Resilient Interdependent Infrastructure Processes and Systems (RIPS)

Spring 2014
ENG Advisory Committee Meeting

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Outline

- Motivation
- Cross-Directorate Program
- Context
- Goals and Objectives
- Themes and Concepts
- Status and Future Plans

Motivation: New Paradigm

"the framework of ***interdependent networks*** and ***systems*** comprising identifiable industries, institutions (including ***people*** and ***procedures***), and distribution capabilities that provide a reliable flow of products and ***services*** essential to the defense and economic security of the United States, the smooth functioning of governments at all levels and society as a whole."

National Infrastructure Protection Plan 2006
Executive Order 13010

Emphasis is on viewing infrastructures as systems of processes with significant human behavioral dependency and cyber components that together deliver services, in contrast with the traditional view as discrete physical elements.

Our approach requires cross-directorate, multidisciplinary research:
collaboration between CISE/ENG/SBE directorates.

PROGRAM SOLICITATION: NSF 14-524

http://www.nsf.gov/pubs/2014/nsf14524/nsf14524.htm

NSF RIPS: A Cross-Directorate Program

- **Directorate for Computer & Information Science & Engineering**
  Division of Computer and Network Systems

  Directorate for Engineering
  Emerging Frontiers in Research and Innovation
  Division of Electrical, Communications and Cyber Systems
  Division of Chemical, Bioengineering, Environmental, and Transport Systems
  Division of Civil, Mechanical and Manufacturing Innovation

  Directorate for Social, Behavioral & Economic Sciences

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Context

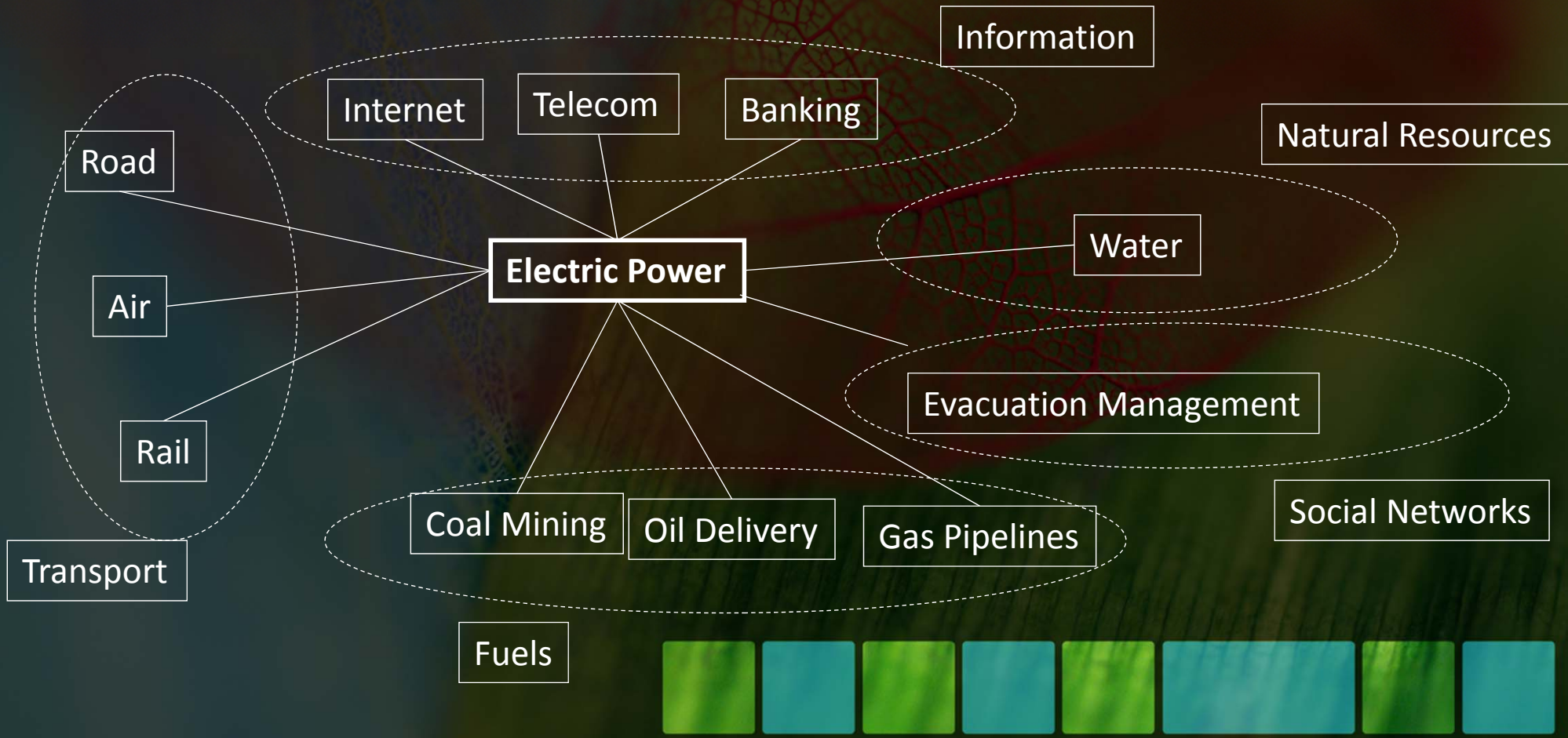
Critical infrastructures are the mainstay of our nation's economy, security and health

These infrastructures are interdependent:

The electrical power system depends on the delivery of fuels to power generating stations through transportation services, the production of those fuels depends in turn on the use of electrical power, and those fuels are needed by the transportation services

These are interactive complex dynamic systems

Examples of Interdependencies



RIPS Program: Goals

- Advance understanding and design of interdependent critical infrastructure systems (ICIs) and processes not only in response to failures from any cause (natural, technological, or malicious) but also in response to normal operations
- Create the knowledge for innovation in ICIs to provide society with new business models along with industries that produce new goods and services
- Develop integrative predictive models that impact decision making
- Foster an interdisciplinary research community

RIPS Program: Objectives

- Create theoretical frameworks and multidisciplinary models of interdependent infrastructure systems, processes and services, capable of
  - Analytical prediction of complex behaviors, in response to system and policy changes
- Increase resilience, interoperation, performance, and readiness in ICIs
- Understand organizational, social, psychological, legal, political and economic obstacles to improving ICI's, and identifying strategies for overcoming those obstacles
- Validate predictive models with real data

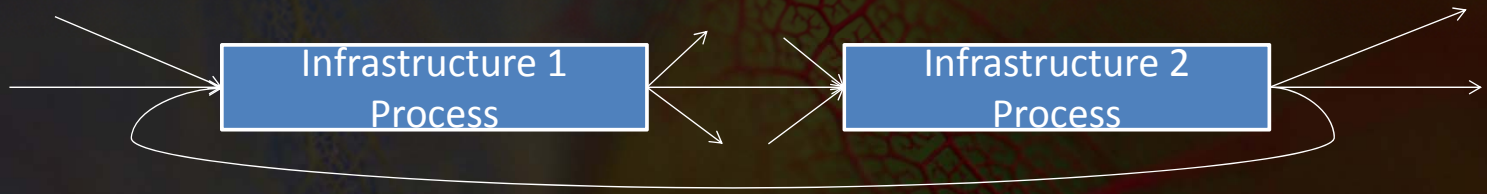
Critical Infrastructures and Key Resources

- Agriculture
- Food
- Water
- Public Health
- Emergency Services
- Government (incl. education)
- Defense Industrial Base
- Information and Telecommunications
- Energy
- Transportation
- Banking and Finance
- Chemical Industry
- Postal and Shipping
- Dams
- Commercial Facilities
- Critical Manufacturing
- National Monuments & Icons
- Nuclear Reactors, Materials and Waste

[1] U.S. Office of Homeland Security. The National Strategy for Homeland Security, July 15th 2002, p31.
[2] National Infrastructure Protection Plan Executive Summary, Partnering to enhance protection and resiliency, 2009, available online https://www.dhs.gov/sites/default/files/publications/nipp executive summary 2009.pdf

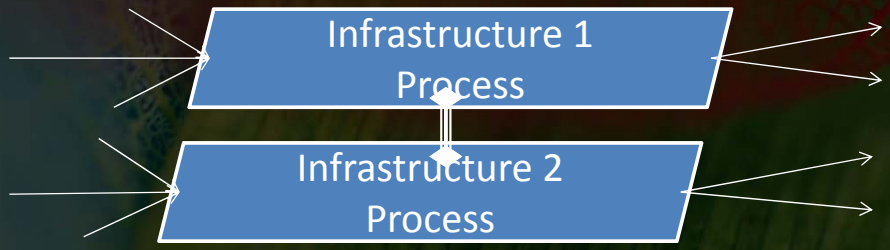
Interdependency vs. Interconnectedness

Interdependent = Infrastructure Processes use each other's outputs as inputs



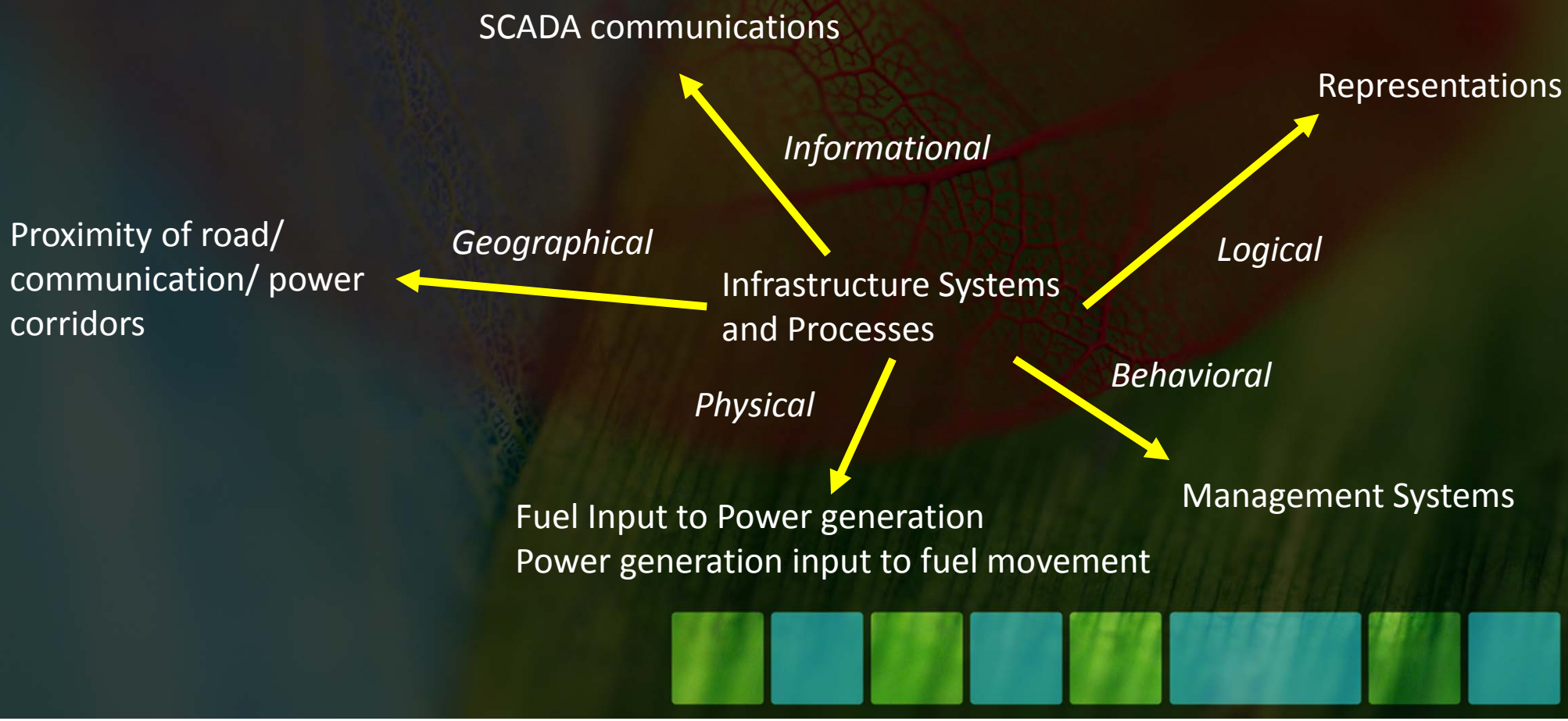
Example: Transportation agency provides information to households during evacuation while evacuation decisions made by households affect the information provided by the agency

Interconnected = Infrastructure states changed by each other due to physical or cyber co-location

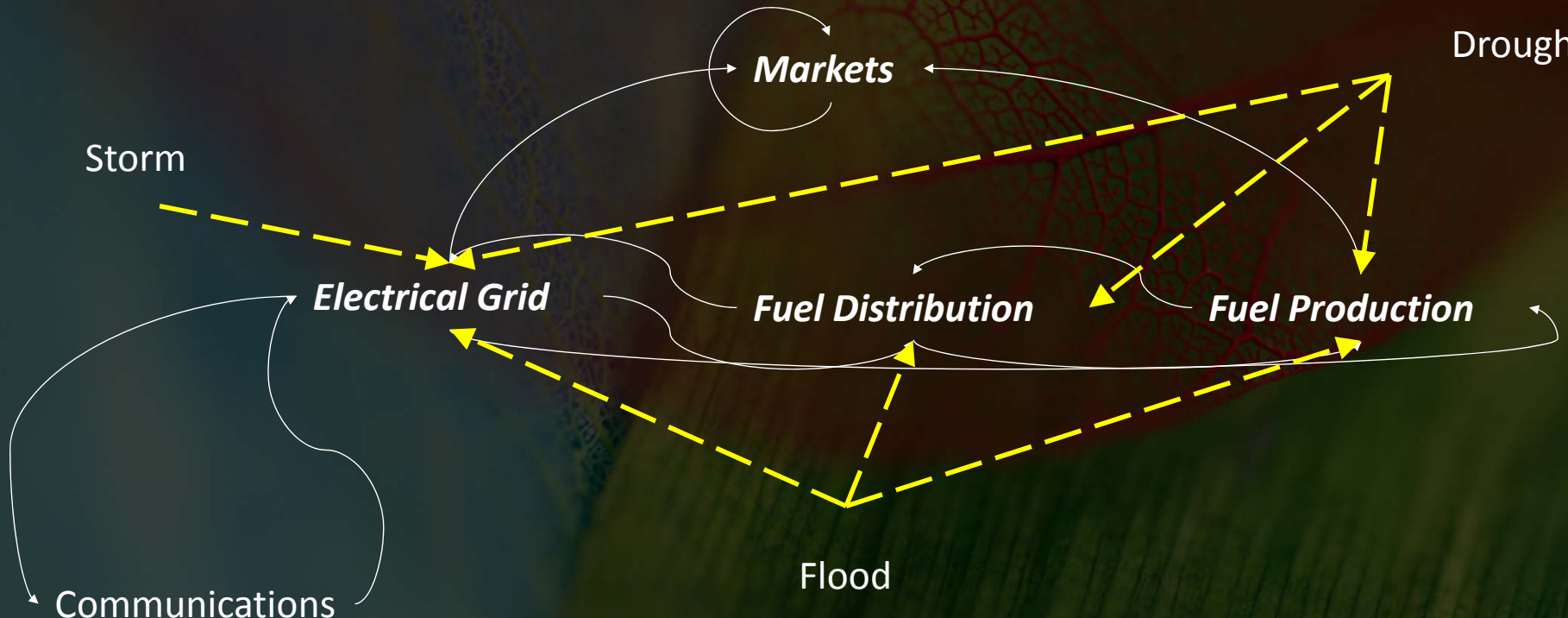


Example: Co-location of electricity wires and optical fibers

Examples of Types of Interdependencies



Time & Length Scales of Interactions



Connectivity and Vulnerability

Spreading by connection

- Cascading “failures” due to load shifts
  - Electrical networks
  - Water networks
  - Transportation networks
  - Natural gas networks

- Infection by contact
  - Disease spread
    - SARS
    - Foot and mouth
    - Bird flu
  - Information spread
    - Markets
    - Terrorist cells
    - Rumors
  - Computer virus spread

Behaviour of ONE of these networks is complex

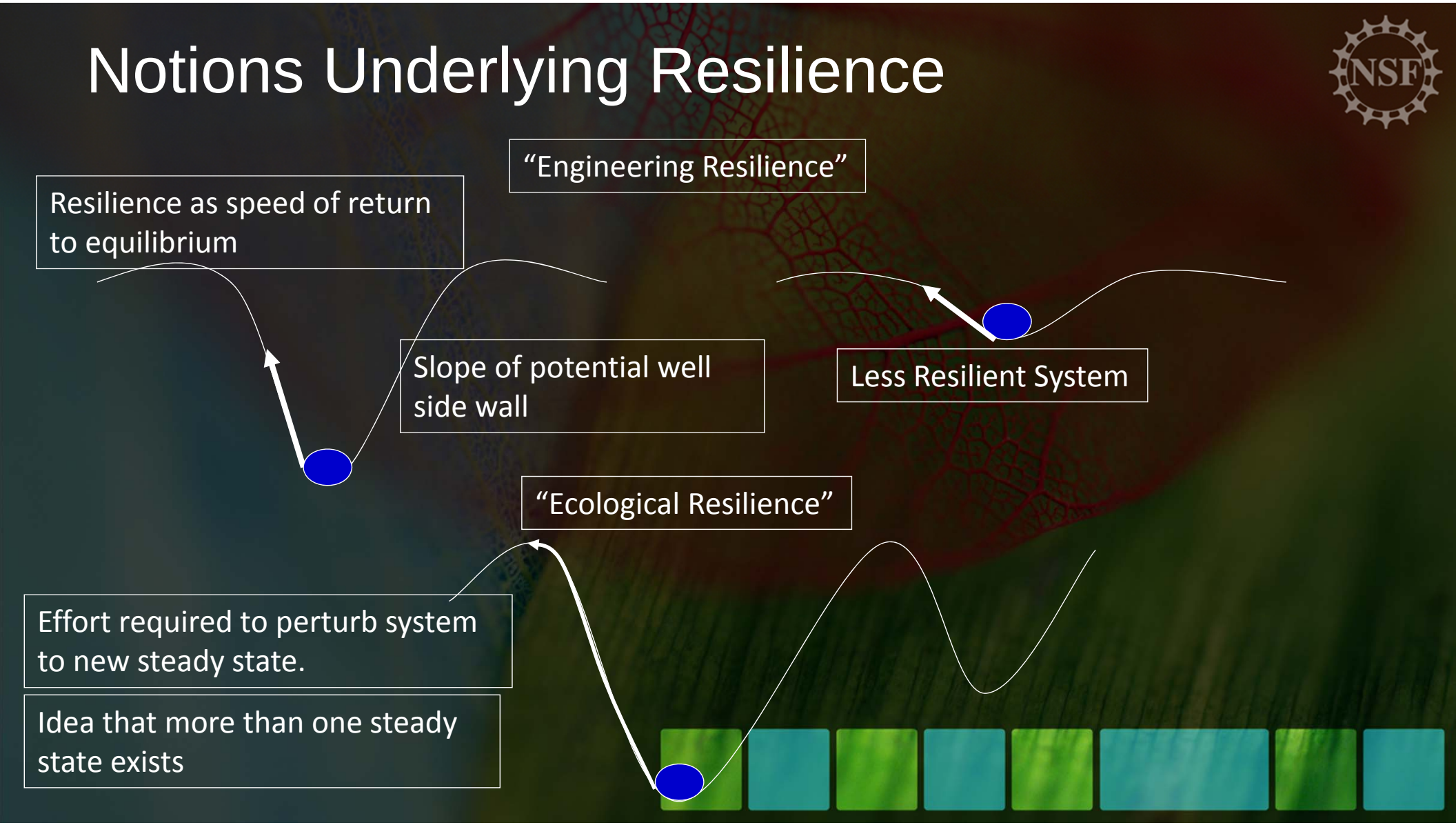
Need to understand how these networks interact

Research Challenge: How to develop models and decision making support for resilient interdependent infrastructure choices.

Resilience

A Definition of Resilience

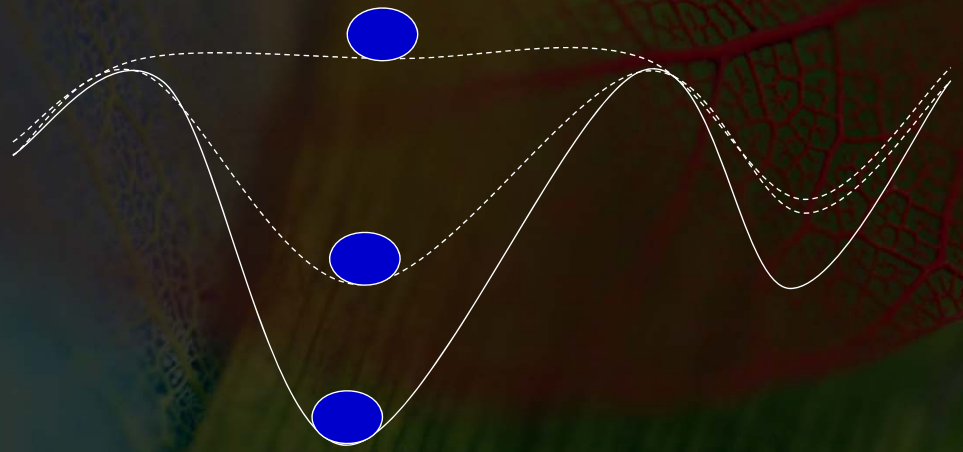
Notions Underlying Resilience



Loss of Resilience

A slow parameter drift can cause the loss of resilience

Smaller perturbations lead to shifts in stability



It is sometimes the case that the system management causes the loss of resilience.

E.g. Spraying of forests for insects

NSF RIPS Program: Themes

- Create conceptual frameworks or theories from a multi-disciplinary perspective
- Test hypotheses and validating explanatory models through empirical work in involving ICIs with either existing or newly collected data
- Build multidisciplinary communities to address ICIs

NSF RIPS Program: Themes

- Understand organizational, social, psychological, political and economic obstacles to improving ICI's, and identifying strategies for overcoming those obstacles
- Understand human responses to the predicted performance of interdependent infrastructures
- Improve control, integrity, and overall stability of services provided by ICIs
- Explore the economics and governance of ICIs
- Explore new multidisciplinary engineering approaches to increase: Resilience, interoperability, performance, and readiness in ICIs

NSF RIPS Program: Themes

- Expand the design space of alternatives, leveraging new interdependencies to increase resilience to extreme conditions and future events
- Determine the socio-economic value of new interdependencies of ICIs to meet societal demands
- Create the knowledge that leads to innovative new ICI services and markets, facilitating transition to practice

RIPS: Program Guidance – Type 1 Proposals

Type 1 Proposals

- Theory, modeling, and metrics projects that will create the knowledge, methodologies and approaches to conceptualize and study interdependent infrastructures
- Not intended for empirical testing of models or theories
- Can be used for team building that will help clarify basic terminology, assumptions and premises that enable theories, model and metric formalizations for interdependent infrastructures as processes and services
- Projects will have duration 1-2 years for a maximum of $300,000 for each project in total direct and indirect costs

RIPS: Program Guidance – Type 2 Proposals

Type 2 Proposals

- Support interdisciplinary research to conduct major new interdependent infrastructure research using empirical data
- Include the creation of knowledge, methodologies, and approaches to conceptualize and study interdependent infrastructures as processes and services.
- Projects will have a duration of 3 years for a maximum of $1,000,000 to $2,500,000 for each project in total direct and indirect costs

Solicitation Status

- 155 proposals were received (including collaborative proposals)
- Type I: 20 individual projects
- Type II: 60 individual projects
- **Funding Amount:** $15,000,000

Future Plans

- RIPS Solicitation was the first effort in this important area of research.
- NSF FY 15 Budget includes request as part of CEMMSS cross-cutting activity:
  - **CRISP:** Critical Resilient Interdependent Infrastructure Systems and Process