Systems of Systems Workshop

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Workshop's Three Major Objectives

(i) Address projected national and international catastrophic impacts of climate change on sea-level rise, and the subsequent projected dire consequences on our coastal infrastructures and communities in a coherent and systematic hierarchical risk management framework

(ii) Facilitate an ongoing process for the nation's and world's leading scientists and engineers to collaborate, and to ultimately partner with private and public professionals responsible for managing and increasing the nation's adaptive capacity to respond to the challenge of climate change

Workshop’s Three Major Objectives (Cont’d)

(iii) document the synthesis of diverse approaches and mechanisms for adaptation under uncertainty, and widely disseminate the proceedings of the workshop to increase its impact on the formulation of public policy that addresses the scientific, engineering, public health and safety, and the imperative joint role of all levels of government and the private sector

Outcomes and Objectives

- Examine and quantify the well-documented sources of risk associated with sea-level/seawater rise, and incorporate this emergent natural phenomenon within the long-term planning of the U.S. National Infrastructure as a system of systems

- Economic losses arising from extreme and seemingly more frequent weather-related events – including floods, droughts, and storms – have been large and are increasing

Outcomes and Objectives (Cont'd)

- Adaptation and adjustments to natural or to human systems in response to actual or expected climate change require a risk management strategy to help protect vulnerable sectors and communities affected by sea-level rise and increased climate variability in terms of hurricanes, typhoons, storm surges, and coastal erosion

- Develop the building blocks of a hierarchical risk management framework that can cut through the "Gordian Knot" of segmented and limited jurisdictional responsibilities and authorities to effectively deal with key uncertainties associated with the planning for, management of, and adaptation strategies to sea-level rise

Outcomes and Objectives (Cont'd)

This framework will focus on three key tiers of an integrated, hierarchical decision-making framework:

(i) Agency implementation processes of climate adaptation guidelines
(ii) Programmatic policies, evaluation principles and decision criteria
(iii) Project level design, planning, and operating rules and decision criteria

What are Systems of Systems?

Complex systems are commonly composed of myriad subsystems, which in their essence constitute *systems of systems* (SoS).

The term SoS is not just a label; it connotes specific configurations of coupled systems and subsystems with shared states, and also commonly shared stakeholders, decisions, and objectives, whose modeling, and thus management, requires non-conventional approaches.

What are Systems of Systems? (Cont'd)

These SoS are commonly hierarchical in terms of systems and sub-sub-systems, states and sub-sub-states, objectives and sub-sub-objectives, and correspondingly a hierarchy of stakeholders.

Although large-scale and complex systems were extensively studied and modeled as early as the 1940s and 1950s as hierarchical systems, the term systems of systems has been in vogue and more extensively used during the last couple of decades.

What are Systems of Systems? (Cont'd)

Each SoS is characterized by a hierarchy of interacting networks and components, with multiple functions, operations, efficiencies, and the cost of use. Clearly, no single model can ever attempt to capture the essence of such systems – their multiple dimensions and perspectives. Indeed, almost every living entity, all infrastructures, and both the natural and constructed environment are systems of systems.

What are Systems of Systems? (Cont'd)

Maier [1998] offers the following five properties of systems of systems:

(i) Operational independence of the individual systems
(ii) Managerial independence of the systems
(iii) Geographic distribution
(iv) Emergent behavior
(v) Evolutionary development

Development of systems of systems is evolutionary over time and with structure, function, and purpose added, removed, and modified as experience with the system grows and evolves over time.

What are Systems of Systems? (Cont'd)

Building on the five principles and on shared states and other essential entities, this workshop attempts to improve our understanding of the intra- and interdependencies and interconnections within and among systems of systems, both infrastructure systems and their respective management systems, affected by sea-level rise and increased climate variability.

The very interdependency of the systems also makes them more vulnerable to natural and human-caused disruptive events such as sea-level rise, and thus introduces challenges for their protection.

Need for Collaboration and the Topics for Workshop Analysis

The federal government has opportunities to limit its exposure and increase the nation's resilience to extreme weather events. Since 1980, the U.S. has experienced 151 weather disasters with damages exceeding $1 billion each. Policymakers are increasingly viewing adaptation as a risk management strategy to protect vulnerable infrastructure that might be affected by climate change. The nation's critical infrastructure provides the essential services that underpin the American way of life.

Need for Collaboration and the Topics for Workshop Analysis (Cont'd)

A vast array of interdependent infrastructure and information technology networks, systems, services, and resources enable communication, facilitate travel, power our homes, run our economy, and provide essential government services.

The aging or deteriorating condition of significant parts of these systems both weak our resilience to the rise of sea level and negatively affect our nation's security and prosperity.

Need for Collaboration and the Topics for Workshop Analysis (Cont'd)

The projected impacts of climate change, including sea-level rise and increasing severity and frequency of extreme weather events, can cause damage or disruptions that result in cascading effects across our communities, with immeasurable costs in lives lost and billions of dollar in property damage.

Need for Collaboration and the Topics for Workshop Analysis (Cont'd)

According to the NRC and the United States Global Change Research Program (USGCRP), changes in the earth's climate – including higher temperatures, changes in precipitation, rising sea levels, and increases in the severity and frequency of extreme weather events – are underway and expected to grow more severe over time. These impacts present significant risks to the nation's energy infrastructure.

Need for Collaboration and the Topics for Workshop Analysis (Cont'd)

While adaptation measures – such as raising river or coastal dikes to protect infrastructure from sea-level rise, building higher bridges, or increasing the capacity of stormwater systems – is costly, there is a growing recognition that the cost of inaction is greater.

Economic losses arising from weather-related events – including floods, droughts, and storms – have been large and are increasing. Adaptation – an adjustment to natural or to human systems in response to actual or expected climate change – is a risk management strategy to help protect vulnerable sectors and communities that will be affected by climate change.

Need for Collaboration and the Topics for Workshop Analysis (Cont'd)

As stated in a 2010 National Research Council [NRC, 2010] report, even though there are still uncertainties regarding the exact nature and magnitude of climate change impacts, mobilizing now to increase the nation's adaptive capacity can be viewed as an insurance policy against the myriad sources of risk associated with climate change. In this context, it is important to understand:

(i) Federal infrastructure investment
(ii) The condition of existing infrastructure
(iii) Climate change adaptation as a risk management tool
(iv) The limited federal role in planning infrastructure projects

Need for Collaboration and the Topics for Workshop Analysis (Cont’d)

With changing climate and development patterns and the severity and frequency of extreme weather events increasing, the U.S. must address the vulnerability of its critical infrastructure. *A record 98 Presidentially-declared disasters occurred in FY 2011 alone.*

Munich Re, the world’s largest risk reinsurer, reported that weather-related catastrophes from 1980-2010 disproportionately impacted North America with economic losses to the United States totaling $1.15 trillion.

The First Day: Theoretical Scientific and Engineering Construct

The multifaceted impacts and complexity of the systems of systems impacted by sea-level rise, we must assess:

(i) Where does the science and engineering knowledge, knowhow, and experience reside?

(ii) How do we make complex decisions and resolve the tension between the different decision-making parties at the different levels?

The Second Day: Specific Sources of Risk Due to Sea-Level Rise

(i) Groundwater contamination due to saltwater intrusion and storm surge
(ii) Myriad environmental and public health, and societal and economic impacts on coastal communities
(iii) Impacts on physical infrastructures (e.g., roads, bridges, telecommunication and electric power systems)

For each of the above three categories of risk, we plan to invite two federal agency representatives ad two local/state presenters, to devise ways of developing an analytical/ workable framework where the parties could meld the ways and means with which to respond to the above climate-driven events.

The Third Day

(i) Lessons learned from current U.S. preparedness, response and recovery practice to extreme climate events

(ii) Lessons learned for current international preparedness, response and recovery practice to extreme climate events (we expect participants from the UK, Australia, and the Netherlands); Lessons learned from the first two days of the workshop

(iii) Plans for future collaboration and communication among the participants and the universities, institutions, agencies, and organizations they represent

(iv) Plans for the dissemination of the workshop’s findings, lessons learned, recommendations for future steps and action

Dissemination of Workshop Recommendations and Proceedings and its Contribution to the Enhancement and Improvement of Science, Engineering, and Education

The proceedings of presentations, papers, deliberations, and scientific and policy analyses generated during the workshop will be published and disseminated to establish a proactive federal blueprint for action.

The broader impact of the workshop will be to foster collaboration by and among scientists, engineers, and policymakers in the public and private sectors to form a coordinated and effective response to the greatest environmental challenge of the 21st century. The alliance of the University of Virginia and the IWR Research Center of the USACE is unique and important. Scientists, engineers, and policy analysts of the USACE will be invited to present papers and lectures at the workshop.

Dissemination of Workshop Recommendations and Proceedings and its Contribution to the Enhancement and Improvement of Science, Engineering, and Education (Cont'd)

The Society for Risk Analysis, the American Society of Civil Engineers, the International Council on Systems Engineering, and the American Academy of Water Resources Engineers, which have endorsed the workshop, will be enlisted to promote the workshop and help in the dissemination of the findings, research, policies, and education resources produced by the workshop.