Computational Analysis in US Foreign and Defense Policy

Claudio Cioffi-Revilla* and Sean P. O'Brien**

*Center for Social Complexity, Krasnow Institute for Advanced Study, George Mason University
**IPTO, Defense Advanced Research Projects Agency (DARPA)
Emails: ccioffi@gmu.edu and Sean.P.Obrien@darpa.mil

Abstract

Foreign and defense policy is typically affected by complex issues that can benefit from advanced social science methodologies. In this paper we identify a salient set of issues and the contribution—current and potential—that the main analytical approaches and methods from computational social science might bring to bear on such issues. The issues consist of terrorism, WMD proliferation, state failure, and global issues ranging from human rights to global change. The main computational methods consist of automated information extraction systems, social network analysis, social GIS, complexity modeling, and social simulation models. After a review of issues and methods, we discuss some present and future trends in the application of computational analysis to national security policy.

1. Introduction

American foreign and defense policy—i.e., national security policy—is increasingly challenged by an environment with issues of unprecedented uncertainty and complexity. This is because in recent times the international or world system has evolved from a relatively disconnected system towards a massively interconnected and interdependent world with billions of individual nodes (people), many more relations of various orders (dyadic, triadic, *N*-adic), but just a few links apart in diameter. This issue environment with unprecedented uncertainty and complexity calls for analytical methods and scientific methods that not only systematically exploit but move beyond previous theories and methods in international relations, national security, and related fields.

NOTE: The views expressed in this paper are those of the authors and do not reflect the policies or views of the U.S. Government or any of its agencies. Prepared for the First International Conference on Computational Cultural Dynamics, University of Maryland, College Park, MD, 27-28 August 2007. Dr. Cioffi's research is funded by Air Force Office of Scientific Research under grant no. FA 9550-05-1-0388. Thanks to Kathleen Carley, Kenneth DeJong, Steven Kaisler, Alexander Levis, Sean Luke, Ed MacKerrow, Susan Numrich, James Olds, Neal Pollard, Robert Popp, Jeffrey Ian Ross, and Maksim Tsvetovat for comments and discussions. The authors are solely responsible for the views and opinions expressed.

In this paper we identify a selection of top issues from the contemporary (and likely future) US national security agenda—comprising the joint foreign and defense policy domains—and a set of leading computational social science approaches that address these issues in terms of innovative analysis. The main purpose is to identify both policy and scientific domains to highlight the extant and potential interactions between the two.

The following sections identify national security policy issues (section 2) and computational social science methods (3), followed by a discussion (4) and summary (5).

2. Top Policy Issues

From a political science and public policy perspective, every polity in the international system consists of a complex adaptive system for managing emerging *public issues* (domestic or international) that arise in the normal life of a society.[1] Key attributes of issues include their priority, salience, resilience or difficulty ("wickedness"), and solution cost (price tag). Terrorism, political stability in fragile societies, proliferation of weapons of mass destruction (WMD), and a critical class of global issues of a transnational nature—e.g., genocide, war crimes and related atrocities, democratization, human trafficking, and human rights—comprise a major portion of the contemporary American policy agenda in the early 21st century (DOD *QDR*; DOS *Strategic Plan*, 2007). Operationally, these are the issues typically included in the Presidential Daily Briefing (PDB) or that may become the subject matter of various high-level advisory boards and inter-agency policy coordinating committees (PCC).

[1] This is the standard systems model of a polity or political system, composed of a society and a system of government in an environment that produces issues that are addressed by policies [Deutsch, Easton, Dahl]. An explicitly computational polity model, based on an object-orientation, is presented in Cioffi-Revilla (2007). This paper focuses on foreign and defense—i.e., external— security policy issues. A similar and related treatment of domestic security would follow comparable lines, focusing on domestic and comparative politics [Landman].

The following specific set of issues aims to be factual or empirical, not normative or judgmental. Other issues—China, global warming, immigration, or sustainability—also form part of the national security agenda, and some would argue are more important, but the following four presently outrank all others: terrorism, state fragility, WMD proliferation, and global issues. Moreover, all four of these are "wicked" policy problems [Rittel & Webber, 1973; Conklin, 2006].

3.1 Terrorism

Terrorism is the top policy issue in the national security agenda, today and for the foreseeable future. This is not because terrorism is a new issue [Kahn; Schelling], but because the 9/11 attacks turned terrorism into the national security issue with highest priority [9/11 Commission].

Terrorism—especially transnational modes—is a "wicked" policy problem for several reasons: definitional problems, high dimensionality, poorly understood causality, and spatio-temporally distributed behaviors in both physical and cultural space, among others.

Terrorism is actually an issue-cluster or "class" of issues, because it comprises several more specific instances, such as attacks (against persons or facilities), kidnappings, political assassinations, and other forms (e.g., cyber-terrorism; CERT). [Jenkins]

3.2 Polity Dynamics

A second cluster or class of issues concerns the macro-dynamics of polities, such as their stability or instability, capacity, fragility, failure, reconstruction, stabilization, democratization, and regime change. Today, and for the near-future, the international system seems replete with polities either at the brink of failing or having already failed [FP index].

By law (Presidential Directive of 7 Dec. 2005), the lead USG agency for the policy issue of polity dynamics is the US Department of State, supported by the Coordinator for Reconstruction and Stabilization (CRS). The DOD, USAID (currently in the process of merging with the DOS), and the USIP also play significant roles in this issue-area.

Although state failure is primarily a governmental event in the life of a polity, the process itself includes the active participation of numerous non-state actors, whether domestic or international. Moreover, although the issue of potentially destabilizing polity dynamics has attracted significant attention by policymakers and decision-makers at the highest levels of government, relatively little analysis seems to draw on the academic social science that exists on the subject [SFTF; PITF, Goldstone et al.; Williams, 2005].

3.3 WMD Proliferation

WMD proliferation has been a critical national security issue since the closing days of World War II [Poundstone]. During the Cold War, vertical vs. horizontal modes of proliferation maintained high salience as national security issues—a policy-relevant distinction that seems now forgotten.

WMD proliferation is a complex national security issue along several dimensions. Just two important dimensions, specifically, span numerous modes of the overall WMD proliferation issue: (i) by actor type (state, domestic, or autonomous actors); and (ii) by weapons type (NRBC or other).

3.3.1 Actors. Past and potential proliferators (vertical or horizontal) include states, domestic non-state actors (e.g., a rouge scientist or Unabomber-type and his team; ETA), or transnational actors (al Qaeda).

3.3.2 Weapons. Forms of weapons proliferation (again, whether vertical or horizontal, and independent of actors) include nuclear, radiological, biological, chemical, or other (high explosives, nano-weapons). Each must be analyzed separately, as well as in combination, because different supply chains and organizational aspects are involved in each mode.

These two dimensions of the WMD proliferation issue yields 3 × 5, or more than a dozen more specific proliferation modes, each with its own production in terms of causal events and actors involved. Note that the Cold War epoch was largely dominated by the single nuclear-state mode, with some notable exceptions[2]. At present, all modes are under consideration by the USG and in urgent need of insightful analyses that can inform our (and our allies') national security policy on proliferation.

Additionally, concrete instances of proliferation often have a specific spatial resolution, such as the case of a specific threat in a given city or facility. This spatial attribute is significant not just for policy purposes (who has jurisdiction?) but also methodologically in terms of specialized tools (e.g., GIS).

3.4 Globalization

Finally, a fourth class of issues consists of geographic, transnational, or global issues [Wood; Schwartz, 1999], including (i) humanitarian issues (human rights, war crimes, genocide and other atrocities, refugee flows,

[2] E.g., radiological terrorism in Italy; chemical warfare between Iran and Iraq; biological agents (anthrax) in urban centers, and other largely isolated cases. During the Cold War the overwhelming majority of WMD instances concerned nuclear issues among state actors.

narcotics, trafficking in persons (TIP), also called “human trafficking”), and (ii) environmental issues (anthropogenic or man-made climate change, sustainability). Although all of these issues have country-specific or regional manifestations (e.g., narcotics in Columbia, refugees in Lebanon or Chad, war crimes in Bosnia, genocide in Sudan), they generally transcend boundaries in their causes and solutions. The presence of spatially distributed networks is a common characteristic of these global issues, as part of their ontology, even when limited to a regional or continental scale (which is rare).

Global issues can be classified as predominantly anthropogenic or natural, depending on the primary drivers. This is often a difference of degree, not a strict taxonomy, since both can combine (e.g., as in the climate change issue).

3.4.1 Humanitarian. Among the most salient humanitarian issues in US foreign and defense policy are the following:

- Atrocities: war crimes and genocide [Midlarsky]
- Refugee flows and internally displaced persons (IDPs)
- Trafficking in persons, also referred to as “human trafficking” [PD Dec. 16, 2002; DOS 2006; GAO 2006], which is a modern form of slavery, including child sex tourism and other forms of exploitation or abuse
- Human rights violations in various degrees;

From a temporal perspective, humanitarian issues can also arise as complex emergencies—either as crises (2006 Lebanon refugee crisis) or as protracted situations (Darfur).

Various USG agencies and PCCs—including DOS, DOD, and the intelligence community (IC)—oversee policy on humanitarian issues, including inter-agency groups on preventing atrocities and prosecuting war criminals, the President’s Interagency Task Force (PITF), and the Senior Policy Operating Group (SPOG); the latter two focused specifically on combating trafficking in persons.

3.4.2 Environmental. Climate change already underway and for the foreseeable future will have significant effects on national security [Schwartz & Randall; Shearer, 2005; CNA, 2007]. Among the most salient threats will be losses to allies, added stress on fragile societies, and many changes that can (and some probably will!) be exploited by adversaries—such as opportunities in coastal and mountain regions. The difficult challenges posed by environmental issues begin with assessment and continue through policy formulation, decision-making, implementation, monitoring, and evaluation—each with a high dose of uncertainty and complexity, individually and collectively.

The issues just outlined—terrorism, polity dynamics, WMD proliferation, and global issues—are not just at the top of the national security policy agenda; they also represent highly complex issues for which not all the necessary social science is known. For instance, although social scientists have developed increasingly valid models of terrorism [e.g., Sandler; Cioffi & Romero, 2006], numerous aspects of terrorism remain poorly understood. Similarly, much social scientific knowledge about state performance [Cioffi, 2007 in press] can be leveraged for understanding state failure and design reconstruction and stabilization—but much is also still unknown from a purely scientific perspective. In the jargon of the military, there is still much “6.1” research to be done (i.e., basic research) although what fundamental knowledge on these issues already exists in the social sciences is hardly ever harvested to improve policy—an issue discussed in Section 4 below.

3. Computational Methods

Computational social science methods refer to those computer-based tools that enable social scientists to investigate human and social dynamics augmented by advanced information technologies. The early stages of computational social science began in the 1960s with the use of computers for conducting data analysis—the early days of SPSS, SAS, and punched-card jobs [Schrodt].

Today, computational social science comprises five fields:

- Automated information extraction
- Social network analysis
- Geospatial analysis (“socio-GIS”)
- Complexity modeling
- Social simulations models

Each computational method contributes new and different scientific insights to the tough challenges of national security policy, in ways that go beyond earlier statistical and mathematical approaches.

3.1 Automated Information Extraction

Content analysis—the unobtrusive method of manually coding documents to extract information [Janda; Sage]—has recently evolved into the computational analysis of multiple media (text, audio, images, video), in both open and classified domains [e.g., OpenSource Center]. A landmark transition in the efficiency of these methods occurred with the introduction of artificial intelligence (AI) algorithms [Schrodt; Bond], an effort that continues today [Schrodt; King].

One of the primary uses of automated information extraction methods is the production of *events data* [O’Brien], which can then be analyzed through a suite of scientific methodologies (time series analysis, semantic analysis, hidden Markov models, wavelet analysis, event life-cycle modeling [Chen et al., 2007]). Intensive computational use of these methods often interacts with others, such as the complexity-theoretic methods in subsection 3.4 below].

3.2 Social network analysis

The foundations of social network analysis [Wasserman & Faust] are in the much earlier and abstract mathematical theory of graphs [Euler; Saaty]. A network consists of a set of nodes and a set of relations, each of which is characterized by its own defining attributes. Alliances, terrorist organizations, trade regimes, belief systems, and the international system itself provide common examples (instances) of networks in foreign and defense policy [see Zinnes (1976) for an early survey of applications].

The purpose of social network analysis (SNA) is to provide insightful information and inferences on the organization and structural properties of a network, given its nodes and relations. Properties such as resilience, vulnerability, decomposability, functionality, and others can provide important information not commonly available through plain observation or more traditional methods of analyzing networks.

An operational principle of networks is that the structure *S* of a given network—the way the relations among nodes are organized—is related to the mission or function *F* of the network, such that there is a unique one-to-one correspondence between function *F* and structure *S*. For instance, the structure of a human trafficking organization will differ from that of an alliance; because their functionality differs. Whereas the former operates as a clandestine organization, an alliance must be overt to produce deterrence.

SNA has numerous immediate applications in foreign policy analysis, including:

- Belief systems [Abelson; Lai, 2004]
- Alliance and treaty systems [Maoz; Tsvetovat]
- International organizations
- Network games [Bienenstock] among proliferators and potential proliferators

In addition, SNA can leverage data and methods from the other computational methods to exploit synergies.

3.3 Social GIS

Geographic information systems (GIS) of social phenomena were first introduced by social geographers and cartographers as tools for visualizing and analyzing spatially-referenced data [Goodchild, 2005; Lee & Wong]. Social GIS has already found many policy-relevant applications in the social sciences, such as criminology [Lum] and regional economics. Applications of social GIS to conflict analysis are especially encouraging [O'Laughlin et al. 1998; Starr, 2002].

The Threat Mapper system [Riese, 2006] provides an example of social GIS for conflict analysis, as do other models that apply layers of sociopolitical or military information onto a geographic (or sometimes Cartesian) space.

More could be leveraged from social GIS modeling and analysis by developing additional cartographic projections that are more suitable for social—as opposed to physical or hypsographic—data [Cioffi-Revilla, 2007 AAG].

3.4 Complexity Modeling

Complexity-theoretic models are mathematical models based on concepts and principles for the analysis of non-equilibrium systems—as is typical of many human and social systems in the cultural landscape of US foreign and defense policy. Human languages, urban settlement patterns, foreign aid distributions, and many aspects of domestic and international conflicts are instances of non-equilibrium dynamics. By contrast, equilibrium systems are characterized by state variables that behave close to a Gaussian or "normal" (i.e., "bell-shaped") distribution, with infrequent departures from a given central tendency.

Power laws are among the best known complexity-theoretic models in computational social science, having first been discovered in economics by Vilfredo Pareto (1906). A power law describes the probability density function (p.d.f.) of a given variable X as $p(x) \sim 1/x^a$, where $a > 0$ is the Pareto exponent.

In conflict analysis—and relevant to US foreign and defense policy and to intelligence analysis—the distribution of several important variables follows a power law:

- War fatalities [Richardson; Cioffi & Midlarsky]
- Insurgency fatalities [Cioffi & Romero, 2006; Spagat]
- Terrorism fatalities [Cioffi]

Besides conflict, many other aspects of social behavior obey power laws and related fat-tailed distributions [Cioffi-Revilla, 2007 forthcoming].

The risk of extreme events, the fragility of unstable conditions, or the early-warning indicators of impending abrupt change, are among the inferences drawn from power laws and related complexity-theoretic models. For instance, computing the Pareto exponent of a given power law (say, of terrorist fatalities in a given theater) provides information on the criticality of conditions in terms of expecting extreme events. This is because the mean value (second moment) of a power law distribution is proportional to $1/(1 - a)$, so as $a \to 1$ the mean value blows up [$E(X) \to \infty$]. In sum, given a policy domain (e.g., terrorism, insurgency, political instability, human trafficking, counterproliferation inspection violations), monitoring and computing the power law parameters of relevant state variables can provide vital information that is unavailable by other means—and generally not available to the adversaries themselves.

3.5 Simulation Models

Some of the earliest simulations in computational social science originated in the national security domain [Project Temper; Milstein & Mitchell; Bobrow; Bloomfield; Luterbacher, 1974]. Among the most important kinds of simulation models today—especially in terms of applications to US foreign and defense policy analysis—are those based on system dynamics and agent-based models [Gilbert & Troitzsch, 2005]. As with all formal models, however, simulation models must meet high standards in terms of internal and external validity [Cioffi-Revilla, 2002, *PNAS*].

A particularly valuable feature of simulation models is their ability to test policies and observe their effects, assuming a sufficiently well-developed base model of a given "target system" (i.e., the empirical reality or part of the real-world being simulated). Another valuable feature for national security policy analysis is the ability to conduct sensitivity analysis over a large parameter space to explore robustness and other properties.

Whereas purely academic simulations are important for obvious scientific purposes, simulations of any value in the policy domain—particularly national security policies—must address the issue of realism. The Axtell-Epstein scale describes the degree of realism of a simulation model, in terms of correspondence between target system and simulation system (model), as follows:

0 = toy model
1 = qualitative fidelity
2 = quantitative fidelity
3 = highest realism

Although originally proposed for agent-based models, the Axtell-Epstein scale is applicable to all types of simulations or models in general.

3.4.1 System dynamics. System dynamics (SD) models are computational simulations that model a given target system as a set of state variables (stocks) and their associated rates of change (flows), based on the pioneering work of Jay Forrester [1968; Sternman]. The most recent implementations of SD are in the Vensim software, for both Windows and Mac, and the object-based approach has also been implemented [Gibon, 1997; Manzoni et al. 1999]. Nonetheless, the ontology of SD models is primarily equation-based, not object-based, with roots in systems of difference equations with feedback loops.

Two early applications of SD modeling to the national security domain where Wallace's (1978) simulation of arms race processes, based on L.F. Richardson's theory (1960), and Ruloff's (1975) simulation of guerrilla insurgency and Soviet intervention in Afghanistan. More recently, an SD model of polity dynamics—for analyzing governance capacity, state failure potential, and stabilization policies—is also being developed [Choucri & Siegel].

3.4.2 Agent-based modeling. Agent-based models (ABMs) are computational simulations that model a given target system based on classes of actors and other social entities interacting in some environment. The basic ontology of an ABM typically includes a set of actors/agents, a set of interaction rules, and some environment. The general problem addressed by ABMs is that of explaining—through a simulation—the emergence of collective or macroscopic behavior based on the individual behavior of agents.

Warfare, political unity and disintegration, ethnosectarian segregation, competition for resources, environmental change, and other foreign and defense policy themes have been of central interest since the first ABMs were developed [Schelling; Axelrod; Epstein & Axtell]. Today, increasingly realistic ABMs (approximating level 3 on the Axtell-Epstein scale) are becoming feasible and valuable for national security analysis. Some examples include:

- The Darfur NOMAD model [Kuznar, 2005]
- An Islamic terrorism model [MacKerrow, 2003]
- A Rwandan genocide model [Bhavnani, 2006]
- A cyberwarfare model [DeJong & Hunt, 2005]

Since many ABMs include a visualization of simulation process and results on a geophysical landscape, increasing the fidelity of the hypsography—morphological features of terrain—remains a challenge, especially for ABMs build to investigate long-term change and adaptation [Cioffi-Revilla et al. 2007].

As with all other kinds of simulations, ABMs are also well-suited for testing alternative policies, as demonstrated by the models cited in this section and others [e.g., Epstein's (2002) model of civil war and peacekeeping intervention]. As always, such tests might aim at early-warning, prevention, shaping, or mitigation. Finally, simulations can also sometimes suggest new policies, or new ways of fine-tuning existing policies.

UML is emerging as a desirable system of graphic representation for agent-based models, especially for representing the ontology (class diagrams) and processes (sequence and state diagrams) that are most relevant for defense and foreign policy domains [JASSS].

3.4.3 Hybrid models: Best of both worlds. Finally, some simulation models combine both SD and ABMs. An instance of this is found in the Redfish model of crime and administration of justice in the UK [Guerin]. Hybrid SD-ABMs are desirable when the target system has salient features related to stocks and flows, as well as salient classes of actors, institutions, or other social objects in the ontology of the target system. The four top policy issues in Section 2 above have these characteristics [prepare a small table], so we may expect more hybrid models in these areas.

4. Discussion

4.1 Today

With some exceptions discussed below, social science theory and methodology were widely ignored by the defense and intelligence communities until quite recently. Lepgold and Nincic (2001) offer several reasons that may explain the lack of interest. First, in their quest to intuit any novel insight about the world, social scientists are tackling smaller or narrower research problems rather than more fundamental problems with a broader policy reach. Second, scientific techniques often trump substantive considerations in the social sciences. So many formal and statistical models have been developed that scholars have difficulty meaningfully comparing their empirical performance. Third, the reputations of university-based social scientists tend to be based on how well their work is perceived within academe, not beyond it. This can reinforce trends toward faddishness of method. Finally, as immortalized by C.P. Snow's *Two Cultures*, there is a wide intellectual chasm between the computational social scientist and the qualitatively-trained defense and intelligence analyst who is often the transition target for new analytical capabilities.

Nevertheless, and despite these tendencies, there are several instances in which social science theory and methodology have been applied with much success to contemporary defense and intelligence issues. Much of what has been harvested and applied toward US national security has been derived from the fields of conflict and crisis early warning and leadership assessments. To the extent that these can be considered applications of computational social science—as opposed to statistical or mathematical methods—these are based primarily on methods for automated information extraction (section 3.1). The other components of computational social science—SNA, socio-GIS, complexity analysis, and social simulation—so far lag behind.

4.1.1 Crisis and conflict early warning. Crisis and conflict early warning involves the identification of a set of factors and criteria which, when met, are typically followed within a pre-specified time-period by a violent episode or series of episodic events, the nature and definition of which are unambiguously specified beforehand. Two types of conflict and crisis forecasts exist (Schrodt, 2002: 3). *Unconditional* forecasting is one of simple extrapolation: "if things continue on a current track, then X, Y, and Z will occur." Examples include Esty et al. (1995;1998) and O'Brien (2002), both of whom use advanced statistical methods and extensive longitudinal data on national-level macro-structural indicators (e.g., life expectancy, infant mortality level, commitment to civil liberties and political rights, and global trading patterns) to forecast the long-term susceptibility of states to "failure" and instability respectively. These factors or "predictors" were derived from well-grounded academic theories of ethnic, religious, and other forms of conflict. O'Brien (2002), for instance, generates future forecasts and provides geo-spatial maps showing where and when countries are likely to experience various levels of intensity of instability through the year 2015. These forecasts, which have proved around 85% accurate since 1999, provide military, diplomatic, and humanitarian planners with insights into where and when resources may need to be allocated or redeployed in the future to either prevent conflicts from occurring or to mitigate their undesirable consequences. The model includes a "what if" capability to explore how changes in variable levels (increase/decrease in democracy, GDP per capita, or public health and welfare measures) will alter the probability the country will experience a certain type and level of intensity of conflict.

Contingent forecasts are of potentially greater interest to scholars and policymakers (Schrodt, 2002),. They involve the continuous manipulation of variables to establish true causal relationships. The social science literature is served by two types of contingent forecasts, each of which has been employed on behalf of the U.S. defense and intelligence communities with positive results. The first example is the "Policon" method based expected utility (Bueno de Mesquita 1981; 1985; 1994, see also Feder, 2002), one of the most successful examples of applied social science. Using a set of algorithms from game theory, decision theory, spatial bargaining, and microeconomics, this method analyzes political dynamics in local, domestic, and international contexts and relies on subject matter experts to rate foreign decision-makers based on criteria designed that measure (1) their preferred policy position; (2) the resources available to them for imposing their will on other decision-makers; and (3) the value they place on achieving their policy goals relative to the value they place on simply being on the winning side. The model simulates the bargaining behavior among political elites and forecasts outcomes in the form of decisions that ultimately emerge with respect to almost any policy issue. According to Feder (2002:118-119), the CIA has used this method to forecast thousands of real world decisions including the following:

- What policy is Egypt likely to adopt toward Israel?
- How fully will France participate in the Strategic Defense Initiative?
- What is the Philippines likely to do about US bases?
- What policy will Beijing adopt toward Taiwan's role in the Asian Development Bank?

A declassified CIA study (Feder 1995:57) concluded that the Policon model has been correct in over 90% of the real world applications for which the CIA used it. Furthermore, in every case in which the forecasts differed from the forecasts of the subject matter experts who provided the input data it was the Policon forecasts that proved to be correct. Policon's successor (called Senturion) was used by the Department of Defense (see Abdollahian et al. 2006) to accurately forecast developments in the aftermath of Operation Iraqi Freedom including, among others:

- The lack of consensus around Iraqi government institutions
- The deteriorating disposition of Iraqis toward U.S. forces
- Al Sadr's active opposition toward U.S. interests
- How removing Saddam Hussein would cause more vigorous opposition from Shia parties.

Another example of contingent forecasting involves *events data analysis* based on automated information extraction through "sparse parsers" (Schrodt and Bond)—integrated computer programs that search newswires for data on all the events that transpire around the world on a daily basis; who is doing what to whom, when, where, and how. Modeled on speech recognition techniques, sparse parsers search through news reports and identify proper nouns (e.g., Yasser Arafat, Palestinian students), direct and indirect objects, and verbs ("threatened," "attacked", "agreed"). Each event is tagged to an action-verb and used to compile indices of the character and level of intensity of interaction between groups, individuals, and countries that are tracked over time. The event data matrices reflect the evolution and changes in cooperation and violence between actors in most countries around the world. Not only is official Washington observing the development of these capabilities with a measure of curiosity, so too is the popular press (Arkin 2002; Glenn 2002; Zimmerman 1996).

Scholars have invested considerable efforts using the modern computational methods of event data analysis to search for event sequences that provide reliable indications of impending conflict weeks or months in the future (Bond et al. 1997; Davies and Harff 1998; Harff 1998; Jenkins and Bond 2001; Pevehouse and Goldstein 1999; Schrodt 1997, 1998; Schrodt and Gerner 1997). Some of these analyses have produced policy-relevant insights. For instance, one study monitored the interactions (in near real-time) between the U.S., Serbia, and Kosovars during the NATO hostilities in Kosovo in 1999 (Pevehouse and Goldstein, 1999), demonstrating that the U.S. bombing of Serbia was—contrary to its stated intention—contributing to the acceleration of Serbia's ethnic cleansing of ethnic Albanians in Kosovo. Had this type of analysis been performed in Washington (and a similar effort might have indeed been performed, but in a classified venue), military commanders and policymakers might have had occasion to reconsider their strategies and tactics in the conduct of the war.

Doug Bond, a Harvard political scientist and President of Virtual Research Associates (Westin, MA) takes this policy-relevant research a step further with his development of event data visualization tools. His company maintains a restricted-access website that allows clients in the defense and NGO communities to monitor these event data indices for countries around the world in (near) real time. Bond and his colleagues use the events data they collect to construct and monitor three principal indices:

• *Civil contentiousness* (*CC*): proportion of civil actions reported as contentious or "direct" and thus challenge a state's monopoly on conflict regulation (normed against all actions by civil actors).

• *State repression* (*SR*): Proportion of state actions that are reported as extra-institutional or direct, both in response to direct challenges from civil actors and those initiated by the state to repress and control opposition (normed against all state actions).

• *Violent contention* (*VC*): Proportion of actions entailing physical damage to persons or property (normed against all contentious actions in society).

These indices are constructed using the proportion of events reported by news sources for each type relative to all events. A country's "conflict-carrying capacity" (*CCC*) is defined as the ability of the state to regulate intense internal conflict without loss of system integrity (Jenkins and Bond 2001). A country's *CCC* is then measured by the multiplicative interactions between acts of civil contention, acts of government repression, and violent contention, or $CCC = CC \times SR \times VC$.

In this model, countries that experience high levels of violence remain stable so long as government repression and civil contentiousness are low; states are also generally stable when government repression is high, but contentiousness and violence (Jenkins and Bond, 2001). Likewise, governments can withstand high levels of civil contentiousness, so long as overall levels of violence are low and the government refrains from using too much repression. It is when all three key indices begin to move simultaneously—when civil contention begets ruthless state repression and vice versa, and is attended by spirally levels of violence—that a government's ability to maintain system integrity deteriorates markedly. This method has been applied to demonstrate how it could have been used to forecast the civil war in Algeria in 1992, the generally non-violent "Velvet Revolution" in Poland (1989), and the return to stability in Peru following President Fujimori's crackdown on Shining Path guerillas in the early 1990s. A study by the U.S. Army (O'Brien 2004) demonstrated the close correspondence between events data indices and real world developments in the Former Yugolsavia, Bosnia, Croatia, Serbia and Montenegro, Israel, Iraq, Afghanistan, and Venezuela.

4.1.2 Leadership Assessment

Whereas models such a Policon and Senturion are highly dependent on input from subject matter experts, others (e.g., Hermann, 1999; Walker 2000; Lazarevska and Sholl 2005; Sholl et al. 2004) have pioneered applications of automated text extraction techniques for remotely assessing leadership preferences, styles, and operational codes. Having assessed the individual differences of 122 leaders from 46 countries over the last two decades (Hermann, 1980a, 1980b, 1984, 1987, 1988, 1993) seven traits have been identified as particularly useful in assessing leadership style:

- the belief one can control events
- the need for power and influence
- conceptual complexity
- self-confidence
- the tendency to focus on problem solving and accomplishing something vs. maintenance of the group and dealing with others' ideas and sensitivities
- an individual's general distrust or suspiciousness of others, and
- the intensity with which a person holds an ingroup bias.

The presence, absence, intensity, and configuration of these characteristics provide the profile of a leader, along with a set of theoretical expectations for how the leader will approach decisions, relate to other leaders, or behave in certain circumstances. For instance, leaders who challenge constraints, are closed to information, and surround themselves with like-minded advisors will take an evangelistic approach to leadership, focusing attention on persuading others to join in their mission and mobilizing others around their message. Combine these traits with a significant distrust of others and high ingroup bias, and the leader is likely to focus on eliminating potential threats and problems, a profile that might fit Hitler, Saddam Hussein, or Idi Imine. Hermann's former student, Michael Young, formed a company called Social Science Automation, Inc, and developed a software system, Profiler Plus (Young 1999), to profile foreign leaders for a variety of customers in the defense and foreign policy arenas. Profiler Plus performs an automatic content analysis of the transcripts of interviews given by target foreign leaders, and measures each leadership trait along a continuum based on the relative frequency in the usage of certain key words and phrases. Since leaders deliver a variety of speeches to a variety of audiences, in different contexts throughout their tenure, one can use this capability to detect shifts in the profile, both over time and by context. Such an assessment framework has obvious utility to both anticipate a leader's behavior and develop alternative courses of action to influence them.

4.2 Tomorrow

Axtell (n.d.) refers to a coevolution of the information and social sciences, whereby advances in one field stimulate advances in the other. He sees one specific IT-facilitated development in particular—multi-agent systems and agent-based models (section 3.5.2 earlier)—as holding the promise of fundamentally altering the ways in which social science models are conceived, built, explored, and evaluated. Indeed given developments in information technology, grid computing, and computational social science theory and methodology, and assuming Moore's Law continues, it is possible to envision the development of several far-reaching capabilities.

One such possibility is a real time human behavior simulator—a TIVO-like capability—to monitor global human behavior in any major city, country, or region, in near real time. Imagine the possibilities if we could do that. We could monitor emergent behavior in any major city at any point, rewind 30 days, and determine what conditions and causal dynamics generated the emergent behaviors we're seeing there. Or, we could spin the system foreward to find out what is likely to happen in the future. If we didn't like what we see, we could systematically evaluate alternative Courses of Actions (COAs) to identify those that are most likely to push the situation in a direction more beneficial for national security interests. Once executed, we could monitor the effectiveness of the COA in near real time and recommend adjustments on the fly.

At first blush, it might seem wishful thinking that we could build such a system. But the ingredients for such a system exist or are in advanced states of maturation. They include the following.

- Increasing interest in and sophistication of agent-based simulations
- the explosion of data sources, about individuals, their beliefs and characteristics, and real time news feeds and discussion forums (blogs, etc.)
- the maturation of human, social, cultural, and behavioral (HSCB) theories .

Many of the HSCB theories are in competition. Most cannot be studied effectively with traditional social science methods. All of them need to be formalized and integrated. But the capabilities we envision may allow us to subject these theories to rigorous empirical evaluations in ways that could revolutionize not only the social sciences, but also the ways in which foreign policy and defense personnel track, monitor and anticipate human behavior abroad, how leaders make decisions, contemplate their effects and determine how alternative courses of action will achieve strategic, operational, and tactical objectives—all of this potentially in real time.

Several factors are needed to make agent-based simulations operationally useful (i.e., achieve a score of 3 on the Axtell-Epstein scale). One involves creating agents that mirror the actual people and organizations they are intended to represent. The other is to leverage the hundreds of human, social, cultural, and behavioral theories to develop the set of rules that govern the interactions among agents. It is this set of rules that ultimately serves as the basis for anticipating how people and organizations are likely to react to events and policies in the regions they inhabit. The more closely the rules (or theories) reflect how people actually behave and respond to stimulus, the more closely the simulated behaviors will mirror real world behaviors.

The first step in creating realistic agents is to obtain access to good data on people abroad, data that describe peoples' characteristics, who they are and what they believe about their neighbors, their government, other governments and policies, and life in general. We have long had access to data that describe countries—the type of regime they have, aggregate demographic statistics, economic indicators, and the like. More recently, we have seen a proliferation of real time global news feeds, and we now have tools for turning that unstructured text into structured data that describes who is doing what to whom, when, where, and how around the world and in near real time. This access to new data sources has greatly expanded our ability to analyze the dynamic interactions between people and the leaders who govern them. But several other sources of data have recently expanded the horizon even further.

For instance, one can now obtain detailed census reports for nearly every country online.[3] These reports are the crown jewels for obtaining data on the characteristics of people throughout the world, such as age, income, education, occupation, ethnicity, religion, and gender distributions. Another relatively recent source of data is *The World Values Survey* (WVS), a global network of social scientists who have surveyed the basic values and beliefs of the citizens of more than 80 societies, on all six inhabited continents. To date, some 92,000 people in 80 countries have responded to 250 questions about their beliefs, and the data are now available for 1981–2006. The University of Maryland has developed OASYS, a system to automatically measure the intensity of popular support or opposition to nearly any issue in many countries throughout the world, in multiple languages, potentially in real time and on the fly.

Complimenting the values survey is the UN Globe Study, with data on the cultural characteristics of 17,000 people in 62 countries from Albania to Zimbabwe. These data provide insight into how different cultures view the world, how their views shape their standards of behavior, and how they are likely to interact with people from within other cultures.

"Smearing" these demographic, opinion, and cultural characteristics data across millions of agents would get us one step closer to building agents that represent real people around the world. And that would get us one step closer to being able to use agent-based simulations as a synthetic laboratory for realistically examining human interactions and responses to events around them. If not individuals, at least household-agents or group-agents with realistic attributes and interactions would mark a significant step forward.

But having agents that look like real people tells us nothing about how they will behave under different circumstances. Today, many practitioners of social simulation simply make up a set of rules that govern behavior, but they often bear little resemblance to the way real people in diverse cultures truly behave and react to events around them. And the outcomes generated by such simulations, though perhaps plausible, have little chance of being reliably predictive in any meaningful sense.

There is a better way. Spread throughout the social science literature are hundreds of theories that provide a set of expectations for how diverse groups and individuals, endowed with specific cognitive, demographic, and cultural characteristics, develop goals, preferences and standards of behavior; form, alter, and act upon beliefs; join or leave radical/violent organizations; and respond to events around them. Some of these theories have been tested for correspondence to the real world; most have not because the tools of the social scientist often do not lend themselves to rigorous empirical evaluations. And even if they did, until recently, we lacked the data to perform the analyses. We now have better data, and the agent-based environment offers an outstanding methodology for formalizing and testing these theories. But here's a challenge: how do we bring together the most compelling theories, formalize them, integrate them, and instantiate them within an agent-based environment? To our knowledge, this has never been done before. What is the best form of formalism? How do we integrate bottom up and top down theories from across multiple disciplines and levels of analysis? If we could do this, the formalized theoretical synthesis would need to be tested for correspondence to real world behaviors and events around the world in many diverse societies. This would allow us to prove or disprove alternative theories and identify the boundary conditions under which any particular theory or set of theories applies, and identify gaps, where new theories would need to be developed to account for discrepancies between simulated and real world behavior.

[3] See, for instance, http://unstats.un.org/unsd/methods/inter-natlinks/sd_natstat.asp

But it would probably also entail the need for new tools and techniques for validation.

There are other technical challenges as well. For instance, we would need to integrate the simulation with real time data feeds. Real people change their repertoires of behavior over time—as people age and achieve greater (or lesser) socio-economic status, their attitudes change, their priorities change, depending for instance on how much stress or vulnerability they feel. We would need to process changes in the attributes of agents in a timely manner. We need to come up with new ideas and technologies to identify, process, and accommodate these changes in near real time.

But let's pause here and imagine the possibilities if we could do this—create a simulation environment, where the agents are designed to represent real people of interest—true with respect to their characteristics, beliefs, standards of behavior—and these agents are observing, processing and reacting to real events as reported in real time data feeds, and interacting among themselves in theoretically realistic manners. And we could confirm that the behaviors we witness in the simulation environment mirror those that are occurring in the real world.

For one, the simulation would provide us with a window on what is occurring in the world, a window that is not visible with traditional intelligence tools like HUMINT, COMINT, and SIGINT. Short of placing clandestine video cameras on every street corner from Abuja to Ziwani, the capability we've sketched is our only real alternative.

We could stop the simulation at anytime to better study events that occurred—or spin the thing foreword to see what might occur in the absence of intervention. Used in a post-dictive mode, such a simulation might even have appeal among historians, besides the obvious use in examining alternative futures.

We could explore how different strategic, operational, and tactical COAs could mitigate impending, adverse emergent behaviors. This would allow us to evaluate the consequences of different COAs, identify any undesirable 2nd and 3rd order effects, in a stand-off manner. Without such a synthetic computational laboratory, we are vulnerable to applying strategies and tactics that are less than robust, and perhaps counter-productive to our long-term goals and stated objectives. Currently, and all too often, the consequences of sub-optimal strategies are irrevocable.

In fact, if we had a system that would allow us to accurately monitor and forecast how individuals and organizations will react to events and interact among themselves in near real time, around the world, it is difficult to imagine *what* questions with human behavioral implications could *not* be addressed. But it will take immense effort from an interdisciplinary community to get us there.

5. Summary

Today and for the foreseeable future, foreign and defense policy is typically affected by complex issues that can benefit from advanced social science methodologies. In this paper we highlight a salient set of such issues and the contribution—current and potential—that the main analytical approaches and methods from computational social science might bring to bear on such issues. The issues consist of terrorism, WMD proliferation, state failure, and global issues ranging from human rights to global change. The main computational methods consist of automated information extraction systems, social network analysis, social GIS, complexity modeling, and social simulation models. After a review of issues and methods, we discuss some present and future trends in the application of computational analysis to national security policy. Our main desired goal is stated in terms of agent-based modeling, especially a large-scale system that could maintain real-time or near-real-time calibration and would draw on the suite of computational social science components as an integrated system.

References

Abdollahian, Mark, Michael Baranick, Brian Efird, and Jacek Kugler. 2006. "Senturion: A predictive political simulation model." Center for Technology and National Security Policy National Defense University

Arkin, William. 2002. "Mapping the minds in Iraq's regime." *Los Angeles Times* (September 1).

Axtell, Robert L. (n.d.). "The New Coevolution of Information Science and Social Science: From Software Agents to Artificial Societies and Back (or How More Computing Became different Computing." (http://www.econ.iastate.edu/tesfatsi/compsoc.axtell.pdf).

Bueno de Mesquita B. 1981. *The War Trap*.New Haven, CT: Yale Univ. Press.

Bond, Doug, Craig Jenkins, and Kurt Schock. 1997. Mapping mass political conflict and civil society: Issues and prospects for the automated development of event data."*Journal of Conflict Resolution* 41(4): 553-79.

Bueno de Mesquita B, Newman D, Rabushka A. 1985. F*orecasting Political Events: The Future of Hong Kong*. New Haven, CT: Yale Univ. Press.

Bueno de Mesquita B, Stokman eds. 1994. *European Community Decision Making*. New Haven, CT: Yale Univ. Press.

Davies, John L., and Barbara Harff, with Anne L. Speca. 1998. Dynamic data for conflict early warning. In *Preventive measures: Building risk assessment and crisis early warning systems,* edited by John L. Davies and Ted Robert Gurr. Lanham, MD: Rowman and Littlefield Publishers, Inc.

Esty, Daniel C., Jack Gladstone, Ted Robert Gurr, Pamela Surko, and Alan N. Unger. 1995. *Working papers: State failure task force report*. McLean, VA: Science Applications International Corporation.

Esty, Daniel C., Jack Gladstone, Ted Robert Gurr, Barbara Harff, Marc Levy, Geoffrey D. Dabelko, Pamela T. Surko, and Alan N. Unger. 1998. *The State failure task force report: Phase II findings*. McLean, VA: Science Applications International Corporation.

Feder, Stanley. 1995. "Faction and Policon: New ways to analyze politics. In *Inside CIA's private world: Declassified articles from the agency's internal journal, 1955-1992.* ed. H. Bradford Westerfield. New Haven: Yale University Press.

Feder, Stanley. 2002. Forecasting for policy making in the post Cold War period. Annual Review of Political Science. Vol. 5 (111-125).

Glenn, David. 2002. "Calculus of the battlefield." *Chronicle of higher education* (November 8). http://chronicle.com/weekly/v49/iii/11a01401.htm.

Harff, Barbara. 1998. "Early warning of humanitarian crises: Sequential models and the role of accelerators." In *Preventive measures: Building risk assessment and crisis early warning systems,* edited by John L. Davies and Ted Robert Gurr. Lanham, MD: Rowman and Littlefield Publishers, Inc.

Hermann, Margaret G. "Assessing Leadership Style: A Trait Analysis." Social Science Automation, Inc. (http://www.socialscienceautomation.com/docs/Lta.pdf)

Jenkins, J. Craig, and Doug Bond. 2001."Conflict-carrying capacity, political crisis, andreconstruction: A framework for the early warning of political system vulnerability." *Journal of conflict resolution* 45(1): 3-31.

Lazarevska, Elena, and Jayne M. Sholl. 2005. "The Distinctive Lagnuage of Terrorism." Social Science Automation, Inc. (http://www.socialscienceautomation.com/docs/Distinctive%20language%20of%20Terrorists.pdf).

Lepgold, Joseph, and Miroslav Nincic. 2001. *Beyond the ivory tower: International relations theory and the issue of policy relevance.* New York: Columbia University Press.

O'Brien, Sean P. 2002 "Anticipating the good, the bad, and the ugly: An early warning approach to conflict and instability analysis. *Journal of conflict resolution*. 46(6): 791-811.

______. 2004. "Near-term Forecasts of Crisis and Instability Using Text-Based Events (NEAR-TERM FORECITE)." Paper prepared for presentation at the *71st Military Operations Research Society Symposium (MORSS)*, Quantico, VA, June 2003.

Pevehouse, Jon C., and Joshua S. Goldstein. 1999. "Serbian compliance or defiance inKosovo? Statistical analysis and real-time predictions.*"* *Journal of Conflict Resolution* 43: 538-46.

Schrodt, Philip A. 1997. "Early warning of conflict in southern Lebanon using hidden markov models." Paper presented at the annual meeting of the *American Political Science Association*, Washington, D.C.

_____. 1998. "Pattern recognition of international crises using hidden markov models." In *Non-Linear Models and Methods in Political Science*, edited by Diana Richards. Ann Arbor: University of Michigan Press.

_____. 2002. "Forecasts and contingencies: From methodology to policy." Paper presented at the annual meeting of the American Political Science Association, (Boston).

Schrodt, Philip A., and Deborah J. Gerner. 1997. "Empirical indicators of crisis phase in the Middle East, 1979-1995." *Journal of Conflict Resolution* 41(4): 529-52.

Sholl, Jayne M., and E. Lazarevska, R.B. Woyach, and M.D. Young. 2004. "Leadership Profile of Pervez Musharaf." Social Science Automation, Inc.

Walker, Stephen G. 2000. "Forecasting the Political Behavior of Leaders With the Verbs in Context System of Operational Code Analysis." Social Science Automation, Inc. (http://www.socialscienceautomation.com/docs/Operational%20Code%20Analysis.pdf)

Zimmerman, Tim. 1996. "CIA study: Why do countries fall apart? Al Gore wanted to know." *U.S. News and World Report* (March 12).