# Complex Engineered and Natural Systems

- **Definition: Complex, Complexity (adj., n)**
  - Consisting of interconnected or interwoven parts;
  - Involved or intricate, as in structure; complicated.
  - Difficult to understand because of intricacy:
  - A whole composed of interconnected or interwoven parts
  - Engineering Complexity -- the condition of being difficult to explain and predict systems behaviors, robust operation of the same.

- **Need/Impact**
  - Improve our ability to understand, model and manage complex engineered and natural systems; this includes ecosystems, the worldwide web, metabolic pathways, economic markets, spread of infectious disease, and the operation of the power grid.

  - Explain and predict systems behaviors, better engineer and design these systems, and enable robust control responses

- **The challenge**
  - Creation of common principles, unified theories, and methods to design, operate, and protect complex engineered systems.

- **Sources of complexity**:
  - Too much information, too many components, too many constraints, too many parameters for consideration to accomplish a particular task
  - Not enough information about essential elements or components of a system or about their interfaces
  - Not enough information about how elements or components will behave under known or unknown conditions that may lead to unintended consequences

- **NSF’s Role**
  - Research communities address complexity from the point of view of individual disciplines, e.g. complexity in cyberinfrastructure, biology, traffic, urban living, etc.
  - Because complexity projects itself in specialized ways in different disciplines, the benefit here is the ease with which individual communities can develop their own descriptions of complexity and how to approach it; from these results common elements can be derived. A potential danger is that efforts may be domain specific; a broader approach is needed to develop a comprehensive understanding of complexity.
  - Fundamental research themes include modeling and experimentation of physical and human systems, analysis of complex data sets, simulation, prediction, and robust decision making.
  - Mathematicians, engineers, and scientists must collaborate to extend the frontiers of discovery in these research themes so that the goal of understanding, managing, and protecting these complex systems can be realized.
- **Potential Partners**
  - All NSF Directorates
  - Other Agencies

# Critical Infrastructure Systems Resilience and Sustainability

- Need/Impact

  CIS -- networks and systems that provide a continual flow of goods and services essential to the well being of the nation. (Agriculture and food, water and fuel supplies, public health, emergency services, the defense industrial base, information and communications, energy and power, transportation, banking and finance, and healthcare.)

  Need -- *robust* critical infrastructure systems that are *resilient* and *sustainable* against degradation over time and failure in response to natural and other hazards and possess self-monitoring and self-healing properties.

**Challenge: Minimize cascading effects Multiple-impact Catastrophic Natural & Human-Induced Disasters (MCND) by:**

- Providing hazard and disaster information where and when needed;
- Understanding the natural processes that produce hazards;
- Developing hazard mitigation strategies and technologies;
- Recognizing and reducing vulnerability of interdependent critical infrastructures;
- Assessing disaster resilience using innovative methods;
- Identifying effective design of CI operations in dynamic, uncertain and adversarial Environments.

**NSF's Role**

Develop and support research in the area of Multiple-impact Catastrophic Natural Disasters (MCND) to provide fundamental knowledge in how to planning and responding to these events.

**Potential Partners**

All NSF Directorates

Several USG Agencies