most of these were resolved when investigation proved that there had been a miscommunication. Those that could not be resolved that way were treated as bipolar grouping as indicated above, although the group consensus was not identified as weak. The minority position was identified for later running a sensitivity analysis.

#	Cause	#	Effect	Belief cause is true (Score from -5 to +5)	>	Confidence in positive effect (Score from -5 to +5)	Confidence in negative effect (Score from -5 to +5)
1	Rebels decide to avoid violence		**None. This is our root node.**	TBD		N / A	N / A
2	Rebels want coalition in Indonesia	1	Rebels decide to avoid violence	(1.50)	>	2.20	(2.80)
3	Rebels believe coalition will keep peace impartially	1	Rebels decide to avoid violence	(1.00)	>	3.10	(3.88)
4	Rebels believe coalition has resolve to stop them	1	Rebels decide to avoid violence	0.60	>	2.80	(3.75)
5	Rebels believe coalition has military power to stop them	1	Rebels decide to avoid violence	1.70	>	2.20	(3.75)
6	Rebel-GOI peace talks proceeding smoothly	1	Rebels decide to avoid violence	(2.20)	>	3.10	(3.75)
7	Rebels believe coalition will keep peace impartially	2	Rebels want coalition in Indonesia	(1.00)	>	1.80	(4.25)
8	Rebels will deal in good faith with GOI	2	Rebels want coalition in Indonesia	(1.80)	>	(0.80)	(3.00)
9	Rebels will deal in good faith with GOI	6	Rebel-GOI peace talks proceeding smoothly	(1.80)	>	1.10	(4.20)
10	Rebels believe GOI will keep peace impartially	8	Rebels will deal in good faith with GOI	(3.60)	>	2.80	(3.75)
11	Rebels believe GOI has military power to stop them	8	Rebels will deal in good faith with GOI	(1.40)	>	1.40	(2.50)
12	Rebels believe GOI has resolve to stop them	8	Rebels will deal in good faith with GOI	(1.80)	>	0.80	(2.75)
13	GOI will negotiate with rebels in good faith	6	Rebel-GOI peace talks proceeding smoothly	(2.70)	>	(0.30)	(4.13)
14	GOI troops launch an assault on rebels	10	Rebels believe GOI will keep peace impartially	0.20	o	(4.20)	(1.88)
15	GOI cedes control of enclave to rebels	12	Rebels believe GOI has resolve to stop them	(2.50)	o	(1.80)	(0.63)
16	GOI declares resolve to keep peace in Indonesia	10	Rebels believe GOI will keep peace impartially	0.80	>	(0.70)	(2.38)
17	GOI troops launch an assault on rebels	12	Rebels believe GOI has resolve to stop them	0.20	>	(0.50)	(1.80)
18	Rebels believe firm US resolve will hold coalition together	4	Rebels believe coalition has resolve to stop them	1.80	>	1.80	(3.00)

Figure 6. The relationships and their strengths were initially expressed in Excel.

Following this pattern when expressing group beliefs avoided having a "strongly supporting" camp and a "strongly reversing" camp negate each other and show that the group thought there was "not much impact" in a cause-and-effect relationship. The knowledge that a sensitivity analysis would be run to give weight to minority opinions allowed even vigorous supporters of

minority opinions to embrace the use of the influence net. Had this capability of CAESAR II not existed, some SMEs would have cautioned against the use of this net as a decision-making aid. Realizing those minority voices could be heard in "What if . . .?" sensitivity analyses was viewed as a significant step forward.

3.4 The Influence Net in CAT

Once the team of SMEs had completed the description of the influence net, the information contained in the Excel spreadsheet was brought into the CAT influence net tool. This provides a graphical representation of the knowledge of the SMEs, supports visualization of the impact of the selection of multiple actionable events on the key effect, and enables sensitivity analysis.

The influence net model for this scenario is shown in Figure 7. Each node represents an action, event, belief, or decision. A declarative sentence in the form of a proposition is used to express the meaning of each node. The directed arcs between two nodes mean that there is an influencing or causal relation between those nodes. The truth or falsity of the parent node can affect the truth or falsity of the child node. The influence net has been arranged with actions toward the left and the key decisions on the right. This is to indicate visually that the effects of the actions are expected to propagate to intermediate effects over time until their impact reaches

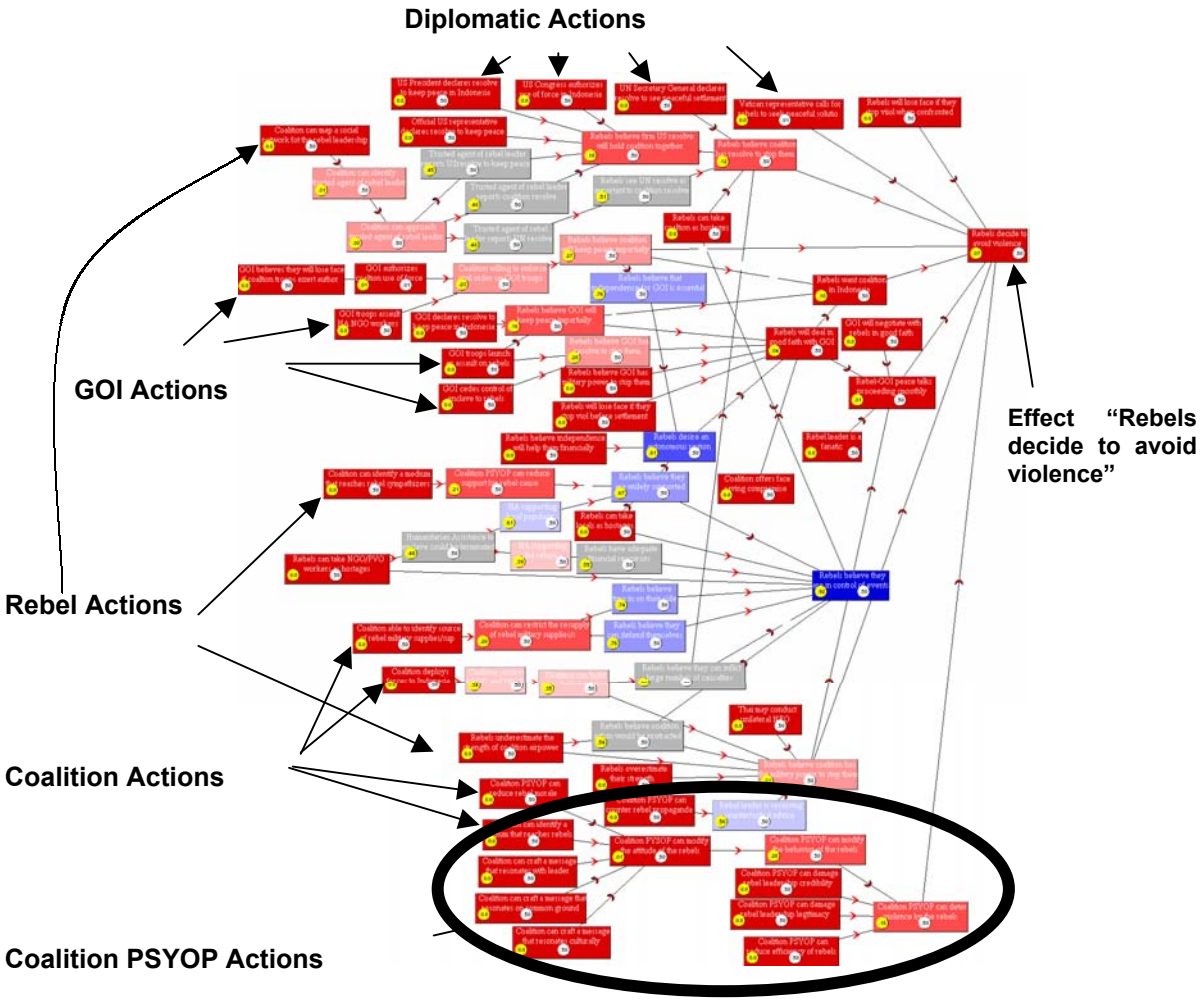

Figure 7. Influence Net of the Indonesian Scenario

the key decisions. The visual construct is that there is a time scale associated with the propagation of effects between nodes of the influence net that moves from left to right. As indicated in the figure, the actions have been grouped by actor or type. There are twenty-six actionable events in these groups. Each is a candidate action (or results of actions) that can comprise a COA that can impact the key effect.

Once the influence net was completed, it was used to evaluate the impact of actions on the effects (decisions) of interest. This was accomplished in several ways. The first, and simplest, method was by setting the probabilities of the actionable events to either zero or one, depending on whether the action was planned or not, and evaluating the influence net. Algorithmically, this meant that the tool propagated these probabilities until all effects were accounted for at the nodes with no children. These nodes are the key decision nodes. In the variant of CAT used to create the example model, the results of this evaluation are visually shown by the color of each node and by providing marginal probability values of each node in a small circle on the lower left corner of the node. In the color scheme, dark red means that the declaration in the node is false, dark blue means the declaration is true, gray means the probability of the declaration is true is near 0.5. Lighter shades of red mean that the probability of the declaration is between zero and 0.5 and lighter shades of blue mean that the same probability is between 0.5 and 1.0. This colorization helps with the visualization of the complete impact of a COA that includes the actions that have been given a probability of one. The influence net in Figure 7 shows the probabilities for all nodes that result when none of the actionable events has occurred, i.e. their probabilities are nil. Under these conditions, the model indicates that the probability that the rebels will act peacefully is only 0.07. An analyst could experiment with the influence net by changing the probabilities of one or more of the actionable events and seeing what the effect would be on the key decision nodes.

3.5 Sensitivity Analysis

To assist in analysis of the affect of the actionable events, both CAT and SIAM have built in Sensitivity Analysis routines. After selecting a node, usually the key decision nodes, the routine indicates the effect each actionable event has on the selected node if the probability of the actionable event is set to either zero or one. This analysis indicates which actionable events increase or promote the likelihood of the key decisions and which actionable events decrease or inhibit that likelihood. It also indicates the magnitude of the effect each actionable event has by itself on the situation. A portion of the Sensitivity Analysis output for the key decision node of the Influence Net of Figure 7 is shown in Table 1.

The Sensitivity Analysis Table indicates that the current probability of the decision node “Rebels decide to avoid violence ” is 0.07. This is based on all of the actionable events not occurring (Marginal Probability = 0.0). The second numerical column of the table indicates the probability of the decision node if the probability of each actionable event is zero. In this case, it is the same as the current marginal probability node of 0.07. The third numerical column shows the marginal probability if each actionable event occurred by itself (and all the others remained unchanged). This column shows that most of the actionable events increase the likelihood of decision although a few of the actionable events decrease its likelihood. Furthermore, no single actionable event can cause a large increase in the effect (there is no “silver bullet”). The same conclusions can be drawn from the fourth numerical column of the table that contains the sensitivity coefficients. Positive coefficients mean that the action promotes the decision and

Table 1. Sensitivity Analysis Output

Sensitivity Analysis for Node: Rebels decide to avoid violence -- Probability : 0.0709

NAME	Marg. Prob.	Prob. at 0	Prob. at 1	Sensitivity
Rebels believe GOI has military pow	0.0000	0.0709	0.0732	0.0002
GOI will negotiate with rebels in g	0.0000	0.0709	0.0883	0.0013
GOI troops launch an assault on reb	0.0000	0.0709	0.0705	-0.0000
GOI declares resolve to keep peace	0.0000	0.0709	0.0714	0.0000
GOI cedes control of enclave to reb	0.0000	0.0709	0.0708	-0.0000
Coalition can map a social network	0.0000	0.0709	0.0732	0.0002
UN Secretary General declares resol	0.0000	0.0709	0.0931	0.0016
US President declares resolve to ke	0.0000	0.0709	0.0881	0.0013
Official US representative declares	0.0000	0.0709	0.0825	0.0009
US Congress authorizes use of force	0.0000	0.0709	0.0830	0.0009
Vatican representative calls for re	0.0000	0.0709	0.0863	0.0011
Coalition PSYOP can damage rebel le	0.0000	0.0709	0.0803	0.0007
Coalition PSYOP can damage rebel le	0.0000	0.0709	0.0790	0.0006
Coalition PSYOP can reduce efficien	0.0000	0.0709	0.0792	0.0006
.....	..	..	..	..

negative coefficients mean that the action inhibits the decision. Comparing the magnitude of the coefficients indicates which actions have the greatest promoting or inhibiting affect.

4 Temporal Analysis of COAs: The Executable Model

Once the analysis of the influence net was completed and the actionable events for the COA were selected, the operational planners assessed the availability of resources to carry out the tasks that would result in the occurrence of the actionable events. The resultant plan indicated when each actionable event would occur. The next step in the COA evaluation process was to convert the influence net to an executable model so that a temporal analysis of the COA could be performed.[17] Using the executable model, an analyst was able to generate the probability profiles that show the marginal probability for any node in the net as a function of time. These profiles indicate how long it would take for the effects of the actionable events to affect various nodes in the influence net. The analyst was able to concentrate on the probability profiles of the key decision nodes, those nodes with no children.

To create the executable model, an analyst had to add two more types of information to the model. The analyst indicated the time-delay that would exist between each node in the influence net and that node's children. This time-delay represented processing and communication time delays that slowed the propagation of knowledge about the events, actions, beliefs, or decisions that were represented by a parent node to its child nodes. The second type of knowledge needed was the timing information of the actionable events. This information came from the operational planners (or the Task Manager of DSSCO).

With the CAESAR II/COA tool, the conversion to the executable model was an automated process. In CAESAR II/COA, the executable model is a CP Net, which is a generalized form of a Discrete Event System Model. With CAESAR II/COA, the CP net is hidden from the user.

[17] Wagenhals, L. W., Shin, I., and Levis, A. H. (1998). "Creating Executable Models of Influence Nets with Coloured Petri Nets," *Int. J. STTT,* Springer-Verlag, Vol. 1998, No. 2, pp. 168-181.

Instead of working with the CP net, the analyst interacted with the model through a web browser interface, such as Netscape or Microsoft Explorer.

To create this executable, the CAT tool automatically exported a special file that contained all the information needed to generate the CP net. This file was placed in a folder on the website that hosts the CAESAR II/COA tool. The analyst then used a browser to access the CAESAR website and create the CP net.

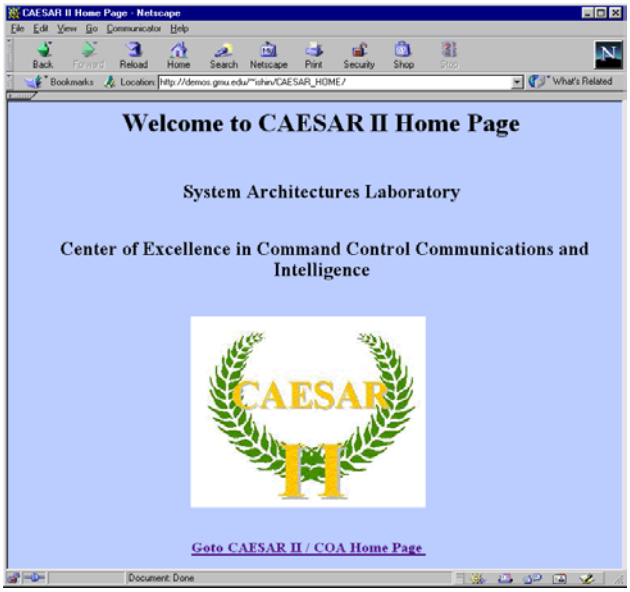

Figure 8. Home page of the CAESAR II/COA Tool Suite

The home page of the website is shown in Figure 8. The analyst initiated the conversion of the influence net to the CP net by clicking on the "Go to CAESAR II/COA Home Page" link. The website automatically brought up the page shown in Figure 9. To create the CP net from the influence net, the analyst typed in the time-delay information into the appropriate boxes in the browser form shown in Figure 9. The analyst then indicated nodes in the influence net for which probability profiles would be generated. Once the form was completed, the analyst clicked on the run button and, in a few seconds, the executable model was generated and automatically placed in a folder in the CAESAR II/COA website so it could be used to perform temporal analysis of the COAs.

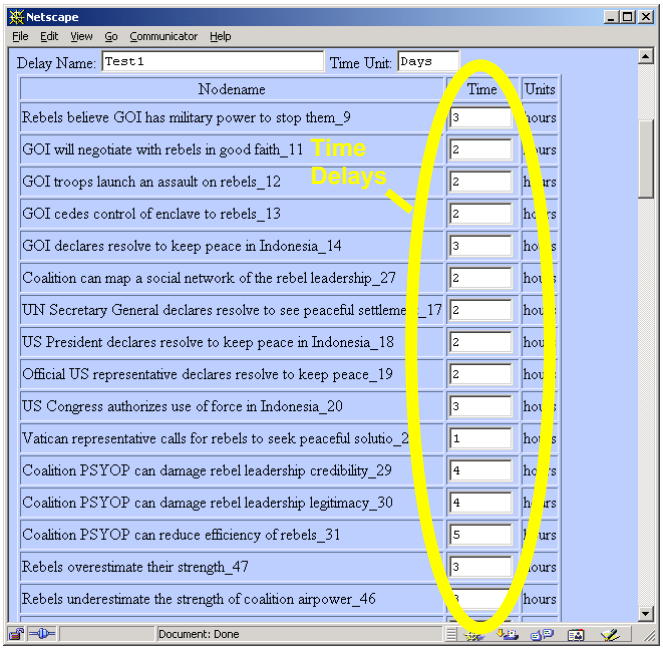

Figure 9. CAESAR II/COA form for setting time delays

Having created the executable model, the analyst could generate the probability profiles for any COA composed of the actionable events and the time each was expected to occur. To do this, the analyst filled in a COA form on the web page found at the CAESAR II/COA website as shown in Figure 10. The form automatically listed all of the actionable events and provided boxes where the probability of the actionable event and the time of the probability could be entered. Note that the executable model is initialized with all actionable events set to a probability of zero to represent the condition that none of the actionable events has (yet) occurred. The analyst also checked the boxes that indicate the nodes for which probability profiles would be generated. After filling out the COA form, the analyst clicked the run button and, in a few seconds, the probability profiles were generated and displayed.

In our scenario of the Indonesian Rebels, the SMEs provided initial timing information for the actionable events. The COAs specified when the Government of Indonesia actions, Coalition Psychological Operations, Diplomatic actions, etc. would take place. The first action was set to time zero. Probability profiles were generated for two COAs. The first was one featuring early use of Psychological Operations. The second indicated what would happen if the Rebels believed they would lose face. The two probability profiles for the node #1 "Rebels decide to avoid violence" are shown superimposed in Figure 11. The annotations in Figure 11 have been added for clarity.

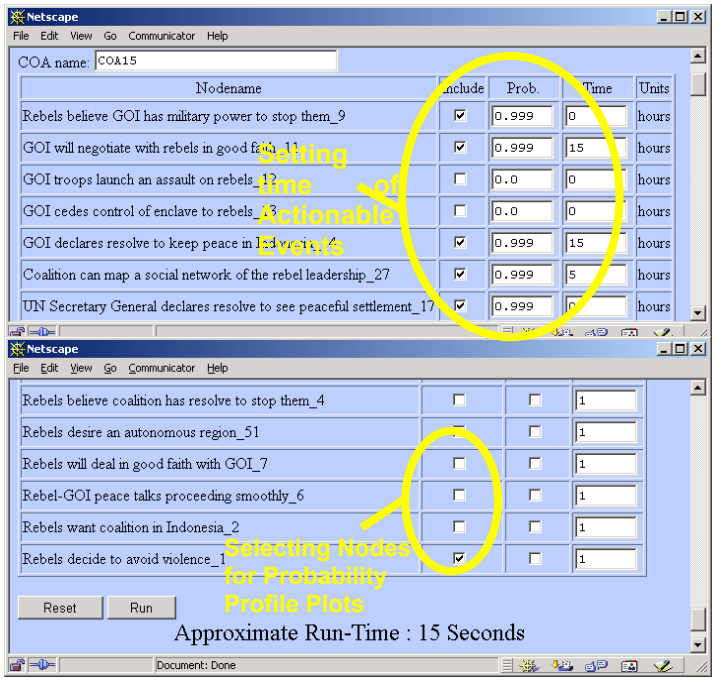

Figure 10. CAESAR II form for generating COAs

These probability profiles indicate four things to the commander and his staff. First, the best that can be expected from taking all of the available actions is to raise the probability of the key effect, "Rebels decide to avoid violence," from 0.07 to 0.34. This is a significant improvement, but certainly no guarantee that the desired effect will be achieved. Second, a combination of actions was needed to maximize the chances of achieving the key effect. Third, it would take a long time for the cumulative influences to maximize the probability of the desired effect. This value does not occur until after 100 days. Furthermore, the more the operations were delayed, the longer it could take to ensure the desired effect. Fourth, the model was very sensitive to the Rebel belief that they were losing face. If this became a reality, the probability that the Rebels would avoid violence dropped dramatically. This meant it was important to consider this fact in all actions that were taken.

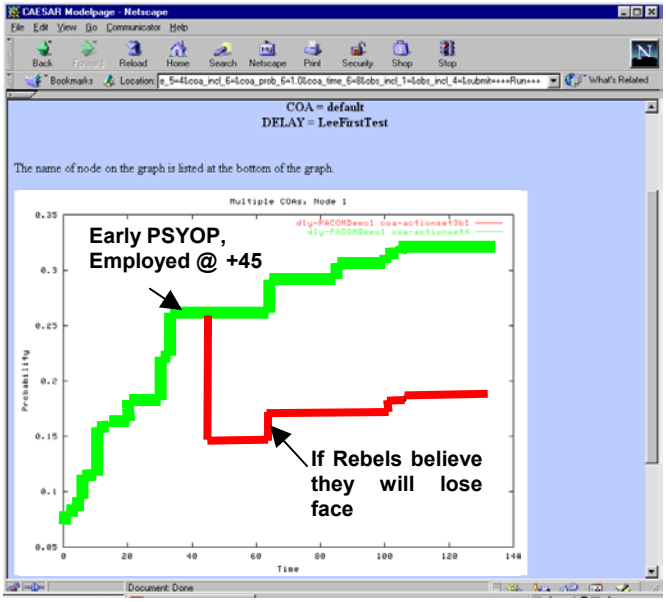

Figure 11. Comparison Probability Profiles

5 Summary

There were three objectives for the use of CAESAR II/COA with DSSCO:

- Determine if CAESAR II/COA has the potential to enhance the assessment and decision-making process in support of COA selection for Coalition Operations

- Gain insight into how the tool can support the OPT at PACOM
- Identify changes that should be made to CAESAR to enhance its usefulness

All three objectives were satisfied. CAESAR II/COA appears to have utility in support of model-driven COA development and evaluation. Sufficient insight was gained to conceive an operational concept for future use of CAESAR II/COA and to develop a detailed operational concept for its current use. As a result of the extensive modeling for the demonstration, several fixes and enhancements both to the tool and the concepts were identified.

In preparation for the demonstration, the operational concept for the use of CAESAR II/COA evolved to the four major steps: creating the influence net, converting the influence net to the discrete event model, evaluating COAs, and preparing explanations of the results and findings. The first step, creating the influence net requires a concerted effort from specialists from different disciplines and is the most challenging step in the process. Accomplishing this step could provide immediate assistance to the OPT by helping structure a framework for conceptualization of the "adversary's" potential reaction to contemplated Coalition actions. While this step does not address any timing issues, it does assist analysts in formulating their analysis and answers to "what if" questions presented by the combination of desires and intentions of the various members of the coalition.

The probability profiles provided by CAESAR II/COA help highlight the timing aspects of coalition actions and potential responses by the "adversary." These profiles both provide insight into the amount of time it will take for desired effects to occur and highlight potential negative influencing events on the outcome.

CAESAR II/COA performs temporal analysis of COAs in a web-based environment making it easy to use. From a web browser, an analyst can automatically convert a static influence net to a discrete-event dynamic system and use web-based forms to add timing information for both influences and actions. The tool automatically displays probability profiles for each timed set of actions and shows critical time windows and adverse effects. As COAs are assessed, the website provides for easy comparison of single and multiple COAs.

5.1 Conclusion

The participation in the PACOM demonstration of the CAESAR II/COA tool, combined with the DSSCO Planning Process Tool and Task Manager, provided an invaluable opportunity to test the theories, tools, and techniques for the use of CAESAR II/COA using an operationally realistic scenario. It illustrated how the CAESAR II/COA tool suite could be used to support COA development and evaluation in a coalition environment. The tool captured the collective knowledge of a team of domain experts. Sensitivity analysis was provided for selection of major actions. The executable model was used for evaluation of task sequencing and timing, providing the visualization of the likelihood of desired and undesired effects over time for a given schedule of tasks developed in the DSSCO Task Manager. We believe it can assist decision-makers in visualizing the impact of the timed actions that are contemplated during COA formulation

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