**Identifying Sources of Balance and Conflict in Militant Networks Using the D‐Wave 2X Computer**

John Ambrosiano, A‐1

Benjamin Sims, CCS‐6

A signed social network is one where the ties between actors can be either positive or negative, reflecting friendly or hostile relationships. Such a network is defined as balanced only if all cycles of three or more nodes in the graph have an odd number of friendly edges. All balanced social networks have the property that either all actors are friendly with each other, or the network can be divided into exactly 2 factions, where all relationships between factions are hostile and all relationships within factions are friendly. Social network studies suggest network imbalance may be associated with conflict, stress, and violence, possibly due to increased ambiguity about factional allegiances.

If only edge relationships are known, determining the balance of a signed network is mathematically equivalent to solving an Ising model where the assignment of nodes to factions minimizes the energy of the system. Although this problem is computationally NP-hard, it can be solved efficiently using quantum annealing methods as implemented in the D-Wave computer. However, because of various technical limitations, the D-Wave can only model a fully-connected network of about 50 nodes per annealing cycle.

In initial efforts funded by the LANL D-Wave Rapid Response call, we worked with data on conflict and cooperation between militant groups, obtained from the Stanford Mapping Militants Project website (<http://web.stanford.edu/group/mappingmilitants>). We focused on datasets for Iraq and Syria, which each include in the range of 20-30 militant groups, well within the size of network that can be represented in a single annealing cycle of the D-Wave machine. From this data, we constructed a series of network snapshots over time from about 2000 to 2016, and analyzed them to create a time series of structural balance in each theater. The D-Wave proved to be a fast and effective tool for performing these computations.

In the Syrian theater, we found a rapid increase in structural imbalance beginning around February of 2014, which is roughly the time when the Islamic State began to operate in Syria, rapidly coming into conflict with almost all existing militant groups. With additional program development funds, we plan to explore our results in more detail, and in particular determine whether the Islamic State was, in fact, the cause of increased imbalance during this time period. To do this, we propose the following:

**1. Conduct a sensitivity analysis of contributors to structural imbalance in the Syria network.** For each time step, this will involve removing militant groups from the network one at a time, and using the D-Wave machine to recalculate structural balance. We hypothesize that the difference in structural balance scores before and after removal of a group will usefully quantify the contribution of that group to structural imbalance. Using this approach, we will generate tables and/or graphs of the relative contribution of each group to imbalance over time. We will then assess the results of this sensitivity analysis method and its potential implications for predictive modeling. Time permitting, we may explore alternative metrics of imbalance or examine additional datasets.

**2. Construct a more comprehensive timeline of the war in Syria.** Based on this timeline, we will assess the possibility of determining causal relationships between imbalance metrics and observed events in the conflict. We will initially assess these relationships at a qualitative level, but depending on results and time permitting, may explore quantitative approaches with possible implications for predictive modeling.

The deliverable for this effort will be a short report describing our findings and potential implications for further work in this area.