Simulating Counterinsurgency and Coalition Strategies

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***Abstract*—We model insurgency (IN) and counterinsurgency (COIN) operations with a large-scale system of differential equations that is connected to a coalition network model. Our simulations analyze components of leadership, promotion, recruitment, financial resources, operational techniques, network communications, coalition cooperation, logistics, security, intelligence, infrastructure development, humanitarian aid, and psychological warfare, with the goal of informing today's decision makers of the options available in counterinsurgency tactics, operations, and strategy. In order to be more effective, the US military must improve its counterinsurgency capabilities and flexibility to match the adaptability of insurgent networks and terror cells. Our simulation model combines elements of traditional differential equation force-on-force modeling with modern social science modeling of networks, psyop, and coalition cooperation to inform the tactics and strategies of counterinsurgency decision makers. We calibrated our model with baseline data intended to keep the balanced strength equilibrium. We show the model development and results of a four-stage counter-insurgency scenario.**

Keywords- counterinsurgency; force-on-force model; differential eqiation; network model

I. THE COIN MODEL

In modeling an insurgent or terrorist organization, we modify the differential equation model in [1] that tracks several groups within the terrorist organization: senior leaders (*l*), junior leaders (*j*), outside supporters (*o*), bomb-makers (*b*), and foot soldiers (*f*). The model also includes equations for the intensity of several terrorism factors: financial support for the organization (*m*), intellectual level of the organization (*i*), public (in-country, local) support for the organization or cause (*p*), and world-wide support for the cause (*w*). These elements all factor into the overall strength of the terror organization (*s*). Considering counterinsurgency factors (all in upper case), we model: public support for the counter-terrorism effort (*C*), the cooperative coalition (multi-national/multi-agency) effort (*CC*), aggressiveness of direct CT operations (*D*), aggressiveness of intelligence gathering (*G*), aggressiveness of PSYOP/information distribution (*P*), aggressiveness of aid to the local public/host country government (*A*), aggressiveness of US/coalition logistics (*L*), and aggressiveness of US/coalition security (*Y*). We then combine these COIN measures to determine the overall strength of the COIN operations (*S*). The model consists of 19 dependent factors with 19 equations and over 80 parameters. The roots of this differential equations model stem from ideas in [2, 3, 4, 5]. Many of the primary factors discussed in [6] for terrorism (T) and counter-terrorism (CT) operations are included in this model. These equations are dynamic and time dependent as we use time (*t*) as our one independent variable.

II. COALITION EFFECTIVENESS AND COLLABORATION

One of the most important aspects of counterinsurgency operation is the effectiveness of the coalition of organizations and agencies involved in the operation [7]. For the purposes of this simulation, we use a coalition network model that consists of three subgroups: US agencies (governmental and nongovernmental), host country organizations, and world-wide organizations (other countries forces and agencies, world-level nongovernmental organizations, and UN organizations).

COIN, IN, T and CT operations involve not only power, force, control, and other military-based components, but also diplomatic and nation-building elements of influence, politics, legitimacy, and service [6, 8, 9, 10, 11]. The agencies that work with the populace along with the military forces form the COIN/CT coalition that wages the counterinsurgency. FM3-24, page 2.1, explains the roles these coalition partners play to succeed in COIN: "Although military efforts are necessary and important, they are only effective if integrated into a comprehensive strategy employing all instruments of national power…. The integration of civilian and military efforts is crucial in COIN and must be focused on supporting the local population and the HN government. Political, social and economic programs are usually more valuable than conventional military operations as a means to address root causes of conflict and undermine an insurgency. In COIN, military personnel, diplomats, police, politicians, humanitarian aid workers, contractors, and local leaders are faced with

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making decisions and solving problems in a complex and acutely challenging environment" [6].

The coordination of effort and cooperation the coalition network is essential. The JP 3-24 explains: "Unified action refers to the synchronization, coordination, and/or integration of military operations with the activities of governmental and nongovernmental entities to achieve unity of effort. The military contribution to COIN must be coordinated with the activities of the United States Government, interagency partners, IGOs (Intergovernmental Organizations), NGOs (Nongovernmental Organizations), regional organizations, the operations of multinational forces, and activities of various HN (Host Nation) agencies to be successful…Successful interagency, IGO, and NGO coordination helps enable the USG to build international support, conserve resources, and conduct coherent operations that efficiently achieve shared goals." [9].

In summary from page 2-1 of FM 3-24, "The preference in COIN is always to have civilians carry out civilian tasks. Civilian agencies of individuals with the greatest expertise for a given task should perform it – with special preference for legitimate local civil authorities… the preferred or ideal division of labor is frequently unattainable. The more violent the insurgency, the more unrealistic is this preferred division of labor" [6].

III. THE COALITION NETWORK MODEL

In order to compute viable measurements for the effectiveness of the coalition, we represent the coalition with a network structure. We model the various organizations as nodes and the strength of the collaboration between the organizations as weighted edges. More precisely, the weights on the edges are the percent of the perfect or desired collaboration between the two connecting organizations. As indicated in [12], some organizations should maintain an intense collaboration with another organization because of the nature of their missions, whereas others may have little need to collaborate in COIN except to maintain communication of basic information. Therefore, in our model, a coalition network with perfect collaboration for their suited purposes is a completely connected graph with all its weighted links all set to 1 (or 100% effective collaboration). A completely dysfunctional coalition with none of the effective collaboration needed is modeled by a completely disconnected network graph.

Our network metrics measure the strength of collaboration. A coalition's collaboration strength (*CCS*) is the weighted density measure of the graph. For a undirected graph, the sums of all the weighs of connecting edges (Σe_k, where k goes from 1 to Z, the total number of possible connections) are divided by the total possible connections of the graph $Z=(M)(M-1)/2$, where M is the number of nodes in the graph or total number of agencies in the network. Subgroups of the overall coalition produce two collaboration measures, its own internal collaboration strength (*ICS*) measured by only taking into account the network of the subgroup and the external collaboration strength (*ECS*) by taking into account the weights of links between the subgroup and its complement.

IV. USING THE NETWORK METRICS IN THE COIN MODEL

As indicated in the model description, one of the key elements in CT/COIN success and a major component in our model is the Cooperation/Coalition factor (*CC*). We use a coalition network model with three subgroups of 1) US --- US forces and organizations (governmental and nongovernmental), 2) Host -- host country forces and organizations, and 3) World -- world-wide forces and organizations (other countries forces and agencies, world-level nongovernmental organizations, and UN organizations) to calculate the metrics to use in our COIN model. The ten network metrics we use are the seven Coalition Network Metrics of CCS, ICS_{US}, ECS_{US}, ICS_{World}, ECS_{World}, ICS_{Host}, ECS_{Host}, the Link Density (LD). CC is computed as a weighted sum of these elements of the CT coalition network while also being proportional to the levels of aggressiveness of security (*Y*), aggressiveness of intelligence gathering (*G*), aggressiveness of PSYOP (*P*), aggressiveness of US aid (*A*), aggressiveness of CT logistics (*L*), number of nations in the coalition squared N^2, and number of total organizations in the coalition as shown in (1). The non-linear squared term for the number of nations is the key part of this measure showing the important nature of that aspect of Coalition strength. The *CC* factor is an influential component of our dynamic COIN model

$$CC = \eta_1 N^2 + \eta_2 M + \eta_3 LD + \eta_4 CCS + \eta_5 ICS_{US} + \eta_6 ECS_{US} + \eta_7 ICS_{Host} + \eta_8 ECS_{Host} + \eta_9 ICS_{World} + \eta_{10} ECS_{World} + \eta_{11} G + \eta_{12} P + \eta_{13} A + \eta_{14} L + \eta_{15} Y + \eta_{16} D \quad (1)$$

V. COIN SCENARIO USING COALITION NETWORKS

To show the effects of the dynamics of the Coalition Network on the COIN model, we simulate a four-stage scenario of Coalition evolution. Since each stage affects the COIN results, we will show the graph of the coalition network model, the computed collaboration metrics, and the results of running the COIN model for the six-month duration at each stage. For this scenario, we keep all six of the resource levels equal and constant at 0.83 to run a balanced COIN strategy.

A. Stage 1: The Initial Coalition (9 nodes)

We start with the US Forces arriving in a Host country to form a small, weakly connected coalition with several Host country organizations. This coalition has no elements outside those of the US and the Host country. The Coalition is modeled by the 9-node network shown in Fig.1. We track the three subgroups US, Host, and World. Subgroup Host contains three nodes, Subgroup World has no nodes, and Subgroup US contains six nodes. From the

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collaboration weights, we compute the seven possible collaboration strength (CS) scores of CCS, ICS_{US}, ECS_{US}, ICS_{World}, ECS_{World}, ICS_{Host}, ECS_{Host}. The CCS is computed as 4.5/36= 0.125. For the Host Subgroup, ICS_{Host} = 1.3/3 = 0.43 and ECS_{Host}=0.6/18=0.03. For the World Subgroup, ICS_{Worls}= ECS_{World}=0, since there are no World organizations in the Coalition. For the US Subgroup, ICS_{US}=2.6/15=0.173 and ECS_{US}= ECS_{Host}=0.6/18=0.03, since there are only two subgroups present in the network, the External Collaboration scores must be the same. The LD is 12/36=0.33. We run the COIN model for 6 months to obtain the results shown in Table I along with the coalition metrics. The collaboration scores show that the US and Host country do not yet collaborate very effectively.

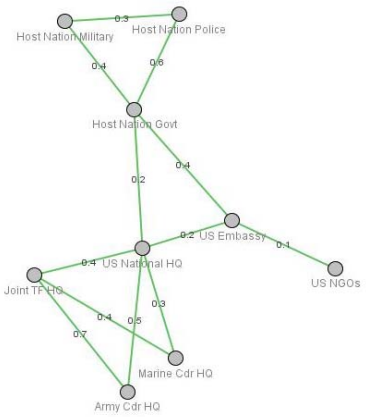

Figure 1. The Coalition Collaboration Network for Stage 1.

TABLE I. RESULTS OF STAGE 1

Collaboration Metrics for the Stage 1 Coalition (N=2 (US and Host), M=9)										
US nodes	Host Nodes	World Nodes	CCS	ICS_{Host}	ECS_{Host}	ICS_{World}	ECS_{World}	ICS_{US}	ECS_{US}	Link Density
6	3	0	0.125	0.43	0.03	0	0	0.173	0.03	0.33
COIN Model Metrics for 6 months with Stage 1 Coalition										
CC	s	S	S/s ratio	change of S/s	% change in o	% change in m	% change in i	% change in p	5 change in w	% change in C
0.4126	0.765	0.817	1.07	-0.003	0	0.014	0.005	-0.01	0.015	0.003

B. Stage 2: The Coalition Grows: World Organizations and Allied Force Arrives (16 nodes)

At this stage, the coalition has added more US forces, maintained the same basic Host nation involvement, and added one other allied country force along with some UN and world-wide organizations. The model for this rudimentary coalition of 16 nodes with the weights of the collaborations is shown in Fig. 2.

This modest growth in the coalition increases the collaboration strengths from Stage 1. The Subgroup Host contains 3 nodes, Subgroup World has 6 nodes, and Subgroup US contains 7 nodes. We compute the seven possible collaboration strength (CS) scores of CCS, ICS_{US}, ECS_{US}, ICS_{World}, ECS_{World}, ICS_{Host}, ECS_{Host}. The CCS is computed as 11.4/120= 0.095. For the Host Subgroup, ICS_{Host} = 1.4/3 = 0.47 and ECS_{Host}=1.6/39=0.04. For the World Subgroup, ICS_{Worls}=2/15=0.133 and ECS_{World}=2.6/60=0.043. For the US Subgroup, ICS_{US}=4.3/21=0.20 and ECS_{US}=2.4/63=0.04. The LD is 27/120= 0.23.

We run the COIN model for six months to obtain the results shown in Table II along with the coalition metrics.

These results show that the collaboration has improved with a higher CC score.

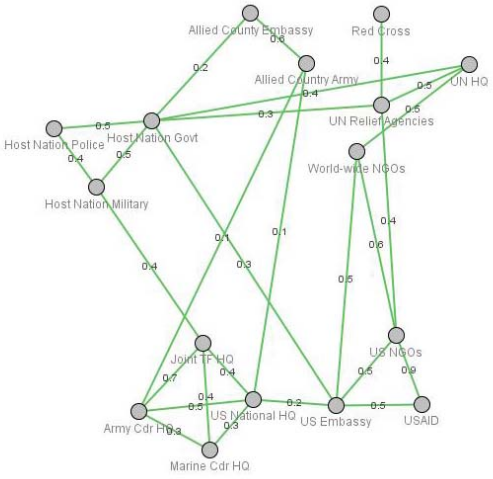

Figure 2. The Coalition Collaboration Network for Stage 2.

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TABLE II. RESULTS OF STAGE 2

Collaboration Metrics for the Stage 2 Coalition (N=3, M=16)										
US nodes	Host Nodes	World Nodes	CCS	ICS_{Host}	ECS_{Host}	ICS_{World}	ECS_{World}	ICS_{US}	ECS_{US}	Link Density
7	3	6	0.095	0.47	0.04	0.133	0.043	0.20	0.04	0.23
COIN Model Metrics for 6 months with Stage 2 Coalition										
CC	s	S	S/s ratio	% change of S/s	% change in o	% change in m	% change in i	% change in p	5 change in w	% change in C
0.7372	0.767	1.189	1.549	0.45	0	.001	-0.005	-0.01	0.01	0.05

C. *Stage 3: The Coaltion Expands (47 nodes)*

During this stage the Coalition grows substantially to 47 organizations and five countries, but they are still sparsely linked with little collaborations across the three subgroups. One of the countries is involved diplomatically, but not militarily and contributes one node to the network ("Involved Country Embassy"). This Coalition network is shown in Fig. 3.

Subgroup Host contains 7 nodes, Subgroup World has 17 nodes, and Subgroup US contains 23 nodes. We show the collaboration and coalition metrics in Table III. We run the COIN model for 6 months to obtain the results shown in Table III.

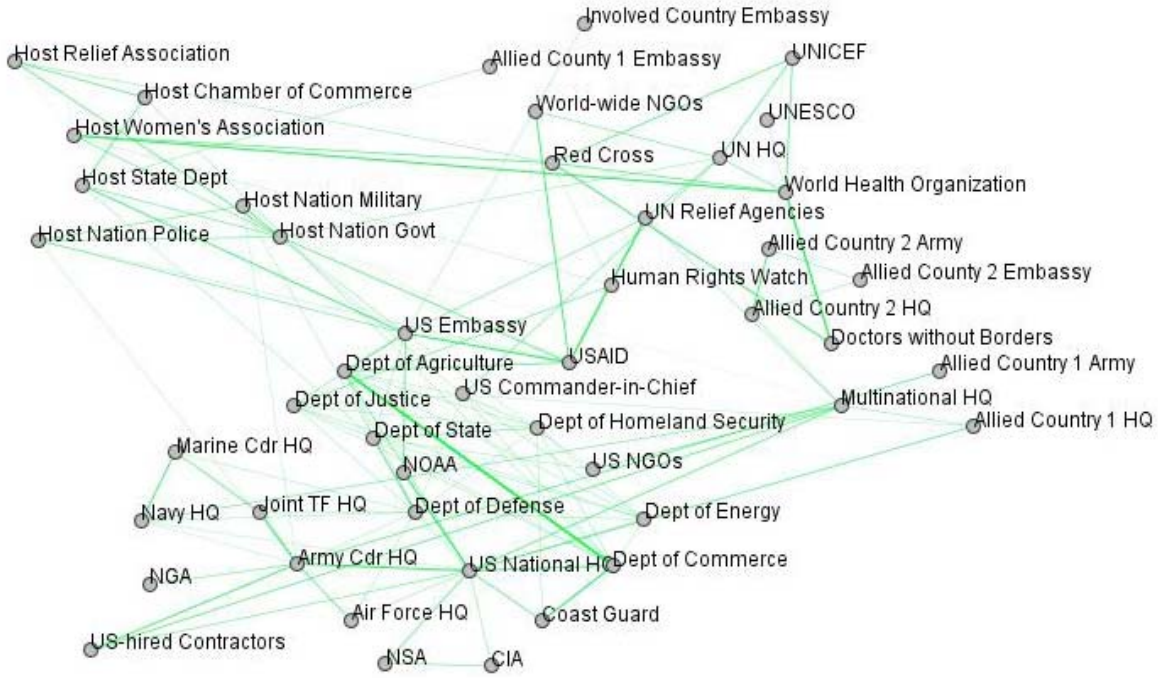

Figure 3. The Coalition Collaboration Network for Stage 3.

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TABLE III. RESULTS OF STAGE 3

Collaboration Metrics for the Stage 3 Coalition (N=5, M=47)										
US nodes	Host Nodes	World Nodes	CCS	ICS_{Host}	ECS_{Host}	ICS_{World}	ECS_{World}	ICS_{US}	ECS_{US}	Link Density
23	7	17	0.04	0.18	0.02	0.05	0.015	0.09	0.017	0.114
COIN Model Metrics for 6 months with Stage 3 Coalition										
CC	s	S	S/s ratio	% change	% change in o	% change in m	% change in i	% change in p	5 change in w	% change in C
1.7872	0.766	2.393	3.126	1.02	-0.01	-0.01	-0.04	-0.01	-0.005	0.02

The rapid growth in the coalition results in a CCS of 0.04, since the collaboration total is just 44.7 out of a possible of 1081. Also, the coalition has a LD of 123/1081=0.114. Just a little over 11% of the possible coordination links are even established by the coalition. The increased size of the coalition (five counties and 47 organizations) and the growing strengths of the three subgroups have resulted in the large increase in the CC value. This increase in CC leads to small decreases in the insurgency measures and a large increase in the strength of the counter insurgency. The effect is that the S/s ratio doubles during this Stage.

D. Stage 4: The Military Forces Coalesce and Strengthen their Collaborations (49 nodes)

In this stage the military forces are able to coordinate their work within and between the US, the three Allied counties, and Host nation. Only two new organizations enter the coalition in this stage. Since the Involved country has now committed military forces, two new organizations (Allied Country 3 HQ and Allied Country 3 Army). Most of the effort during this stage has been to strengthen existing military collaborations. This new stronger Coalition network is shown in Fig. 4 with results provided in Table IV.

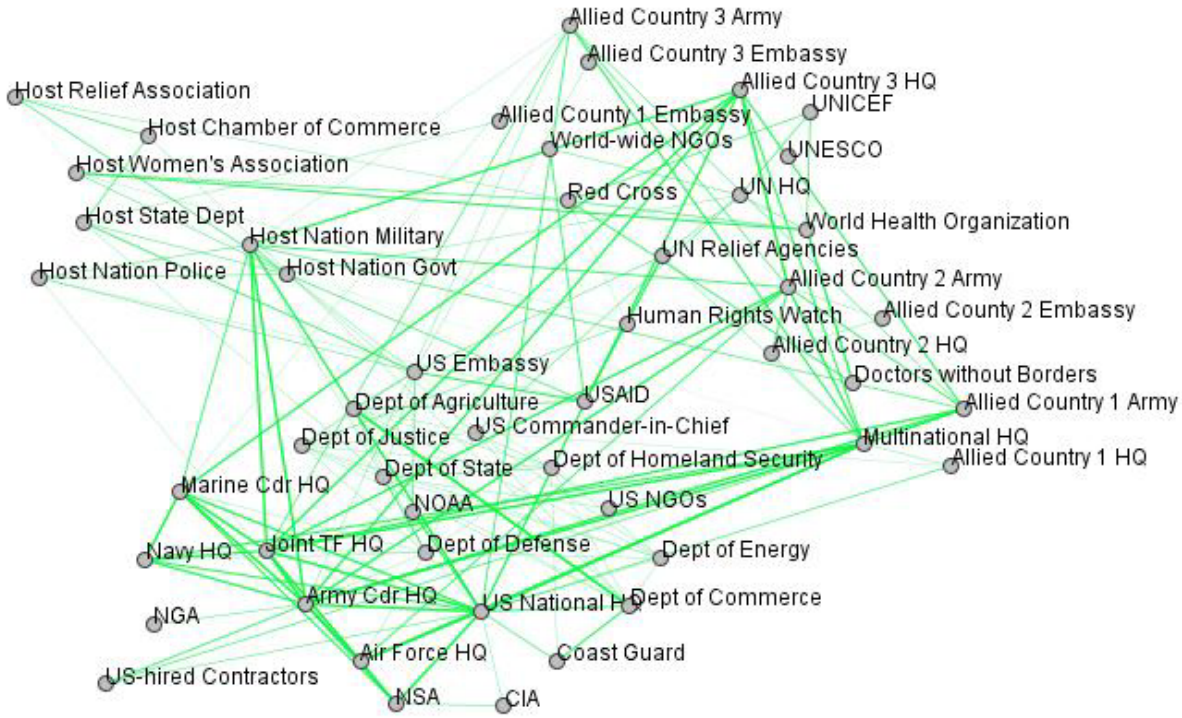

Figure 4. The Coalition Collaboration Network for Stage 4.

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TABLE IV. RESULTS OF STAGE 4

Collaboration Metrics for the Stage 4 Coalition (N=5, M=49)										
US nodes	Host Nodes	World Nodes	CCS	ICS_{Host}	ECS_{Host}	ICS_{World}	ECS_{World}	ICS_{US}	ECS_{US}	Link Density
23	7	19	0.066	0.18	0.04	0.07	0.04	0.13	0.035	0.14
COIN Model Metrics for 6 months with Stage 4 Coalition										
CC	s	S	S/s ratio	% change of S/s	% change in o	% change in m	% change in i	% change in p	5 change in w	% change in C
1.8208	0.7613	2.449	3.222	0.03	-0.01	-0.01	-0.06	-0.005	-0.01	0.03

The increased cooperation of the military forces in the coalition results in increases in all eight collaboration metrics. The COIN operation is starting to show is strength in the model and affect the insurgency elements --- all of which are decreasing.

VI. CONCLUSION

We used this rather small and simple scenario to simulate COIN operations in a dynamic environment to show the functionality of our coalition network model and its interface to the differential equations model. The mathematical issues of combining large networks and large systems of differential and algebraic equations are not known. However, we see this combination as giving us better insights into the complexity of warfare. Our hybrid model (force-on-force, COIN factors, and coalition network model) enables study of the most feared and possibly likely war of the future – a hybrid war. As described in [13 and 14], these full spectrum conflicts will involve many elements of COIN-CT-and full force-on-force operations along with the psychological aspects of conflict on the US populace, basic elements of which are found in our model.

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