2015-05

A systems approach to modeling drivers of conflict and convergence in the Asia-Pacific region in the next 5-25 years

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NPS-SE-15-001

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

A SYSTEMS APPROACH TO MODELING DRIVERS OF CONFLICT AND CONVERGENCE IN THE ASIA-PACIFIC REGION IN THE NEXT 5-25 YEARS

by

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May 2015

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Prepared for: Assistant Secretary of Defense for Research & Engineering/Rapid Fielding Directorate/Rapid Reaction Technology Office (ASD R&E/RFD/RRTO)

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE ***(DD-MM-YYYY)***	**2. REPORT TYPE**	**3. DATES COVERED** ***(From-To)***
05-05-2015	Technical Report	

4. TITLE AND SUBTITLE

A Systems Approach to Modeling Drivers of Conflict and Convergence in the Asia-Pacific Region in the Next 5-25 Years

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER
NPS-SE-15-001

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Assistant Secretary of Defense for Research & Engineering/Rapid Fielding Directorate/Rapid Reaction Technology Office

10. SPONSOR/MONITOR'S ACRONYM(S)
ASD R&E/RFD/RRTO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
The views expressed in this project report are those of the contributing authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government. The use of commercial products in this project and this report does not represent official endorsement by the United States Government or any of its departments and agencies.

14. ABSTRACT
This project is part of a Strategic Multi-Layer Assessment (SMA) for the U.S. Pacific Command (PACOM). This SMA provides planning support for complex operational imperatives requiring multi-agency, multi-disciplinary solutions that are not currently within core PACOM competencies. The Naval Postgraduate School's (NPS) contribution overcomes the current conceptualization limitations by using a Systems Dynamics (SD) viewpoint to examine U.S.–China relations. This approach employs systems thinking and systems dynamics methodologies to analyze the policy structures of major issues of concern common to U.S. and China which result in non-linear and dynamic behavior over time. The SD model developed is composed of four sectors of common concern: energy demand and resources, demographics and stability, economics, and military actions. These sector models are used to model tension between the U.S. and China over the next 25 years. Tension was chosen as an underlying surrogate to overall U.S.–China relations. A simulation tool was developed assist policy makers in better understanding how the system's variables are related, how they influence one another, and how they are influenced by the system's external environment. The simulation tool also supports decision / policy making by allowing analysts to explore the effects of these variables on potential futures.

15. SUBJECT TERMS
Systems dynamics, modeling, China, strategic multilayer assessment

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Clifford A. Whitcomb
Unclassified	Unclassified	Unclassified	UU	134	**19b. TELEPHONE NUMBER** ***(include area code)*** (831) 656-3001

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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The report entitled *"A Systems Approach to Modeling Drivers of Conflict and Convergence in the Asia-Pacific Region in the Next 5-25 Years"* was prepared for the Joint Staff, J39/ Deputy Director for Global Operations and funded by the Assistant Secretary of Defense for Research & Engineering/Rapid Fielding Directorate/Rapid Reaction Technology Office (ASD R&E/RFD/RRTO).

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

A2AD	Anti-Access Area Denial
AOR	Area Of Responsibility
ASD(R&E)	Assistant Secretary of Defense (Research and Engineering)
BTU	British Thermal Unit
CCP	Chinese Communist Party
CEIP	Carnegie Endowment for International Peace
CSIS	Center for Strategic and International Studies
DDGO	Deputy Director for Global Operations
EEZ	Exclusive Economic Zone
GMU	George Mason University
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NHR	Nuclear-Hydroelectric-Renewables
NPS	Naval Postgraduate School
OSD	Office of the Secretary of Defense
PACOM	Pacific Command
PRC	People's Republic of China
REE	Rare Earth Elements
SD	Systems Dynamics
SI	Susceptible-Infectious
SMA	Strategic Multi-Layer Assessment
START	Study of Terrorism and Responses to Terrorism

TAMU	Texas A&M University
U.S.	United States
USEIA	United States Energy Information Administration
USG	U.S. Government
WHO	World Health Organization
WTO	World Trade Organization

I. INTRODUCTION

This project is part of a Strategic Multi-Layer Assessment (SMA) for the U.S. Pacific Command (PACOM) entitled Drivers of Conflict and Convergence in the Asia-Pacific Region in the Next 5-25 Years. In general, SMA provides planning support to Commands for complex operational imperatives requiring multi-agency, multi-disciplinary solutions that are not currently within core Service/Agency competencies. Solutions and participants are sought across the U.S. Government (USG) and beyond in order to cast a wide net to capture the brains needed to study these challenging problems. The products of the SMA are accepted and synchronized by Joint Staff (JS/J-3/DDGO) and executed by ASD (R&E) / RRTO.

Specifically, PACOM desires to identify areas of strategic risk and opportunity in the Asia-Pacific region over the next two decades. The SMA is being organized to:

1. Examine future political, security, societal, and economic trends
2. Identify where U.S. strategic interests are in cooperation or conflict with Chinese and other interests worldwide, and in particular, to the East China Sea
3. Leverage opportunities when dealing with China in a "global context"
    a. Drivers of Divergence/Conflict
    b. Drivers of Convergence

This SMA is expected to develop an outline of areas of strategic risks and conflicting interests as well as potential opportunities for encouraging cooperation between the United States and Asia-Pacific regional actors with particular emphasis on East China Sea to better understand the dynamics of this complex environment and relationship. The project period of performance was March 2014 to April 2015.

Officially referred to as the People's Republic of China (PRC), the nation will be referred to as China throughout this report. References to the Chinese Communist Party (CCP) refer to the ruling political party of the Chinese government. While comprising many different ethnic groups, those people residing in China will be collectively referred to as Chinese.

A. BACKGROUND

A potential shortcoming in current conceptualizations of conflict and cooperation is the inability to integrate our knowledge of the multiple dimensions of the problem—military, trade, demographics, technology, natural resources—into an integrated whole. Treatments of the problem, whether in academic or public discourse, invariably emphasize one aspect or problem area. This fragmentation of knowledge is not a reflection of the way the world works, but rather is the result of the analytic lens we impose—our natural predisposition when confronting a difficult problem to take things apart and treat the parts separately. The challenge to us today in addressing conflict—indeed, many of our persistent inter-state problems—is to "put things back together" again, after they have been examined in pieces. Such a holistic perspective does not imply denying the independent roles of the separate factors (technology, demographics, natural resources), but rather entails integrating them into a broader framework that incorporates the interactions between them—interactions that tend to get lost when the individual mechanisms are examined in isolation.

B. PURPOSE

The Naval Postgraduate School (NPS) partnered in this SMA by providing a systems approach to studying the dynamics of the issues involved to overcome the limitations of current conceptualizations. Among the key issues of mutual concern are U.S.-China economic trade barriers and imbalances, food security, agricultural policies, water management, climate change and carbon-based fuel alternatives, scarcity of resources (from soil nutrients to minerals for manufacturing), freedom / denial of access and intrusion issues (Exclusive Economic Zone (EEZ), cyberspace, et al.), military challenges and opportunities, high technology and academic exchanges, human rights, national demographics and their impacts on economies, human migration, Third World development, and others. Failing to recognize the systemic nature of the issues surrounding the drivers of conflict and convergence and their interconnectedness, and bifurcating "Economic" and "Strategic/Security" topics, robs the USG of an advantage, since China almost certainly views all of these issues within the context of a unified "strategy

C. OBJECTIVE

The primary objective of this strategic planning project is to inform decision makers of the complexity of the environment in which they, and their competitors, operate and to broaden the horizon of their strategic thinking. Research in the areas of complexity and systems thinking covers a spectrum of concepts that frame regional and global environments. Common in much of this analysis is a focus on determining system boundaries, endogenous and exogenous impacts, identification and implementation of feedback loops, and an appreciation of the delays and time frames required to provide a sufficient understanding of relationships within and between systems. An efficacious strategic planning process must be focused on enhancing the ability of decision makers to make sense of an uncertain and complex environment.

D. SCOPE

The NPS effort was not primarily intended to advance and/or contribute to existing theory, but rather to build upon existing understanding of the sources and consequences of conflict as articulated in the Carnegie study. The systems dynamics modeling effort provided the systems thinking methodology and tools to integrate multiple perspectives (economic, political, demographic, technological, etc.) into an integrated whole. Dynamic feedback relationships which are typically represented more qualitatively in other studies were modeled explicitly in systems dynamic terms and their significance is explored through simulation.

E. APPROACH

The NPS approach employs systems thinking and systems dynamics methodologies to analyze, within a single coherent framework, the policy structures of major issues of common U.S./China concern that result in non-linear and dynamic behavior over time. In order to address the tasking provided by PACOM and the Office of the Secretary of Defense (OSD), a team of systems engineering and systems dynamics students and faculty from NPS worked with partner academics and practitioners identified in the SMA study to formulate the structures and key variables in several simple systems dynamics sector models.

The systems dynamics discipline and methodology was created by Jay Forrester at Massachusetts Institute of Technology. Systems dynamics is a powerful method to gain useful insight into situations of dynamic complexity and policy resistance (Sterman 2000). With respect to systems dynamics, John Sterman stated that, “The heuristics we use to judge causal relations lead systematically to cognitive maps that ignore feedbacks, multiple interconnections, time delays, and the other elements of dynamic complexity.” He went on to assert that, “…people use various cues to causality including temporal and spatial proximity of cause and effect, temporal presence of causes, covariation, and similarity of cause and effect…These heuristics lead to difficulty in complex systems…" This process of sense-making has a direct bearing on strategic thinking and planning. Systems dynamics is grounded in the theory of non-linear dynamics and feedback control developed in mathematics, physics, and engineering. Because these tools are applied to the behavior of human as well as physical and technical systems, system dynamics draws on cognitive and social psychology, economics, and other social sciences. Human systems are driven by feedback loops in which both free choice and constraint are present. In a bounded system, the application of systems dynamics can provide both conceptual and qualitative insight. By understanding the mechanisms of these feedback loops, it may be possible to maintain the desired dynamic equilibrium of the system required to achieve or maintain stability. The use of fairly simple systems dynamics models for each of the various sectors was employed as part of a structure for providing insight about the behaviors involved.

These sector models capture, for instance, the bounded problem sets associated with U.S.-China relations in the areas of security/defense (including escalation), economics, energy, the cyber domain, and environmental concerns/resources (food, water, minerals). Each sector was modeled endogenously and linked together in order to determine the collective effects of policy decisions in one sector on the others (the system of systems) in order to evaluate the potential behavior of the relationship over a twenty year time horizon. The models allow decisions-makers to use a "flight control simulator" or "dashboard" to perturbate each system in order to better understand non-linear, potential outcomes over time. While this modeling is non-predictive, it is intended to enhance foresight in a complex strategic environment by exploring both the risk and the opportunity space.

The questions to be addressed for the overall SMA study are divided into three categories, Tier 1, Tier 2, and Tier 3. Although portions of any level of these questions may be addressed during this study, the priority is to address Tier 1 as the highest priority and Tier 3 as the lowest. Items in **bold** are covered in this report.

Tier One Priority Questions:

1. **Identify areas of strategic risk in the Asia-Pacific Region over the next two decades.(model results and section V)**
2. How will maritime balances of power and relative capability change in the Asia-Pacific over the next 20 years?

3. **How does China's strategy and actions impact other nations in the region? (model results and section IV)**
4. **Which areas of strategic risk or opportunity (to the U.S., Chinese, Russians, Indians, and other nations in PACOM's AOR) are most likely to occur in the next 15-20 years? (models results and section V)**
5. How does USPACOM balance requirements for a force capable of conducting theater engagement and security cooperation activities with a force ready to fight tonight?

Tier Two Priority Questions:

1. Who is the next rising power in Asia?
2. **What are reasonable and pragmatic assumptions about the Asia-Pacific region in five year increments out 25 years? (section III and IV)**
3. How does the U.S. strengthen partner nations in the region in a fiscally constrained environment?
4. How does the U.S. encourage more multilateral solutions to challenges in Asia?
5. How does the rise of India affect the region, particularly Chinese strategy? How can USPACOM provide theater security cooperation to emerging partners in the Asia-Pacific in ways that strengthen multilateral cooperation and encourages adherence to international norms of behavior?

Tier Three Priority Questions:

1. What emergent or near-future technologies have the potential to impact Asia or U.S. involvement in Asia? How? What are the consequences of these new technologies?
2. What defines a "good" Asia-Pacific strategy? What recommendations comprise that strategy?

F. TECHNICAL OBJECTIVES

The primary objective for the SMA project is to provide decision makers the tools to make better sense of the non-linear dynamics and feedback mechanisms at play in the complex environment in which they, and their competitors, operate, and to broaden the horizon of PACOM strategic thinking. The Asia-Pacific region was modeled as a dynamic interconnected system of entities that are:

1. Interdependent and adaptive
2. Interactive and co-evolving
3. Respond to their local and global environment

Such systems exemplify bottom-up emergent phenomena that are fundamentally unpredictable. Variables/Levers were identified that provide insights into:

1. Robustness and/or fragility of an interdependent Asia-Pacific region in a global context
2. Assess transitions such as tipping points

Long-term regional assessment was based on significant global trends discussed in the DNI/NIC 2030 report. Key indicators to be assessed include:

1. U.S.-China economic trade barriers, imbalances and opportunities
2. Scarcity of resources (competition and cooperation)
3. Military challenges and opportunities
4. National demographics and their impacts on economies, human migration, Third World development, and others
5. Divergence from projected economic growth

The specific variables associated with these key indicators were determined by the overall SMA project team, with NPS addressing them through development of a systems thinking approach with systems dynamics modeling. The systems dynamics models were used to:

1. Formulate model structures (key variables & nonlinear feedback interactions) for several simple systems dynamics sector models.
2. Model each sector endogenously and link together to determine collective effects of policy decisions in one sector on the others.

a. Models serve as policy "flight control simulator" or "dashboard" allowing decisions-makers to perturb each system in order gain deeper insight into non-linear potential outcomes over time.

b. Enhance foresight in a complex strategic environment by exploring both the risk and the opportunity space.

G. SYSTEMS DYNAMICS MODEL VALUE ADDED SUMMARY

NPS is providing a computational tool to PACOM planners to use directly for dynamic simulation. This provides two utilities that add value to the PACOM approach.

- As a *learning tool.* This will help policy makers better understand how the system's variables are related and how they influence one another and are influenced by the system's external environment, and/or understand where the leverage points are. A great value added is the capacity to make "perfectly" controlled experimentation possible because, unlike in real life, the effect of changing one treatment intervention or environmental factor can be observed while all other factors are held unchanged. In real life, many variables change simultaneously, confounding the interpretation of treatment results. Such controlled experimentation can yield useful insights into the efficacy of different policy options.
- As a decision/policy making tool. Computer models do not have to be passive things, simply telling us about some slice of reality but not really giving us any special insight into how to perhaps shape that reality to our own ends. These models are at their best when they allow us to create what-if scenarios to see how that reality might be bent to our will (e.g., by intervening in different ways to modify the reality or situation that the model represents).

II. SYSTEMS DYNAMICS MODELING OVERVIEW

A. INTRODUCTION

Given that the NPS research effort is intended to develop a learning and decision making tool based on non-linear dynamics and feedback mechanisms it is useful to first review the general approach to the modeling effort.

The NPS team used a systems engineering approach to develop a final “dashboard” or “flight simulator” for PACOM. The NPS model employs a holistic systems approach, typically used in systems engineering, systems thinking, and systems dynamics. Linear thinking is conventional in most Western philosophy and thinking habits (Senge, Kleiner, Roberts, Ross, and Smith 1994). Systems thinking is a way of thinking about forces and interrelationships that shape the behavior of systems (Senge, Kleiner, Roberts, Ross, and Smith 1994). Systems thinking is “…the ability to see the world as a complex system, to understand how everything is connected to everything else. With a holistic worldview, it is argued, we would be able to learn faster and more effectively, identify high leverage points, avoid policy resistance and make decisions consistent with our long-term best interests” (Sterman 2002). In particular, NPS uses systems dynamics to implement systems thinking. Systems dynamics “is designed to help us learn about the structure and dynamics of the complex systems in which we are embedded, design high-leverage policies for sustained improvement, and catalyze successful implementation and change” (Sterman 2002). Sterman also asserts that, “…system dynamics often involves the development of formal models and management flight simulators to capture complex dynamics, and to create an environment for learning and policy design.” (Sterman 2002).

Simply stated, the NPS approach recognizes that the variables involved in modeling and studying this problem have a high degree of interdependence, rather than a more traditional approach that considers a dependent and independent variable structure. In a way, we are attempting to provide some methods and tools to transform PACOM into a learning organization that will be able to look forward to creating, and shaping, the new world as it emerges, instead of simply reacting to it (Senge, Kleiner, Roberts, Ross, and Smith 1994).

We partitioned the problem space into separate areas, and modeled each area using a commercially off-the-shelf systems dynamics modeling software tool, iThink. The individual models allowed us to study each in isolation to verify their behavior. These individual models were then interconnected to form a holistic model. This modular approach allows for thinking about and studying the systems within the overall complex system of systems (traditionally thought of as subsystems – though they exist as independent systems in their own right) individually, and then as a whole.

We began by using archetypes which are used as “training wheels” to get used to thinking about the problem in a systems dynamics way, using some standard categories of model structures. The archetypes assist in initially forming an interconnected model, but are not used for the final modeling process, as models will deviate from standard structures in their own unique way. Causal loop diagrams were developed to further the study and development of the problem, and as a basis for developing the computational simulation models in iThink.

B. BUILDING BLOCKS

Two major building blocks of systems dynamics models must be explained before any research specific diagrams are presented. The first is a reinforcing loop (Figure 1). A reinforcing

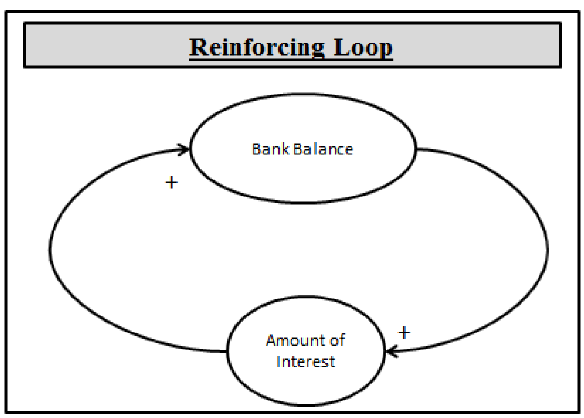

Figure 1. Reinforcing Loop

loop is used to model a scenario where an increase in one action results in an increase in a second action, which in turn results in an increase to the first action. Growth is exponential and unlimited for the life of the system. A useful example is interest in a bank account. As the amount of money in an account increases, the amount of interest increases, as the amount of interest increases the amount of money in the account increases.

Note that Figure 1 also utilizes two plus signs. The plus signs are used to show polarity (not necessarily directionality). As such, the loop shows two scenarios. The first scenario is one where an increasing Bank Balance results in an increasing Amount of Interest which results in an increasing Bank Balance. The second scenario is one where a decreasing Bank Balance results in a decreasing Amount of Interest which results in a decreasing Bank Balance. The plus sign simply indicates that the second entity will trend in the same direction of the first entity, not that the first entity increases the second entity. Similarly, a minus sign indicates that a second entity will trend in the opposite direction of the first entity, not that the first entity decreases the second entity. Minus signs will be used in the second major building block of systems dynamics model, balancing loops.

Balancing loops (e.g. Figure 2) limit growth, maintain stability, and achieve equilibrium (Senge, Kleiner, Roberts, Ross, and Smith 1994, 117). In a balancing loop, one action results in

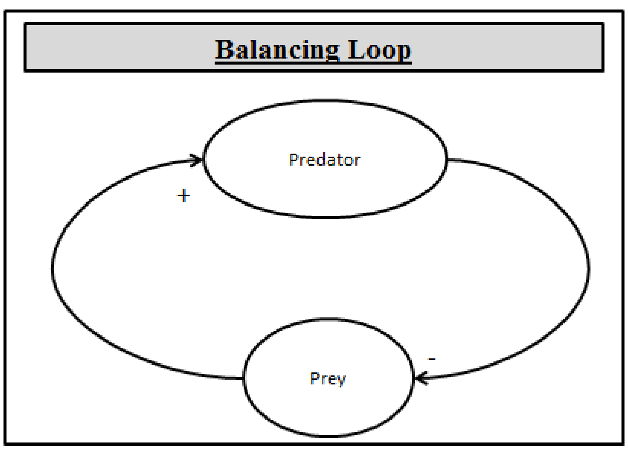

Figure 2. Balancing Loop

an increase to a second action, and increases to that second action result in a decrease to the first action. Similarly, decreases to the second action result in increases to the first action. A predator-prey situation is a traditional example of a balancing loop. As the population of the predators increase, the population of prey decreases. As the population of prey decreases, the population of predators decreases. As the population of predators decrease, the population of prey increases.

As the population of prey increases, the population of predators increases. Uninterrupted, this loop will continue in a balancing fashion infinitely.

Note the importance of defining the plus signs and minus signs in terms of polarity, rather than directionality. The minus sign near the arrowhead next to the prey means the number of prey reacts inversely to the number of predators (more predators lead to less prey, fewer predators lead to more prey).

C. ASIA-PACIFIC CONFLICT AND CONVERGENCE MODEL OVERVIEW

Given that general construct for systems dynamics modeling, the first step towards development of a comprehensive model was the identification of the overall model boundary as well as the key variables that define each segment of the model. Figure 3 presents a high level overview of the NPS model. Once contributions from other SMA partners were received, the model structures were altered as necessary. Data from those partner reports were also used in support of the models.

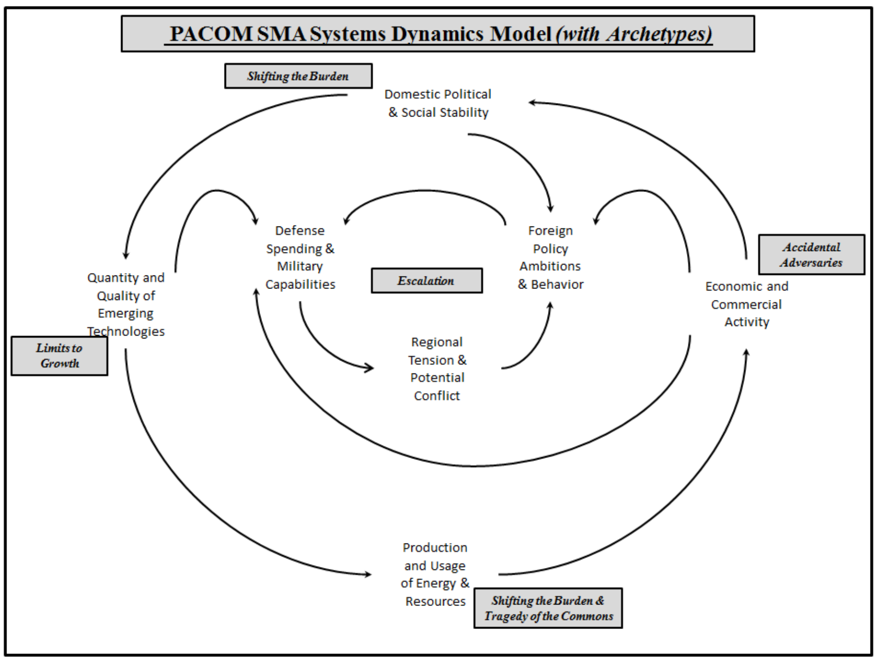

Figure 3. Asia-Pacific Conflict and Convergence Model (with Archetypes)

Note that there are five major archetypes are presented in Figure 3 (Accidental Adversaries, Shifting the Burden, Tragedy of the Commons, Limits to Growth, and Escalation). Each of these archetypes corresponds to a major component of the overall model. The first four archetypes are clearly associated with a model subcomponent (note that Shifting the Burden and

Tragedy of the Commons are both utilized in the Energy and Resources model). The Escalation archetype is at the center of three components (Defense Spending & Military Capabilities, Regional Tension & Potential Conflict, and Foreign Policy Ambitions & Behavior) which were aggregated into a more comprehensive Military sub-model. A brief overview of each archetype is appropriate to precede more detailed descriptions of each sub-model. After presentation of each sub-model, the overall Asia-Pacific Conflict and Convergence Model will be reviewed and clarified.

1. Archetype Descriptions

One of the most important, and potentially most empowering, insights to come from the field of systems thinking is that different systems—whether engineering, military, or economic—share common principles in the ways in which system components work together to perform some well-defined function. Just as in literature there are common themes and recurring plot lines that get recast with different characters and settings (or, in biology, where the mixing and matching of only four DNA molecules produce the enormous variety of living things from daisies to dinosaurs), these building blocks (archetypes) are common to a very large variety of systems and phenomena revealing an elegant simplicity underlying the complexity of systems.

The following archetypes have been identified as potentially useful for modeling the drivers of conflict and convergence. The archetypes were modeled to present a more accurate description of the nuances of each domain, but it is useful to review the basics of each archetype in the abstract before they are modified for the specific research problem. The definitions of each archetype are taken from (Senge, Kleiner, Roberts, Ross, and Smith 1994). The archetypes are presented in increasing order of complexity.

a. Escalation

An escalation archetype is a reinforcing loop. The Escalation archetype occurs when one party’s actions are perceived by another party to be a threat, and the second party responds in a similar manner, further increasing the threat. It hypothesizes that the interactions will create a reinforcing loop, resulting in threatening actions by both parties that grow exponentially over time.

b. Limits to Growth

The Limits to Growth archetype is used to model scenarios where a growth process (a set of activities conducted in pursuit of a goal) is counteracted by a limiting process (some constraint on the potential performance which can be obtained by the activities conducted in the growth process. This limiting process can be either external or internal to the system, it is only important that it counteract the otherwise uninhibited growth process. In systems dynamics terms, the Limits to Growth archetype is defined by a reinforcing loop connected to a balancing loop. A useful example of an external limiting process is fishing, a growth process (where an increase in the number of fisherman should result in unlimited increases to the number of fish caught) which is counteracted by a limiting process (the reproductive capacity of the fish).

c. Shifting the Burden

The Shifting the Burden archetype is used to model scenarios where a problem is attempting to be solved by curing or correcting the symptoms instead of the root cause(s). These two processes (problem and symptom-correcting) may be balanced initially but often the symptom-correcting process has unintended side-effects that may create an addiction loop where the fix is actually feeding the root cause of the problem. In systems dynamics terms, the Shifting the Burden archetype is defined by two connected balancing loops (with normally the symptom-correcting process quicker than the problem process) with one or more reinforcing loops from the symptom to the problem root cause. A useful example is 'crisis heroism' in business where normal procedures are bypassed to 'do whatever it takes' to succeed in a product roll-out. That hero is rewarded by management therefore more normal procedures are bypassed for the next product roll-out to get better results and the business gets addicted to the quick fixes at the expense of making fundamental long-term adjustments to normal procedures.

d. Tragedy of the Commons

The Tragedy of the Commons archetype is used to model scenarios where individual actors are each incentivized to consume a common resource (the "Commons") which is unable to support such a large level of demand (often it is nonrenewable or replenishment is delayed). The value of that resource is subsequently reduced and thereby the gains realized by each actor are reduced (and may eventually crash). The most widely used example of tragedy of the commons is a large fishery, where many fishermen must share a common population of fish, which will decrease as the level of fishing increases.

e. Accidental Adversaries

The Accidental Adversaries archetype is used to model scenarios in which two actors who want to be in partnership and who ought to be in partnership end up in opposition by taking actions that result in tension and resentment. Each actor recognizes that it is possible to support the other (and sometimes will) but, in an attempt to maximize utility, independently pursues solutions that are unintentionally obstructive to the counterpart's success (Senge, Kleiner, Roberts, Ross, and Smith 1994, 147).

The causal loop diagrams for the economic and commerce, energy and resources, and defense and military aspects are summarized as the major basis for the model.

D. ECONOMY AND COMMERCE NON-LINEAR SYSTEMS DYNAMICS

Economic and Commerce trends are a major component of the overall Asia-Pacific Conflict and Convergence Model. Note that the Economy and Commerce sub-model directly feeds Domestic Political and Social Stability, Defense Spending and Military Capabilities, and Foreign Policy Ambitions and Behavior. Accordingly, proper modeling of the economic interrelationships between actors in the Asia-Pacific region is vital to capturing potential drivers of conflict and convergence in the region. Figure 4 presents a high level overview of the Economy and Commerce relationships between the United States and China. Additional nations could be added as a follow on effort to this project after the accuracy of the model is demonstrated. The structure of those models will most likely be similar. Data came from various SMA reports and was supplemented by data from the International Monetary Fund and World Bank as needed.

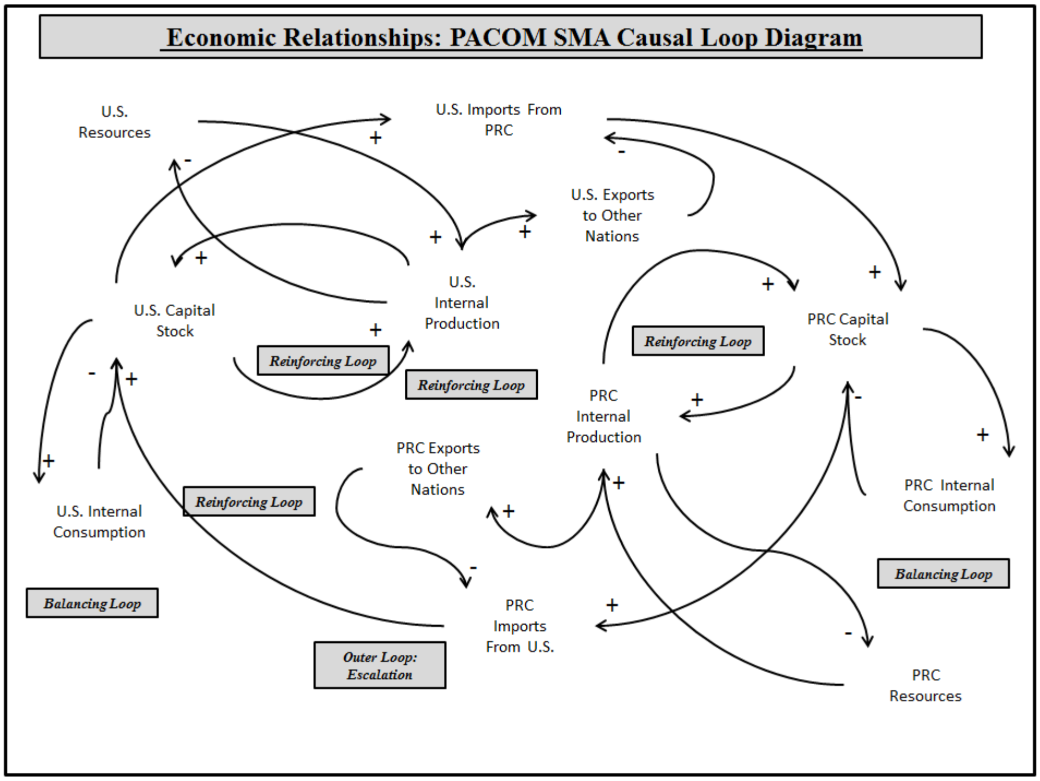

Figure 4. Economic Relationships Causal Loop Diagram

Figure 4 is necessarily rather complex and is better understood by isolating various components and rebuilding the overall model. The simplest possible deconstruction of the economic relationship between the United States and China is shown in Figure 5.

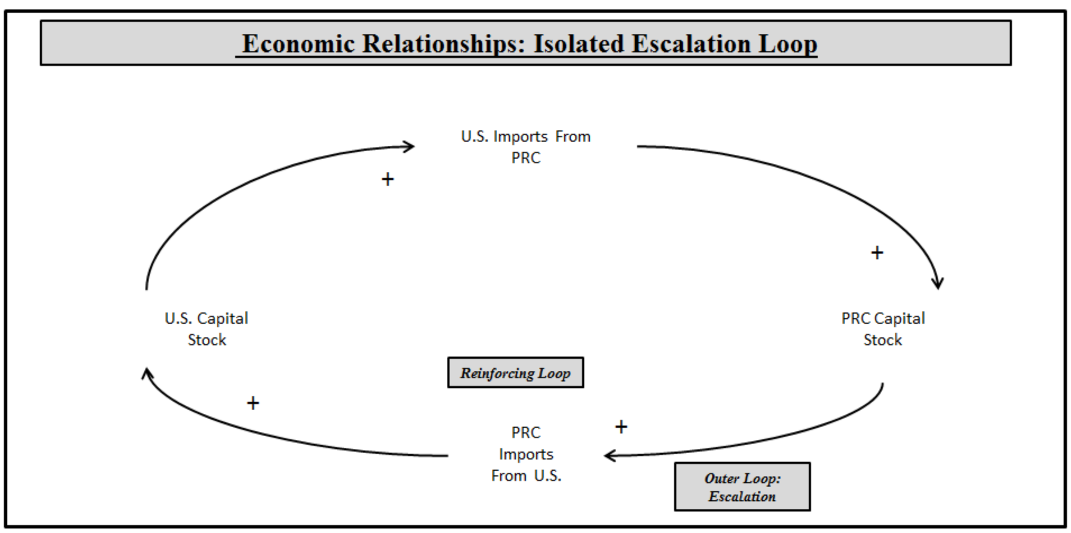

Figure 5. Economic Relationships Isolated Escalation Loop

Figure 5 demonstrates that the economic relationship between the United States and China, if considered in isolation, would result in uninhibited economic growth (a large reinforcing loop). As the United States imports from China, the Chinese capital stock increases. As the Chinese capital stock increases, they increase their imports from the United States. The United States capital stock increases as the United States exports more to China. As the U.S. capital stock increases, the U.S. imports more from China. Although the model is rather simplistic (see shortcoming mentioned previously), the model serves to illustrate that, considered in isolation, both the United States and China have an incentive to support the economic success of the other country. The economic situation is complicated, but not degraded, by the addition of internal production as shown in Figure 6.

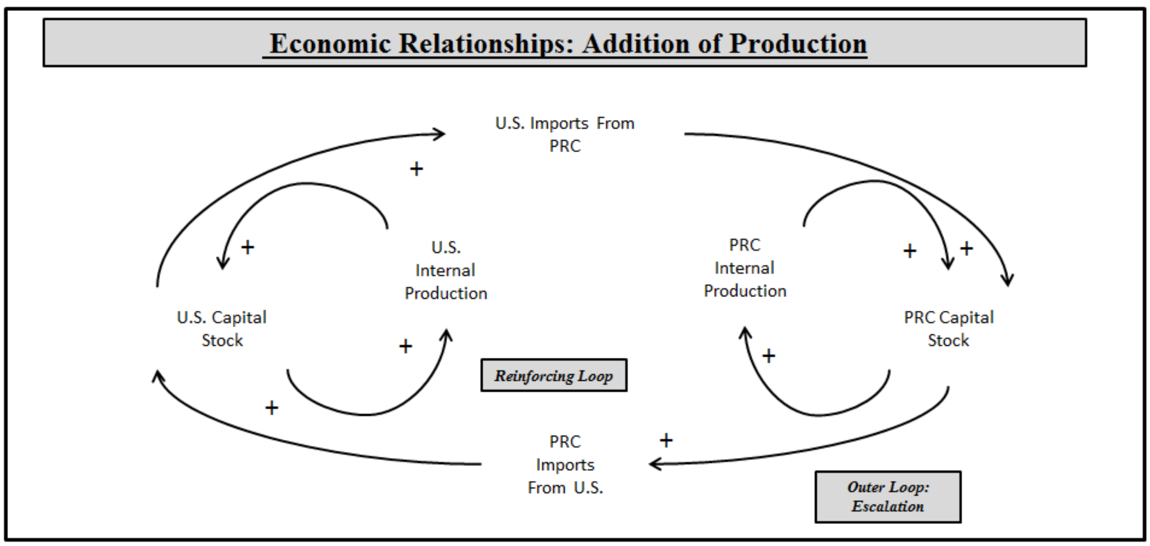

Figure 6. Economic Relationships Addition of Production

The addition of internal production, both within the United States and China, simply adds two additional reinforcing loops. Internal production increases a country's capital stock, which in turn increases internal production. In such a scenario, capital stock would grow infinitely. Figure 7 shows the addition of internal consumption to the model which serves as a limit to that growth, but still does not result in any direct competition.

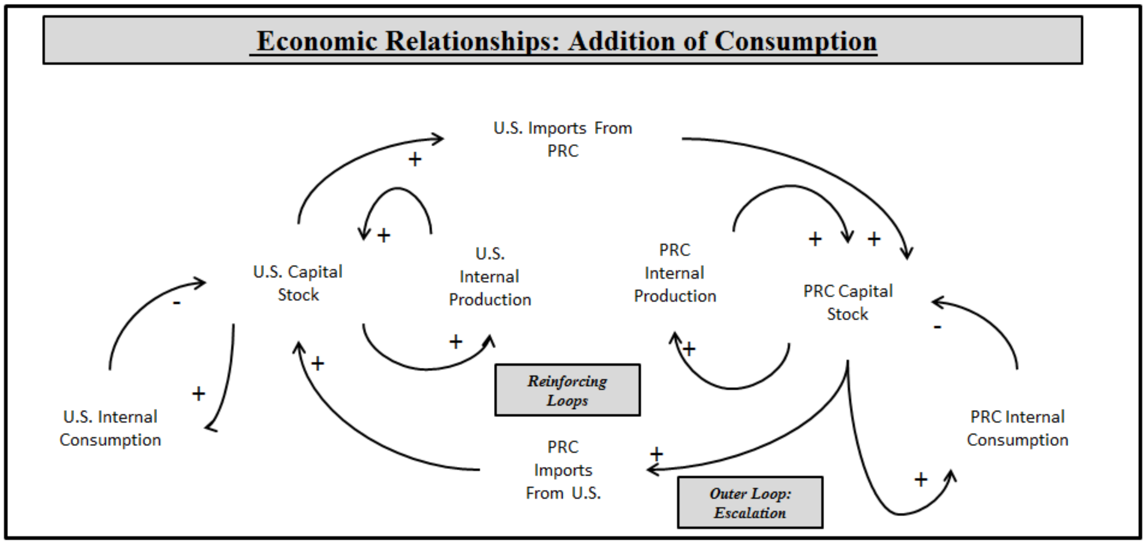

Figure 7. Economic Relationships Addition of Consumption

The addition of consumption serves to balance the increase in capital stock caused by internal production and export. Notice that Production and Consumption form a Limit to Growth Archetype for capital stock. As capital stock increases (via export and production) consumption also increases. However, as consumption increases, capital stock decreases. This serves as the first limit to economic growth. The introduction of additional foreign trade introduces competition and a second limit to economic growth (Figure 8).

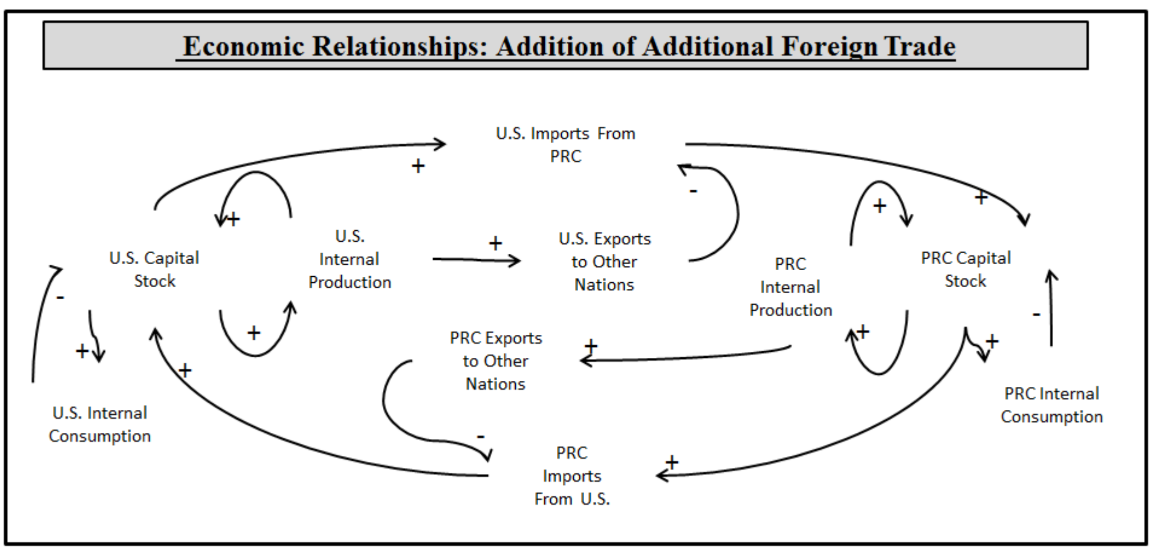

Figure 8. Economic Relationships Addition of Foreign Trade

Figure 8 highlights the main reasons that economic growth cannot continue without limits. As a nation increases internal production, it will begin to trade with multiple nations. This trade with other nations will subsequently decrease the imports from the original second nation. This will subsequently reduce the second nation's capital stock. The United States may not be directly trying to reduce China's capital stock, but by acting independently to improve its own results it is unintentionally obstructive to China's goals. This is a major source of friction between the United States and China. Figure 9 introduces a linkage to the availability of resources, which serves as a further limit to each nation's capital stock.

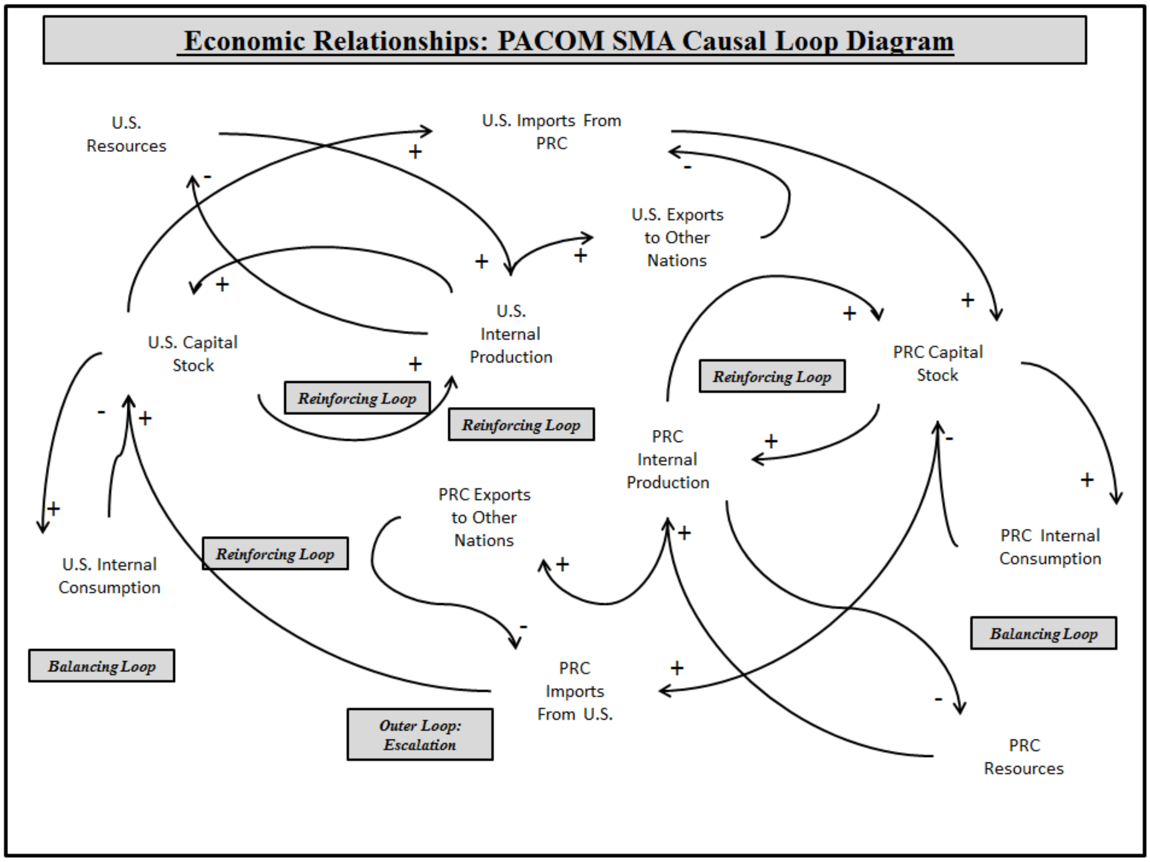

Figure 9. Economic Relationships Addition of Resources

It is now evident why development of an accurate Energy and Resources sub-model is vital to the development of large systems dynamics model of conflict and convergence in the Asia-Pacific region. A reduced availability of internal resources in China will result in decreased internal production. That decrease in internal production may result in an increase in imports from other nations, which results in a decrease in China's capital stock. Similarly, an increase in resource availability may result in increased production, increased exports to other nations, and an increase to China's capital stock. An accurate energy and resource model provides a clear input to the Economy and Commerce model, which serves as an input to Defense Spending &

Military Capabilities, Foreign Policy Ambitions & Behavior, and Domestic Political & Social Stability.

Note that the goal of this effort was not to develop a macroeconomic model that forecasts the level of economic activity over the next 25 years. Rather, the goal was to build a model that is capable of representing the major economic drivers of conflict and convergence and, more importantly, their interactions with resource availability, energy consumption, policy, etc. Accordingly, existing macroeconomic models may be used to validate the economic systems dynamics model. Finally, it is important to note that two major changes to the model could be addressed in future follow on iterations:

1. The assumption that an increase in capital stock results in an increase in Imports is too simplistic. The overall behavior is correct, but the causes need to be identified more clearly.
2. The addition of a "Monetary Authority" will be vital to the proper behavior of the model. The Chinese decision to couple the value of the Yuan to the dollar must be modeled (as well as the recent pressures to decouple the currencies)

E. ENERGY AND RESOURCES NON-LINEAR SYSTEMS DYNAMICS

Energy and resource consumption are key contributors to the overall PACOM SMA systems dynamics model. Although they do not directly contribute to potentially escalating regional tension and potential conflict, they are key indicators of potential stressors in the SD model. Additionally, outputs from the energy and resource consumption mechanisms input directly into the other non-linear dynamics of the economy, social stability, and emerging technologies that directly affect the regional tension and potential conflict model.

The energy consumption model for the PACOM SMA encompasses commonly used and globally traded energy resource supplies that are utilized to produce energy including oil, coal, liquefied natural gas (LNG), nuclear, hydroelectric, and other renewables such as wind, solar and tidal. In addition, demand for energy is aggregated into a total whether it is for the population's usage or production regardless of the reason for that consumption (agriculture, manufacturing, transportation, etc.).

Historical information as well as emerging supply and demand trends on energy both for the region and China was used to base the model. Information compiled from the United States

Energy Information Administration (USEIA) was the primary source data along with open source trade publications.

The energy consumption SD model is a Shifting-the-Burden Casual Loop Archetype with two addiction loops, as illustrated in Figure 10. This model archetype highlights the balancing loops where China is attempting to manage its various energy supply sources and internal demands. However, there are also two reinforcing loops that degrade the system's balance where increasing economic activity and energy consumption as a percentage of the available supply at any time drive further energy production for additional consumption. Note that the slashed lines on several of the arcs indicate a delay.

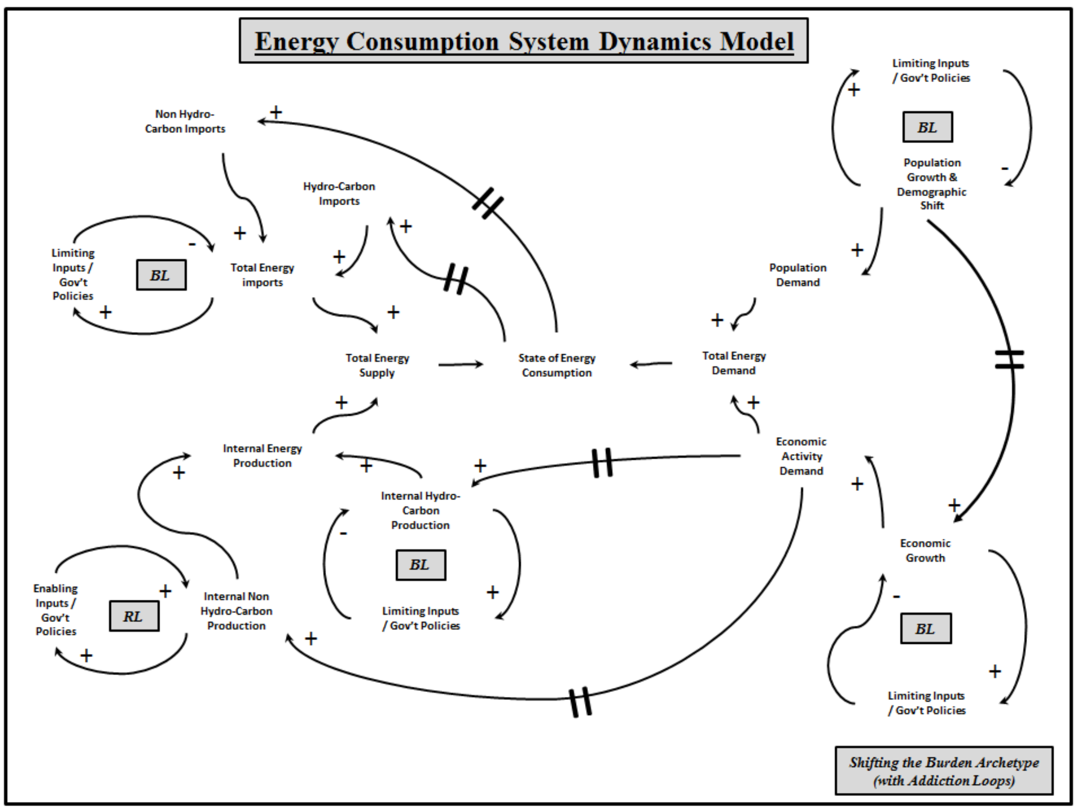

Figure 10. PACOM Energy Consumption Causal Loop Diagram

The following will explain Figure 10 model's features starting in the upper right corner with population growth and proceed clockwise. The explanation will only refer to China within the model but future versions of this model will include multiple PACOM states' supply and demand activities to eventually encompass the PACOM region. This modeling approach allows the outputs to be scalable to view an individual state's dynamics or the entire PACOM region as a whole. Energy production and consumption is quantified in quadrillion British Thermal Units (BTUs) that USEIA utilizes in macro-economic analysis.

1. Population and Demographic Shift: As China's expected population grows and potentially shifts from rural to urban and more people as a percentage of the state's population leave poverty the population demand for energy will increase (The World Bank Group 2014). This will increase China's total energy demand. The balancing loop takes into account government policies that limit unchecked population growth as well as other limitations such as access to fresh water.

2. Economic Growth: This value is supplied as an output from the Economy & Commerce model. Acting upon it is population growth, after a delay, and China's balancing loop that takes into account government policies that limit unchecked economic growth as well as potentially limiting factors such as resources other than energy like rare earth elements (REE) or delayed access to emerging technologies. Economic growth over the timeframe will increase economic activity demand for energy and fuel the expansion of China's overall internal energy consumption. This forms one of the addiction loops as economic growth drives more internal energy production, after a delay, to capitalize on increasing energy demand.

3. China's internal energy resource and production capability was aggregated to two casual relationships: hydro-carbon production including oil, coal, and LNG; and non-hydrocarbon including nuclear, hydro-electric and other renewable sources (USEIA 2014). While China currently has balancing policy inputs on hydro-carbon production due to environmental impacts, renewables are actually reinforced by government policies to expand their percentage of the energy market (Chinese Academy of Social Science 2012). Together they form China's internal energy production capacity.

4. As China is currently a net energy importer, energy imports are accounted for in terms of hydro-carbon and non-hydro-carbon (USEIA 2014). It is necessary to break these out as China attempts to control hydro-carbon energy imports and mitigate unchecked dependence on hydro-carbon imports (Tu et al. 2012). Both internal and imported energy form the total energy supply available to China. If there is excess, then the exporting of that energy is accounted for in the economic activity demand.

5. Both energy supply and demand are the inputs to the state of energy consumption both for China and scalable eventually to the entire PACOM region. This is the source of the second addiction loop that as the demand nears the total available supply, prices rise on the global markets and there is a delayed reaction toward the increase in supply of energy available (Finley 2014).

The following outputs could be viewed independently for analysis or utilized as inputs in other portions of the PACOM SMA SD Model over the specified timeframe:

1. As the state of energy consumption margin decreases and global energy market prices increase, this would be a negative input into the economy and commerce model.
2. The amount of internal hydro-carbon production has a balancing influence on domestic political and social stability. As production increases, harmful effects on the environment have a negative impact to the social contract the Chinese government has with its people.
3. The percentage of internal energy production to imported energy is an input to foreign policy. The pressure on China to import more energy to remain globally competitive has an effect on foreign policy decisions. This can also act as a driver to secure energy resources abroad to make up the gap in state energy demand and internal energy production.
4. China’s energy capacity and portfolio both independently and as a part of the region over the timeframe to see indicators of dependent relationships.

F. DEFENSE AND MILITARY NON-LINEAR SYSTEMS DYNAMICS

The tension module is based on an escalation archetype. The escalation archetype is based on two competing players taking actions to balance the actions of the other player. These reinforcing actions continue to escalate a system until one or both of the parties are eliminated or change their goals. In this particular system China and the U.S. both have goals to influence the East Asia region. China’s goals stem from their belief that ancient historical boundaries entitle them to exercise sovereignty over certain territories. The U.S.’s goals stem from the many alliances that they have in the region which in some instances obligate them to military action. There are also economic drivers for both of these nations that drive the desire to maintain influence in the region, and these actions are modeled in the economic and energy modules. With regards to the tension module, the assumption is that China and the U.S. will take military action to gain influence in the region.

The causal loop shown in Figure 11 can be illustrated using the Senkaku islands as an example scenario. One can start with the Japanese government's attempt to purchase the islands from a private Japanese owner (Harper 2013). This economic move forced China to acknowledge whether or not the islands were owned by the Japanese. Acknowledging this action would give the perception that the United States and its ally had a greater influence in the region. This corresponds to the causal loop element stating that China perceives the U.S. or U.S. ally has a greater influence in East Asia. This caused China to take action in the form of sea and air defense identification zones to state that they did not recognize Japanese ownership, and further state that China had sovereignty over the territory. This action in China's mind gave them greater influence in the region. As seen in Figure 11, there is a delay between China's influence and the U.S. perception of China's influence. If the U.S. perceives China's actions as giving them a greater influence in the region then they will take military action.

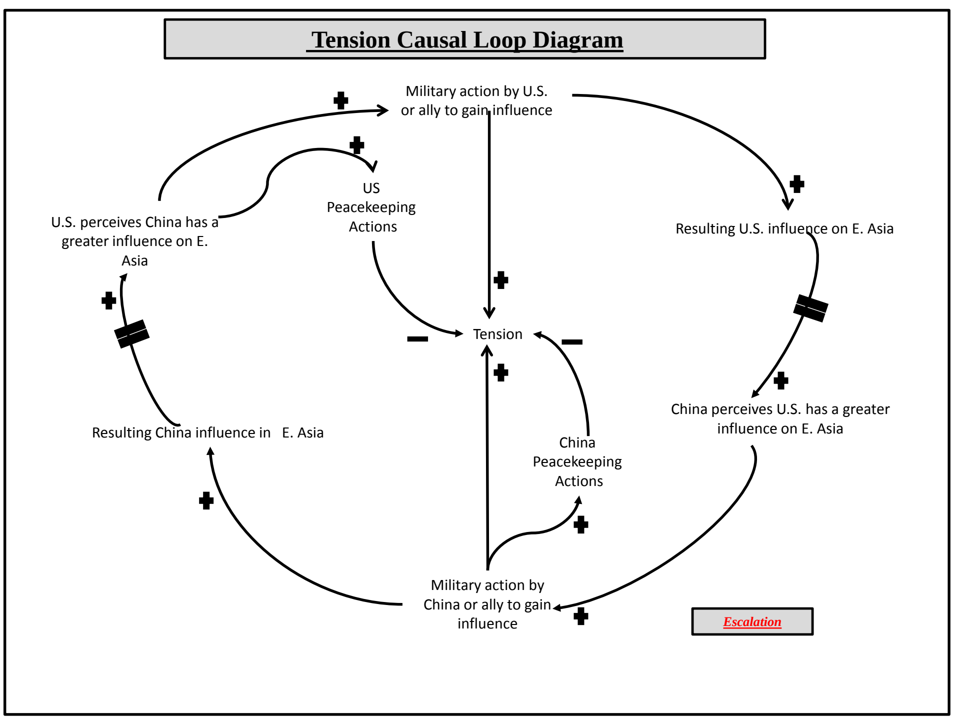

Figure 11. PACOM Tension Causal Loop Diagram

In this particular instance, the U.S. military made a strategic shift to pivot to the Pacific. They also sent military ships and aircraft through the identification zone to state that they did not recognize China’s authority in the region. The military action of China’s establishment of the air defense identification zone and the U.S. response both contributed to increased tensions between China and the United States, which is illustrated in the causal loop diagram. At the present time, China has not taken direct action against vessels violating the identification zone. They are taking indirect actions like increasing their Anti-Access Area Denial (A2AD) capability and increasing their defense spending to facilitate possible direct actions in the future.

Tensions will continue to increase unless a situation arises that allow the militaries of China and the U.S. to cooperate. Examples of this occur in joint exercises conducted to combat piracy as well as joint exercises to aide nations that encounter natural disasters. These peacekeeping actions will lower tensions temporarily but the tension problem will not be solved completely through military means. There must be some economic or other contributions that lead to a consistent downward trend of tension.

The Senkaku island dispute is an example of a scenario that follows the escalation archetype. There are several other military actions that will lead to scenarios that are similar to the Senkaku islands and these actions can be modeled using the causal framework described above. Examples of military actions that can be modeled by this tension module are (Carnegie 2014):

1. Increase in Defense spending above a certain threshold by China, U.S., or ally.
2. Disputes involving military vessels between China and U.S. or China ally and U.S. ally.
3. Declaration of exclusion zone in international sea space using military vessels as enforcement.
4. Introduction of new militarily significant technology.
5. Military occupation of disputed territory.
6. Nuclear proliferation issues.
7. Official visits by high profile U.S. political figures to U.S. allies in the Pacific.
8. Official visits by high profile Chinese political figures to China allies in the Pacific.
9. China’s actions in North Korea.

10. Cybersecurity.

The primary source of information for these variables was the Carnegie study as well as the article entitled “China’s Three Warfares”.

III. INPUT REVIEW

A. INTRODUCTION

NPS used PACOM project participant products within a systems dynamics context in support of model building efforts. What follows is a brief overview of these products and their relation to NPS's systems dynamics model. Elements of divergence and correspondence between these products and the model are noted.

B. CSIS DELIVERABLES I, II, AND III

CSIS provided three deliverables in support of this SMA. Each deliverable respectively addressed priority questions one through three.

CSIS Deliverable One addressed SMA priority one questions, broadly categorized as requirements for theater engagement. Within this context, CSIS examined historical growth patterns and demographic patterns of both China and the US. There is a high degree of correspondence between those researched by CSIS and those used in the NPS model. Additionally, NPS instantiated CSIS's conclusion that relations between China and the U.S. depend not only on each country's perception of the other's influence, but also on each country's perception of their own influence.

Deliverable Two addressed SMA priority two questions, generally identifying opportunities of cooperation with emerging partners in the Asia-Pacific region. Emerging energy patterns, demographics, and sources correlate closely with those used to build NPS's systems dynamic model. CSIS also identifies potential cooperation avenues. NPS's model, however, creates general categories of cooperation and conflict, leaving the model user to identify specifics. Additionally, both products caution against reliance on future predictions.

Emergent technologies and U.S. strategy (linking ways and means) in the Asia-Pacific region were addressed in CSIS's Deliverable Three. While less tangible than the previous two deliverables, topics in this report were included in the NPS model via potential events. However, no direct input for technology or strategy was included.

C. TAMU

TAMU's report provides analysis of open source media and understanding of key cultural scripts and paradigms within Chinese culture. While not directly included within the model, TAMU's report provides invaluable reference to key cultural drivers and insight to potential political unrest within China.

D. NSI

NSI provided modeling review and feedback to ensure verification and completeness. Additionally, NSI provided analysis of points of congruence and incongruence between the NPS model and other participants with respect to model assumptions and hypotheses. Their Integration Report: ICONS Overview, February 20, 2015, provides a concise summary of the efforts of all of the collaborator findings.

E. MONITOR 360

Monitor 360's report combines its Futures Analysis methodology with insights from SMEs to explore how internal dynamics in China could drive shifts in the geostrategic environment of the East China Sea. It focuses on internal dynamics and provides de-escalation objectives and considerations that can inform PACOM efforts to preempt, shape, or de-escalate rising tensions. Further, this report presents a series of gradual change and escalatory pathways in U.S.– China relations. While these projected pathways are not incorporated directly into the NPS model, certain aspects of the report are included within the Chinese Protestor, Domestic Political, and Defense and Military sub-models. These aspects include economic growth using historical data and SME projections, potential domestic unrest using a disease transmission model, and potential military incidents using a tension and perception model.

F. START

START's mid-term deliverable provides a review of current team deliverable from Monitor 360, CSIS, TAMU, CEIP, and START. START's effort was invaluable in collating team inputs into the model.

Further, START's mid-term deliverable, Empirical Assessments of the Sources of Conflict and Cooperation in PACOM AOR, provided numerical correlation to establish potential sources of feedback within the Defense and Military sub-model, to include those from surrounding nations.

G. CEIP

CEIP provided variable identification and database collection which helped greatly with narrowing inputs to the model to a manageable level. Key indicators identified by CEIP, such as energy imports and flashpoints, are directly included in the economic and military models.

Additionally, CEIP provided review and verification of model input. Discussion generated during CEIP's review of the economic, military, and resource sub-models led to changes within these modeling efforts.

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IV. SYSTEMS DYNAMICS MODELS AND ANALYSIS

A. INTRODUCTION

This section describes each of the major sub-models and results obtained from each. Additionally, these sub-models are integrated into a single encompassing model with resulting analysis described.

B. MODEL DESIGN AND ANALYSIS

1. Energy Demand and Resources Sub-Model

China's demand for energy and resulting energy resources consumption potentially contributes to escalating regional tension and conflict (McKinsey 2014). Dynamic relationships in China's internal demand for energy along with the sources of the energy resources consumed to meet that demand are indicators of potential stressors in the overall PACOM SMA SD model. Additionally, interactions with the economic and social stability models affect the overall regional tension and potential conflict model.

Most historical trend and resources data are from the 1980s to 2012, the last full year available that was published openly. Where possible, current energy related inputs up to September 2014 were utilized, including agreements such as the 2014 Russian-Chinese agreement implementing additional Liquefied Natural Gas (LNG) pipelines from Russian reserves to China.

The USEIA was the primary source for historical and projected worldwide and Chinese-specific energy demand and resource consumption trends. Whenever reference data conflicted, USEIA data was utilized as the tie-breaker and quality assurance check. Other key information and trend references are included in the report reference section.

Energy demand, resources and consumption rates were standardized to quadrillion (10^{15}) of British Thermal Units (BTUs) annually to allow all demand drivers and resources to be dynamically related on an equivalent scale.

Assumptions:

Utilizing historical data as well as state and energy industry projections, the following assumptions were made in modeling the relationships regarding energy demand and energy resources consumption:

i. No energy related transformational technology will be significantly fielded in the next 25 years
    a. Although research continues on technologies such as fusion nuclear reactors and wireless energy transmission, the model assumes those technologies will not be fielded commercially or encompass greater than 1-2% of the annual Chinese energy portfolio in the 25 year timeframe (Xu 2014).
    b. New technologies being fielded, improved and becoming more cost competitive such wind turbines, biomass renewables and shale gas drilling are accounted for in the model and part of the reason those energy resources expand over the next 25 years.

ii. The baseline energy model does not account for dramatic geo-political actions such as a politically motivated embargo of energy resources by export states or blockade of China's energy resource imports due to war. The baseline energy model is meant to account for events up to, but not including, war.

iii. The effect of the global cost of energy is resident in the Economic SD model. Should economic conditions indicate an economic recession, depression, or multi-year spike in economic growth, those effects will translate to the energy demand and energy resources consumption relationships but are not resident in the baseline energy model itself.

iv. China will continue energy demand and resource trends in the following areas:
    a. Limit internal coal mining growth and scale back consumption, using increasing coal imports to fill the demand gap in current coal-powered energy systems (Tu et al. 2012).
    b. Continue to favor importing energy resources over attempts to meet internal environmental goals (McKinsey 2014).
    c. Continue to incentivize population urbanization and reducing average household size and energy usage per household. This trend is currently forecast to continue through 2035 (Karplus 2014)..

d. Continue to stress and incentivize non-industrial economic ventures that utilize fewer energy resources over heavy-industrial economic ventures that utilize more energy resources for the equivalent economic activity (Tu et al. 2012).

e. Chinese macro-economic growth rate will taper off from the last decade's 8-10% annualized growth to a reduced and sustainable 4-6% annualized growth. However, with this reduction in macro-economic growth there will be a net increase in internal consumption of energy intensive technology such as expanding vehicle use per household and number of personal electronic devices per person (Monitor360 2014).

a. Chinese Energy Demand and Energy Resources Consumption Model Discussion:

Figure 12 is a graphical depiction of the overall iThink 10.0.6 SD model for China's energy demand and energy resources consumption. The following sections discuss the model and key interactions in more detail.

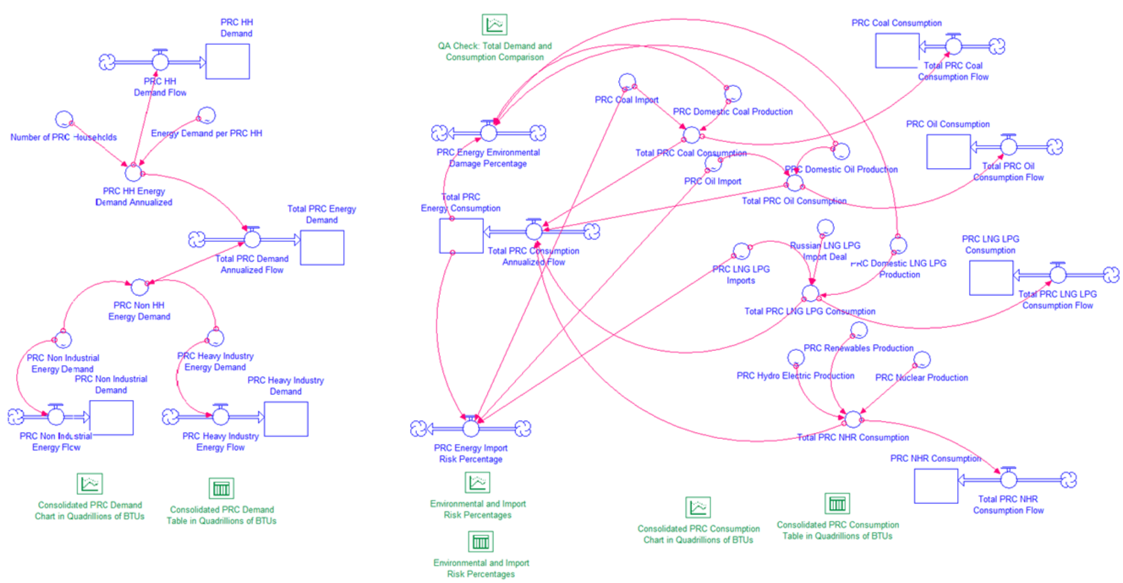

Figure 12. China's Energy Demand and Energy Resources Consumption Model

Figure 13 shows China's energy demand modeled in the following three categories:

- Household Energy Demand: the population's demand for energy annualized.

- Heavy Industry Energy Demand: The economy's demand for energy to support construction, mining, commercial transportation, traditional manufacturing, etc. The majority of Chinese military energy demand falls into this category.
- Non-Industrial Energy Demand: The economy's demand for energy to support information technologies, office buildings, education facilities, health care facilities, etc. The majority of Chinese state government energy demand falls into this category with the exception of state owned heavy industrial companies.

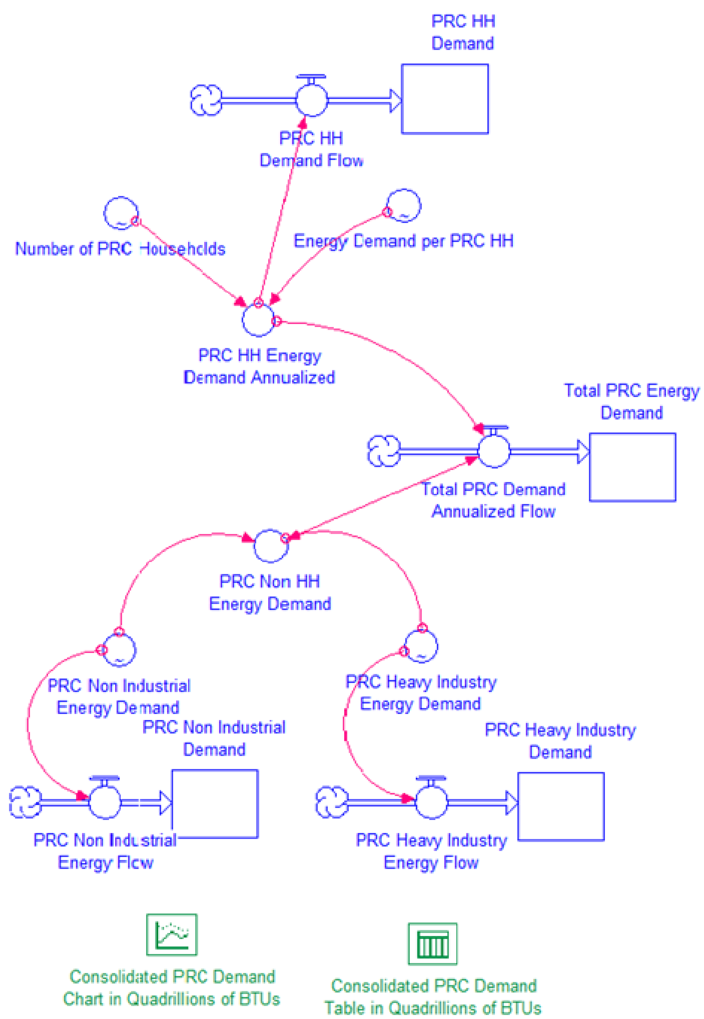

Figure 13. China's Energy Demand Section of the SD Model

Baseline Chinese household energy demand takes into account both the forecast number of households in China as well as the forecast energy demand per household.

- The number of Chinese households is forecast to increase in 25 years from approximately 430 million to a little over 500 million (The World Bank Group 2012). This is due to both projected population increase and decreasing average Chinese household size. Household size is decreasing due to a combination of Chinese incentives promoting urbanization, reduced number of children per couple, and a growing middle class which tends to have fewer children per household.
- Chinese household energy demand per household is forecast to decrease from 2015 to 2040 due to a combination of factors, including a reduced number of persons per household, more energy efficient buildings, and planned upgrades to energy transmission infrastructure. China's per household energy demand would actually be lower by 2040 due to the above factors but they are partially offset by forecast energy demand increases due to greater personal vehicle usage and more personal electronic devices per person (Monitor360 2014).

The baseline Chinese heavy industry and non-industrial energy demand model shows significant changes based on economic trends and China's state policy decisions (Karplus 2014). China's non-industrial energy demand will make up a greater percentage of its overall energy demand through 2040 at an increasing rate. Population urbanization (expected to remain a factor through 2035) and expansion of its information technology economy are the primary factors driving this growth in the timeframe. It's growth significantly curtails from 2025-2030 due to decreasing rates of construction and state policy decisions made to cap heavy industry growth due to internal economic and environmental sustainability reasons.

As a result of the above, the baseline model shows Chinese energy demand nearly doubling in 25 years from 120 to 220 quadrillion BTUs annually. The rate of growth, however, is constantly decreasing. China's energy demand will change significantly where non-industrial energy demand will overtake household demand and make-up a larger percentage of overall energy demand. This change will have an effect on the types of energy resources consumed required to satisfy demand through 2040 in the baseline model. The overall Chinese baseline energy demand model results from 2015 to 2040 are graphically illustrated in Figure 14 and listed by category in Table 1.

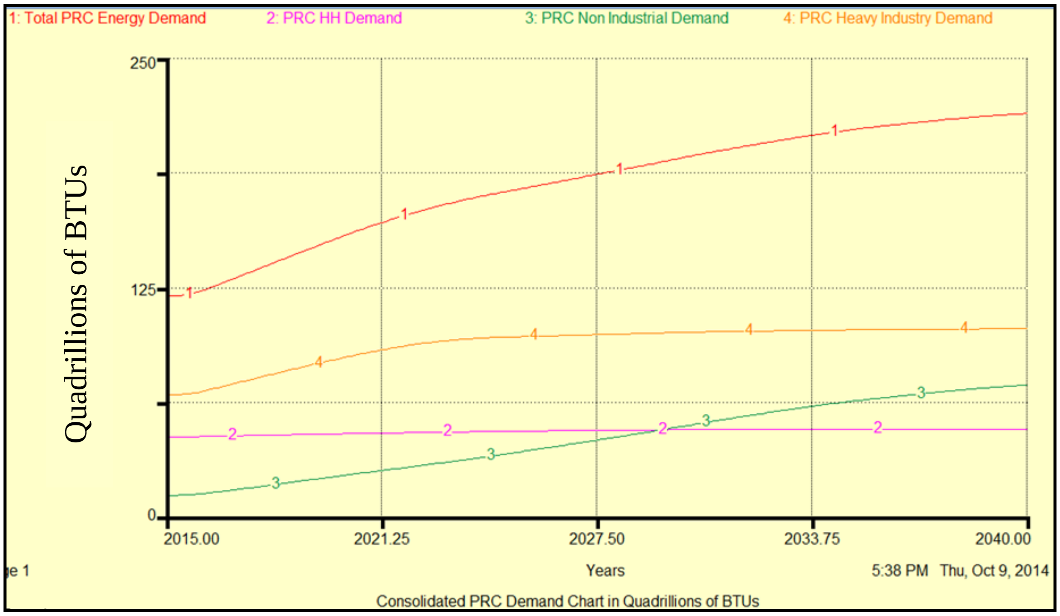

Figure 14. China’s Baseline Energy Demand Chart from 2015 – 2040

Consolidated PRC Demand Chart in Quadrillions of BTUs

5:38 PM 10/9/2014 Consolidated PRC Demand Table in Quadrillions of BTUs (Consolidated PRC Demand Chart in Quadrillions of BTUs)

Years	PRC HH Demand	PRC Heavy Industry Demand	PRC Non Industrial Demand	Total PRC Energy Demand
Initial	43.00	66.00	11.00	120.00
2015	43.17	68.08	11.99	123.24
2016	43.56	72.69	14.27	130.52
2017	43.94	77.24	16.70	137.88
2018	44.31	81.70	19.21	145.21
2019	44.66	86.00	21.71	152.37
2020	44.99	89.90	24.11	159.00
2021	45.27	93.09	26.46	164.82
2022	45.54	95.45	28.91	169.91
2023	45.80	96.93	31.45	174.18
2024	46.04	97.68	34.12	177.84
2025	46.25	98.17	36.94	181.36
2026	46.43	98.66	39.81	184.89
2027	46.58	99.15	42.70	188.43
2028	46.72	99.64	45.69	192.05
2029	46.84	100.14	48.78	195.77
2030	46.93	100.53	51.84	199.30
2031	46.98	100.78	54.83	202.59
2032	47.01	101.03	57.72	205.76
2033	47.02	101.29	60.34	208.65
2034	47.02	101.54	62.61	211.18
2035	47.02	101.73	64.66	213.36
2036	47.02	101.83	66.60	215.31
2037	47.02	101.93	68.44	217.14
2038	47.02	102.04	70.00	218.66
2039	47.02	102.14	71.24	219.85
2040	47.02	102.24	72.30	220.81

Table 1. China’s Baseline Energy Demand Table from 2015 – 2040

b. China’s Energy Resources Consumption Discussion:

China’s energy resources consumption was analyzed and modeled in the following four categories. These are graphically illustrated with their relationships in the SD consumption model in Figure 15

1. Coal: Broken down by amount imported and domestically produced (USGS 2012).
2. Oil: Primary liquid crude, broken down by amount imported and domestically produced (Ross 2013).
3. Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG): Broken down by amount imported primarily by sea through the PACOM AOR and by existing or planned pipelines from the 2014 Russian-Chinese LNG-LPG agreement and domestically produced (British Petroleum 2013).
4. Nuclear-Hydroelectric-Renewables (NHR): Broken down by domestic nuclear production, hydro-electric production, and renewables to include solar, wind and biomass production (USEIA 2014).

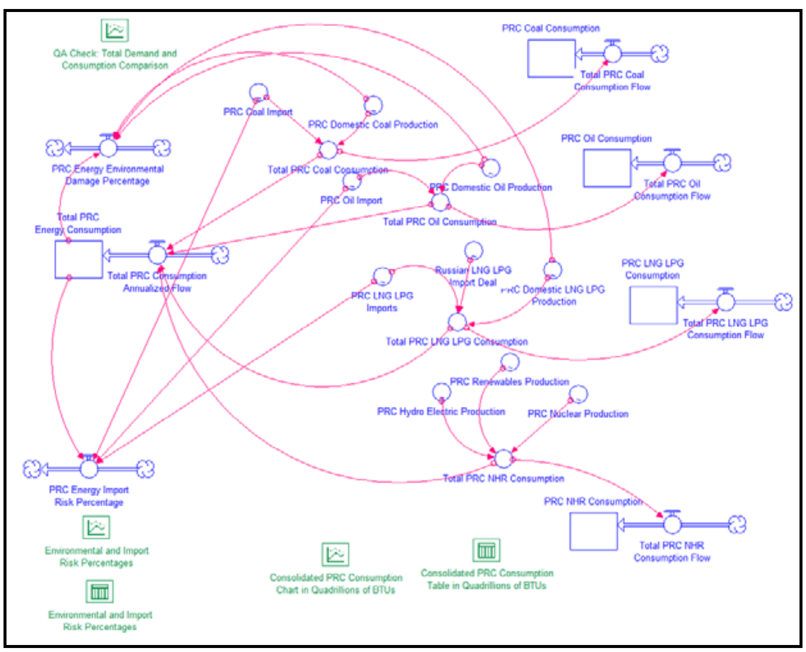

Figure 15. China’s Energy Resources and Consumption Section of the SD Model

The baseline energy resources and consumption model takes into account the following trends and forecast changes:

Coal: Although China has the second largest proven coal reserves in the world, only behind the United States, the state is actively limiting expansion of internal mining operations and gradually converting coal powered energy systems to other resources, primarily oil or LNG-LPG (USGS 2012). China has recently begun importing coal and that trend is forecast to increase (Tu et al. 2012). Although China is limiting domestic coal resource mining due to a variety of reasons, coal driven energy systems are not converting as fast due to large investment capital required. This leaves a gap that is being met by imported coal. That gap is forecast to increase in the near term as China has stated goals of reducing coal as its primary energy resource from 60-65% of all resources consumed to 50-55% by 2040 as a percentage of energy resources consumed (USEIA 2014).

Oil: China has fairly limited proven domestic reserves of oil compared to the size of its economy (USEIA 2014). As domestic inland growth of crude oil drilling is limited, crude oil imports are expected to triple over the next 25 years, with delivery routes primarily by sea through the PACOM AOR. This is one of the drivers for China to secure energy resource rights near its shores by the nine-dashed line. This is also a reason why domestic construction of oil tankers has increased, oil pipelines from Myanmar have expanded, and been a stated reason for increase in the size, capability and reach of the PLAN to protect energy related economic interests abroad (Monitor360 2014).

LNG-LPG: Several state documents and articles show a relatively recent emphasis on expanding LNG-LPG consumption due to its relatively environmentally cleanliness compared to coal and oil (Chinese Academy of Social Sciences 2013). However, unlike the United States, the majority of known Chinese domestic gas reserves are not as economically feasible extract due to geological formation differences (USGS 2012). Those two drivers are leading to a forecast increase imported LNG-LPG either by sea through the PACOM AOR or through interior pipelines. Chinese LNG-LPG consumption is forecast to expand over four times in the next 25 years, primarily being limited by the speed of infrastructure construction.

NHR: Domestic nuclear energy production will continue to increase as more reactors come online, however growth is being limited by the state (USEIA 2014). After recent incidents such as Fukushima, Japan, China placed a temporary nuclear building freeze as permitting and safety standards were increased. Although construction rates have resumed, there is forecast a temporary reversal in the growth of nuclear generated power available from 2031-2035. Domestic hydroelectric production of energy is forecast to steadily increase as new power generating facilities come online and legacy facilities are expanded or made more efficient. However, this internal resource is considered near capacity due to environmental considerations and little excess growth potential is available. Renewable energy resources, primarily in the solar, wind, and biomass, will see the largest growth. Renewable energy infrastructure is being considerably subsidized to spur growth and state policies are incentivizing it to investors. Renewable energy resources are forecast to increase ten times in the next 25 years (Xu et al. 2014). They have additional potential should current economic trends continue and construction and operating costs come down. Despite this forecast growth, renewables will only make-up 5% of energy resource consumption by 2040 in the baseline model.

The resulting overall Chinese baseline energy resource and consumption model results from 2015 to 2040 are graphically illustrated in Figure 16. They are listed by category in Table 2.

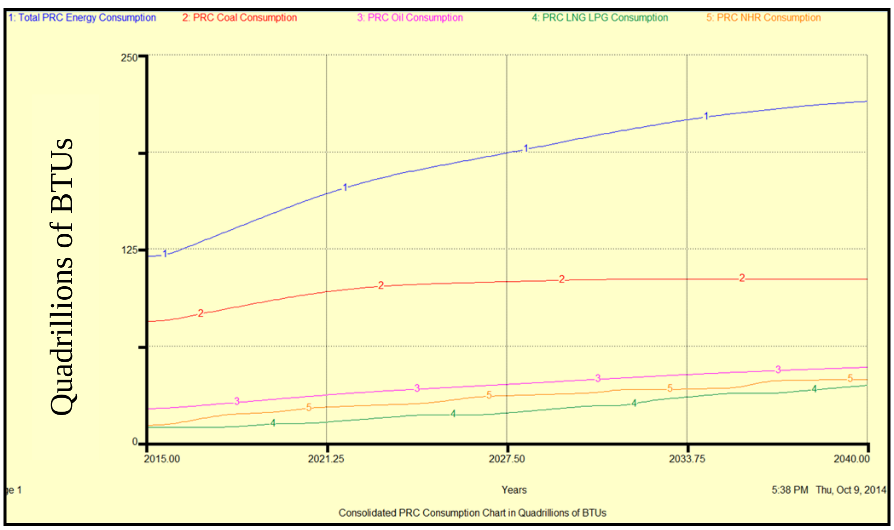

Figure 16. Chinese Baseline Model Energy Resources Consumption Chart from 2015 -2040

Consolidated PRC Consumption Table in Quadrillions of BTUs					
5:38 PM 10/9/2014	Consolidated PRC Consumption Table in Quadrillions of BTUs (Consolidated PRC Consumption Table in Quadrillions of BTUs)				
Years	PRC Coal Consumption	PRC Oil Consumption	PRC LNG LPG Consumption	PRC NHR Consumption	Total PRC Energy Consumption
Initial	78.00	21.60	9.60	10.80	120.00
2015	79.65	22.28	9.60	12.24	123.24
2016	83.30	23.80	9.60	15.57	130.51
2017	86.90	25.36	9.85	17.93	137.88
2018	90.36	26.94	11.19	18.88	145.20
2019	93.60	28.51	11.91	20.50	152.36
2020	96.40	30.00	12.51	22.25	158.99
2021	98.61	31.37	13.94	23.08	164.81
2022	100.30	32.61	15.38	23.79	169.91
2023	101.43	33.70	16.83	24.39	174.18
2024	102.15	34.70	17.48	25.72	177.85
2025	102.71	35.68	17.48	28.03	181.36
2026	103.23	36.67	18.00	29.59	184.89
2027	103.70	37.67	19.51	30.15	188.43
2028	104.16	38.70	21.07	30.73	192.06
2029	104.61	39.77	22.68	31.33	195.78
2030	104.90	40.80	23.42	32.80	199.30
2031	105.02	41.80	24.91	33.73	202.60
2032	105.03	42.79	27.70	33.77	205.77
2033	105.03	43.72	29.38	34.23	208.64
2034	105.03	44.59	31.05	34.63	211.17
2035	105.03	45.39	31.47	36.91	213.35
2036	105.03	46.15	31.70	39.60	215.31
2037	105.03	46.89	33.32	39.93	217.14
2038	105.03	47.56	34.92	40.20	218.66
2039	105.03	48.17	36.49	40.42	219.85
2040	105.03	48.53	37.46	40.58	220.28

Table 2. Chinese Baseline Model Energy Resources Consumption Table from 2015-2040

c. Modeling Linkages

As mentioned, the model results above are a based on historical data and forecast trends for the next 25 years in energy. Links between the Energy SD model directly to the tension, social stability and economic models shall provide inputs to them as well as taking outputs dynamically from them.

Economy: Should the economic model show a rapid decrease in activity indicating recession or depression, there will be corresponding decreases in demand and lagging decreases in the amount of energy resources imported. Should the slowdown be deep and long, eventually domestic energy resource consumption will reduce as well. Should China's economy heat up beyond projections, demand will increase and initially available imports will spike to meet demand until domestic production catches up.

Social Stability: Domestically mined coal, oil and LNG-LPG as well as their consumption produce a negative environmental effect, pollution and reduced standard of living, on the population potentially leading to instability. This relationship is one driver why China's domestic coal mining is being artificially limited (USEIA 2014). The amount of domestic negative environmental damage from energy resource mining and consumption shall feed into the social stability model and potentially social stability outputs could lead to further caps on domestic mining.

Tension: Should a military or destabilizing action interfere with Chinese energy demand or energy imports, the energy model will show spikes or dips in the appropriate activities. Additionally, the amount of energy China imports as a percentage of its overall demand can increase tension. As China becomes more reliant on external sources of energy to meet its economic goals, the state perceives more risk to its energy import activities by other nations. That risk is one driver why China is looking to expand its near off-shore influence and control as well as expand the reach of the PLAN to protect vital energy import sea lanes.

d. Potential Key Relationships for PACOM Planners:

Two examples of potential key relationships with regard to Chinese energy demand and resource consumption are provided in the baseline model.

First is the percentage of energy resources consumed from domestic environmentally-damaging sources such as coal, oil, and LNG-LPG with respect to China's overall total energy resource consumption. The higher the percentage, the more potential damage might be done to China's environment. This is a factor which is at least partially driving China's state policy to limit domestic coal and oil extraction as well as incentivize conversion to renewable energy resource consumption.

The baseline model graphically illustrates in Figure 17 and in Table 3 the projected percentage of environmentally damaging energy resource consumption compared to entire Chinese energy resource consumption. If state policy and forecasts hold, China will reduce consumption of environmentally damaging energy resources considerably. This should allow the state to mitigate harm done to the local environment over time. However, should events from other models such as a 'third party destabilizing event' preclude conversion to renewables or limit imports, China will potentially extract more domestic environmentally-damaging resources, potentially increasing China's internal social instability.

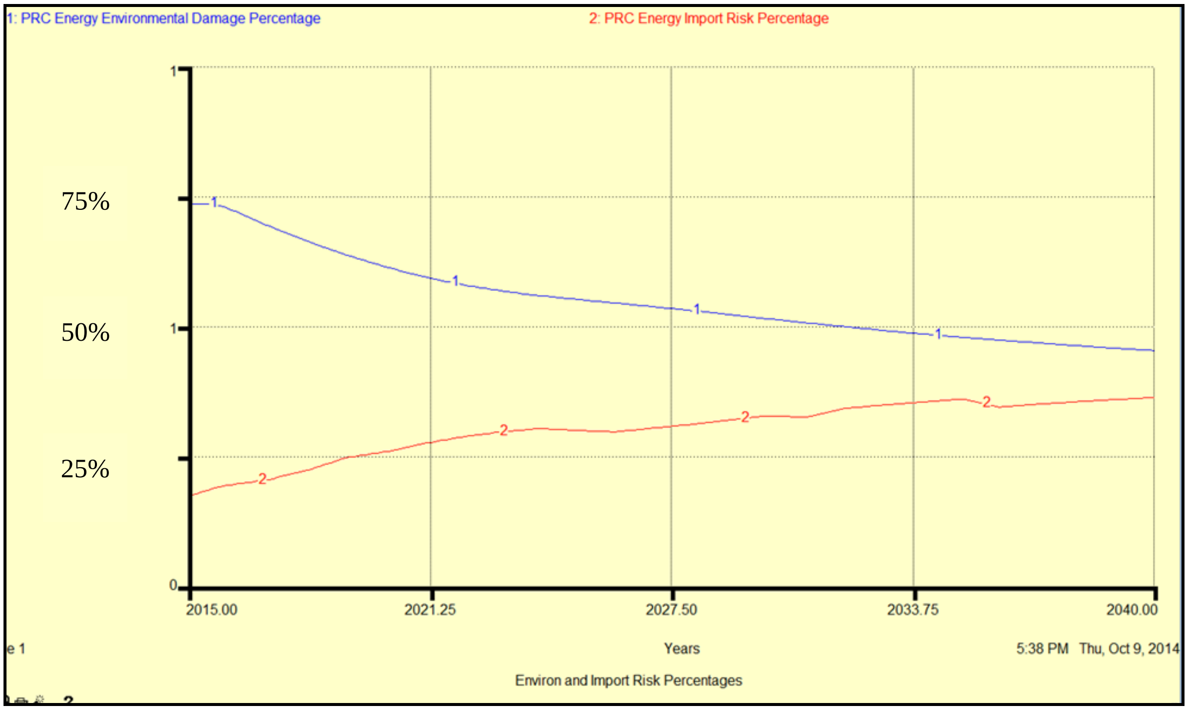

Figure 17. Chinese Baseline Model Environmental Damage and Energy Import Risk Chart from 2015 -2040

Environmental and Import Risk Percentages

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Years	PRC Energy Environmental Damage Percentage	PRC Energy Import Risk Percentage
Initial		
2015	0.73	0.18
2016	0.71	0.20
2017	0.68	0.21
2018	0.65	0.23
2019	0.63	0.25
2020	0.61	0.26
2021	0.59	0.28
2022	0.57	0.29
2023	0.56	0.30
2024	0.56	0.30
2025	0.55	0.30
2026	0.54	0.30
2027	0.53	0.31
2028	0.53	0.31
2029	0.52	0.32
2030	0.51	0.33
2031	0.50	0.33
2032	0.50	0.34
2033	0.49	0.35
2034	0.48	0.36
2035	0.48	0.35
2036	0.47	0.35
2037	0.47	0.35
2038	0.46	0.36
2039	0.46	0.36
2040	0.45	0.36

Table 3. Chinese Baseline Model Environmental Damage and Energy Import Risk Table from 2015 -2040

Second is the percentage of Chinese energy resources consumed that are imported through the PACOM AOR, primarily by sea. Historically this has not been a high percentage of the overall Chinese energy portfolio but as the economy has dramatically increased in the last decade-plus, so has this percentage. Forecasts indicate the percentage will increase as Chinese state policy limits domestic mining but has economic growth projections that exceed internal energy resources. The baseline energy model reflects that. This is one of the drivers for China to secure more energy resource rights near its shores by the nine-dashed line. This is also a stated reason for increase in the size, capability and reach of the PLAN to protect energy related economic interests abroad. As the percentage of required energy is imported the potential is that tension will rise as China seeks to secure those resources.

2. Economic Sub-Model

Economics and commerce play a key role in the relationships among the US, the PRC, and other nations in the PACOM AOR. While the current sub-model focuses on the dynamics of the US-PRC economic relationship, the model can be extended to include other bilateral relationship dynamics as well.

a. Economic Sub-Model Discussion:

The Economic Sub-Model is shown in Figure 18. The Economic Sub-Model directly contributes to potentially escalating regional tension and the potential for conflict. The sub-model was developed using open source trend and proven resources model data provided by the United Nations for 2012. All the economic data was converted to 2012 U.S .dollars for comparison purposes. Other data sources (e.g. the International Monetary Fund, the World Bank) were considered for inclusion but ultimately not used at this time. The UN economic data was used with a statistics package curve-fitting application to generate equations that reflect the real world U.S. and PRC economic indicators through 2012. Figures 19 through 22 compare the US and PRC economic performance based on this analysis.

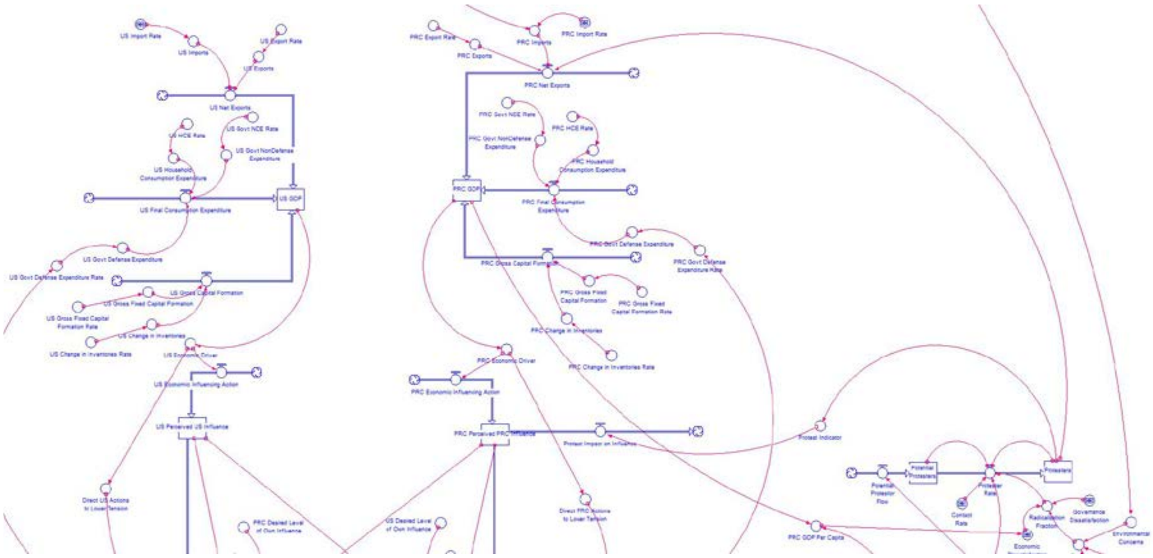

Figure 18. PACOM SMA Economic Sub-Model

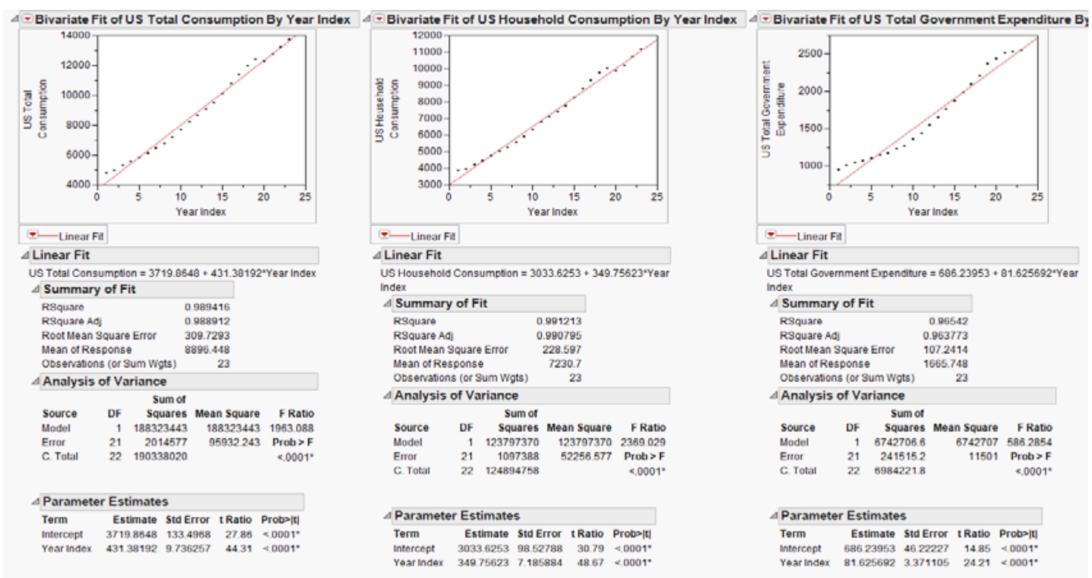

Figure 19. US Total Consumption, Household Consumption, and Government Expenditure by Year

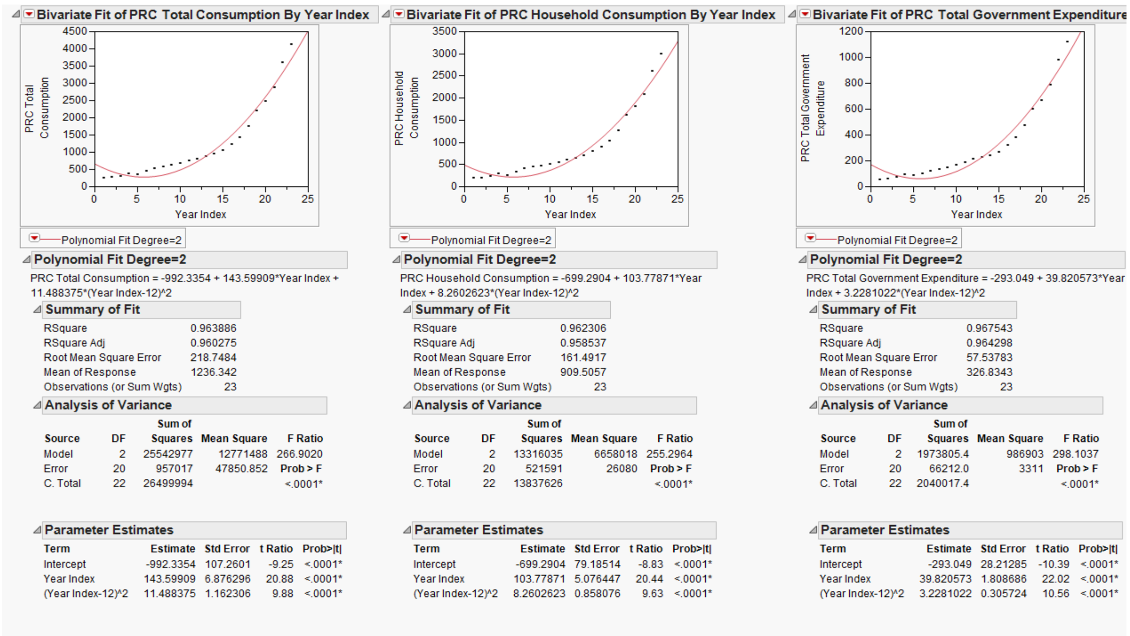

Figure 20. PRC Total Consumption, Household Consumption, and Government Expenditure by Year

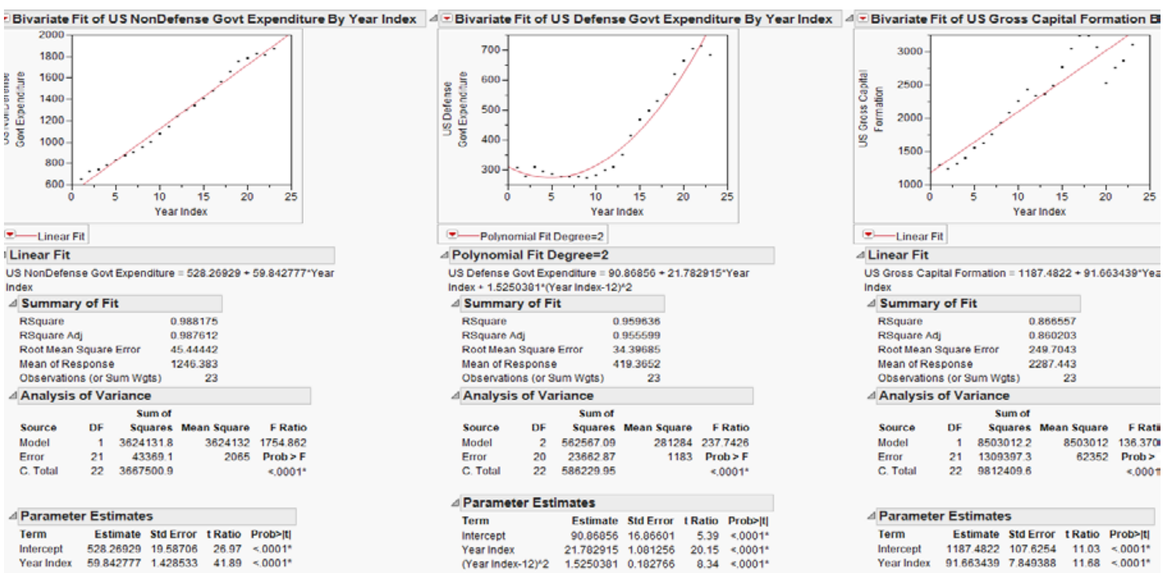

Figure 21. US Non-defense Spending, Defense Spending, and Gross Capital Formation by Year

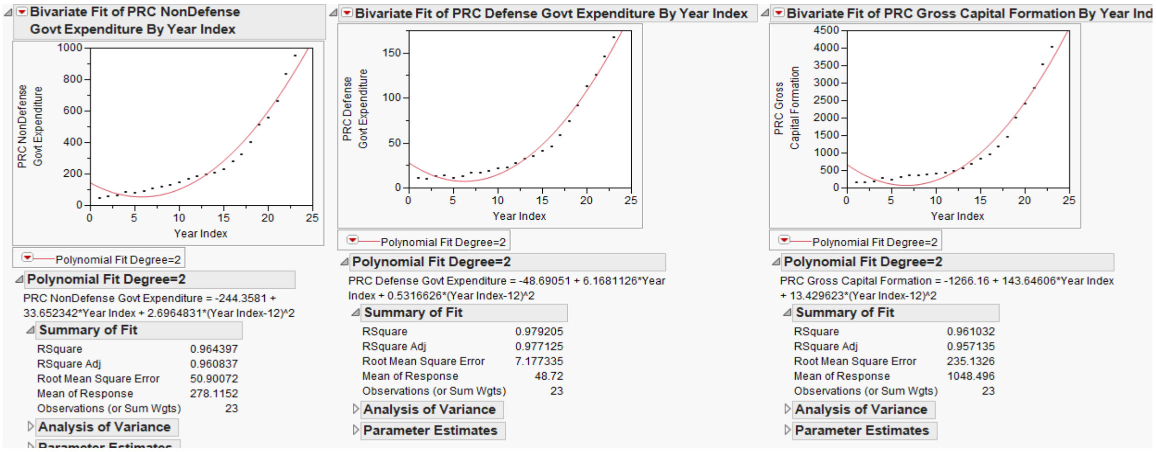

Figure 22. PRC Non-defense Spending, Defense Spending, and Gross Capital Formation by Year

Currently, users of the economic model cannot alter the pre-established expected growth equations for individual economic component; however, users can control the multiplying coefficients to examine the potential impact of growth/decline for individual economic component

b. Assumptions:

The economic sub-model assumes that the U.S.-China economic relationship will continue for the foreseeable future to be one of mutual benefit, albeit with competitive aspects.

3. Tension Sub-Model

Tension is the metric that is used to illustrate the probability of conflict or convergence occurring in the defense and military model. High tension levels suggest that conflict is likely to occur while lower tension levels indicate that the nations involved are pursuing normal diplomatic relations.

a. Tension Model Discussion:

The defense and military tension model appears in Figure 23. The tension model is driven by perceptions and desires of influence in the region. The Chinese have a perception of their influence in the region and a perception of the United States' influence in the region. The Chinese also have a desired level of influence the region and an assumed goal of limiting other nations influence in the region. If the Chinese desired influence is less than their perceived influence then the Chinese will take action to close the gap between their perceived influence and their desired influence in the region. Similarly, if the Chinese perceive a difference between their perceived level of U.S. influence in the region and their desired U.S. influence, this will likely lead to actions to counter the perceived deficit.

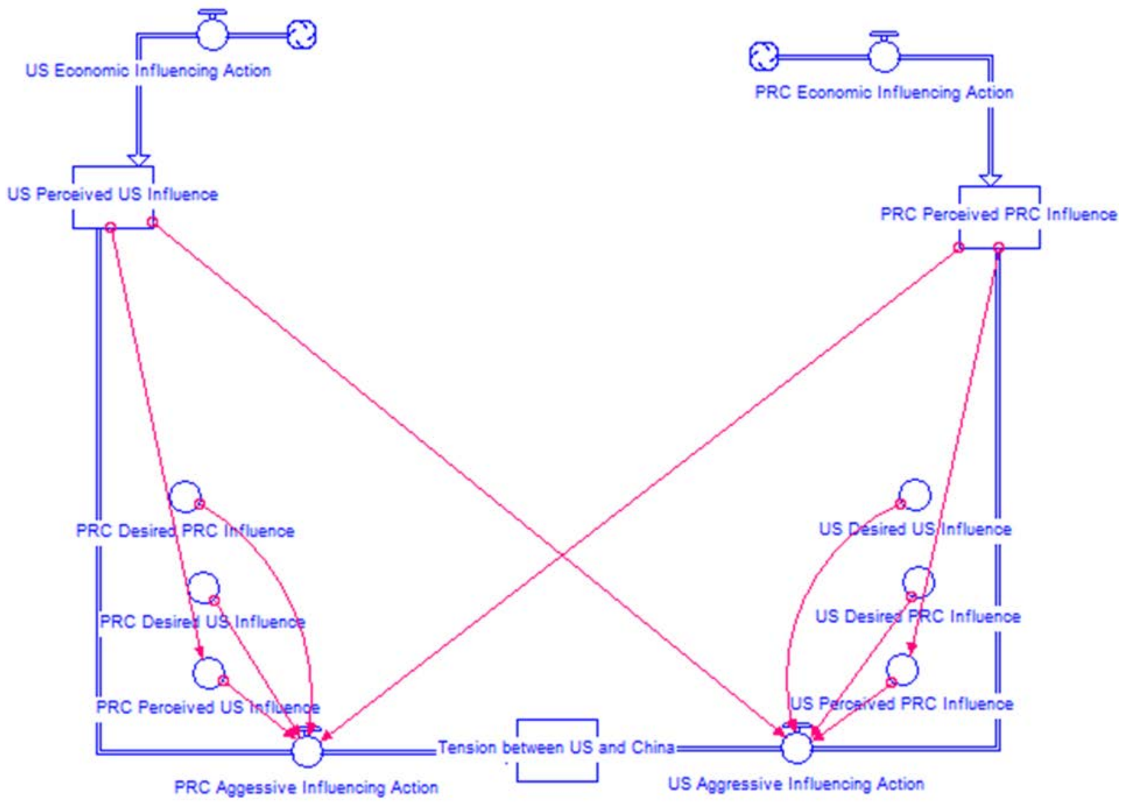

Figure 23. Tension Sub-Model

From a United States perspective the model works in the same manner. The U.S. will take influencing actions if their desired influence is lower than their perceived influence, or if China's perceived influence in the region is higher than the desired level of Chinese influence. From a military perspective, these influencing actions will likely come from one of the five possible categories of military scenarios. These are explained in more detail in the following sections.

Stabilizing actions will likely come in the form of economic cooperation through trading and investing. Military cooperation is also possible through joint exercises, disaster relief, and counter-piracy operations.

b. Assumptions:

(1) This model assumes that China and the U.S. will combine to account for 100% of influence in the Pacific region. Future model developments will consider other nations perceptions of influence within the region.

(2) The model receives input from subject matter experts on the tension unit increase for each military action and assumes these opinions are correct.

(3) Tension levels that indicate a high probability of conflict or a high probability of cooperation must be determined through discussions with subject matter experts.

4. Military Actions Sub-Model

As stated previously, the U.S. currently has the predominant influence in the Pacific region. China will likely take actions over the next 25 years to limit U.S. influence and freedom of action in the region. Based on conversations with subject matter experts at CEIP, START and Monitor 360, five categories of military actions were developed. These actions are considered to be destabilizing actions that increase tension as seen in Figure 24.

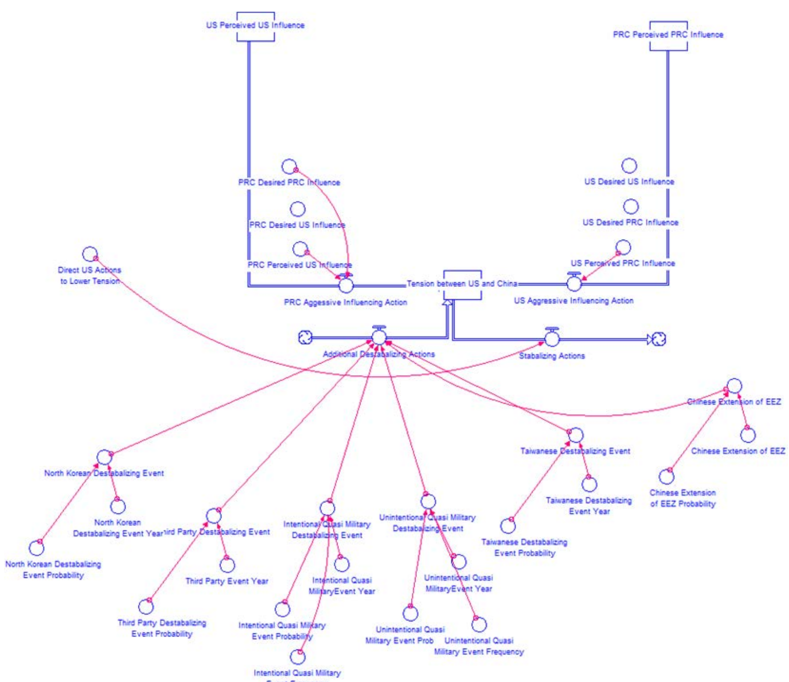

Figure 24. Tension Model with Military Actions

<u>Unintentional Quasi-Military Actions</u>.

An example of an unintentional action is a collision at sea by a Chinese vessel and one from a U.S. or allied nation. This situation could potentially escalate depending on the actions of the local actors involved. In the past, these situations have raised tensions but usually are resolved through discussions between leaders of both governments.

Intentional Quasi-Military Actions.

An example of an intentional quasi-military action would be the establishment of an exclusion zone by China. Usually the purpose of this would be to gauge the resolve of the opposing nation. In the example of the most recent exclusion zone established by China, the U.S. and Japan responded with their quasi-military action of continuing to send aircraft or ships through the zone. These incidents have the potential to escalate based on the resolve of each nation. When China set up the exclusion zone and the U.S. and Japan sent fighters through the zone, China scrambled jets but did not escalate the situation further.

Conflict Over Taiwan:

This is the least likely but also the most dangerous scenario. This will bring tensions to the highest levels and likely lead to war if the situation isn't balanced by a stabilizing action. An example of this would be if the Chinese government loses patience with the continued sale of U.S. arms to Taiwan, or if the U.S. gives Taiwan a new technology that significantly increases Taiwan's defense capabilities. This could cause the Chinese to respond with an aggressive military action.

Conflict Over North Korea.

Currently, China has publicly condemned North Korea's pursuit of nuclear weapons. However, a change in rhetoric by North Korea, such as the threat of collapse, could alter China's policy toward North Korea. It could cause China to change its stance on North Korea's nuclear ambitions. This would likely lead to more aggressive U.S. intervention to stop nuclear proliferation, and this would certainly raise tensions to the highest levels.

China or U.S. Dragged into 3rd Party Conflict.

This is different from the 2nd category because it originates with an action initiated from a third party whereas the above scenario deals with a Chinese or U.S. action specifically in Taiwan or North Korea. An example of this would be if Japan took actions to aggressively occupy South China Sea islands, and was confronted by Chinese military units. Even though the U.S. may not agree with Japanese actions, they could get dragged into a conflict based on their treaty obligations. Similarly, if North Korea's nuclear development reaches a level that the U.S. perceives as dangerous, this could cause the U.S. to take action, and these actions could invoke the Sino-North Korean treaty obligating China to get involved. This scenario likely could be resolved by China and U.S. unless one of those two nations responds very aggressively to the third party.

There are many events that can be grouped into one of these three categories but in speaking with the subject matter experts, military actions will fall into one of these three categories within the next 25 years.

5. Demographics and Stability Sub-Model

The PACOM SMA Demographics and Stability Sub-Model is a SD model intended to communicate the dependencies and interrelationships that affect the domestic political and social stability of countries in the Asia-Pacific region.

The iThink graphical representation of the PACOM SMA Demographics and Stability Sub-Model is shown in Figure 25. The description of the model's structure, assumptions and limitations, inputs/outputs, and interfaces follow.

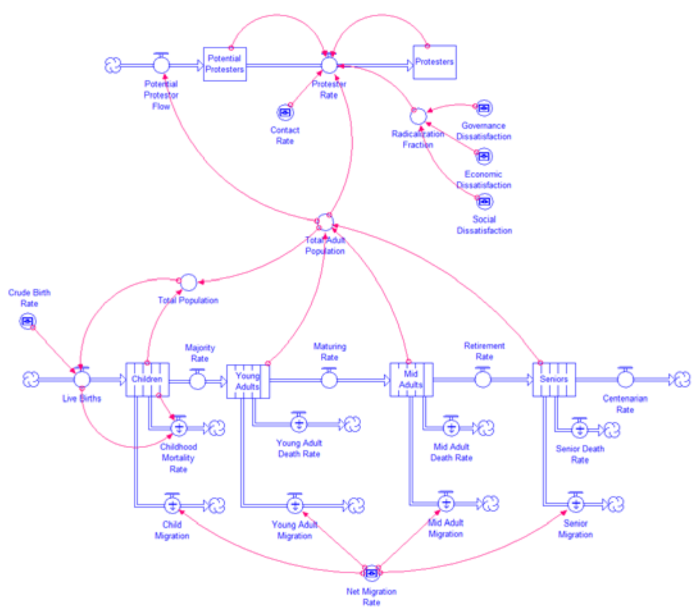

Figure 25. The iThink representation of the PACOM SMA Demographics and

Stability Sub-Model

In modeling either social or political stability it is necessary first to be clear or define what is meant by "stability". One way of defining stability would be as the lack or relative rarity of instability actions or events. Note that stability doesn't necessarily mean lack of change. Stability means that changes occur within a framework that does not threaten the continuation of the entity (Dowding and Kimber, 1983). Thus a political system can be very dynamic (e.g. the United States), but stable in that the changes to the political system occur within the allowed rules of the system (i.e. free and open elections, legislation by representatives, judicial overview of legislation, balance of power).

In China, stability is a primary goal (the other being economic development) of the Chinese Communist Party (CCP). There is a reinforcing relationship between economic development and political stability that has been studied extensively. In terms of external relations, external perception of the stability of a country affects the willingness of foreign investors to make direct investments in that country, thus affecting economic development. Greater economic development tends to promote greater internal stability.

Several frameworks such as the NSI StaM (Stability Model) (NSI, 2014) and JPL Athena model (Chamberlain and Duquette, 2012) exist to help analyze and organize analysis concerning the stability of countries. These models help analysts define and categorize the factors that that effect stability. Systems dynamics can provide a further step that describes how the non-linear interactions between factors affect the dynamic behavior of the system (in this case, countries within a geographical region).

The PACOM Demographics and Stability Sub-Model is composed of two components – a Chinese Demographics Sub-Model and a Protestor Sub-Model.

a. The Chinese Demographics Sub-Model

Figure 26 shows the iThink graphical depiction of the Chinese Demographics Sub-model. A demographic model is necessary to consider when modeling potential political or

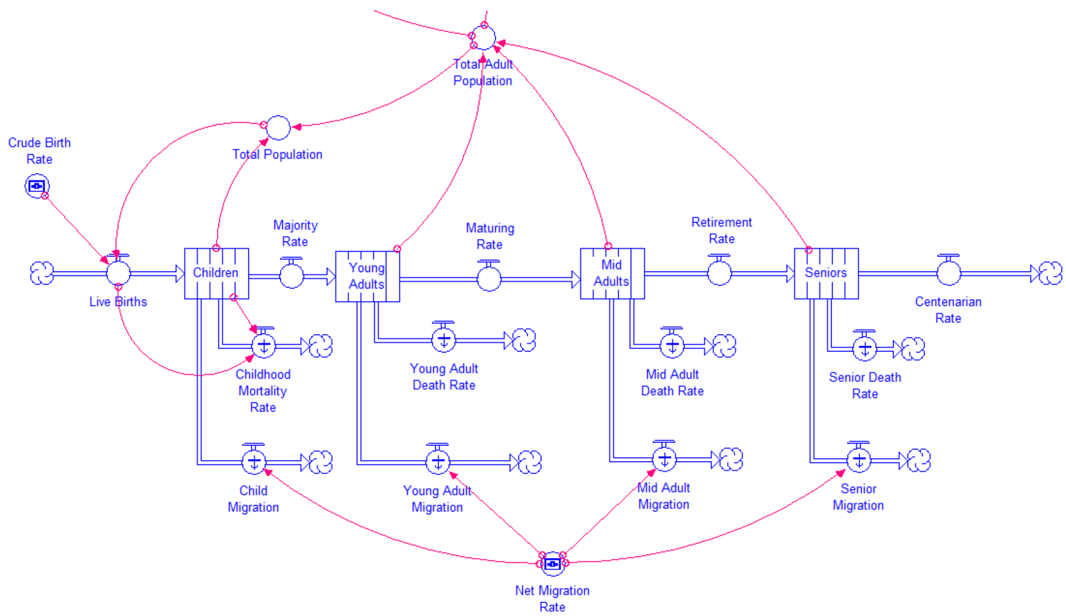

Figure 26. Chinese Demographics Sub-Model

social instability because different factors will affect different segments of the population in different manners. For example, if one of the factors affecting stability is the level of dissatisfaction with the social support mechanisms for the aged population 65 years or older, then that issue is more prominent when a large portion of the population is age 65+ or soon facing retirement. Likewise, the segment of the population most likely to participate in destabilizing actions as a result of dissatisfaction is adults over 18 years old.

The population is modeled as four age groups – Children (birth through 17 years), Young Adults (18 through 39 years), Mid-Adults (40 through 64 years) and Seniors (65 through 99 years). Each age group is modeled in iThink as a "conveyer belt" entity. Each conveyer belt consists of a number of slats, one slat for each year in the age group. Each slat is initially loaded with the number of individuals at that age from the 2010 census. As the simulation progresses, the people in each slat are moved to the next slat, simulating aging of that population cohort.

Each conveyer belt entity allows for "leakage", i.e. individuals that are removed from the conveyer belt for one reason or another. In this model, the leakage from each age group is attributed to either death or migration. China currently has a net negative migration rate, which will probably continue during the timeframe of this study. Reliable data exist from the World Bank, the World Health Organization, and the Chinese government itself for statistics such as crude birth rate, infant and childhood mortality, and migration rate (although not by age group). The conveyer belt entity also allows leakage to be modeled as either linear or exponential, and distributed either across the entire time period or a portion of the time period. For example, the current settings on the Seniors allows a 99% exponential leakage (death) from 77 years (current average Chinese life expectancy) through 99 years old.

(1) Assumptions and Limitations.

The current Chinese Demographics Sub-Model does not divide the age cohorts into male-female components, ethnicity components, or rural-urban components. Demographers sometimes make such distinctions as required to support research, but with the possible exception of a rural-urban distinction, finer classification of population groups was not necessary to support the Protestor Sub-Model.

The data available for the Chinese Net Migration Rate is not given by age. Therefore the allocation of the rate across the four age groups was assigned subjectively. Further research into Chinese migration may provide more data upon which to assign the weights among the four age groups.

The duration of the age groups was assigned based on the following reasoning:

- Children Ages 0-17 – Children are still too young to take part in large scale political actions, or are under the control of their parents
- Young Adults Ages 18-39 – Prime pairing and child bearing years.
- Mid Adults Ages 40-65 – Prime career and work years.
- Seniors Ages 65-99 – Most adults in retirement.

(2) Sub-Model Inputs.

Currently the Chinese Demographics Sub-Model has a single user-controllable input parameter, Crude Birth Rate. The CIA World Fact Book defines crude birth rate as "… the average annual number of births during a year per 1,000 persons in the population at midyear…"

The Fact Book goes on to state, “The birth rate is usually the dominant factor in determining the rate of population growth. It depends on both the level of fertility and the age structure of the population." The slider on the iThink Interface View allows the user to select from 0 to 20 live births/1,000 population.

(3) Sub-Model Outputs.

The Chinese Demographics Sub-Model produces a graph (Figure 27) showing the number of people in each age group including a Total Population over time (the current

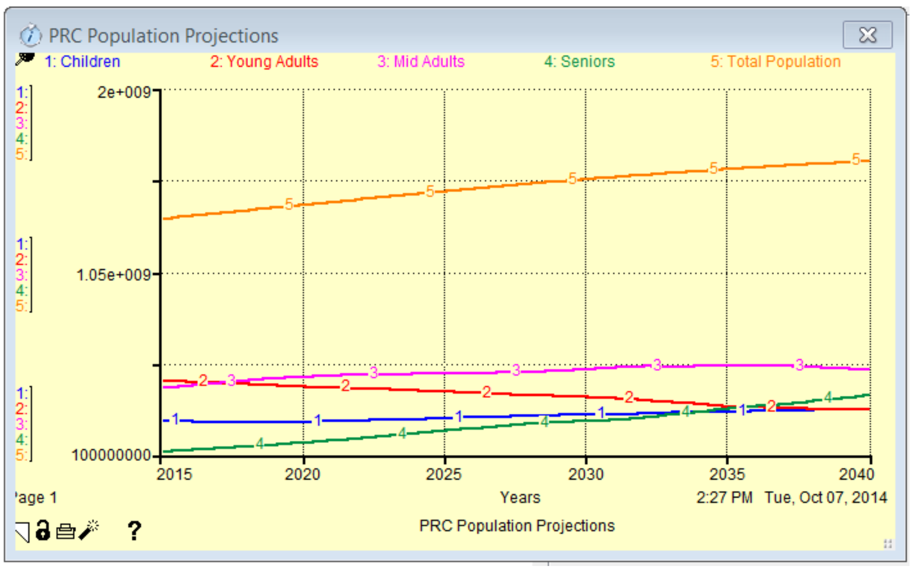

Figure 27. Chinese Population Projections from the Demographics Sub-Model

simulation duration, 25 years). Note the slow decline in the number of young adults, an expected result from the reduction in birth rates due to the One Child Policy and reduced family sizes due to economic pressures of transferring to more urban environments.

(4) Data Sources:

Demographic data on China was drawn from the government’s 2010 Census as reported both on official Chinese Government web-sites and the CIA World Fact Book. Additional values for Crude Birth Rate, and Childhood Morality Rate were drawn from the World Health Organization.

(5) Sub-Model Interfaces.

The Chinese Population Sub-Model has a single interface to other parts of the PACOM Stability Model, namely Total Adult Population. Total Adult Population defines the population of potential protestors available to become active protestors.

b. The Chinese Protestor Sub-Model.

Figure 28 shows the iThink graphical depiction of the Chinese Protestor Sub-Model. For purposes of this sub-model, a "protestor" is defined as a person willing to take an extra-legal action as a result of dissatisfaction with some aspect of governance, economics, or social circumstances or a combination thereof. Actions can run the entire spectrum of violence, from peaceful civil disobedience through large scale public demonstrations to riots, destruction of property, and armed attacks on the existing mechanisms of governance (i.e. the CCP). The legality of the protest action is defined by the existing government. As can be seen during the recent protests in Hong Kong, the government can decide whether peaceful demonstrations present enough of a perceived threat to public order and stability as to be declared illegal.

The basic structure of the Protestor Sub-Model is that of a classical infectious disease

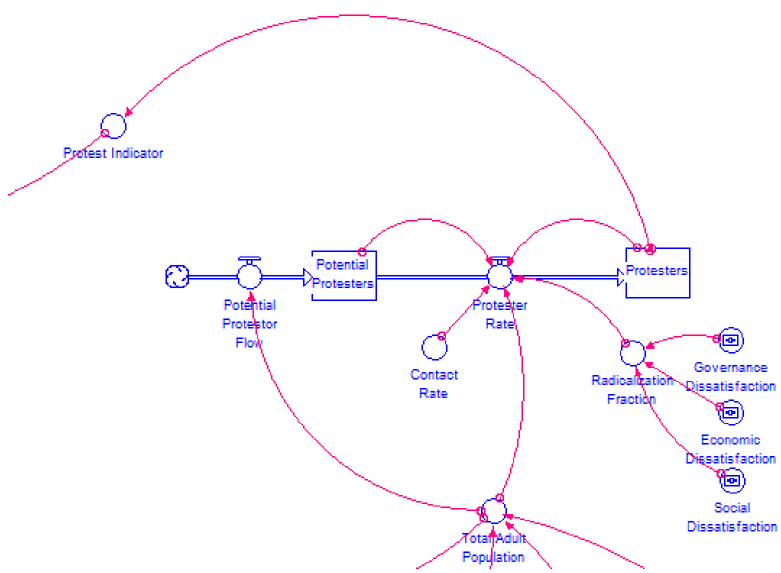

Figure 28. Chinese Protestor Sub-Model

model. The same structure has been used to model the adoption of new ideas or technologies.

The model consists of two pools of people; the Potential Protestors (those adults who could decide or be persuaded to engage in extra-legal actions) and Protestors (those people willing to take part in extra-legal actions). A person who is dissatisfied with some aspect of government or society does not present an existential threat to the existing order unless that individual takes actions against the government. You can be as dissatisfied as you want, as long as you don't do anything about it.

The term "extra-legal" is used instead of "illegal" to describe actions taken outside the acceptable framework of dissent. A small peaceful demonstration may technically not be sanctioned by the government because proper permits and permissions were not obtained, but the demonstration may in effect be permitted by the government's inaction against the demonstrators as long as the perceived threat does not cross some threshold.

(1) Assumptions and Limitations.

The limitations of the basic infectious disease model (or "SI" model for "Susceptible-Infected") are well known.

- This model assumes a homogeneous distribution of Potential Protestor and Protestor. This does not take into account geographic distribution of population. The contact rate is uniform with respect to spatial distribution.
- There is no recovery (i.e. movement from Protestor back to Potential Protestor) once you become a Protestor.
- The Potential Protestor population cannot be "vaccinated" against becoming a Protestor. There may be education and propaganda means by which the Potential Protestor population may be reduced.
- Eventually the SI model will produce a 100% infected population, or in this case eventually 100% of the Total Adult Population will become Protestors.

(2) Sub-Model Inputs.

The Chinese Protestor Sub-Model has four user-controllable inputs; Contact Rate, Governance Dissatisfaction, Economic Dissatisfaction, and Social Dissatisfaction. Contact Rate is the average number of times per year a member of the Potential Protestor population comes into contact with a member of the Protestor population. In an infectious disease situation, contact can be defined in relation to the disease transmission mechanism, e.g. contact with another person's bodily fluids, unprotected sexual contact, using unsafe water sources, etc. In the case of ideas, the concept of "contact" can be more ethereal, not relying on person-to-person contact. Contact might be exposure to media (traditional or digital) urging a person to join in a protest movement. In the case of digital media, Contact Rate would be affected by such factors as internet penetration, media censorship, and availability of social networking.

The Governance Dissatisfaction, Economic Dissatisfaction, and Social Dissatisfaction factors are summed together into the Radicalization Fraction, which represents the probability that any contact between a Potential Protestor and a Protestor will result in conversion ("radicalization") of the Potential Protestor into a Protestor. The dissatisfaction factors are added together to reflect an assumption that on the average it is not just a single factor that will cause a Potential Protestor to become a Protestor, but rather the accumulation of dissatisfaction with a number of issues.

(3) Sub-Model Outputs.

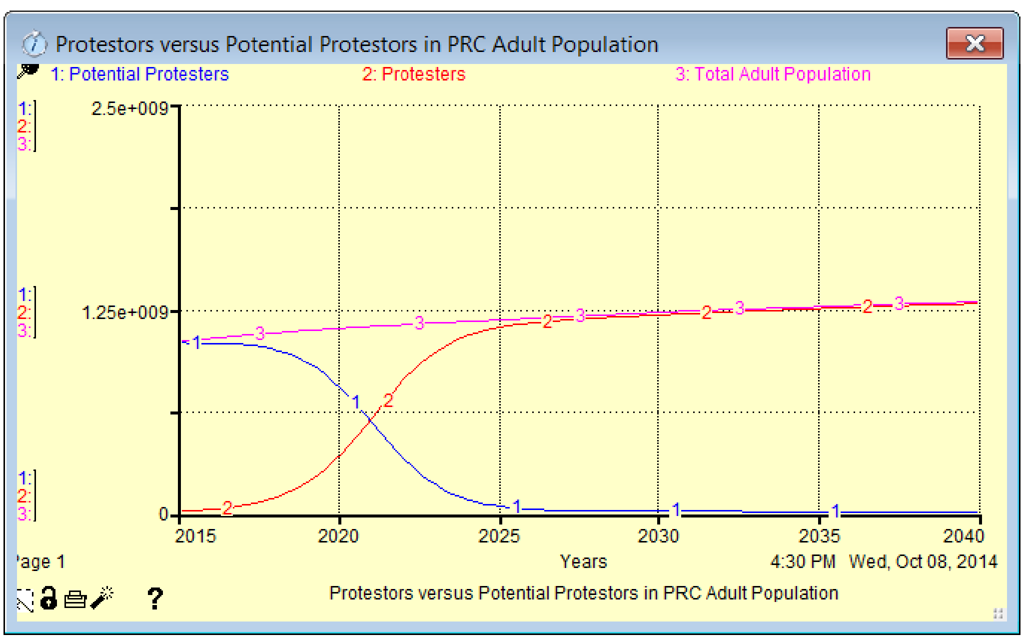

Figure 29. Example graph of Chinese Protestors versus Potential Protestors over time for a given set of inputs.

The Chinese Protestor Sub-Model produces a graph (Figure 29) showing the number of Protestors and Potential Protestors compared to the Total Adult Population over time (the current simulation duration, 25 years). The crossover point between Potential Protestors and Protestors depends on the input parameters. This example graph shows a situation that the Chinese government would want to avoid at all costs, namely a runaway radicalization of the adult population resulting in total loss of stability and probable end to the existing regime.

The formulation of the Protestor Sub-Model as an infectious disease model gives some insight into how the CCP might choose to prevent a runaway radicalization (an “epidemic of rioters”). The Chinese government could seek to lower the Contact Rate through censorship of media, limitations on public gatherings, quarantine of “infectious” individuals though arrest, detention, imprisonment, or exile of dissidents. The Chinese government could also seek to reduce the radicalization fraction by either effectively addressing the root causes of dissatisfaction, or raising the barriers to becoming a Protestor through intimidation, threat of imprisonment, or violent crackdowns against protest demonstrations. While such actions may not lower the level of dissatisfaction among potential protestors, the more severe the potential consequences are for participating in extralegal actions the less likely potential protestors are to convert from passive to active participation as a protestor.

(4) Data Sources.

The Total Adult Population is based on data from China’s 2010 Census as reported both on official Chinese Government web-sites and the CIA World Fact Book. There exists little identifiable data that quantifies such factors as the portion of protestors in the Chinese population and how likely the average Chinese adult is to become a protestor as a function of governance, economic, or social dissatisfaction. These factors are modeled as user-selectable input so that users can experiment and observe the effects of changing values on the dynamic behavior of quantities of interest.

(5) Sub-Model Interfaces.

The Protestor Sub-Model interfaces to the Chinese Demographics Sub-Model though the Total Adult Population. The sub-model also interfaces to the Tension Sub-Model through the

Protest Indicator and the Chinese Perceived Chinese Influence. As currently configured, a 5% increase in the number of Protestors in a year triggers a loss in the Chinese Perceived Chinese Influence.

V. DASHBOARD FLIGHT SIMULATOR

A. INTRODUCTION

The term "Dashboard Flight Simulator" (Figure 30) refers to a streamlined user interface to the PACOM SMA SD model. The iThink® software offers an Interface layer on which user controls, model inputs and outputs can be arranged to give users a cleaner interface without the need to delve into the details of the actual models. Simulation controls are provided to facilitate repetitive simulation runs, thus encouraging users to conduct "what if" analysis by varying the values of the inputs.

B. DESIGN OVERVIEW

The Dashboard Flight Simulator is divided into three functional areas; inputs, outputs, and controls. The graphs on the left side display results (outputs) of the simulation runs. Underneath the graphs are a series of simulation controls that let the user start, pause, stop, and reset simulation runs. On the right side of the screen is an area containing user input controls, in this case toggle switches and sliders that let the user decide which potential destabilizing events will occur, and the likelihood and frequency of such events occurring. See the Model Quick Start Guide for further details.

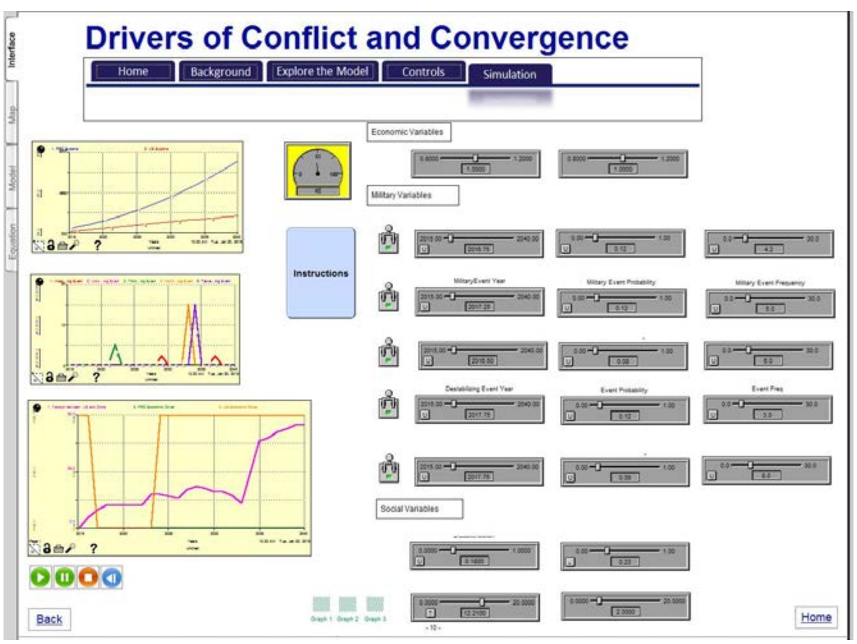

Figure 30. PACOM SMA Dashboard Flight Simulator Interface

C. MODEL DEMONSTRATION

The following example illustrates how the SD model might be used during a wargame simulation to gain insights into the dynamics of the U.S.-China relationship. A series of model screenshots are used to provide a simple demonstration. Figure 31 establishes a baseline where no changes are made to the underlying model and the three graphs correspond to (top to bottom) U.S. Defense Expenditure, Tension Resulting from External Destabilizing Events, and the Number of Protestors in China. While any number of variables may be shown, in this example the user decided to observe the impact destabilizing events may have on U.S. and Chinese military spending and the potential number of protestors within China.

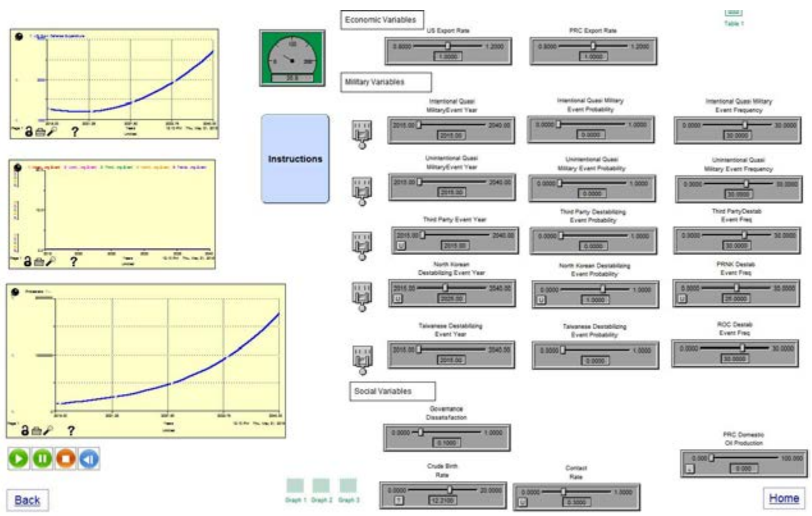

Figure 31. Dashboard Interface Demonstration: Baseline Model

Note that this example chooses to include the full interface rather than focus in detail on the graphs on the left side of the interface. While this makes it difficult to view the exact numbers on each graph, this example is intended to demonstrate how the model can be used to identify general trends and identify relationships between variables, rather than make specific numerical predictions. The tool contains more numerical detail which can used to demonstrate the impact of each modeling event in this demonstration.

Suppose during the wargame an exercise injection is introduced consisting of a destabilizing incident on the Korean Peninsula in 2025. The user would open the Dashboard Flight Simulator Interface and switch off all the destabilizing events in order to run a baseline case with no destabilizing events (as shown in Figure 31). The user would decide which model variable(s) are of interest to observe the impact of the exercise inject. The user would then modify one of the graphs (e.g. the top graph) on the interface to display U.S. and Chinese military spending as a function of time. After making sure the bottom graph, which shows the number of protestors in China, is set to show comparative runs (meaning that the graphs will populate with new information on top of the information obtained in previous model runs), the user then examines the impact that the destabilizing event has on each variable of interest (Figure 32).

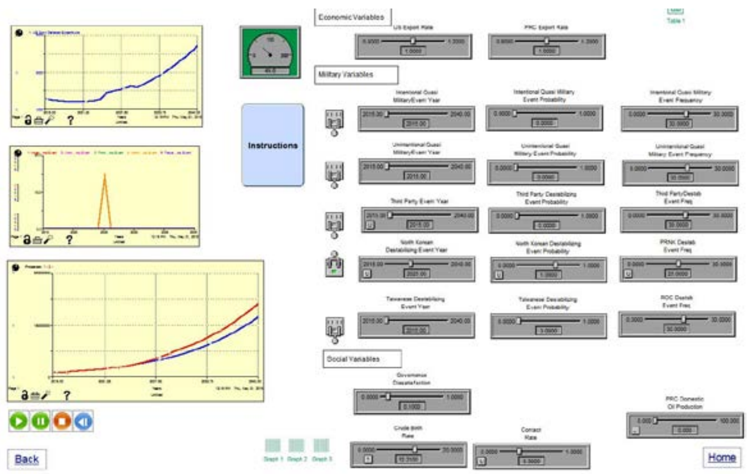

Figure 32. Dashboard Interface Demonstration: Korean Destabilizing Event

Notice the changes in each of the graphs. The center graph, showing the tension resulting from a destabilizing event, now shows a spike during the year 2025 corresponding to the Korean event. The top graph shows an associated increase in defense spending, which persists for five years and subsequently reverts to expected levels. The bottom graph, where the blue line corresponds to the baseline run and the red line corresponds to the new run, shows an increase in the number of protestors beginning around the time of the event and not returning to expected levels at any point, suggesting that any increase in the number of protestors is difficult to correct.

The model can examine an alternative scenario that demonstrates large perturbations are not necessary to prompt substantial changes to the model behavior. In Figure 33, the Korean destabilizing event is removed from the model (accomplished through the use of the associated on/off switch) but an alternative wargame inject of increased Chinese reliance on domestic oil is introduced.

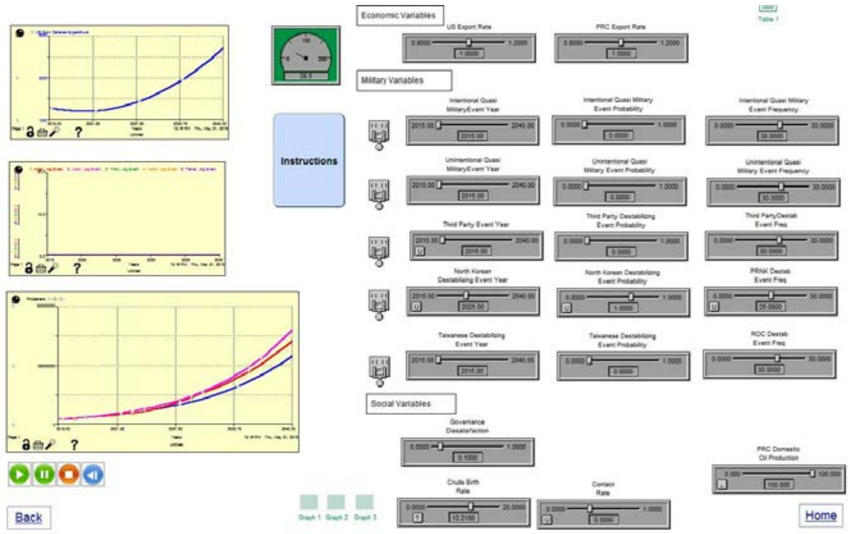

Figure 33. Dashboard Interface Demonstration: Increased Chinese Domestic Oil Consumption

Note that the top two graphs mirror the baseline case, but the bottom graph suggests that this persistent reliance on oil (which is assumed to occur as a percentage increase from 2025-2040) actually has a greater impact on the number of protestors than does the previously introduced destabilizing event on the Korean peninsula (as shown by the purple line). Detailed examination of the graphs shows that the destabilizing event will result in a 23% increase in the number of protestors while the increased reliance on domestic sources of oil will result in a 37% increase in the number of protestors. The relationship between those potentially impactful future events can be examined through a third potential wargame inject, where the multiplying effect of both an increased reliance on domestic oil in China and a destabilizing event on the Korean peninsula are modeled (Figure 34).

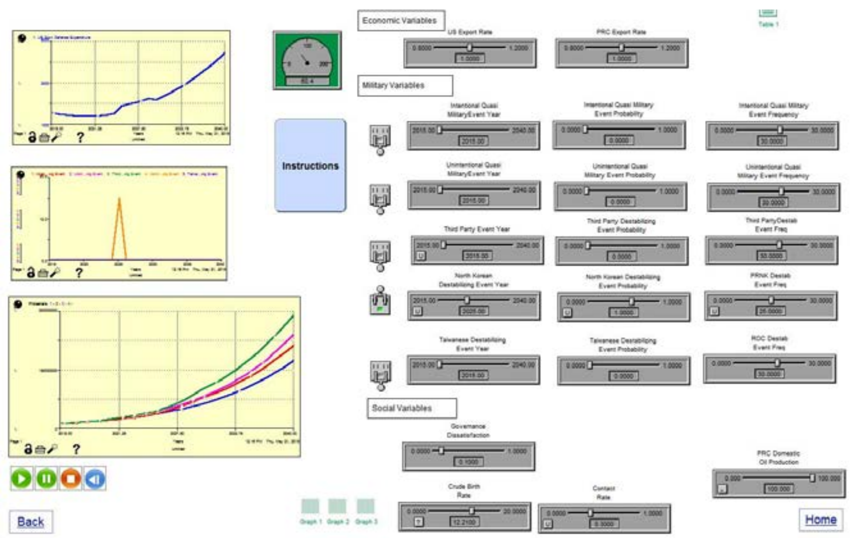

Figure 34. Dashboard Interface Demonstration: Increased Chinese Domestic Oil Consumption and Korean Peninsula Destabilizing Event

Notice that the top graph again shows a brief increase in defense spending resulting from the destabilization of the Korean peninsula. The bottom graph now shows the multiplying effect of both potential wargame injects (green line). Further examination of the graph within the tool suggests that the increased reliance on domestic oil and the destabilizing event in 2025 results in a 66% increase in the number of protestors, a far greater impact than when either event was modeled in isolation. Using the tool to examine the final number of protestors reinforces the utility of the model in identifying relationships between events and variables. Specifically, if the results of wargame injects one and two were considered separately and a prediction was made about the potential impact of both injects occurring simultaneously, simply summing the number of protestors of each individual model run would underestimate the number of protestors by 11% when compared to the model run that considered the events simultaneously. Stated differently, the true utility of the model is the ability to model the interactions between events/variables, the impact of which may be misrepresented through an isolated study of each event or variable.

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VI. CONCLUSIONS

A. KEY POINTS AND RECOMMENDATIONS

International relations are complex interactions in which multiple actors (both nation-states and non-nation-states) are presumably pursuing agendas to maximize their own interests. These interactions led to secondary and tertiary effects that are often difficult to foresee, and could possibly even have deleterious effects on national interests. Systems dynamics modeling provides a way to holistically integrate and visualize relationships and simulate outcomes based on these highly interconnected, non-linear relationships. The PACOM SMA SD model integrates economic, energy, military and political stability views into a greater picture that can inform PACOM strategic planners and provide a tool for planners to examine possible scenarios within the US-PRC relationship.

Recommend that the PACOM SMA SD model to given to PACOM strategic planners for their use, and their feedback be incorporated into a revised SD model.

B. AREAS TO CONDUCT FUTURE RESEARCH

The current PACOM SMA SD model focuses mostly on the U.S.-China relationship and the level of tension in the PACOM AOR between the US and China. There are other important regional actors (North and South Korea, Japan, Taiwan, Indonesia, Malaysia, Philippines) that could be added to the model.

Based on feedback from use of the PACOM SMA Dashboard Flight Simulator Interface during the ICONS simulation, the interface can be improved to increase its clarity and usefulness to potential users.

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VII. SUMMARY

During the period March 2014 through April 2015, faculty and students from the Naval Postgraduate School (NPS) took part in the Strategic Multi-Layer Assessment (SMA) for the U.S. Pacific Command (PACOM). The SMA process provides planning support for complex operational imperatives requiring multi-agency, multi-disciplinary solutions that were not currently within core competencies of Combatant Commands. The PACOM SMA focused on identifying the drivers of conflict and convergence in the PACOM Area of Responsibility (AOR) over the next 25 years (2015-2040).

The NPS contribution to the SMA overcomes current conceptualization limitations by using a Systems Dynamics (SD) viewpoint to examine U.S.–China relations. This approach employed systems thinking and systems dynamics methodologies to analyze the policy structures of major issues of concern common to U.S. and China which result in non-linear and dynamic behavior over time. Causal loop diagrams were developed to describe economic relationships, energy consumption, and tension between the U.S. and China. Tension was selected as an underlying surrogate to overall U.S.–China relations. A commercial SD software package, iThink® 10.0.6, was used to build a model composed of four sectors of common concern: energy demand and resources, demographics and stability, economics, and military actions. These sector models were then used to model tension between the U.S. and China over the next 25 years.

An interface to the SD model was developed that allowed users to run simulations whose dynamic outputs were determined by the model's relationships and user defined values for key variables. The intent was to provide a tool that would assist policy makers to better understand how the system's variables are related, how they influence one another, and how they are influenced by the system's external environment. The simulation tool also supported decision / policy making by allowing analysts to explore the effects of these variables on potential futures. The tool was provided as part of an SMA products package to a treatment group of participants in a war-gaming simulation to investigate the usefulness of SMA products to combatant commands.

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APPENDIX A – MODEL VARIABLES AND DEFINITIONS

Additional Destabilizing Actions	Based on conversations with subject matter experts at CEIP, START and Monitor 360, five categories of military actions were developed. These actions are considered to be destabilizing actions that increase tension. (Dimensionless)
Centenarian Rate	Rate at which seniors leave the potential protestor population. (People/year)
Child Migration	Rate at which children migrate out of China. (People/year)
Childhood Mortality Rate	Rate at which children leave the total Chinese population. (People/year)
Children	Total number of children in the Chinese population. (People)
Contact Rate	Control variable which governs the flow of people from the potential protestor group to the protestor group. (Dimensionless)
Crude Birth Rate	Rate at which the total Chinese population can generate children. (People/year)
Direct PRC Actions to Lower Tension	Actions taken by China to reduce the level of tension in US-China relations. (dimensionless)
Direct US Actions to Lower Tension	Actions taken by the US to reduce the level of tension in US-China relations. (dimensionless)
Economic Dissatisfaction	Fraction of Chinese population dissatisfied due to economic concerns. (Dimensionless)
Energy Demand per PRC HH	Annualized Chinese energy demand per household (HH) in BTU equivalents. Chinese household energy demand per household is forecast to decrease from 2015 to 2040 due to a combination of factors, including a reduced number of persons per household, more energy efficient buildings, and planned upgrades to energy transmission infrastructure.
Environmental Concerns	Fraction of Chinese population dissatisfied due to environmental concerns. (Dimensionless)
Ethnic Conflict	Fraction of Chinese population dissatisfied due to ethnic concerns. (Dimensionless)
Governance Dissatisfaction	Fraction of Chinese population dissatisfied due to governance concerns. (Dimensionless)

Intentional Quasi Military Destabilizing Event	An example of an intentional quasi-military action would be the establishment of an exclusion zone by China. Usually the purpose of this would be to gauge the resolve of the opposing nation. In the example of the most recent exclusion zone established by China, the U.S. and Japan responded with their quasi-military action of continuing to send aircraft or ships through the zone. These incidents have the potential to escalate based on the resolve of each nation. When China set up the exclusion zone and the U.S. and Japan sent fighters through the zone, China scrambled jets but did not escalate the situation further.
Intentional Quasi Military Event Frequency	Frequency with which this type of event will occur. Probability will affect each year of occurrence.
Intentional Quasi Military Event On?Off	Control variable which turns this type of event on or off. "Off" is equivalent to setting event probability to zero.
Intentional Quasi Military Event Probability	Probability that this type of event will occur in the year and with the frequency specified.
Intentional Quasi Military Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.' The event will re-occur every xx years, as specified by frequency.
Live Births	Rate at which children join the total Chinese population. Random variable with Normal distribution. (People/year)
Majority Rate	Rate at which children become young adults (People/yr)
Maturing Rate	Rate at which young adults become mid-adults (People)
Mid Adult Death Rate	Rate at which mid-adults leave the total Chinese population. (People/year)
Mid Adult Migration	Rate at which mid-adults migrate out of China. (People/year)
Mid Adults	Total number of mid-adults in the Chinese population. (People)
Net Migration Rate	Rate at which all population groups migrate out of China.(People/year)
North Korea On?Off	Control variable which turns this type of event on or off. Equivalent to setting event probability to zero.
North Korean Destabilizing Event	Currently, China has publicly condemned North Korea's pursuit of nuclear weapons. However, a change in rhetoric by North Korea, such as the threat of collapse, could alter China's policy toward North Korea. It could cause China to change its stance on North Korea's nuclear ambitions. This would likely lead to more aggressive U.S. intervention to stop nuclear proliferation, and this would certainly raise tensions to the highest levels.
North Korean Destabilizing Event Probability	Probability that this type of event will occur in the year and with the frequency specified.

North Korean Destabilizing Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.' The event will re-occur every xx years, as specified by frequency.
Number of PRC Households	Projected number of households in China The number of Chinese households is forecast to increase in 25 years from approximately 430 million to a little over 500 million. This is due to both projected population increase and decreasing average Chinese household size. Household size is decreasing due to a combination of Chinese incentives promoting urbanization, reduced number of children per couple, and a growing middle class which tends to have fewer children per household.
Potential Protesters	Group within the total Chinese population that has the potential to become protestors. The very young and very old typically do not become protestors. (People)
Potential Protestor Flow	Rate at which the total adult population can become potential protestors. (People/year)
PRC Aggressive Influencing Action	Action taken by the Chinese to increase actual/perceived influence. The use of the word aggressive signifies that this action is beyond normal Chinese action and is meant to send a clear message. (dimensionless)
PRC Change in Inventories	Projected Chinese on hand inventories ($Billions 2012)
PRC Change in Inventories Rate	Control variable allowing user to input a percentage change in Chinese inventories .
PRC Coal Consumption	Stock representing Chinese Coal consumption (Quadrillion BTU)
PRC Coal Import	Graphical variable of projected yearly coal imports (Quadrillion BTU)
PRC Desired Level of Own Influence	Level of influence China desires to have within the PACOM AOR. (dimensionless)
PRC Desired US Influence	Level of influence China desires the US to have within the PACOM AOR. (dimensionless)
PRC Domestic Coal Production	Graphical variable of projected yearly coal production (Quadrillion BTU)
PRC Domestic LNG LPG Production	Graphical variable of projected yearly domestic LNG/LPG production (Quadrillion BTU)
PRC Domestic Oil Production	Graphical variable of projected yearly domestic oil production (Quadrillion BTU)
PRC Economic Driver	Control variable linking Chinese GDP to influence within the PACOM AOR. (dimensionless)
PRC Economic Influencing Action	Economic actions China takes to reduce the level of tension in US-China relations. (dimensionless)

PRC Energy Environmental Damage Percentage	Percentage of energy resources consumed from domestic environmentally-damaging sources such as coal, oil and LNG-LPG with respect to China's overall total energy resource consumption. The higher the percentage, the more potential damage might be done to China's environment. (%)
PRC Energy Import Risk Percentage	Percent of total Chinese energy consumption provided by imports. (%) As China becomes more reliant on external sources of energy to meet its economic goals, the state perceives more risk to its energy import activities by other nations. That risk is one driver why China is looking to expand its near off-shore influence and control as well as expand the reach of the PLAN to protect vital energy import sea lanes.
PRC Export Rate	Control variable allowing user to input a percentage change in Chinese gross export.
PRC Exports	Projected Chinese gross exports. ($Billions 2012)
PRC Final Consumption Expenditure	Project Chinese govt and household expenditures. ($Billions 2012)
PRC GDP	Projected total Chinese Gross Domestic Product. ($Billions 2012)
PRC GDP Per Capita	Chinese Per capita GDP. ($Billions 2012/person)
PRC Govt Defense Expenditure	Projected Chinese govt defense expenditures. ($Billions 2012)
PRC Govt Defense Expenditure Rate	Control variable allowing user to input a percentage change in Chinese DE.
PRC Govt NDE Rate	Control variable allowing user to input a percentage change in Chinese NDE.
PRC Govt NonDefense Expenditure	Projected Chinese govt non-defense expenditures. ($Billions 2012)
PRC Gross Capital Formation	Projected Chinese capital formation which includes fixed capital and value of inventories. ($Billions 2012)
PRC Gross Fixed Capital Formation	Projected Chinese capital formation. ($Billions 2012)
PRC Gross Fixed Capital Formation Rate	Control variable allowing user to input a percentage change in Chinese gross fixed capital formation.
PRC HCE Rate	Control variable allowing user to input a percentage change in Chinese HCE.
PRC Heavy Industry Demand	The Chinese economy's projected demand for energy to support construction, mining, commercial transportation, traditional manufacturing, etc. The majority of Chinese military energy demand falls into this category. (Quadrillion BTU)
PRC Heavy Industry Energy Demand	Graphical variable of the Chinese economy's projected demand for energy to support construction, mining, commercial transportation, traditional manufacturing, etc. The majority of Chinese military energy demand falls into this category. (Quadrillion BTU)

PRC Heavy Industry Energy Flow	The Chinese economy's projected annualized demand for energy to support construction, mining, commercial transportation, traditional manufacturing, etc. The majority of Chinese military energy demand falls into this category. (Quadrillion BTU/year)
PRC HH Demand	The Chinese household's projected demand for energy (Quadrillion BTU)
PRC HH Demand Flow	The Chinese household's projected annualized demand for energy. (Quadrillion BTU/year)
PRC HH Energy Demand Annualized	Graphical variable of the Chinese economy's projected demand for energy. (Quadrillion BTU)
PRC Household Consumption Expenditure	Projected Chinese household consumptions expenditures. ($Billions 2012)
PRC Hydro Electric Production	Chinese projected production of energy from hydroelectric energy sources. (Quadrillion BTU)
PRC Import Rate	Control variable allowing user to input a percentage change in Chinese gross imports.
PRC Imports	Gross Chinese imports. Affected by Total_PRC_Energy_Consumption. ($Billions 2012)
PRC LNG LPG Consumption	Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG): Broken down by amount imported primarily by sea through the PACOM AOR and by existing or planned pipelines from the 2014 Russian-Chinese LNG-LPG agreement and domestically produced. (Quadrillion BTU)
PRC LNG LPG Imports	Graphical variable of the Chinese economy's projected demand for imported Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG) (Quadrillion BTU)
PRC Net Exports	Projected Chinese net exports. Net exports are influenced by the number of Chinese protestors in the social and demographics sub-model. ($Billions 2012)
PRC NHR Consumption	Nuclear-Hydroelectric-Renewables (NHR) broken down by domestic nuclear production, hydro-electric production, and renewables to include solar, wind and biomass production. (Quadrillion BTU)
PRC Non HH Energy Demand	Total energy demand from Chinese heavy industry and non-industrial sources. (Quadrillion BTU)
PRC Non Industrial Energy Demand	Graphical variable of the Chinese economy's projected demand for energy to support information technologies, office buildings, education facilities, health care facilities, etc. The majority of Chinese state government energy demand falls into this category with the exception of state owned heavy industrial companies. (Quadrillion BTU)

PRC Non Industrial Demand	The Chinese economy's projected demand for energy to support information technologies, office buildings, education facilities, health care facilities, etc. The majority of Chinese state government energy demand falls into this category with the exception of state owned heavy industrial companies. (Quadrillion BTU)
PRC Non Industrial Energy Flow	The Chinese economy's projected annualized demand for for energy to support information technologies, office buildings, education facilities, health care facilities, etc. The majority of Chinese state government energy demand falls into this category with the exception of state owned heavy industrial companies. (Quadrillion BTU/year)
PRC Nuclear Production	Chinese projected production of energy from all nuclear energy sources. (Quadrillion BTU)
PRC Oil Consumption	Stock representing Chinese oil consumption; primary liquid crude, broken down by amount imported and domestically produced. (Quadrillion BTU)
PRC Oil Import	Graphical variable of projected yearly oil imports (Quadrillion BTU)
PRC Perceived PRC Influence	Level of influence China perceives itself as having within the PACOM AOR. (dimensionless)
PRC Perceived US Influence	Level of influence China perceives the US as having within the PACOM AOR. (dimensionless)
PRC Renewables Production	Chinese projected production of energy from all renewable (except hydroelectric) energy sources. (Quadrillion BTU)
PRNK Destab Event Freq	Frequency with which this type of event will occur. Probability will affect each year of occurrence.
Protest Impact on Influence	Control variable linking civil unrest in China with Chinese influence within the PACOM AOR. (dimensionless)
Protest Indicator	Control variable set when the total number of protestors increases faster that a given rate. (Dimensionless)
Protester Rate	Rate at which the population of potential protestors becomes protestors. (People/year)
Protesters	Total Chinese population of protestors. (People)
Radicalization Fraction	Control variable which governs the flow of people from the potential protestor group to the protestor group. Contains economic, social, and governance dissatisfaction. (Dimensionless)
Religious Conflict	Fraction of Chinese population dissatisfied due to religious concerns. (Dimensionless)
Retirement Rate	Rate at which mid-adults become seniors. (People/year)
ROC Destab Event Freq	Frequency with which this type of event will occur. Probability will affect each year of occurrence.

Russian LNG LPG Import Deal	Graphical variable depicting potential for China and Russia to agree to LNG/LPG pipeline and trade agreement. (Quadrillion BTU)
Senior Death Rate	Rate at which seniors leave the total Chinese population(People/year)
Senior Migration	Rate at which seniors migrate out of China. (People/year)
Seniors	Total number of seniors in the Chinese population(People)
Social Dissatisfaction	Fraction of Chinese population dissatisfied due to religious, ethnic, or environmental concerns. (Dimensionless)
Stabilizing Actions	Actions taken by the US or China to reduce the level of tension in relations. (dimensionless)
Taiwan On?Off	Control variable which turns this type of event on or off. Equivalent to setting event probability to zero.
Taiwanese Destabilizing Event	This is the least likely but also the most dangerous scenario. This will bring tensions to the highest levels and likely lead to war if the situation isn’t balanced by a stabilizing action. An example of this would be if the Chinese government loses patience with the continued sale of U.S. arms to Taiwan, or if the U.S. gives Taiwan a new technology that significantly increases Taiwan’s defense capabilities. This could cause the Chinese to respond with an aggressive military action.
Taiwanese Destabilizing Event Probability	Probability that this type of event will occur in the year and with the frequency specified.
Taiwanese Destabilizing Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.’ The event will re-occur every xx years, as specified by frequency.
Tension between US and China	Analogue for US-Chinese relations. (dimensionless)
Third Party Destab Event Freq	Frequency with which this type of event will occur. Probability will affect each year of occurrence.
Third Party Destabilizing Event	This is different from the 2nd category because it originates with an action initiated from a third party whereas the above scenario deals with a Chinese or U.S. action specifically in Taiwan or North Korea. An example of this would be if Japan took actions to aggressively occupy South China Sea islands, and was confronted by Chinese military units. Even though the U.S. may not agree with Japanese actions, they could get dragged into a conflict based on their treaty obligations. Similarly, if North Korea’s nuclear development reaches a level that the U.S. perceives as dangerous, this could cause the U.S. to take action, and these actions could invoke the Sino-North Korean treaty obligating China to get involved. This scenario likely could be resolved by China and U.S. unless one of those two nations responds very aggressively to the third party.
Third Party Destabilizing Event Probability	Probability that this type of event will occur in the year and with the frequency specified.

Third Party Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.' The event will re-occur every xx years, as specified by frequency.
Third Party On?Off	Control variable which turns this type of event on or off. Equivalent to setting event probability to zero.
Total Adult Population	Total Chinese adult population. (People)
Total Population	Total Chinese population. (People)
Total PRC Coal Consumption	Projected annualized projected PRC coal consumption (Quadrillion BTU)
Total PRC Coal Consumption Flow	Flow variable to translate Total_PRC_Coal_Consumption into a stock (Quadrillion BTU/year)
Total PRC Consumption Annualized Flow	Projected, annualized flow variable translating Chinese energy resource consumption into a stock. (Quadrillion BTU/year)
Total PRC Demand Annualized Flow	Flow variable to translate total annual energy into a stock (Quadrillion BTU/year)
Total PRC Energy Consumption	Projected Chinese energy resource consumption in four primary categories: Coal, oil, LNG/LPG/, and Nuclear/Hydro/Renewables. (Quadrillion BTU)
Total PRC Energy Demand	Total Chinese energy demand from household, heavy industry, and non-industrial demand sources. (Quadrillion BTU)
Total PRC LNG LPG Consumption	The Chinese economy's projected annual demand for Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG) (Quadrillion BTU/year)
Total PRC LNG LPG Consumption Flow	The Chinese household's projected annualized demand for LNG/LPG. (Quadrillion BTU/year)
Total PRC NHR Consumption	Projected annualized projected PRC NHR consumption (Quadrillion BTU)
Total PRC NHR Consumption Flow	Flow variable to translate NHR consumption into a stock (Quadrillion BTU/year)
Total PRC Oil Consumption	The Chinese economy's projected annual demand for oil. (Quadrillion BTU/year)
Total PRC Oil Consumption Flow	Flow variable to translate Total_PRC_Oil_Consumption into a stock (Quadrillion BTU/year)
Unintentional Quasi Military Destabilizing Event	An example of an unintentional action is a collision at sea by a Chinese vessel and one from a U.S. or allied nation. This situation could potentially escalate depending on the actions of the local actors involved. In the past, these situations have raised tensions but usually are resolved through discussions between leaders of both governments.
Unintentional Quasi Military Event Frequency	Frequency with which this type of event will occur. Probability will affect each year of occurrence.
Unintentional Quasi Military Event On?Off	Control variable which turns this type of event on or off. Equivalent to setting event probability to zero.

Unintentional Quasi Military Event Probability	Probability that this type of event will occur in the year and with the frequency specified.
Unintentional Quasi Military Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.' The event will re-occur every xx years, as specified by frequency.
US Aggressive Influencing Action	Action taken by the US to increase actual/perceived influence. The use of the word aggressive signifies that this action is beyond normal US action and is meant to send a clear message. (dimensionless)
US Change in Inventories	Projected US on hand inventories ($Billions 2012)
US Change in Inventories Rate	Control variable allowing user to input a percentage change in US inventories.
US Desired Level of Own Influence	Level of influence the US desires within PACOM AOR. (dimensionless)
US Desired PRC Influence	Level of influence the US desires China to have within the PACOM AOR. (dimensionless)
US Economic Driver	Control variable linking US GDP to influence within the PACOM AOR. (dimensionless)
US Economic Influencing Action	Economic actions the US takes to reduce the level of tension in US-China relations. (dimensionless)
US Export Rate	Control variable allowing user to input a percentage change in US gross export.
US Exports	Projected US gross exports. ($Billions 2012)
US Final Consumption Expenditure	Project US govt and household expenditures. ($Billions 2012)
US GDP	Projected total US Gross Domestic Product. ($Billions 2012)
US Govt Defense Expenditure	Projected US govt defense expenditures. ($Billions 2012)
US Govt Defense Expenditure Rate	Control variable allowing user to input a percentage change in US DE.
US Govt NDE Rate	Control variable allowing user to input a percentage change in US NDE.
US Govt NonDefense Expenditure	Projected US govt non-defense expenditures. ($Billions 2012)
US Gross Capital Formation	Projected US capital formation which includes fixed capital and value of inventories. ($Billions 2012)
US Gross Fixed Capital Formation	Projected US capital formation. ($Billions 2012)
US Gross Fixed Capital Formation Rate	Control variable allowing user to input a percentage change in US gross fixed capital formation.
US Household Consumption Expenditure (HCE) Rate	Control variable allowing user to input a percentage change in US Household Consumption Expenditure.
US Household Consumption Expenditure	Projected US household consumptions expenditures. ($Billions 2012)

US Import Rate	Control variable allowing user to input a percentage change in US gross imports.
US Imports	Gross US imports. Affected by Total_PRC_Energy_Consumption. ($Billions 2012)
US Net Exports	Projected US net exports. Net exports are influenced by the number of US protestors in the social and demographics sub-model. ($Billions 2012)
US Perceived PRC Influence	Level of influence the US perceives China as having within the PACOM AOR. (dimensionless)
US Perceived US Influence	Level of influence the US perceives itself as having within the PACOM AOR. (dimensionless)
Young Adult Death Rate	Rate at which young adults leave the total Chinese population(People/year)
Young Adult Migration	Rate at which young adults migrate out of China. (People/year)
Young Adults	Total number of young adults in the Chinese population(People)

APPENDIX B – FULL MODEL EQUATIONS LISTING

The following equation listing is generated by the iThink software package, and represents a complete listing of the equations that constitute the systems dynamics model.

Potential_Protesters(t) = Potential_Protesters(t - dt) + (Potential_Protestor_Flow - Protester_Rate) * dt

INIT Potential_Protesters = 0.99*INIT(Total_Adult_Population)

INFLOWS:

Potential_Protestor_Flow = Total_Adult_Population-DELAY(Total_Adult_Population,1)

OUTFLOWS:

Protester_Rate = Potential_Protesters*Contact_Rate*Radicalization_Fraction*(Protesters/Total_Adult_Population)

PRC_Coal__Consumption(t) = PRC_Coal__Consumption(t - dt) + (Total_PRC_Coal_Consumption_Flow) * dt

INIT PRC_Coal__Consumption = 78

INFLOWS:

Total_PRC_Coal_Consumption_Flow = Total_PRC__Coal_Consumption

PRC_GDP(t) = PRC_GDP(t - dt) + (PRC_Net_Exports + PRC_Gross_Capital_Formation + PRC_Final_Consumption_Expenditure) * dt

INIT PRC_GDP = 2000

INFLOWS:

PRC_Net_Exports = IF Protesters-delay(Protesters,1)>1.01 THEN (PRC_Exports-PRC_Imports-(delay(PRC_Exportfus,1)-delay(PRC_Imports,1)))-TRIANGULAR(0,45,90) ELSE (PRC_Exports-PRC_Imports-(delay(PRC_Exports,1)-delay(PRC_Imports,1)))

PRC_Gross_Capital_Formation = PRC_Gross_Fixed_Capital_Formation+PRC_Change_in_Inventories-(delay(PRC_Gross_Fixed_Capital_Formation,1)+delay(PRC_Change_in_Inventories,1))

PRC_Final_Consumption_Expenditure = PRC_Govt_NonDefense__Expenditure+PRC_Household_Consumption_Expenditure+PRC_Govt_Defense_Expenditure-(delay(PRC_Govt_NonDefense__Expenditure,1)+delay(PRC_Household_Consumption_Expenditure,1)+delay(PRC_Govt_Defense_Expenditure,1))

PRC_Heavy_Industry_Demand(t) = PRC_Heavy_Industry_Demand(t - dt) + (PRC_Heavy_Industry_Energy_Flow) * dt

INIT PRC_Heavy_Industry_Demand = 66

INFLOWS:

PRC_Heavy_Industry_Energy_Flow = PRC_Heavy_Industry_Energy_Demand-delay(PRC_Heavy_Industry_Energy_Demand,1)

PRC_HH_Demand(t) = PRC_HH_Demand(t - dt) + (PRC_HH_Demand_Flow) * dt

INIT PRC_HH_Demand = 43

INFLOWS:

PRC_HH_Demand_Flow = PRC_HH_Energy_Demand_Annualized

PRC_LNG_LPG_Consumption(t) = PRC_LNG_LPG_Consumption(t - dt) + (Total_PRC_LNG_LPG__Consumption_Flow) * dt

INIT PRC_LNG_LPG_Consumption = 9.6

INFLOWS:

Total_PRC_LNG_LPG__Consumption_Flow = Total_PRC_LNG__LPG_Consumption

PRC_NHR__Consumption(t) = PRC_NHR__Consumption(t - dt) + (Total_PRC_NHR_Consumption_Flow) * dt

INIT PRC_NHR__Consumption = 10.8

INFLOWS:

Total_PRC_NHR_Consumption_Flow = Total_PRC_NHR_Consumption

PRC_Non_Industrial_Demand(t) = PRC_Non_Industrial_Demand(t - dt) + (PRC_Non_Industrial_Energy_Flow) * dt

INIT PRC_Non_Industrial_Demand = 11

INFLOWS:

PRC_Non_Industrial_Energy_Flow = PRC_Non_Industrial__Energy_Demand-delay(PRC_Non_Industrial__Energy_Demand,1)

PRC_Oil__Consumption(t) = PRC_Oil__Consumption(t - dt) + (Total_PRC_Oil__Consumption_Flow) * dt

INIT PRC_Oil__Consumption = 21.6

INFLOWS:

Total_PRC_Oil__Consumption_Flow = Total_PRC__Oil_Consumption

PRC_Perceived_PRC_Influence(t) = PRC_Perceived_PRC_Influence(t - dt) + (PRC_Economic_Influencing_Action - US_Aggressive_Influencing_Action - Protest_Impact_on_Influence) * dt

INIT PRC_Perceived_PRC_Influence = 0

INFLOWS:

PRC_Economic_Influencing_Action = PRC_Economic_Driver

OUTFLOWS:

US_Aggressive_Influencing_Action = IF US_Desired_Level__of_Own_Influence-US_Perceived_US_Influence >= 0 OR US_Desired_PRC_Influence-US_Perceived_PRC_Influence < 0 THEN 5 ELSE 0

Protest_Impact_on_Influence = Protest_Indicator

Protesters(t) = Protesters(t - dt) + (Protester_Rate) * dt

INIT Protesters = .01*INIT(Total_Adult_Population)

INFLOWS:

Protester_Rate = Potential_Protesters*Contact_Rate*Radicalization_Fraction*(Protesters/Total_Adult_Population)

Tension_between__US_and_China(t) = Tension_between__US_and_China(t - dt) + (US_Aggressive_Influencing_Action + PRC_Aggessive_Influencing_Action + Additional_Destabilizing_Actions - Stabilizing_Actions) * dt

INIT Tension_between__US_and_China = 0

INFLOWS:

US_Aggressive_Influencing_Action = IF US_Desired_Level__of_Own_Influence-US_Perceived_US_Influence >= 0 OR US_Desired_PRC_Influence-US_Perceived_PRC_Influence < 0 THEN 5 ELSE 0

PRC_Aggessive_Influencing_Action = IF PRC_Desired_Level_of_Own_Influence-PRC_Perceived_PRC_Influence >= 0 OR PRC_Desired_US_Influence-PRC_Perceived_US_Influence < 0 THEN 5 ELSE 0

Additional_Destabilizing_Actions = Third_Party_Destabilizing_Event+Intentional_Quasi_Military_Destabilizing_Event+Unintentional_Quasi_Military_Destabilizing_Event+North_Korean_Destabilizing_Event+Taiwanese__Destabilizing_Event

OUTFLOWS:

Stabilizing_Actions = Direct_PRC_Actions_to_Lower_Tension+Direct_US_Actions_to_Lower_Tension

Total_PRC_Energy_Consumption(t) = Total_PRC_Energy_Consumption(t - dt) + (Total_PRC_Consumption__Annualized_Flow) * dt

INIT Total_PRC_Energy_Consumption = 120

INFLOWS:

Total_PRC_Consumption__Annualized_Flow = Total_PRC__Coal_Consumption+Total_PRC__Oil_Consumption+Total_PRC_LNG__LPG_Consumption+Total_PRC_NHR_Consumption

Total_PRC_Energy_Demand(t) = Total_PRC_Energy_Demand(t - dt) + (Total_PRC_Demand_Annualized_Flow) * dt

INIT Total_PRC_Energy_Demand = 120

INFLOWS:

Total_PRC_Demand_Annualized_Flow = PRC_Non_HH_Energy_Demand+PRC_HH_Energy_Demand_Annualized

US_GDP(t) = US_GDP(t - dt) + (US_Net_Exports + US_Final_Consumption_Expenditure + US_Gross_Capital_Formation) * dt

INIT US_GDP = 2000

INFLOWS:

US_Net_Exports = US_Exports-US_Imports-(delay(US_Exports,1)-delay(US_Imports,1))

US_Final_Consumption_Expenditure = US_Govt_NonDefense__Expenditure+US_Household_Consumption_Expenditure+US_Govt_Defense_Expenditure-(delay(US_Govt_NonDefense__Expenditure,1)+delay(US_Household_Consumption_Expenditure,1)+delay(US_Govt_Defense_Expenditure,1))

US_Gross_Capital_Formation = US_Gross_Fixed_Capital_Formation+US_Change_in_Inventories-(delay(US_Gross_Fixed_Capital_Formation,1)+delay(US_Change_in_Inventories,1))

US_Perceived_US_Influence(t) = US_Perceived_US_Influence(t - dt) + (US_Economic_Influencing_Action - PRC_Aggessive_Influencing_Action) * dt

INIT US_Perceived_US_Influence = 0

INFLOWS:

US_Economic_Influencing_Action = US_Economic_Driver

OUTFLOWS:

PRC_Aggessive_Influencing_Action = IF PRC_Desired_Level_of_Own_Influence-PRC_Perceived_PRC_Influence >= 0 OR PRC_Desired_US_Influence-PRC_Perceived_US_Influence < 0 THEN 5 ELSE 0

Children(t) = Children(t - dt) + (Live_Births - Majority_Rate - Childhood_Mortality_Rate - Child_Migration) * dt

INIT Children = 20775369, 18790521, 18024484, 15893800, 15225032, 15399559, 13935714, 14454357, 14248825, 13666956, 13429161, 14804470, 14732137, 15220041, 15250805, 15617375, 15657955, 13786434

TRANSIT TIME = 18

CAPACITY = INF

INFLOW LIMIT = INF

INFLOWS:

Live_Births = NORMAL(Total_Population*Crude_Birth_Rate/1000, 1000000)

OUTFLOWS:

Majority_Rate = CONVEYOR OUTFLOW

Childhood_Mortality_Rate = LEAKAGE OUTFLOW

LEAKAGE FRACTION = 17.62*(Live_Births/1000)/Children

LEAK ZONE = 0% to 10%

Child_Migration = LEAKAGE OUTFLOW

LEAKAGE FRACTION = .2*Net_Migration_Rate

LEAK ZONE = 0% to 100%

Mid_Adults(t) = Mid_Adults(t - dt) + (Maturing_Rate - Retirement__Rate - Mid_Adult_Death_Rate - Mid_Adult_Migration) * dt

INIT Mid_Adults = 9951467, 10791633, 11276853, 13029125 , 13618204, 13701998, 16167933, 16093888, 17738127, 17610528, 16847642, 18351980, 16617709, 12838832, 14097008, 11228960, 20075084, 26972157, 23355778, 23962574, 24012158, 21355748, 27032542, 24956297, 27397219

TRANSIT TIME = 25

CAPACITY =

INFLOW LIMIT =

INFLOWS:

Maturing_Rate = CONVEYOR OUTFLOW

OUTFLOWS:

Retirement__Rate = CONVEYOR OUTFLOW

Mid_Adult_Death_Rate = LEAKAGE OUTFLOW

LEAKAGE FRACTION = 0.001

LEAK ZONE = 42% to 100%

Mid_Adult_Migration = LEAKAGE OUTFLOW

LEAKAGE FRACTION = 0.3*Net_Migration_Rate

LEAK ZONE = 0% to 100%

Seniors(t) = Seniors(t - dt) + (Retirement__Rate - Centenarian_Rate - Senior_Death_Rate - Senior_Migration) * dt

INIT Seniors = 35934, 38231,54689, 68648, 90889, 117522, 156456, 209291, 287676, 371079, 553805, 715398, 858879, 1065276, 1344215, 1648160, 1824190, 2237138, 2757918, 2816693, 3737259, 3706915, 4254858, 5082383, 5175500, 5632477, 6080173, 6343869, 6893225, 6265718, 7389412, 7715897, 7740868, 7942141, 8640965, 9073411

TRANSIT TIME = 36

CAPACITY =

INFLOW LIMIT =

INFLOWS:

Retirement__Rate = CONVEYOR OUTFLOW

OUTFLOWS:

Centenarian_Rate = CONVEYOR OUTFLOW

Senior_Death_Rate = LEAKAGE OUTFLOW

LEAKAGE FRACTION = 0.99

LEAK ZONE = 28.999999999999996% to 100%

Senior_Migration = LEAKAGE OUTFLOW

LEAKAGE FRACTION = .1*Net_Migration_Rate

LEAK ZONE = 0% to 100%

Young_Adults(t) = Young_Adults(t - dt) + (Majority_Rate - Maturing_Rate - Young_Adult_Death_Rate - Young_Adult_Migration) * dt

INIT Young_Adults = 25211795, 24730460, 23990208, 22906980, 21186516, 20689024, 18179478, 19474874, 19866458, 18928369, 19568009, 22322147, 19480836, 19709177, 19933683, 22658768, 25695955, 24474192, 26556649, 28026954, 21543466, 20755274

TRANSIT TIME = 22

CAPACITY =

INFLOW LIMIT =

INFLOWS:

Majority_Rate = CONVEYOR OUTFLOW

OUTFLOWS:

Maturing_Rate = CONVEYOR OUTFLOW

Young_Adult_Death_Rate = LEAKAGE OUTFLOW

LEAKAGE FRACTION = 0.001

LEAK ZONE = 0% to 100%

Young_Adult_Migration = LEAKAGE OUTFLOW

LEAKAGE FRACTION = .4*Net_Migration_Rate

LEAK ZONE = 0% to 100%

Contact_Rate = 2

Crude_Birth_Rate = 12.21

Direct_PRC_Actions_to_Lower_Tension = IF(PRC_Economic_Driver<0)THEN(TRIANGULAR(1,5,10))ELSE(0)

Direct_US_Actions_to_Lower_Tension = IF(US_Economic_Driver>=5)THEN(TRIANGULAR(1,5,10))ELSE(0)

Economic_Dissatisfaction = IF PRC_GDP_Per_Capita/DELAY(PRC_GDP_Per_Capita,1)<1.01 THEN 0.3 ELSE 0.2

Energy_Demand_per_PRC_HH = GRAPH(TIME)

(2015, 1e+008), (2016, 1e+008), (2017, 1e+008), (2018, 1e+008), (2019, 1e+008), (2020, 1e+008), (2021, 9.9e+007), (2022, 9.9e+007), (2023, 9.9e+007), (2024, 9.9e+007), (2025, 9.9e+007), (2026, 9.8e+007), (2027, 9.8e+007), (2028, 9.8e+007), (2029, 9.7e+007), (2030, 9.7e+007), (2031, 9.7e+007), (2032, 9.6e+007), (2033, 9.6e+007), (2034, 9.5e+007), (2035, 9.5e+007), (2036, 9.5e+007), (2037, 9.4e+007), (2038, 9.4e+007), (2039, 9.3e+007), (2040, 9.3e+007)

Environmental_Concerns = 0.1*(PRC_Energy_Environmental_Damage_Percentage/DELAY(PRC_Energy_Environmental_Damage_Percentage,1))

Ethnic_Conflict = 0.05

Governance_Dissatisfaction = 0.1

Intentional_Quasi_MilitaryEvent_Year = 5

Intentional_Quasi_Military_Destabilizing_Event = Intentional_Quasi_Military_Event_On?Off*(IF RANDOM(0,1)<=Intentional_Quasi_Military_Event_Probability THEN 1 ELSE 0)*(PULSE(2,Intentional_Quasi_MilitaryEvent_Year,Intentional_Quasi_Military_Event_Frequency))

Intentional_Quasi_Military_Event_Frequency = 30

Intentional_Quasi_Military_Event_On?Off = 0

Intentional_Quasi_Military_Event_Probability = 0

Net_Migration_Rate = 0.00032

North_Korean_Destabilizing_Event = North_Korea__On?Off*(IF (RANDOM(0,1)<=North_Korean_Destabilizing_Event_Probability)THEN 1 ELSE 0)*(PULSE(15,North_Korean_Destabilizing_Event_Year,PRNK_Destab_Event_Freq))

North_Korean_Destabilizing_Event_Probability = 0

North_Korean_Destabilizing_Event_Year = 5

North_Korea__On?Off = 0

Number_of_PRC_Households = GRAPH(TIME)

(2015, 4.3e+008), (2016, 4.3e+008), (2017, 4.4e+008), (2018, 4.4e+008), (2019, 4.5e+008), (2020, 4.5e+008), (2021, 4.5e+008), (2022, 4.6e+008), (2023, 4.6e+008), (2024, 4.7e+008), (2025, 4.7e+008), (2026, 4.7e+008), (2027, 4.8e+008), (2028, 4.8e+008), (2029, 4.8e+008), (2030, 4.8e+008), (2031, 4.9e+008), (2032, 4.9e+008), (2033, 4.9e+008), (2034, 4.9e+008), (2035, 4.9e+008), (2036, 5e+008), (2037, 5e+008), (2038, 5e+008), (2039, 5e+008), (2040, 5e+008)

PRC_Change_in_Inventories = 0.95*(PRC_Change_in_Inventories_Rate*(-33.59071 + 5.6484289*(TIME-2015)+0.7135475*(TIME-(2015+12))^2))

PRC_Change_in_Inventories_Rate = 1

PRC_Coal_Import = GRAPH(TIME)

(2015, 3.72), (2016, 6.64), (2017, 9.54), (2018, 12.3), (2019, 14.9), (2020, 17.2), (2021, 19.0), (2022, 20.3), (2023, 21.1), (2024, 21.4), (2025, 21.6), (2026, 21.9), (2027, 22.1), (2028, 22.4), (2029, 22.8), (2030, 23.2), (2031, 23.4), (2032, 23.6), (2033, 23.8), (2034, 23.8), (2035, 23.7), (2036, 23.4), (2037, 23.2), (2038, 22.9), (2039, 22.4), (2040, 21.9)

PRC_Desired_Level_of_Own_Influence = 60

PRC_Desired_US_Influence = 20

PRC_Domestic__Coal_Production = GRAPH(TIME)

(2015, 74.3), (2016, 75.0), (2017, 75.8), (2018, 76.5), (2019, 77.3), (2020, 78.1), (2021, 78.8), (2022, 79.4), (2023, 80.0), (2024, 80.4), (2025, 80.8), (2026, 81.2), (2027, 81.4), (2028, 81.6), (2029, 81.7), (2030, 81.7), (2031, 81.6), (2032, 81.4), (2033, 81.2), (2034, 80.8), (2035, 80.4), (2036, 80.0), (2037, 79.4), (2038, 78.8), (2039, 78.0), (2040, 77.3)

PRC_Domestic__LNG_LPG__Production = GRAPH(TIME)

(2015, 4.12), (2016, 4.37), (2017, 4.62), (2018, 4.87), (2019, 5.12), (2020, 5.38), (2021, 5.63), (2022, 5.88), (2023, 6.13), (2024, 6.38), (2025, 6.63), (2026, 6.88), (2027, 7.13), (2028, 7.39), (2029, 7.64), (2030, 7.89), (2031, 8.14), (2032, 8.39), (2033, 8.64), (2034, 8.89), (2035, 9.14), (2036, 9.40), (2037, 9.65), (2038, 9.90), (2039, 10.2), (2040, 10.4)

PRC_Domestic__Oil_Production = GRAPH(TIME)

(2015, 9.82), (2016, 9.91), (2017, 9.99), (2018, 10.1), (2019, 10.2), (2020, 10.3), (2021, 10.3), (2022, 10.4), (2023, 10.5), (2024, 10.6), (2025, 10.7), (2026, 10.8), (2027, 10.9), (2028, 10.9), (2029, 11.0), (2030, 11.1), (2031, 11.2), (2032, 11.3), (2033, 11.4), (2034, 11.4), (2035, 11.5), (2036, 11.6), (2037, 11.7), (2038, 11.8), (2039, 11.9), (2040, 12.0)

PRC_Economic_Driver = IF PRC_GDP/DELAY(PRC_GDP,1)<=1.01 THEN 5 ELSE 0

PRC_Energy_Environmental_Damage_Percentage = (PRC_Domestic__Coal_Production+PRC_Domestic__LNG_LPG__Production+PRC_Domestic__Oil_Production)/Total_PRC_Energy_Consumption

PRC_Energy_Import_Risk_Percentage = (PRC_Coal_Import+PRC_Oil_Import+PRC_LNG_LPG_Imports)/Total_PRC_Energy_Consumption

PRC_Exports = 0.95*(PRC_Export_Rate*(-758.5989+95.045751*(TIME-(2015-15))+6.8886838*(TIME-((2015+12)-15))^2))

PRC_Export_Rate = 1

PRC_GDP_Per_Capita = PRC_GDP/Total_Population

PRC_Govt_Defense_Expenditure = 0.95*(PRC_Govt_Defense_Expenditure_Rate*(-48.69051 + 6.1681126*(TIME-2015) + 0.5316626*(TIME-(2015+12))^2))

PRC_Govt_Defense_Expenditure_Rate = IF US_Aggressive_Influencing_Action < 10 THEN 1 ELSE 2

PRC_Govt_NDE_Rate = 1

PRC_Govt_NonDefense__Expenditure = 0.95*(PRC_Govt_NDE_Rate*(-244.3581 +33.652342*(TIME-2015)+2.6964831*(TIME-(2015+12))^2))

PRC_Gross_Fixed_Capital_Formation = 0.95*(PRC_Gross_Fixed_Capital_Formation_Rate*(-1232.572 + 137.99788*(TIME-2015) + 12.71608*(TIME-(2015+12))^2))

PRC_Gross_Fixed_Capital_Formation_Rate = 1

PRC_HCE_Rate = 1

PRC_Heavy_Industry_Energy_Demand = GRAPH(TIME)

(2015, 66.0), (2016, 70.6), (2017, 75.2), (2018, 79.7), (2019, 84.1), (2020, 88.3), (2021, 91.8), (2022, 94.6), (2023, 96.5), (2024, 97.5), (2025, 98.0), (2026, 98.4), (2027, 98.9), (2028, 99.4), (2029, 99.9), (2030, 100), (2031, 101), (2032, 101), (2033, 101), (2034, 101), (2035, 102), (2036, 102), (2037, 102), (2038, 102), (2039, 102), (2040, 102)

PRC_HH_Energy_Demand_Annualized = ((Number_of_PRC_Households*Energy_Demand_per_PRC_HH)/1000000000000000)-delay((Number_of_PRC_Households*Energy_Demand_per_PRC_HH)/1000000000000000,1)

PRC_Household_Consumption_Expenditure = 0.95*(PRC_HCE_Rate*(-699.2904 + 103.77871*(TIME-2015)+8.2602632*(TIME-(2015+12))^2))

PRC_Hydro_Electric__Production = GRAPH(TIME)

(2015, 7.20), (2016, 7.63), (2017, 8.07), (2018, 8.52), (2019, 8.95), (2020, 9.37), (2021, 9.74), (2022, 10.1), (2023, 10.4), (2024, 10.6), (2025, 10.8), (2026, 12.8), (2027, 13.1), (2028, 13.3), (2029, 13.6), (2030, 13.9), (2031, 14.1), (2032, 14.3), (2033, 14.5), (2034, 14.7), (2035, 14.9), (2036, 17.1), (2037, 17.3), (2038, 17.4), (2039, 17.6), (2040, 17.6)

PRC_Imports = 0.95*(IF Total_PRC_Energy_Consumption-HISTORY(Total_PRC_Energy_Consumption,TIME-(2015+12)) > 0.1 THEN 1.05*(PRC_Import_Rate*(-667.5138+81.764536*(TIME-2015)+6.2245124*(TIME-2027)^2)) ELSE PRC_Import_Rate*(-667.5138+81.764536*(TIME-2015)+6.2245124*(TIME-(2015+12))^2))

PRC_Import_Rate = 1

PRC_LNG_LPG_Imports = GRAPH(TIME)

(2015, 5.48), (2016, 4.08), (2017, 2.48), (2018, 2.10), (2019, 3.23), (2020, 2.88), (2021, 4.05), (2022, 5.24), (2023, 6.44), (2024, 7.63), (2025, 7.04), (2026, 6.42), (2027, 7.65), (2028, 8.93), (2029, 10.3), (2030, 11.7), (2031, 11.0), (2032, 14.5), (2033, 15.9), (2034, 17.3), (2035, 18.8), (2036, 15.9), (2037, 17.2), (2038, 18.6), (2039, 19.9), (2040, 21.2)

PRC_Non_HH_Energy_Demand = PRC_Non_Industrial__Energy_Demand+PRC_Heavy_Industry_Energy_Demand-DELAY(PRC_Non_Industrial__Energy_Demand,1)-DELAY(PRC_Heavy_Industry_Energy_Demand,1)

PRC_Non_Industrial__Energy_Demand = GRAPH(TIME)

(2015, 11.0), (2016, 13.2), (2017, 15.6), (2018, 18.1), (2019, 20.6), (2020, 23.1), (2021, 25.4), (2022, 27.8), (2023, 30.3), (2024, 32.9), (2025, 35.7), (2026, 38.5), (2027, 41.4), (2028, 44.3), (2029, 47.4), (2030, 50.5), (2031, 53.5), (2032, 56.5), (2033, 59.3), (2034, 61.6), (2035, 63.8), (2036, 65.7), (2037, 67.7), (2038, 69.4), (2039, 70.8), (2040, 71.8)

PRC_Nuclear__Production = GRAPH(TIME)

(2015, 2.40), (2016, 5.09), (2017, 8.07), (2018, 8.52), (2019, 8.95), (2020, 9.37), (2021, 9.74), (2022, 10.1), (2023, 10.4), (2024, 10.6), (2025, 10.8), (2026, 11.0), (2027, 11.2), (2028, 11.4), (2029, 11.7), (2030, 11.9), (2031, 12.1), (2032, 10.2), (2033, 10.4), (2034, 10.5), (2035, 10.6), (2036, 10.7), (2037, 10.8), (2038, 10.9), (2039, 11.0), (2040, 11.0)

PRC_Oil_Import = GRAPH(TIME)

(2015, 11.8), (2016, 13.2), (2017, 14.7), (2018, 16.1), (2019, 17.6), (2020, 19.1), (2021, 20.4), (2022, 21.7), (2023, 22.8), (2024, 23.7), (2025, 24.6), (2026, 25.5), (2027, 26.4), (2028, 27.3), (2029, 28.3), (2030, 29.3), (2031, 30.2), (2032, 31.1), (2033, 32.0), (2034, 32.8), (2035, 33.5), (2036, 34.2), (2037, 34.9), (2038, 35.5), (2039, 36.0), (2040, 36.5)

PRC_Perceived_US_Influence = 1.05*US_Perceived_US_Influence

PRC_Renewables__Production = GRAPH(TIME)

(2015, 1.20), (2016, 1.27), (2017, 1.35), (2018, 1.42), (2019, 1.49), (2020, 3.12), (2021, 3.25), (2022, 3.36), (2023, 3.45), (2024, 3.53), (2025, 5.39), (2026, 5.50), (2027, 5.61), (2028, 5.71), (2029, 5.82), (2030, 5.93), (2031, 8.05), (2032, 8.17), (2033, 8.30), (2034, 8.40), (2035, 8.50), (2036, 10.7), (2037, 10.8), (2038, 10.9), (2039, 11.0), (2040, 11.0)

PRNK_Destab_Event_Freq = 30

Protest_Indicator = IF Protesters -DELAY(Protesters,1)>0.05 THEN 1 ELSE 0

Radicalization_Fraction = Governance_Dissatisfaction+Economic_Dissatisfaction+Social_Dissatisfaction

Religious_Conflict = 0.01

ROC_Destab_Event_Freq = 30

Russian_LNG_LPG_Import_Deal = GRAPH(TIME)

(2015, 0.00), (2016, 0.00), (2017, 0.00), (2018, 1.43), (2019, 1.43), (2020, 1.43), (2021, 1.43), (2022, 1.43), (2023, 1.43), (2024, 1.43), (2025, 1.43), (2026, 1.43), (2027, 1.43), (2028, 1.43), (2029, 1.43), (2030, 1.43), (2031, 1.43), (2032, 1.43), (2033, 1.43), (2034, 1.43), (2035, 1.43), (2036, 1.43), (2037, 1.43), (2038, 1.43), (2039, 1.43), (2040, 1.43)

Social_Dissatisfaction = Environmental_Concerns+Ethnic_Conflict+Religious_Conflict

Taiwanese_Destabilizing_Event_Probability = 0

Taiwanese_Destabilizing_Event_Year = 5

Taiwanese__Destabilizing_Event = Taiwan_On?Off*(IF RANDOM(0,1)<=Taiwanese_Destabilizing_Event_Probability THEN 1 ELSE 0)*(PULSE(15,Taiwanese_Destabilizing_Event_Year,ROC_Destab_Event_Freq))

Taiwan_On?Off = 0

Third_Party_Destabilizing_Event = Third_Party_On?Off*(IF RANDOM(0,1) <=Third_Party_Destabilizing_Event_Probability THEN 1 ELSE 0)*(PULSE(5,Third_Party_Event_Year,Third_Party_Destab_Event_Freq))

Third_Party_Destabilizing_Event_Probability = 0

Third_Party_Destab_Event_Freq = 30

Third_Party_Event_Year = 5

Third_Party_On?Off = 0

Total_Adult_Population = Young_Adults+Mid_Adults+Seniors

Total_Population = Children+Total_Adult_Population

Total_PRC_LNG__LPG_Consumption = PRC_LNG_LPG_Imports+PRC_Domestic__LNG_LPG__Production+Russian_LNG_LPG_Import_Deal-delay(PRC_LNG_LPG_Imports,1)-delay(PRC_Domestic__LNG_LPG__Production,1)-delay(Russian_LNG_LPG_Import_Deal,1)

Total_PRC_NHR_Consumption = PRC_Nuclear__Production+PRC_Renewables__Production+PRC_Hydro_Electric__Production-delay(PRC_Nuclear__Production,1)-delay(PRC_Renewables__Production,1)-delay(PRC_Hydro_Electric__Production,1)

Total_PRC__Coal_Consumption = PRC_Coal_Import+PRC_Domestic__Coal_Production-delay(PRC_Coal_Import,1)-delay(PRC_Domestic__Coal_Production,1)

Total_PRC__Oil_Consumption = PRC_Domestic__Oil_Production+PRC_Oil_Import-delay(PRC_Domestic__Oil_Production,1)-delay(PRC_Oil_Import,1)

Unintentional_Quasi_MilitaryEvent_Year = 5

Unintentional_Quasi_Military_Destabilizing_Event = Unintentional_Quasi_Military_Event_On?Off*(IF RANDOM(0,1)<=Unintentional_Quasi_Military_Event_Probability THEN 1 ELSE 0)*(PULSE(2,Unintentional_Quasi_MilitaryEvent_Year,Unintentional_Quasi_Military_Event_Frequency))

Unintentional_Quasi_Military_Event_Frequency = 30

Unintentional_Quasi_Military_Event_On?Off = 0

Unintentional_Quasi_Military_Event_Probability = 0

US_Change_in_Inventories = US_Change_in_Inventories_Rate*(27.63913)

US_Change_in_Inventories_Rate = 1

US_Desired_Level__of_Own_Influence = 30

US_Desired_PRC_Influence = 50

US_Economic_Driver = IF US_GDP/DELAY(US_GDP,1)<=1.1 THEN 6 ELSE 0

US_Exports = US_Export_Rate*(352.89447+68.809*(TIME-2015))

US_Export_Rate = 1

US_Govt_Defense_Expenditure = US_Govt_Defense_Expenditure_Rate*(90.868+21.782*(TIME-2015)+1.525*(TIME-(2015+12))^2)

US_Govt_Defense_Expenditure_Rate = IF PRC_Aggessive_Influencing_Action < 10 THEN 1 ELSE 2

US_Govt_NDE_Rate = 1

US_Govt_NonDefense__Expenditure = US_Govt_NDE_Rate*(528.269 + 59.842*(TIME-2015))

US_Gross_Fixed_Capital_Formation = (1152.26+92.294*(TIME-2015))*US_Gross_Fixed_Capital_Formation_Rate

US_Gross_Fixed_Capital_Formation_Rate = 1

US_HCE_Rate = 1

US_Household_Consumption_Expenditure = US_HCE_Rate*(3033.6253 + 349.75623*(TIME-2015))

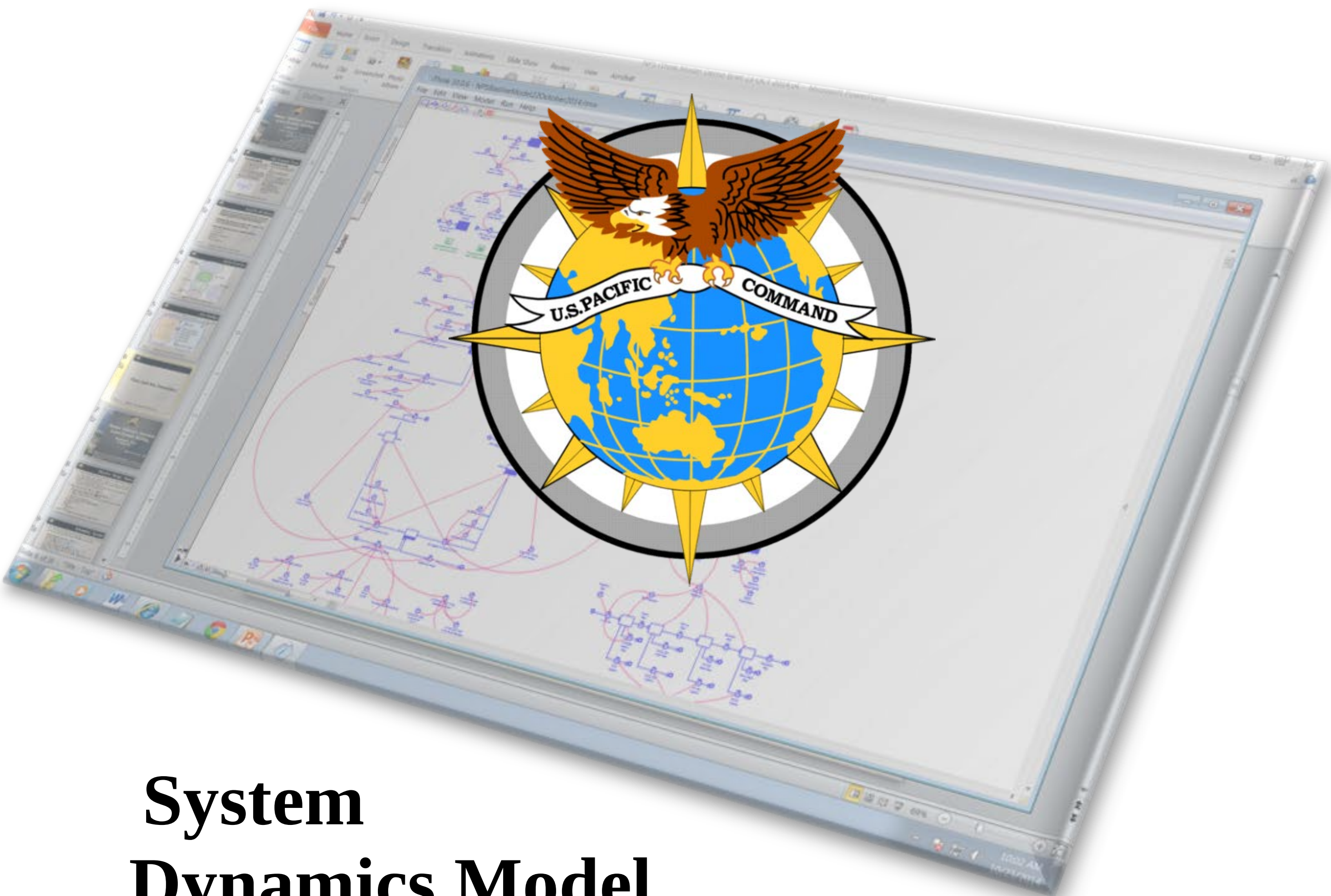
US_Imports = US_Import_Rate*(316.23043+101.68043*(TIME-2015))

US_Import_Rate = 1

US_Perceived_PRC_Influence = 1.05*PRC_Perceived_PRC_Influence

APPENDIX C – QUICK START GUIDE

USPACOM Strategic Multilayer Assessment



System Dynamics Model

Quick Start Guide

8 April 2015

Prepared by:

Naval Postgraduate School
Department of Systems Engineering
777 Dyer Road
Monterey, California 93943-5001

Introduction

This Quick Start Guide addresses the iThink® System Dynamics (SD) model developed by the Naval Postgraduate School as part of a Strategic Multi-Layer Assessment (SMA) for the U.S. Pacific Command (PACOM) entitled "Drivers of Conflict and Convergence in the Asia-Pacific Region in the Next 5-25 Years". The SMA is being conducted to:

1. Examine future political, security, societal, and economic trends.
2. Identify where U.S. strategic interests are in cooperation or conflict with Chinese and other interests worldwide, and in particular, to the East China Sea.
3. Leverage opportunities when dealing with China in a "global context"

The SMA is expected to develop an outline of areas of strategic risks and conflicting interests as well as potential opportunities for encouraging cooperation between the United States and Asia-Pacific regional actors with particular emphasis on East China Sea to better understand the dynamics of this complex environment and relationship. The SMA project's period of performance was January 2014 to March 2015.

In this Quick Start Guide, the term "China" will be used when referring to the nation officially titled the People's Republic of China (PRC). References to the Chinese Communist Party (CCP) refer to the ruling political party of the Chinese government. While comprising many different ethnic groups, those people residing in China will be collectively referred to as Chinese.

Getting Started

iTHINK 10.0.6

iThink is a registered trademark of a commercial SD modeling software package developed and sold by isee Systems, Inc. (http://www.iseesystems.com/) which recommends the following minimum system requirements (Figure 1) to run iThink:

For Windows:
Microsoft Windows™ XP/Vista/7/8
256 MB RAM
200 MB disk space
QuickTime

For Macintosh:
Intel-based Mac
Mac OS 10.6 or higher
256 MB RAM
200 MB disk space

Figure 1. System Requirements for running iThink

The iThink developer's description page can be found on the web at http://www.iseesystems.com/softwares/Business/IthinkSoftware.aspx, along with links to tutorials, available commercial training and seminars, and contact information at isee Systems.

OPENING THE MODEL

iThink files are labeled with a file extension of *.itmx, *.itm, *.itr, or *.itt . The PACOM SMA Model filename is "NPS_Baseline_Model_2014-12-01.itmx". Ensure this file is on the computer and located somewhere you can remember (e.g. on the desktop or in a file with an appropriate name). Once you have the iThink software installed, you can establish a default program association as appropriate for your operating system (Windows or Mac OS). This will enable you to launch the iThink application and load a model by simply double-clicking on the model file with one of the iThink filename extensions.

There are two ways to open the PACOM SD model:

- If you have already set the default program association, double-click the model's filename, NPSBaslineModel07Nov2014-FrontEndAdded.itmx
- You can also first launch the iThink application (e.g. via a shortcut icon on your desktop). iThink will open with a blank, untitled project as shown in Figure 2. Pull down the "File" menu located in the upper left corner of the initial screen, and select "Open…" Follow the pop-up box to locate and select the PACOM SD model file.

Pull down "File" menu to find "Open…"

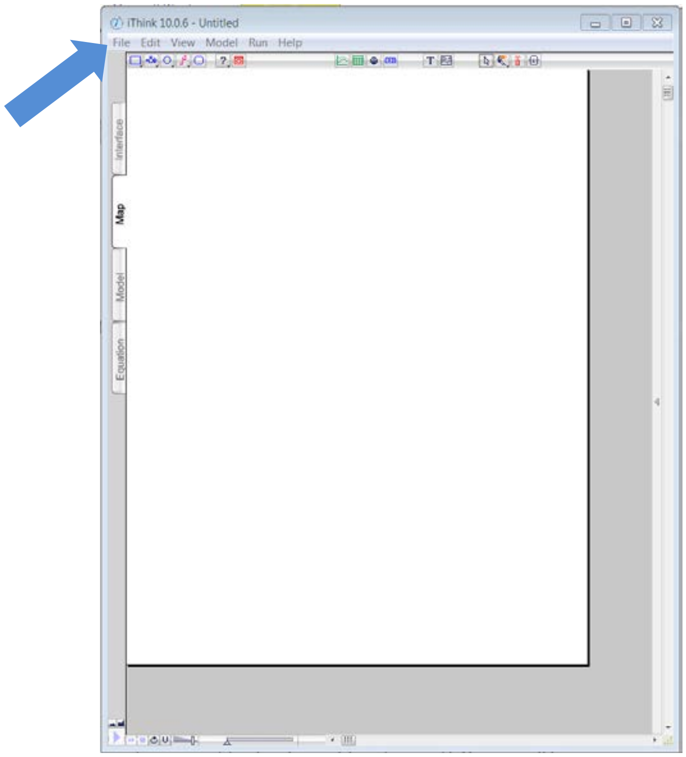


Figure 2. Initial screen when opening the iThink application

UNLOCKING THE MODEL

This section applies only to users that are authorized to unlock and modify the model. Once you open the model, if you do not see four tabs marked Interface, Map, Model, and Equation down the left side it means the model has been "locked" to prevent changes from being made by unauthorized persons to the model itself. The model itself will still work, the controls can still be manipulated by the user, and the simulation can still be run in the "locked" mode. If you have been authorized to change the model, you can unlock the model by pulling down the **File** menu, choosing **Lock Model…** and then supplying the password in the pop-up box.

NAVIGATING THE MODEL

Once you open the PACOM SD model, you should see the Home Page as shown in Figure 3. There are five tabs across the top of the Home Page: Home, Background, Explore the Model, Controls, and Simulation. By clicking on any of the tabs, you are taken to another page on the Interface level. At the bottom of each page there are "Next" and "Back" buttons that will take you to the next or previous page. You can skip directly to the desired page by using the navigation tabs at the top of the page in any page view.

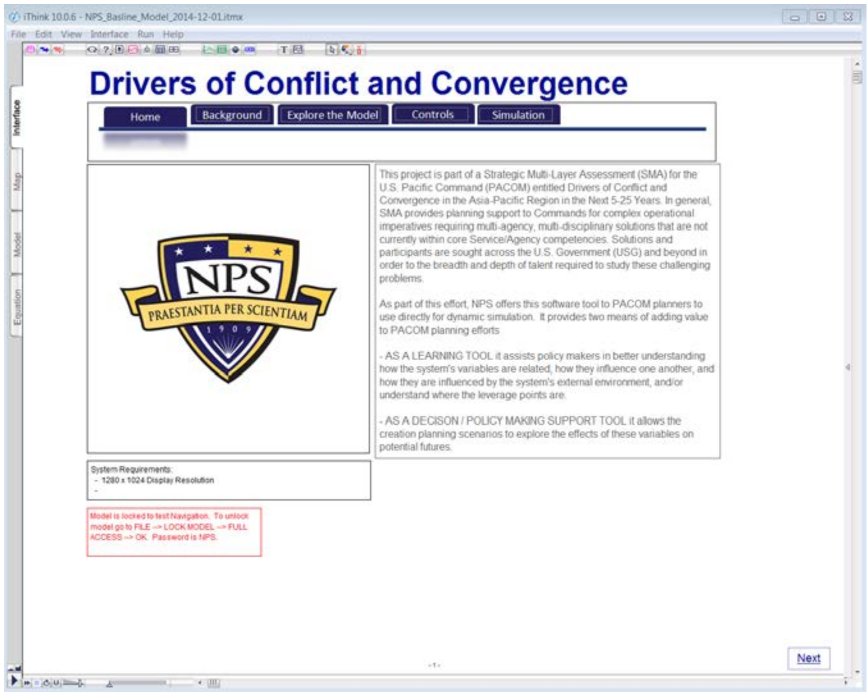


Figure 3. PACOM SD Model Home Page

- **Home** and **Background Pages** - The Home and Background Pages are text pages that give general information to users. The Explore the Model Page (**Figure 4**) has an additional set of tabs down the left border labeled Model Overview, Energy Demand and Resources Sub-Model, Defense and Military Sub-Model, Political and Social Stability Sub-Model, and Chinese Protestor Sub-Model. Users can navigate to pages containing more detailed information about each of the sub-models by clicking on the tabs. The "Back" button on the lower left side returns the user to the next tab closer to the top of the page. For example, if the user is on the Chinese Protestor Sub-Model, clicking "Back" will navigate to the Political and Social Stability Sub-model Page. Clicking on "Back" again will move the user to the Defense and Military Sub-Model Page. A user always has the option to navigate directly to a specific page by clicking on the appropriate tab.
- **Controls Page** - The Controls Page (**Figure 5**) provides users information about the various input devices and output graphs seen on the Simulation Page. The controls on the Controls Page are not actual controls. Clicking on the controls will do nothing since they are only pictures of the controls as seen on the Simulation Page.
- **Simulation Page** - The Simulation Page (Figure 6) is the primary interface between the

SD Model and most users. Unlike the Controls Page, the buttons and slider bars on the Simulation Page actually run the iThink model and allow users to change certain input parameters (see Simulation Inputs section). The Simulations Page consists of three areas Inputs, Outputs, and Controls. Each area is explained in more detailed in the following sections.

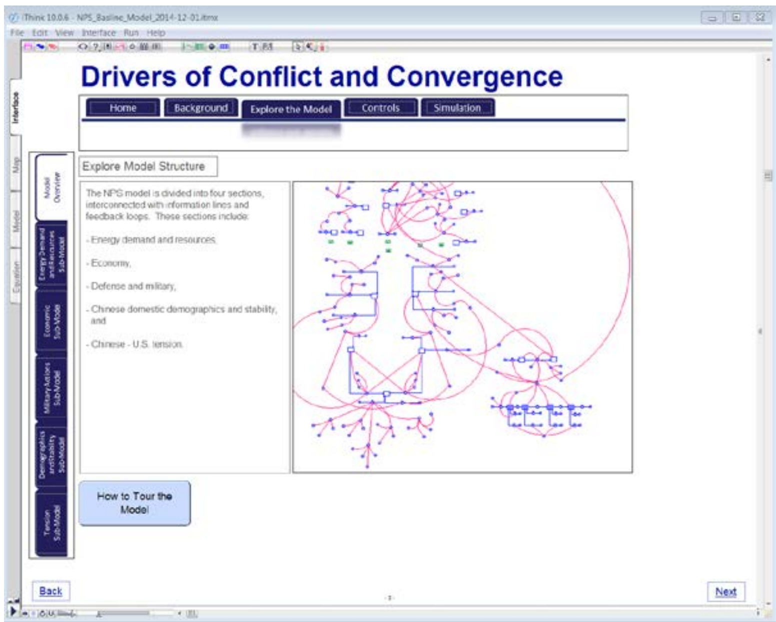


Figure 4. The Explore the Model Page.

SIMULATION INPUTS

The Inputs section of the Simulations Page consists of on-off switches and graphical slider controls that enable a user to change the values of constants in the underlying simulation, or enable/disable certain military actions from occurring during the simulation. For each type of military action (e.g. Unintentional Quasi-Military Destabilizing Event or North Korean Destabilizing Event) there is an on/off switch and three slider controls.

- **Event Year** - The first slider control (Event Year) lets a user specify the earliest year (from 2015 to 2040) that the event could possibly occur.
- **Event Probability** - The second slider (Event Probability) lets the user set a desired probability that the event will occur. For example, setting the Event Probability to 0.6 means that when the simulation reaches that possible event time, there is a 60% the event will occur. Setting the Event Probability to 1.0 is equivalent to saying “the Event will occur”. It should be noted that setting the Event Probability to 0.0 is equivalent to turning

the on/off switch to “off” – the event will never occur.

- **Event Frequency** - The third slider allows the user to specify how often (in years) the event can possibly reoccur. For example, setting the Event Frequency to 2.5 tells the simulation that every 2.5 years after the first possible occurrence (the “Event Year”) the simulation determines whether the event reoccurs with the probability set by the Event Probability. Setting the Event Frequency to 30 years in effect means the event occurs only once, since the overall length of simulated time is only 25 years.

The random number generators used in the simulation currently use a new seed number each time the simulation is run. Thus, if you run the simulation a second time without changing any of

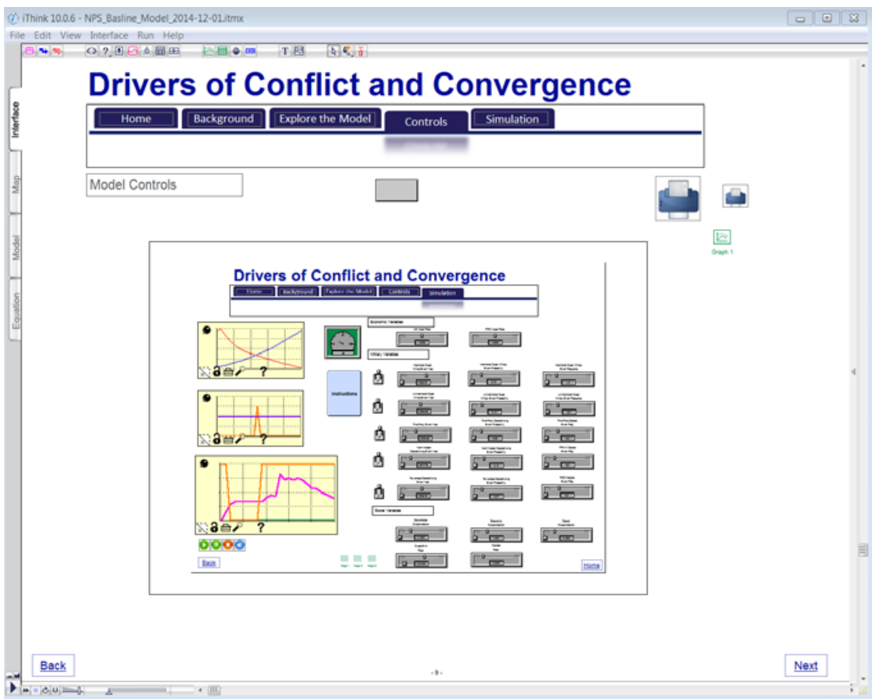


Figure 5. The Controls Page.

the inputs, the possible destabilizing events are likely to occur at different times. It is possible to change the simulation so that repeated runs of the simulation have destabilizing events occurring at the same time each run, but doing so requires the model to be unlocked for editing and requires the editor to be knowledgeable about using the iThink software.

SIMULATION OUTPUTS

The Outputs section of the Simulations Page consists of three graphs on the left side of the page. Each graph shows the value of some variable or variables in the simulation as a function of simulation time (years 2015-2040). There are 154 variables in the simulation that can displayed on graphs – users are encouraged to choose variables that are meaningful to them and support their analytical needs. Currently the graphs compare US and PRC Gross Domestic Product (GDP), shows the occurrence of military and quasi-military events, and shows the level of tension between the US and PRC. Any of the graphs can be modified to display the information most useful to the user (see Changing Graphs section).

- **US and PRC GDP** – this graph compares the projected GDPs of the United States and China for the period 2015 – 2040.
- **Military and Quasi-military Events –** this graph shows the occurrence of destabilizing military or quasi-military events, subject to the event probabilities and frequencies set in the Input section. The vertical scale is a relative scale that shows how significant each event is in raising tensions.
- **Tension between the US and PRC** – this graph shows the level of tension between the United States and China during the period 2015-2040.

SIMULATION CONTROLS

The controls to run the simulation are found at the lower left corner of the Simulation Page. The icon buttons conform to conventional symbology for running the simulation.

Run – starts the simulation, or resumes simulation execution after a pause.

Pause – temporarily halts the execution of the simulation. Pressing "Run" after "Pause" resumes execution of the current simulation run.

Stop – ends execution of the simulation. Pressing "Run" after "Stop" starts a new simulation run.

Reset – ends the current simulation run and resets the sliders to their default values.

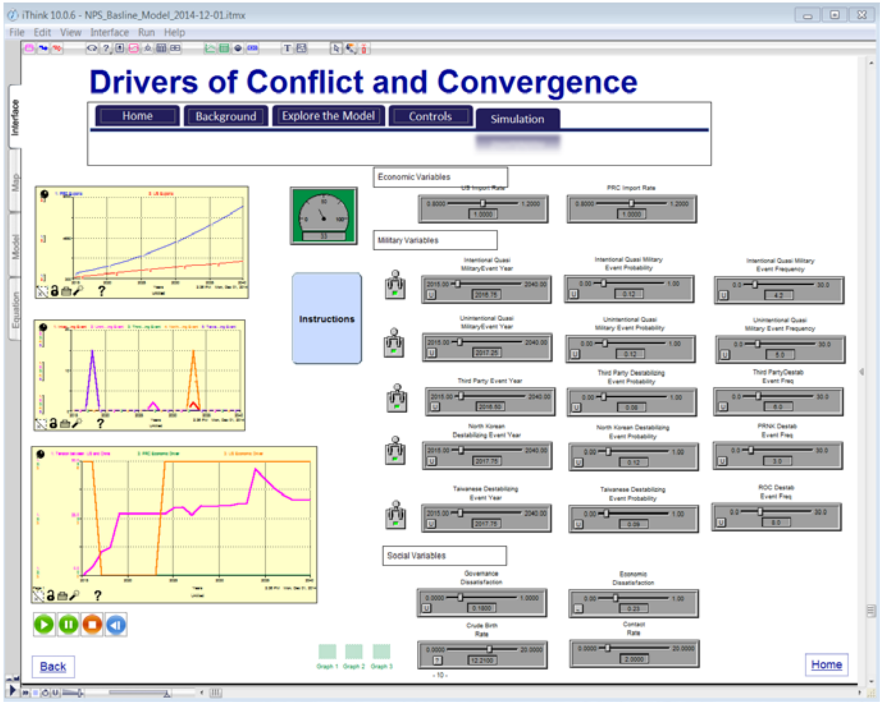


Figure 6. The Simulation Page.

Modifying the Simulation

It is generally suggested that users do not try to directly modify the underlying model unless they are very familiar with the iThink software and system dynamics modeling. If users wish to make modifications themselves and have the necessary permissions, the developers offer the following suggestions:

Rule #1 – Never modify the baseline model itself. Always open the baseline model and then use **File → Save As…** to make a copy of the original baseline model with a distinct new name. Make your modifications and test them on the copy, not the original or baseline copy. iThink 10.0.6 has a very limited "Undo" capability, i.e. it can only undo the last action. Don't think that you can undo the last six changes you just made by repeatedly pressing an "Undo" button.

Changing Graphs

The graphs on the Interface Layer can be changed by double-clicking anywhere within the graph the user wishes to change to open a "Define Graph" Dialogue Box (**Figure 7**).

To change variables displayed

Select variables you do not wish to have displayed from the "Selected" box and press the "remove button" << to remove them from the graph. To add new variables to the graph, select the variable in the "Allowable" window and press the "Add button" >> to add to the graph. NOTE: iThink limits the number of variables that can be shown on one graph to five (5).

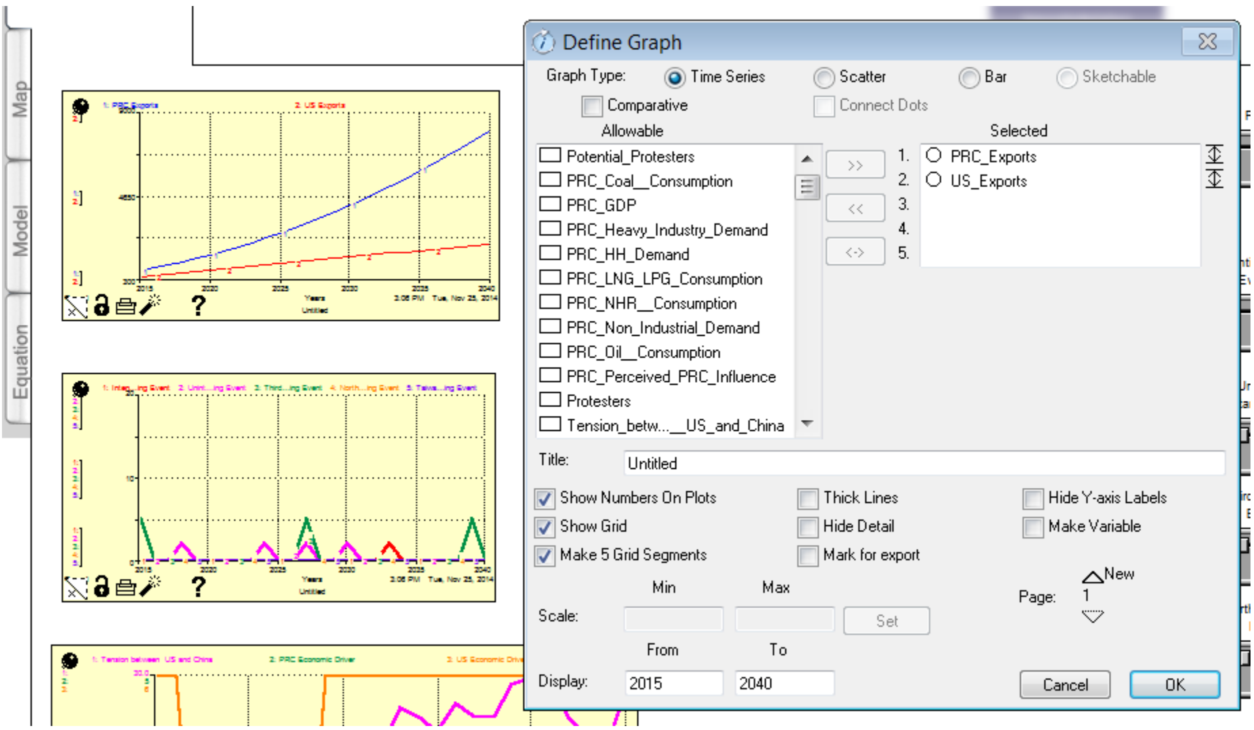


Figure 7. The Define Graph Dialogue Box

To change the type of graph

Occasionally users may wish to display the behavior of a variable during several runs on the same graph for comparison purposes. Open a Define Graph Dialogue box as shown in **Figure 7** and check the "Comparative" box. Now subsequent runs will be plotted on the same graph. **Figure 8** shows US and China tension level on six runs of the simulation plotted on the same graph.

Adding New User Controls

NOTE: Establishing a user control does not change the structure of the model, but allows a user to easily change the value of selected variables without having to into the model and directly change values in equations in the Model Layer.

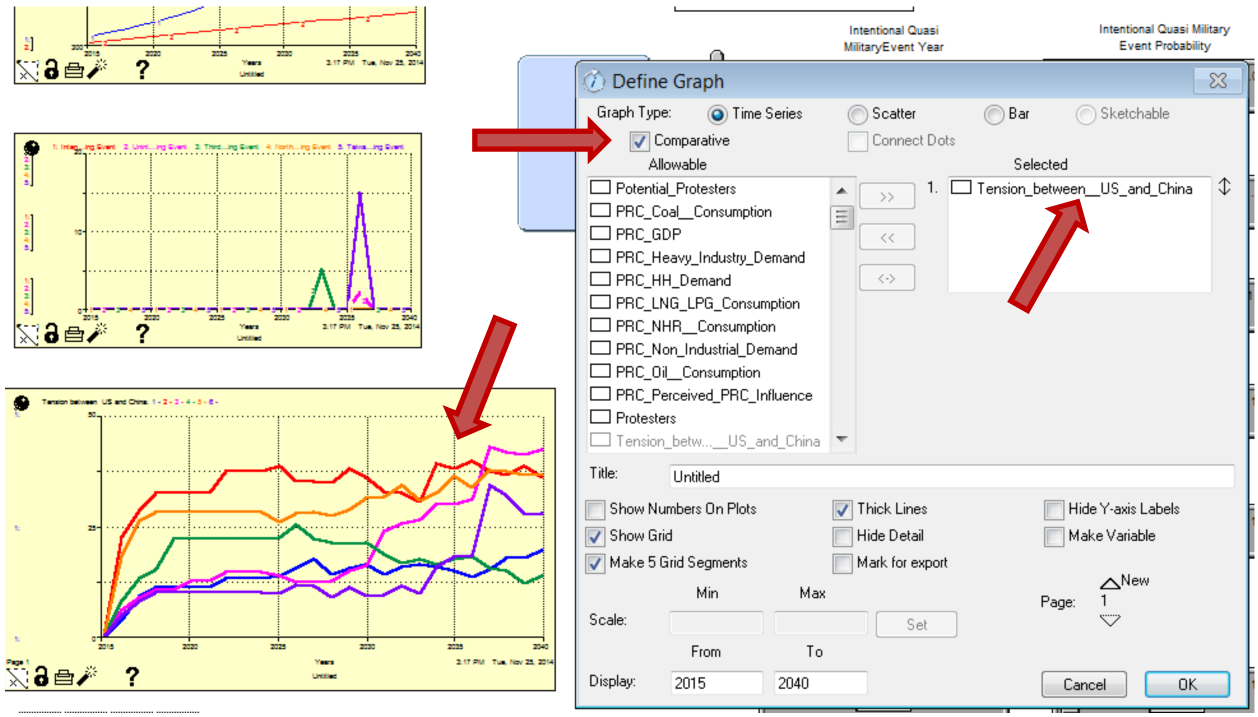


Figure 8. A Comparative Time Series Graph of US and PRC Tension

To add a new user control on the Simulations Page, click on one of the control icons in the upper left corner (**Figure 9**) and then click on an empty space on the Simulation Page. A blank user control will be inserted on the page. Now you must assign a variable to the control. Double-click on the blank control to bring up a Control Dialogue box as shown in **Figure 10**. Choose a variable from the “Allowable” list and then assign it to the control by clicking the “Add” button. 

Depending on the control chosen, a number of options will be available to customize such things as permissible range of values, value precision, icon size, etc.

A complete table of variables available in the NPS iThink US-China Model is included in Appendix A.

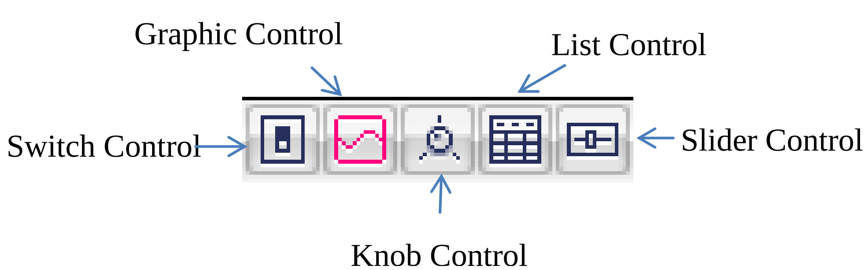


Figure 9. User Control Icons

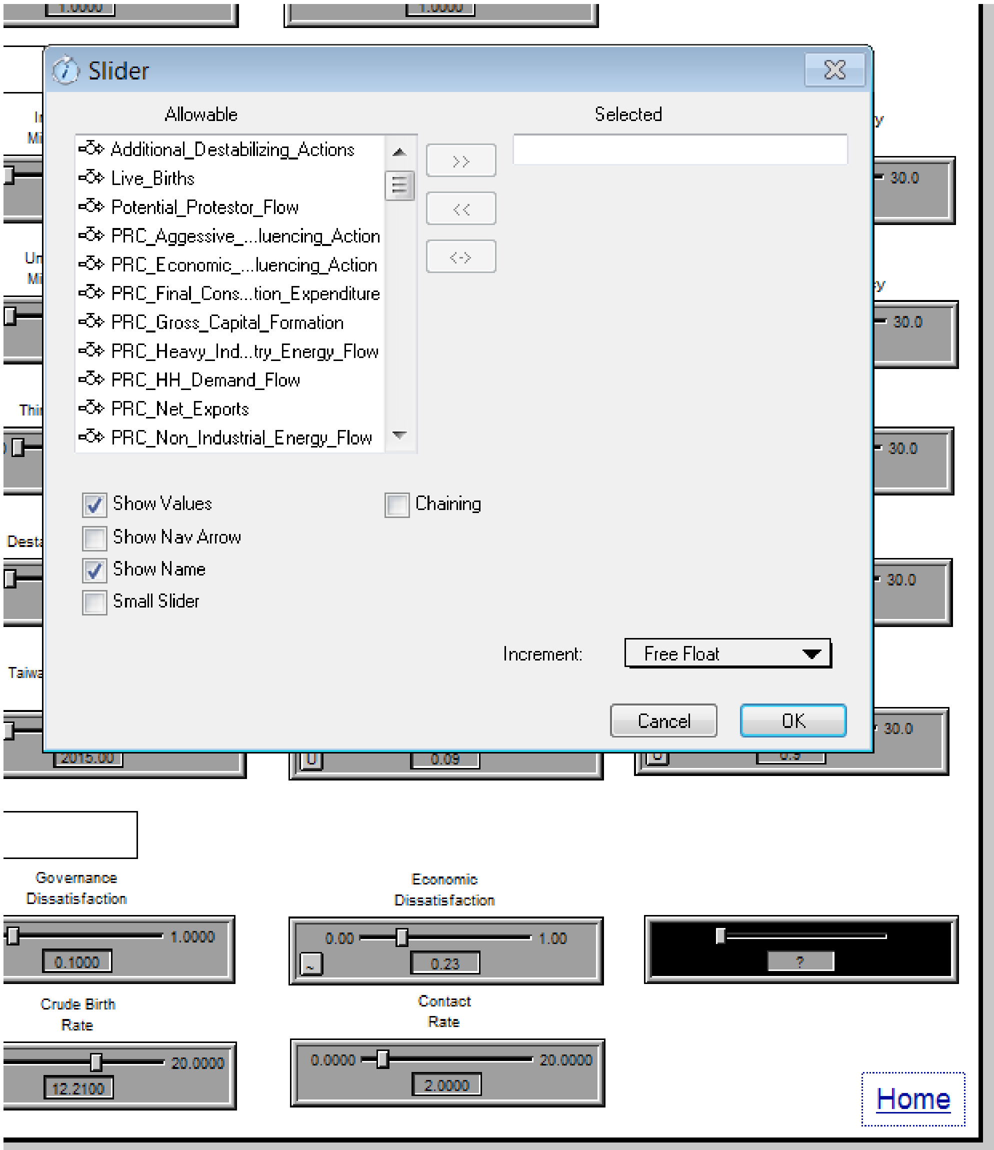


Figure 10. Slider Input Device Dialogue Box

Where to Get Help

Help concerning this model can be obtained by contacting the NPS Developer Team:

Name	Title	Email
Dr. Clifford Whitcomb	Principal Investigator	cawhitco@nps.edu
Mr. Paul Beery	Faculty Associate	ptbeery@nps.edu
Mr. Gary Parker	Faculty Associate	gwparker@nps.edu
Mr. Chris Wolfgeher	Faculty Associate	cwolfghe@nps.edu

References and Resources

- The iThink software is developed by isee Systems, Inc. whose website is www.iseesystems.com.

The isee Systems website includes several resources to include articles about systems thinking, training available for the iThink and STELLA software, and product descriptions.

- An 86-page pdf document titled, “Getting started with iThink and STELLA”, dated January 2013, is available for download at the following URL:

http://www.thoughtmap.com/storage/files/Getting%20Started%20with%20iThink%20and%20STELLA.pdf

- A well-known textbook for systems dynamics is Dr. John Sterman’s “Business Dynamics: Systems Thinking and Modeling for a Complex World”, 2000, McGraw-Hill, ISBN: 978-0-07-321135-8

Appendix A. Table of Variables in the iThink US-China Model

Additional Destabilizing Actions	Based on conversations with subject matter experts at CEIP, START and Monitor 360, five categories of military actions were developed. These actions are considered to be destabilizing actions that increase tension. (Dimensionless)
Centenarian Rate	Rate at which seniors leave the potential protestor population. (People/yr)
Child Migration	Rate at which children migrate out of China. (People/yr)
Childhood Mortality Rate	Rate at which children leave the total Chinese population. (People/yr)
Children	Total number of children in the Chinese population. (People)
Contact Rate	Control variable which governs the flow of people from the potential protestor group to the protestor group. (Dimensionless)
Crude Birth Rate	Rate at which the total Chinese population can generate children. (People/yr)
Direct PRC Actions to Lower Tension	Actions taken by China to reduce the level of tension in US-China relations. (dimensionless)
Direct US Actions to Lower Tension	Actions taken by the US to reduce the level of tension in US-China relations. (dimensionless)
Economic Dissatisfaction	Fraction of Chinese population dissatisfied due to economic concerns. (Dimensionless)
Energy Demand per PRC HH	Annualized Chinese energy demand per household (HH) in BTU equivalents. Chinese household energy demand per household is forecast to decrease from 2015 to 2040 due to a combination of factors, including a reduced number of persons per household, more energy efficient buildings, and planned upgrades to energy transmission infrastructure.
Environmental Concerns	Fraction of Chinese population dissatisfied due to environmental concerns. (Dimensionless)
Ethnic Conflict	Fraction of Chinese population dissatisfied due to ethnic concerns. (Dimensionless)
Governance Dissatisfaction	Fraction of Chinese population dissatisfied due to governance concerns. (Dimensionless)

Intentional Quasi Military Destabilizing Event	An example of an intentional quasi-military action would be the establishment of an exclusion zone by China. Usually the purpose of this would be to gauge the resolve of the opposing nation. In the example of the most recent exclusion zone established by China, the U.S. and Japan responded with their quasi-military action of continuing to send aircraft or ships through the zone. These incidents have the potential to escalate based on the resolve of each nation. When China set up the exclusion zone and the U.S. and Japan sent fighters through the zone, China scrambled jets but did not escalate the situation further.
Intentional Quasi Military Event Frequency	Frequency with which this type of event will occur. Probability will affect each year of occurrence.
Intentional Quasi Military Event On?Off	Control variable which turns this type of event on or off. Equivalent to setting event probability to zero.
Intentional Quasi Military Event Probability	Probability that this type of event will occur in the year and with the frequency specified.
Intentional Quasi Military Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.' The event will re-occur every xx years, as specified by frequency.
Live Births	Rate at which children join the total Chinese population. Random variable with Normal distribution. (People/yr)
Majority Rate	Rate at which children become young adults (People/yr)
Maturing Rate	Rate at which young adults become mid-adults (People)
Mid Adult Death Rate	Rate at which mid-adults leave the total Chinese population. (People/yr)
Mid Adult Migration	Rate at which mid-adults migrate out of China. (People/yr)
Mid Adults	Total number of mid-adults in the Chinese population. (People)
Net Migration Rate	Rate at which all population groups migrate out of China.(People/yr)
North Korea On?Off	Control variable which turns this type of event on or off. Equivalent to setting event probability to zero.
North Korean Destabilizing Event	Currently, China has publicly condemned North Korea’s pursuit of nuclear weapons. However, a change in rhetoric by North Korea, such as the threat of collapse, could alter China’s policy toward North Korea. It could cause China to change its stance on North Korea’s nuclear ambitions. This would likely lead to more aggressive U.S. intervention to stop nuclear proliferation, and this would certainly raise tensions to the highest levels.

North Korean Destabilizing Event Probability	Probability that this type of event will occur in the year and with the frequency specified.
North Korean Destabilizing Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.' The event will re-occur every xx years, as specified by frequency.
Number of PRC Households	Projected number of households in China The number of Chinese households is forecast to increase in 25 years from approximately 430 million to a little over 500 million. This is due to both projected population increase and decreasing average Chinese household size. Household size is decreasing due to a combination of Chinese incentives promoting urbanization, reduced number of children per couple, and a growing middle class which tends to have fewer children per household.
Potential Protesters	Group within the total Chinese population that has the potential to become protestors. The very young and very old typically do not become protestors. (People)
Potential Protestor Flow	Rate at which the total adult population can become potential protestors. (People/yr)
PRC Aggressive Influencing Action	Action taken by the Chinese to increase actual/perceived influence. The use of the word aggressive signifies that this action is beyond normal Chinese action and is meant to send a clear message. (dimensionless)
PRC Change in Inventories	Projected Chinese on hand inventories ($Billions 2012)
PRC Change in Inventories Rate	Control variable allowing user to input a percentage change in Chinese inventories .
PRC Coal Consumption	Stock representing Chinese Coal consumption (Quadrillion BTU)
PRC Coal Import	Graphical variable of projected yearly coal imports (Quadrillion BTU)
PRC Desired Level of Own Influence	Level of influence China desires to have within the PACOM AOR. (dimensionless)
PRC Desired US Influence	Level of influence China desires the US to have within the PACOM AOR. (dimensionless)
PRC Domestic Coal Production	Graphical variable of projected yearly coal production (Quadrillion BTU)
PRC Domestic LNG LPG Production	Graphical variable of projected yearly domestic LNG/LPG production (Quadrillion BTU)
PRC Domestic Oil Production	Graphical variable of projected yearly domestic oil production (Quadrillion BTU)

PRC Economic Driver	Control variable linking Chinese GDP to influence within the PACOM AOR. (dimensionless)
PRC Economic Influencing Action	Economic actions China takes to reduce the level of tension in US-China relations. (dimensionless)
PRC Energy Environmental Damage Percentage	percentage of energy resources consumed from domestic environmentally-damaging sources such as coal, oil and LNG-LPG with respect to China's overall total energy resource consumption. The higher the percentage, the more potential damage might be done to China's environment. (%)
PRC Energy Import Risk Percentage	Percent of total Chinese energy consumption provided by imports. (%) As China becomes more reliant on external sources of energy to meet its economic goals, the state perceives more risk to its energy import activities by other nations. That risk is one driver why China is looking to expand its near off-shore influence and control as well as expand the reach of the PLAN to protect vital energy import sea lanes.
PRC Export Rate	Control variable allowing user to input a percentage change in Chinese gross export.
PRC Exports	Projected Chinese gross exports. ($Billions 2012)
PRC Final Consumption Expenditure	Project Chinese govt and household expenditures. ($Billions 2012)
PRC GDP	Projected total Chinese Gross Domestic Product. ($Billions 2012)
PRC GDP Per Capita	Chinese Per capita GDP. ($Billions 2012/person)
PRC Govt Defense Expenditure	Projected Chinese govt defense expenditures. ($Billions 2012)
PRC Govt Defense Expenditure Rate	Control variable allowing user to input a percentage change in Chinese DE.
PRC Govt NDE Rate	Control variable allowing user to input a percentage change in Chinese NDE.
PRC Govt NonDefense Expenditure	Projected Chinese govt non-defense expenditures. ($Billions 2012)
PRC Gross Capital Formation	Projected Chinese capital formation which includes fixed capital and value of inventories. ($Billions 2012)
PRC Gross Fixed Capital Formation	Projected Chinese capital formation. ($Billions 2012)
PRC Gross Fixed Capital Formation Rate	Control variable allowing user to input a percentage change in Chinese gross fixed capital formation.
PRC HCE Rate	Control variable allowing user to input a percentage change in Chinese HCE.

PRC Heavy Industry Demand	The Chinese economy's projected demand for energy to support construction, mining, commercial transportation, traditional manufacturing, etc. The majority of Chinese military energy demand falls into this category. (Quadrillion BTU)
PRC Heavy Industry Energy Demand	Graphical variable of the Chinese economy's projected demand for energy to support construction, mining, commercial transportation, traditional manufacturing, etc. The majority of Chinese military energy demand falls into this category. (Quadrillion BTU)
PRC Heavy Industry Energy Flow	The Chinese economy's projected annualized demand for energy to support construction, mining, commercial transportation, traditional manufacturing, etc. The majority of Chinese military energy demand falls into this category. (Quadrillion BTU/year)
PRC HH Demand	The Chinese household's projected demand for energy (Quadrillion BTU)
PRC HH Demand Flow	The Chinese household's projected annualized demand for energy. (Quadrillion BTU/year)
PRC HH Energy Demand Annualized	Graphical variable of the Chinese economy's projected demand for energy. (Quadrillion BTU)
PRC Household Consumption Expenditure	Projected Chinese household consumptions expenditures. ($Billions 2012)
PRC Hydro Electric Production	Chinese projected production of energy from hydroelectric energy sources. (Quadrillion BTU)
PRC Import Rate	Control variable allowing user to input a percentage change in Chinese gross inports.
PRC Imports	Gross Chinese imports. Affected by Total_PRC_Energy_Consumption. ($Billions 2012)
PRC LNG LPG Consumption	Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG): Broken down by amount imported primarily by sea through the PACOM AOR and by existing or planned pipelines from the 2014 Russian-Chinese LMG-LPG agreement and domestically produced. (Quadrillion BTU)
PRC LNG LPG Imports	Graphical variable of the Chinese economy's projected demand for imported Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG) (Quadrillion BTU)
PRC Net Exports	Projected Chinese net exports. Net exports are influenced by the number of chinese protestors in the social and demographivs sub-model. ($Billions 2012)

PRC NHR Consumption	Nuclear-Hydroelectric-Renewables (NHR) broken down by domestic nuclear production, hydro-electric production, and renewables to include solar, wind and biomass production. (Quadrillion BTU)
PRC Non HH Energy Demand	Total energy demand from Chinese heavy industry and non-industrial sources. (Quadrillion BTU)
PRC Non Industrial Energy Demand	Graphical variable of the Chinese economy's projected demand for energy to support information technologies, office buildings, education facilities, health care facilities, etc. The majority of Chinese state government energy demand falls into this category with the exception of state owned heavy industrial companies. (Quadrillion BTU)
PRC Non Industrial Demand	The Chinese economy's projected demand for energy to support information technologies, office buildings, education facilities, health care facilities, etc. The majority of Chinese state government energy demand falls into this category with the exception of state owned heavy industrial companies. (Quadrillion BTU)
PRC Non Industrial Energy Flow	The Chinese economy's projected annualized demand for for energy to support information technologies, office buildings, education facilities, health care facilities, etc. The majority of Chinese state government energy demand falls into this category with the exception of state owned heavy industrial companies. (Quadrillion BTU/yr)
PRC Nuclear Production	Chinese projected production of energy from all nuclear energy sources. (Quadrillion BTU)
PRC Oil Consumption	Stock representing Chinese oil consumption; primary liquid crude, broken down by amount imported and domestically produced. (Quadrillion BTU)
PRC Oil Import	Graphical variable of projected yearly oil imports (Quadrillion BTU)
PRC Perceived PRC Influence	Level of influence China perceives itself as having within the PACOM AOR. (dimensionless)
PRC Perceived US Influence	Level of influence China perceives the US as having within the PACOM AOR. (dimensionless)
PRC Renewables Production	Chinese projected production of energy from all renewable (except hydroelectric) energy sources. (Quadrillion BTU)
PRNK Destab Event Freq	Frequency with which this type of event will occur. Probability will affect each year of occurrence.
Protest Impact on Influence	Control variable linking civil unrest in China with Chinese influence within the PACOM AOR. (dimensionless)
Protest Indicator	Control variable set when the total number of protestors increases faster that a given rate. (Dimensionless)

Protester Rate	Rate at which the population of potential protestors becomes protestors. (People/yr)
Protesters	Total Chinese population of protestors. (People)
Radicalization Fraction	Control variable which governs the flow of people from the potential protestor group to the protestor group. Contains economic, social, and governance dissatisfaction. (Dimensionless)
Religious Conflict	Fraction of Chinese population dissatisfied due to religious concerns. (Dimensionless)
Retirement Rate	Rate at which mid-adults become seniors. (People/yr)
ROC Destab Event Freq	Frequency with which this type of event will occur. Probability will affect each year of occurrence.
Russian LNG LPG Import Deal	Graphical variable depicting potential for China and Russia to agree to LNG/LPG pipeline and trade agreement. (Quadrillion BTU)
Senior Death Rate	Rate at which seniors leave the total Chinese population(People/yr)
Senior Migration	Rate at which seniors migrate out of China. (People/yr)
Seniors	Total number of seniors in the Chinese population(People)
Social Dissatisfaction	Fraction of Chinese population dissatisfied due to religious, ethnic, or environmental concerns. (Dimensionless)
Stabilizing Actions	Actions taken by the US or China to reduce the level of tension in relations. (dimensionless)
Taiwan On?Off	Control variable which turns this type of event on or off. Equivalent to setting event probability to zero.
Taiwanese Destabilizing Event	This is the least likely but also the most dangerous scenario. This will bring tensions to the highest levels and likely lead to war if the situation isn't balanced by a stabilizing action. An example of this would be if the Chinese government loses patience with the continued sale of U.S. arms to Taiwan, or if the U.S. gives Taiwan a new technology that significantly increases Taiwan's defense capabilities. This could cause the Chinese to respond with an aggressive military action.
Taiwanese Destabilizing Event Probability	Probability that this type of event will occur in the year and with the frequency specified.
Taiwanese Destabilizing Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.' The event will re-occur every xx years, as specified by frequency.

Tension between US and China	Analogue for US-Chinese relations. (dimensionless)
Third Party Destab Event Freq	Frequency with which this type of event will occur. Probability will affect each year of occurrence.
Third Party Destabilizing Event	This is different from the 2nd category because it originates with an action initiated from a third party whereas the above scenario deals with a Chinese or U.S. action specifically in Taiwan or North Korea. An example of this would be if Japan took actions to aggressively occupy South China Sea islands, and was confronted by Chinese military units. Even though the U.S. may not agree with Japanese actions, they could get dragged into a conflict based on their treaty obligations. Similarly, if North Korea's nuclear development reaches a level that the U.S. perceives as dangerous, this could cause the U.S. to take action, and these actions could invoke the Sino-North Korean treaty obligating China to get involved. This scenario likely could be resolved by China and U.S. unless one of those two nations responds very aggressively to the third party.
Third Party Destabilizing Event Probability	Probability that this type of event will occur in the year and with the frequency specified.
Third Party Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.' The event will re-occur every xx years, as specified by frequency.
Third Party On?Off	Control variable which turns this type of event on or off. Equivalent to setting event probability to zero.
Total Adult Population	Total Chinese adult population. (People)
Total Population	Total Chinese population. (People)
Total PRC Coal Consumption	Projected annualized projected PRC coal consumption (Quadrillion BTU)
Total PRC Coal Consumption Flow	Flow variable to translate Total_PRC_Coal_Consumption into a stock (Quadrillion BTU/yr)
Total PRC Consumption Annualized Flow	Projected, annualized flow variable translating Chinese energy resource consumption into a stock. (Quadrillion BTU/yr)
Total PRC Demand Annualized Flow	Flow variable to translate total annual energy into a stock (Quadrillion BTU/yr)
Total PRC Energy Consumption	Projected Chinese energy resource consumption in four primary categories: Coal, oil, LNG/LPG/, and Nuclear/Hydro/Renewables. (Quadrillion BTU)

Total PRC Energy Demand	Total Chinese energy demand from household, heavy industry, and non-industrial demand sources. (Quadrillion BTU)
Total PRC LNG LPG Consumption	The Chinese economy's projected annual demand for Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG) (Quadrillion BTU/yr)
Total PRC LNG LPG Consumption Flow	The Chinese household's projected annualized demand for LNG/LPG. (Quadrillion BTU/year)
Total PRC NHR Consumption	Projected annualized projected PRC NHR consumption (Quadrillion BTU)
Total PRC NHR Consumption Flow	Flow variable to translate NHR consumption into a stock (Quadrillion BTU/yr)
Total PRC Oil Consumption	The Chinese economy's projected annual demand for oil. (Quadrillion BTU/yr)
Total PRC Oil Consumption Flow	Flow variable to translate Total_PRC_Oil_Consumption into a stock (Quadrillion BTU/yr)
Unintentional Quasi Military Destabilizing Event	An example of an unintentional action is a collision at sea by a Chinese vessel and one from a U.S. or allied nation. This situation could potentially escalate depending on the actions of the local actors involved. In the past, these situations have raised tensions but usually are resolved through discussions between leaders of both governments.
Unintentional Quasi Military Event Frequency	Frequency with which this type of event will occur. Probability will affect each year of occurrence.
Unintentional Quasi Military Event On?Off	Control variable which turns this type of event on or off. Equivalent to setting event probability to zero.
Unintentional Quasi Military Event Probability	Probability that this type of event will occur in the year and with the frequency specified.
Unintentional Quasi Military Event Year	First year that this type of event may occur. Probability that the event occurs in this year is set by 'event probability.' The event will re-occur every xx years, as specified by frequency.
US Aggressive Influencing Action	Action taken by the US to increase actual/perceived influence. The use of the word aggressive signifies that this action is beyond normal US action and is meant to send a clear message. (dimensionless)
US Change in Inventories	Projected US on hand inventories ($Billions 2012)
US Change in Inventories Rate	Control variable allowing user to input a percentage change in US inventories.
US Desired Level of Own Influence	Level of influence the US desires within PACOM AOR. (dimensionless)
US Desired PRC Influence	Level of influence the US desires China to have within the PACOM AOR. (dimensionless)

US Economic Driver	Control variable linking US GDP to influence within the PACOM AOR. (dimensionless)
US Economic Influencing Action	Economic actions the US takes to reduce the level of tension in US-China relations. (dimensionless)
US Export Rate	Control variable allowing user to input a percentage change in US gross export.
US Exports	Projected US gross exports. ($Billions 2012)
US Final Consumption Expenditure	Project US govt and household expenditures. ($Billions 2012)
US GDP	Projected total US Gross Domestic Product. ($Billions 2012)
US Govt Defense Expenditure	Projected US govt defense expenditures. ($Billions 2012)
US Govt Defense Expenditure Rate	Control variable allowing user to input a percentage change in US DE.
US Govt NDE Rate	Control variable allowing user to input a percentage change in US NDE.
US Govt NonDefense Expenditure	Projected US govt non-defense expenditures. ($Billions 2012)
US Gross Capital Formation	Projected US capital formation which includes fixed capital and value of inventories. ($Billions 2012)
US Gross Fixed Capital Formation	Projected US capital formation. ($Billions 2012)
US Gross Fixed Capital Formation Rate	Control variable allowing user to input a percentage change in US gross fixed capital formation.
US HCE Rate	Control variable allowing user to input a percentage change in US HCE.
US Household Consumption Expenditure	Projected US household consumptions expenditures. ($Billions 2012)
US Import Rate	Control variable allowing user to input a percentage change in US gross imports.
US Imports	Gross US imports. Affected by Total_PRC_Energy_Consumption. ($Billions 2012)
US Net Exports	Projected US net exports. Net exports are influenced by the number of US protestors in the social and demographics sub-model. ($Billions 2012)
US Perceived PRC Influence	Level of influence the US perceives China as having within the PACOM AOR. (dimensionless)
US Perceived US Influence	Level of influence the US perceives itself as having within the PACOM AOR. (dimensionless)
Young Adult Death Rate	Rate at which young adults leave the total Chinese population (People/yr)

Young Adult Migration	Rate at which young adults migrate out of China. (People/yr)
Young Adults	Total number of young adults in the Chinese population (People)

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