Synthesizing Information for Senior Policy Makers using Simulation: Working through an EBO example with system dynamics

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Abstract:

Modern computer systems have made ever-increasing amounts of processing power available to senior governmental decision makers, but this technology has at times overwhelmed them with large amounts of hard-to-interpret data. Modeling and simulation generally, and *System Dynamics* (SD) specifically, addresses data overload by "boiling down" the data and synthesizing information at the macro-level. This capability is demonstrated by showing that SD applies to Effects Based Operations (EBO) problems and by addressing an EBO example problem. In so doing, specific requirements are detailed and defined including visualization, quantification, data acquisition, system complexity, system integration, and model Verification, Validation, and Accreditation (VV&A). The paper concludes that, given the large amount of work that has gone into developing the SD methodology, current policy-tool development efforts that address fundamentally similar policy questions are likely to prove unsuccessful. An alternate path of using system dynamics as the policy tool *of first choice*, identifying requirements and gaps based on that effort, and then developing tools informed by those gaps will likely prove more successful.

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0. Introduction

Senior government decision makers face an increasingly complex policy environment. Blending military with other forms of diplomatic and economic national power has always proven challenging, but the modern policy context posed by ongoing globalization and attendant, incipient insurgencies have only served to increase the topic's salience. Consequently, the Department of Defense (DoD) has been forced to coordinate its activities with other government agencies, most notably the State Department. Effects Based Operations (EBO), a way for the DoD to address complex policy questions, has thus been described as a, "grand challenge for the analytic community" (Davis 2001). And while some technical, computer-based tools have been applied to the EBO problem, significant opportunities remain.

This paper makes the case that an extant simulation methodology, *System Dynamics* (SD), answers many of the fundamental EBO questions and requirements and can fruitfully be applied to hard foreign policy questions in the short term (Lofdahl 2001). The argument is made in three sections. The first section establishes the policy context and makes the argument that EBO is a new take on a longstanding, fundamental policy problem. Second, the technical requirements of an EBO relevant technology are spelled out and discussed in terms of the SD simulation methodology. And third, an example problem is addressed using SD to show how the capabilities described in the second section can actually be used to solve an EBO problem. The paper concludes with some observations regarding how to think about using SD in a policy context.

1. Policy Context

Creating foreign policy has always been challenging given 1) the pervasive lack of time and information and 2) the potential seriousness of the consequences. Former US Secretary of State and National Security Advisor Henry Kissinger said that senior decision makers, "work in darkness" as they make their policy choices (Kissinger 1979; Tetlock and McGuire 1985). This, in a phrase, is the *policy problématique*, the difficulty associated with marshalling information from the past to make choices in the present that improve the future.

These difficulties extend beyond the United States Government (USG) interacting with other countries; just getting the various USG agencies to coordinate their actions among themselves is difficult with the most emblematic interaction being that between the Defense and State departments (Destler 1994). Coordination problems stem from the perspectives associated with each agency: the DoD focuses on the hard, military elements of national power and State on the softer, diplomatic, psychological, and economic elements. Improving their interaction is thus an ongoing USG opportunity.

The policy problems confronting today's leaders have gotten harder since the Cold War with the traditional strategic threats of submarines, bombers, and missiles morphing into failed states, terrorism, and weapons of mass destruction (Popp 2005). Thus the DoD has increasingly incorporated non-military or "non-kinetic" notions into its thinking. The Army has emphasized diplomatic, psychological, and economic factors in its counterinsurgency strategy (US Army 2006; Hix 2006) given its hard won experience in

Iraq and Afghanistan, and the Navy too has also incorporated non-kinetic into its sea shaping maritime strategy (US Navy 2007). Recognizing that kinetic and non-kinetic, military and non-military factors need to be considered together when formulating policy is not new: Hawley's (2005) work on political and military or "pol-mil" planning is emblematic of this realization. However, applying computer technology and complex systems insights to extend and increase the fidelity of these analyses remains an open opportunity.

EBO is based on the system successes of the DoD in the first Gulf War of the early 1990s that better applied air power in support of national objectives (Deptula 2001). The use of precision munitions and computers to understand their effects gave a sense of optimism that these analytic gains could be extended to policy more generally. Representative of this view are two DoD acronyms, DIME which stands for the diplomatic, informational, military, and economic policy levers that the USG can manipulate to influence countries of interest, and PMESII which describes the political, military, economic, social, informational, and infrastructure systems within the country of interest. Note two things: first, that these acronyms are essentially *reductionist* in that they break down a complex whole into parts; and second, that this complexity is simplified into an acronym. It should thus be noted that these two acronyms are properly interpreted as *notional* rather than *definitional*. Lofdahl (2002, 222) observes that geopolitical scholars have for generations provided reductionist definitions of national power (e.g., Morgenthau 1948), PMESII is thus a modern definition among many.

JFCOM (2004) develops the notion of an Operational Net Assessment (ONA) that provides methodological support for EBO. Enough time has passed to allow for reflection and assessment of the ONA, which is in fact two things – first, a set of system insights, and second, an actual computer-based tool, both of which support EBO notions, intuitions, and thinking. The system insights draw from modern complexity theory, which stresses system wholeness and synthesis. The ONA tool implementations however have tended to be databases that instead decompose DIME and PMESII systems into parts. This is not what senior decision makers require (Forrester 1971), and so opportunities exist to improve the application of EBO to hard policy problems (Gladwell 2005, ch. 4). The next section develops the notion of SD as a synthetic policy tool.

2. Synthetic Technical Solution

The key EBO gap entails the synthesis of information, which is necessary for senior decision makers to make sense of the overwhelming amount of policy relevant detail, data, and complexity. However, this gap persists because computers perform simple, serial tasks well, not pattern matching or information synthesis. This paper proposes system dynamics (SD) simulation as a technical solution to the EBO synthesis gap, and this section details the requirements that SD must meet: 1) visualization, 2) problem focus, 3) quantification, 4) data acquisition, 5) complexity, 6) integration, and 7) verification, validation, and accreditation (VV&A).[1]

[1] This list is derived, with some interpretation, from Hillson (2007).

The first requirement is *visualization*, which is the most natural and intuitive way to convey complex information and relationships to senior decision makers. Moreover, the very process visualization implies *synthesis* as many parts are viewed together quickly, intuitively, and holistically. At the center of SD is the ability to both to view equations in a more visual form and also to view connections among different parts of the simulation.

The second EBO requirement is *problem focus*: in itemizing the aspects of the policy problem to be represented within a simulation, the SD methodology must support the ability to decide what should be included or made *endogenous* and what should be excluded or made *exogenous*. Some feel that anything possibly relevant should be included in a simulation, but reality is too complex to allow this on a consistent basis. It is true everything is connected, but SD teaches that complex and confusing behaviors can obtain from seemingly simple systems, so creating a useful simulation need not entail enumerating and connecting all relevant items and objects.[2]

The third requirement is *quantification*. Most policy analysis is text based, and SD provides the ability to articulate more specific and synthetic quantitative relationships. Moreover, the quantification remains manageable due to SD's visual representation.

The fourth requirement regards *data acquisition*, a traditionally thorny topic. Unlike most quantitative methodologies, SD is expertise rather than data limited. This allows for

[2] Simon (1981, 20) notes conversely that, "The more we are willing to abstract from the detail of a set of phenomena, the easier it becomes to simulate the phenomena. Moreover we do not have to know, or guess at, all the internal structure of the system but only that part of it that is crucial for the abstraction."

several policy relevant benefits. First, as the DoD usually operates in areas with little infrastructure to collect data, and what data exists is usually classified and hard to access, SD allows for quantitative analysis in situations where little data exists. Second, through a process called Requirements Based Collection or RBC (S2 2007), SD can be used to identify crucial types of data that may not be intuitively apparent without a structured, synthetic, and computer-aided analysis. Thus with RBC, small amounts of key data can be sought for intentionally rather than large amounts of dubious data received passively. Third, data can be used to check, test, and tune SD models (Sterman 2001, ch. 21).

The fifth requirement regards *complexity*: Davis (2001, back cover) states the EBO is a systems framework that addresses the full range of direct, indirect, and cascading consequences. SD directly addresses such consequences by directly representing three types of complex causal relationships – 1) nonlinear, 2) feedback, and 3) integrative stock flow – that tend to confound decision makers and confuse policy (Forrester 1961; Forrester 1971; Sterman 2001). In so doing, SD addresses the *dynamic* complexity that dominates and drives policy problems rather than the *detail* complexity addressed by databases (Sterman 2001, 21-23). SD's simulation capability allows for scenario analysis and low-cost learning of these hard to comprehend dynamic environments.

The sixth requirement regards system synthesis or *integration*. The DIME and PMESII decompositions are the standards for organizing and directing EBO analyses. However, SD allows for their constituent components to be connected, integrated, and

analyzed together. Moreover, SD grants a way for alternate, particular system definitions to be created to better address the problem at hand.

The seventh requirement is Verification, Validation, and Accreditation (VV&A). In order for a simulation to be used confidently to formulate policy, it must make a claim to correctness beyond the intuitions and opinions of the model creator. The SD methodology provides a defined and accepted way to test that the responses of a model make sense. Sterman (2001, ch. 21) articulates twelve measures of correctness:

- Boundary adequacy
- Structure assessment
- Dimensional consistency
- Parameter assessment
- Extreme conditions
- Integration error
- Behavior reproduction
- Behavior anomaly
- Family member
- Surprise behavior
- Sensitivity analysis
- System improvement

Such tests do not guarantee that a model is correct, but each additional test provides evidence that the model can be confidently used to formulate policy.

3. A Policy Simulation Example

America has experience in nation-building (Dobbins 2003), but no single government agency has explicit responsibility, so lessons-learned tend not to be captured and the hard-won expertise is lost, leaving the next generation of nation-builders ill-informed and poised for failure. Covey et al. (2005) seeks to correct this by writing up their operational

experiences in Kosovo and Bosnia. The example developed herein applies their four-part strategy to Iraq:

- Political strategy,
- Rule of Law strategy,
- Security strategy, and
- Political economic strategy.

This example focuses primarily on integrating military and economic strategies, a traditional foreign policy problem (Destler 1994). In Iraq, this question takes the following form: What comes first, security or development? The Departments of Defense and State each have their own view, but having a clear, coherent understanding of their relationship will result in better policy.

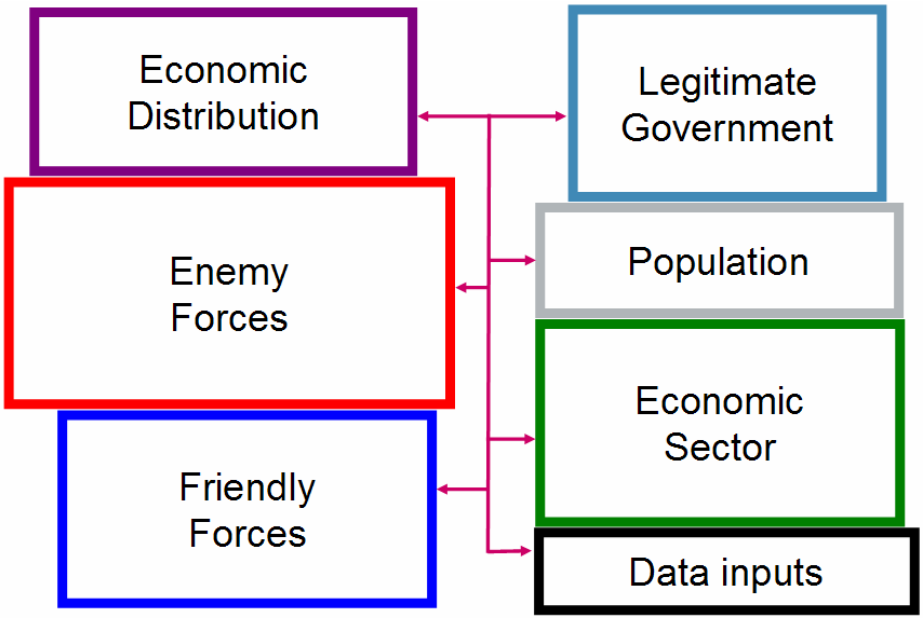

Figure 1, Combined Military and Political Economy Concerns

Figure 1 shows a high-level model decomposition featuring combined military and economic concerns. Military concerns are decomposed into friendly and enemy forces, while economic concerns are decomposed into an economic sector that produces goods and services and an economic distribution sector that allocates those goods. Military and economic concerns combine when economic resources are distributed to the criminal,

enemy forces of an illegitimate state. Friendly force intervention therefore must not only defeat the enemy militarily but also economically by redistributing economic resources so that they benefit the nascent, legitimate government as well as the general population. The final sector contains data inputs can be manipulated by senior-decision makers including DIME policy levers.

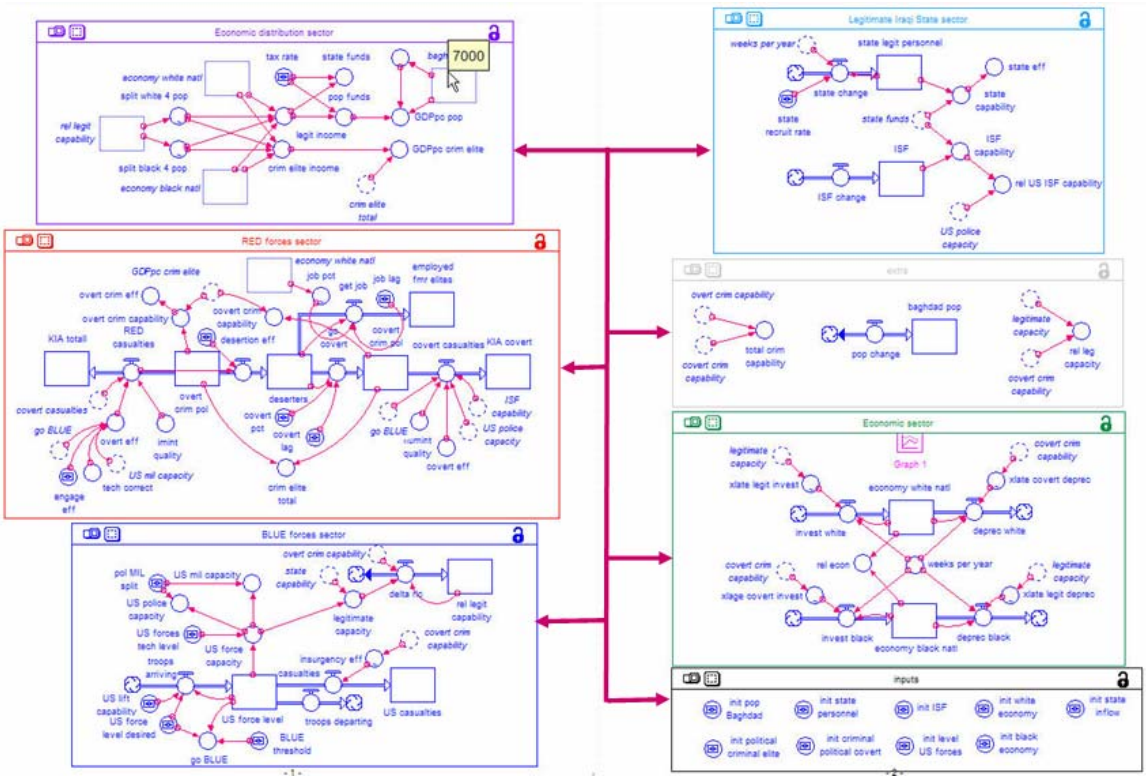

Figure 2, Specified Military and Economic Concerns

Figure 2 specifies the sectors identified in Figure 1. Using the system dynamics simulation methodology, primary, secondary, and cascading consequences are explicitly represented within each sector. It is the representation and simulation of these causal connections that makes system dynamics so applicable to EBO questions (Davis 2001).

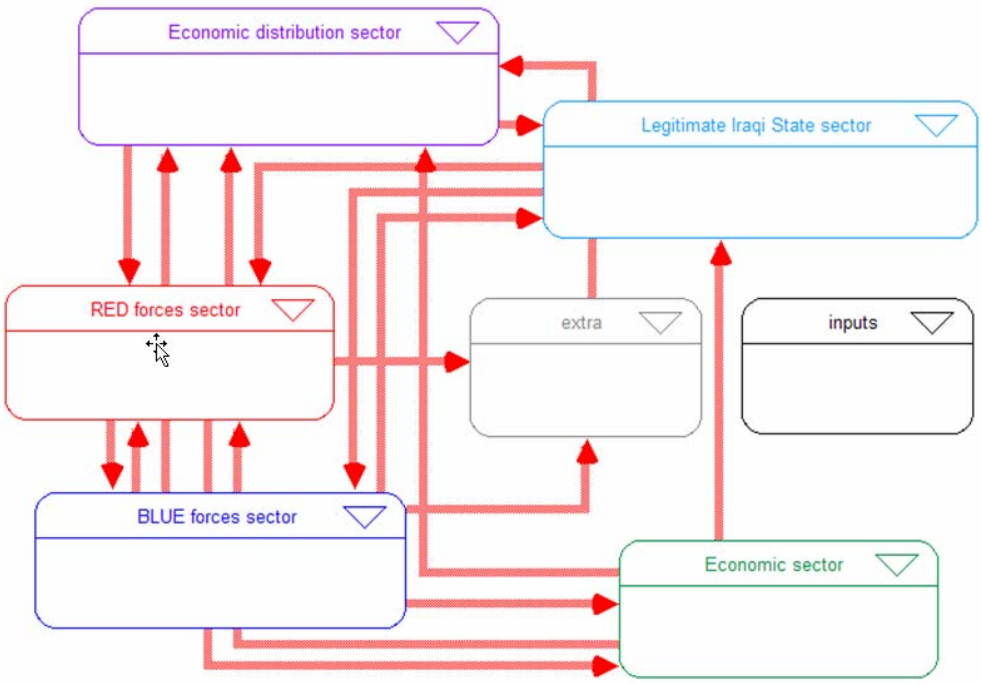

Figure 3, Integrated Military and Economic Concerns

Figure 3 provides an explicit depiction of the connections among sectors. Note especially the connections between the military and economic sectors as these allow synthetic, integrated policies to be simulated and evaluated.

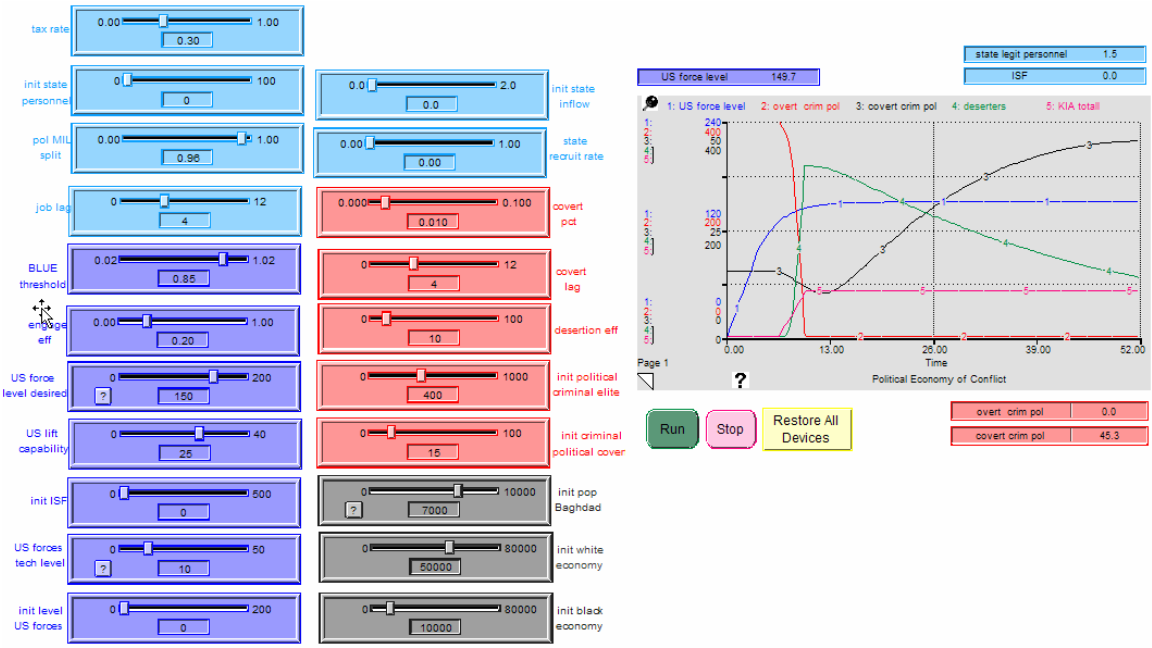

Figure 4, Policy Levers and Dynamic Results

Figure 4 shows the graphical user interface comprised of policy levers to the left and dynamic results to the right. Note that this interface hides the complexity of figures 2 and 3, instead revealing to decision makers only what they need to get their job done – the items over which they have control and their results. Simulations usually run on the order of seconds, so decision makers receive quick feedback between the time they enter their policy decisions and receive the results of those decisions, which greatly speeds learning. When the simulation results reveal counterintuitive conclusions, they need to be investigated to determine whether they are indeed truly interesting results or a modeling error. This implies the modeler both delving into the figure 2 model and working closely with the senior-level decision maker. As decision makers become familiar with the analytic capabilities afforded by simulation, it is likely that they will work more closely with simulation analysts.

4. Conclusion

There is a long history of senior policy makers working in darkness (Kissinger 1979), a situation that has not improved markedly in today's era of advanced information technology (Tetlock 2006). More subtle uses of computers are required, and SD provides a means to represent complex policy relationships and synthesize information for policy makers. This capability is sorely needed, and R&D efforts continue to provide a turnkey, engineering solution. SD is instead a modeling solution that relies on mature technical products developed over decades (e.g., Richardson 2001 and Ventana 2002). Often these R&D efforts focus on integrating multiple modeling paradigms into a single solution, and though the vision is attractive, such efforts ignore the capability provided by a mature

simulation methodology unified within a single vision. This is not mere methodological parochialism. These R&D efforts are intended to provide problem analysis but usually get mired down in engineering problems rather than focusing on and solving the driving problem. Working from an established methodology supported by mature tools allows for immediate focus on the problem. If the SD methodology proves incapable of addressing the problem, then the effort provides a rationale and requirements for follow-on models.

For example, an SD analytic framework provides the perspective to address key EBO shortcomings. In the Millennium Challenge experiment (Gladwell 2005, ch. 4), using a less developed tool in a crisis-action situation resulted in personnel looking to the tool for answers. The vision promoted here is a methodology that focuses thinking for deliberate planning efforts. The results should then be used to design C2 systems that better support crisis actions efforts, but specifying those details is outside the scope of this paper.

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