William J. Perry International Security Fellowship

The William J. Perry International Security Fellowship at the Center for International Security and Cooperation (CISAC) within Stanford University is awarded through competitive selection of research applicants with a record of outstanding work in natural science, engineering or mathematics who are dedicated to solving international security problems. A former U.S. Secretary of Defense, Dr. Perry is also a distinguished professor and entrepreneur whose career has been noted as “a model of scientifically informed, pragmatic and far-sighted problem solving in public policy.” Stanford endowed the fellowship in his name to honor Dr. Perry’s visionary leadership in the cause of peace. CISAC is an interdisciplinary research center whose mission is “to produce policy-relevant research on international security problems, to teach and train the next generation of security specialists, and to influence policymaking in international security.” CISAC is part of the Freeman Spogli Institute for International Studies (FSI). The University’s flagship center for innovative research on major international challenges, FSI is home to researchers and visiting scholars working on issues such as nuclear proliferation, chemical and bioterrorism, food security and the environment, energy and sustainable development, democracy and the rule of law, conflict prevention, and international health policy among others. Many FSI investigators take advantage of the potential for collaboration with faculty and students at Stanford’s schools of business, earth sciences, education, engineering, humanities and sciences, law and medicine.

Dr. Robert J. Glass of Sandia National Laboratories has been named the 2011-12 Perry Fellow. Dr. Glass leads the Complex Adaptive Systems-of-Systems (CASoS) Engineering Initiative at Sandia National Laboratories which focuses innovative engineering theories, technologies, tools, and approaches to solve problems within the socio-economic-technical systems at the foundation of national and global security. As the Perry fellow, Glass will design policies engineered for cooperative investment and advantage while leveraging the adaptive dynamics of nation state and corporate interactions to mitigate disruptions. His prospectus for the fellowship period follows.

Understanding Global Interdependency to Promote International Security

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Global interdependency and the speed at which goods, services, technology, ideas, information, people, disease and even mood travel across the planet is increasing at a scale and degree far beyond historical experience. As illustrated by the current events in Egypt, political unrest has given rise to regional tension, a rapid disruption of global financial markets, the possible disruption of global crude and refined oil transfer via the Suez Canal and the Sumed pipeline, as well as possible shocks to global cotton and wheat prices (among others). To help understand the ramifications of escalating interdependency for issues of international security, the global system can be conceptualized as a Complex Adaptive System of Systems (CAoS) where economic, social and governmental processes combine to structure the flow of goods and services; support the security of individual nations, regions and treaty partners;
and form the basis for the health, happiness and prosperity of all nations. Within such a system, the
design of policy to achieve a set of objectives at a variety of scales can be viewed as CASoS Engineering,
a new and growing initiative at Sandia National Laboratories.

Objectives

My objectives for the fellowship period at CISAC and Stanford are three fold:

1. Research: My research at CISAC will bring the perspective of CASoS Engineering to focus on three
areas of international security: 1) nuclear security and nonproliferation, 2) energy security, and 3) 
food security. Employing a framework that forces clarity of thought, this perspective integrates and
distills many diverse views within a single conceptualization of the system of interest. Modeling that
system and the influence of various policies in context of inevitable shocks to the system allows
those policies to be explicitly weighed against each other. Through this approach, I hypothesize that
policies clearly better in the short and/or long term, for the individual and/or the collective, can be
identified. Additional data or conceptual clarity required to distinguish policy benefits can also be
identified as are the actions needed to obtain them. For each of the three focal areas of
international security, specific high impact scenarios will be evaluated and results placed in historical
context.

2. Interconnection: Through my research efforts, I will strengthen and broaden connection between
CISAC and Sandia researchers. Both CISAC researchers and Sandia members of the CASoS
Engineering Initiative will be actively engaged over the course of the year to refine and challenge the
CASoS Engineering principles and modeling approaches as I apply them to the global system of
nations and issues of international security. In addition, I will work to develop a joint CISAC-Sandia
proposal for funding in the realm of global security using CASoS Engineering.

3. Education: Finally, I will develop and teach a short course in CASoS Engineering applied to
international security to introduce students of international security to concepts of CASoS and the
evaluation and design of policy using quantitative modeling approaches. I have recently taught with
success a week long short course at the University of Rome on CASoS Modeling and Engineering.
This course will be refined and focused for the purposes of CISAC faculty, fellows and students.

Background on CASoS Engineering and Modeling CASoS

The CASoS Engineering Initiative at Sandia has evolved over
the past few years through analysis of a series of high
consequence security issues including: Congestive Failure in
electric power and large banking systems; systemic risk in
Payment Systems that form the backbone of interbank funds
transfer within the US and the globe; the design of
mitigation measures for Pandemic Influenza; and the
modeling of Global Energy Systems and Global Financial
Systems to evaluate control policy tradeoffs (follow the links
for greater detail on these and other applications of CASoS
Engineering at Sandia). Through these efforts, a generalized
conceptual lens for modeling CASoS (figure to the right) has
emerged similar to those in physics, biology, economics, and
other diverse areas where Complexity Science has provided fruitful insights. We render the system as entities (nodes) that interact with other entities via links to “neighbor” entities to form a network. The behavior of individual entities can be influenced by that of their neighbors and adjusted based on perceived performance of themselves, others or the collective (up to the global scale). This influence can cause change in interactions or network connection and bring about growth, evolution or adaptation at a variety of scales. Networks are connected to other networks to form systems of systems with appropriate entity and interaction behaviors. Computational implementation of the conceptual model rendered by the lens can take a variety of mathematical forms including continuous to discrete, system dynamics to agent based with infinite to finite state machines, or approaches that hybridize these forms.

**Proposed Research**

Through engagement at CISAC, I will focus on three areas of international security: 1) nuclear security and nonproliferation, 2) energy security, and 3) food security. Evaluating and designing policy that promotes security in each of these areas at national to global scales must be accomplished in context of complex global interdependency. The general conceptual lens described above can be used to model this interdependency. Analysis of model behavior focused on finding policy that promotes system robustness or resilience in the face of inevitable perturbations is hypothesized to lead to the categorization and ranking of policy approaches and repercussions at different scales (individual nations, regions, the global system). The set of perturbations imposed must be comprehensive ranging from random shocks at a variety of levels and frequencies in resource production or flows, to slow increases in such shocks as a consequence of climate change, to orchestrated scenarios such as the case of a strategic assault (naming a few).

**Preliminary work** at Sandia has used the general conceptual lens to model individual nations composed of a variety of entities representing the government and major economic sectors, and internal markets that define domestic interactions among sectors (brokers for spot and contractual arrangements, figure below). Each entity seeks health through consumption and production and domestic markets can be taxed by the government to provide for national security and defense.

![National Sector Interdependency](image)
My research at CISAC will extend this single nation model to a global system of nations. The first step will be to extend the national sub-sector flows (e.g., raw materials, industrial goods, services) to the global scale. Nations differ in their resource endowments and in the capacity and efficiency of the production processes of their component sub-sector entities. International markets influenced by trade agreements define patterns of interconnection – for example water and labor markets might only connect bordering nations, while markets for goods and energy might be global. The efficiency of global markets can be modulated by imposing levies of varying amounts in each market to reflect trade agreements and the cost of transport. The second step will be to incorporate security interactions among government entities where alliances are conceived to reduce the influence of perturbations within member nations. A conceptual view of the proposed model is shown below with regional trading and security agreements (brokers) connecting several nations that are likewise connected to others to define a global system of nested interdependencies.

For a given set of nations, production/consumption parameter values, interconnecting markets, and trade and security agreements, numerical simulation will evolve the system to a dynamic equilibrium pattern of resource flows within and among nations. Perturbations can then be imposed relevant to the three focal areas of international security. A sudden change to the topology or efficiency of the international energy market, for example, can be used to represent embargoes or destruction of large terminals. As a simple illustration, results for an abstract problem with nine interacting nations are shown below. In the left panel, the evolution to dynamic equilibrium is shown with three nations who primarily produce raw materials falling well below the health of the other six. In the middle panel, a small shock removes a portion of the raw materials within the system and the health of nations that produce the raw material goes up while those that require it goes down, followed by a resettling to the original equilibrium values. In the panel to the right, the shock is large and causes disruption from which the system cannot recover (note the change in scale for this right panel).
Using the principles and modeling approaches of CASoS Engineering, protective and/or mitigative policies may be evaluated (and designed) to increase the robustness and/or resilience of systems at scales from the individual national sector to the alliance or trading bloc to the global set of nations in the face of random to structured perturbations. Example policies such as used in today’s world which could be considered include tariffs, embargos, loans, aid, and direct intervention. The design of potential new policy (or policy combinations) that may be more effective at achieving a given set of objectives is the ultimate goal. Engagement from CISAC faculty, fellows and students will be essential.

**Letters of Support**

**Jill Hruby:** Vice President of the Energy, Nonproliferation and High Consequence Security Division (Org 6000) at Sandia National Laboratories. The Division supports Sandia’s mission efforts by applying world-class technologies, and innovative system solutions to meet our national security needs. Capabilities range from research and development to systems applications that span across nonproliferation, energy, and defense programs. Jill also leads Sandia’s International, Homeland, and Nuclear Security Strategic Management Unit (SMU). This SMU is responsible for Sandia’s homeland security programs, homeland defense and force protection, critical asset protection, and global security, as well as the corporate strategic thrust on Nuclear Security.

**Arian Pregenzer:** Senior Scientist in Non-Proliferation and Cooperative Threat Reduction Center (Org 6840) at Sandia National Laboratories. Arian initiates new programs in nuclear arms control, nonproliferation, and Asian and Middle East security. She established the Cooperative Monitoring Center (CMC) in 1994 to enable international cooperation on technical approaches to arms control, nonproliferation, the environment and other security issues.

**Stephen Kleban:** Manager of the Systems Research, Analysis, and Applications Department (Org 6132) at Sandia National Laboratories. As a computer scientist, Stephen has published in complex systems and analysis, optimization, knowledge-based reasoning systems, collaborative systems, computer security, and distributed computer architectures. His staff performs modeling and analysis in numerous complex adaptive systems of systems contributing to national level decisions.