Space Weather: Organizational, Institutional and Public Policy Issues

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Socio-Economic Effects of Extreme Space Weather: Principal Arguments

- Space weather can have serious effects on power, communications, transport --> critical infrastructures, a.k.a "Large Technical Systems" (LTS)
- Effects are infrequent, but potentially catastrophic --> Low Frequency, High Consequence Events (LFHCE)
- Creeping dependency and risk migration present real but untestable problems for rapidly-changing large complex systems
- LFHCEs challenge public policy and risk management processes
  - Sustaining policy attention
  - Developing regulatory responses
  - Securing technical design compliance
  - Managing rare, catastrophic geomagnetic events across an interconnected world

Critical Infrastructure Interdependencies: Complex and Increasing

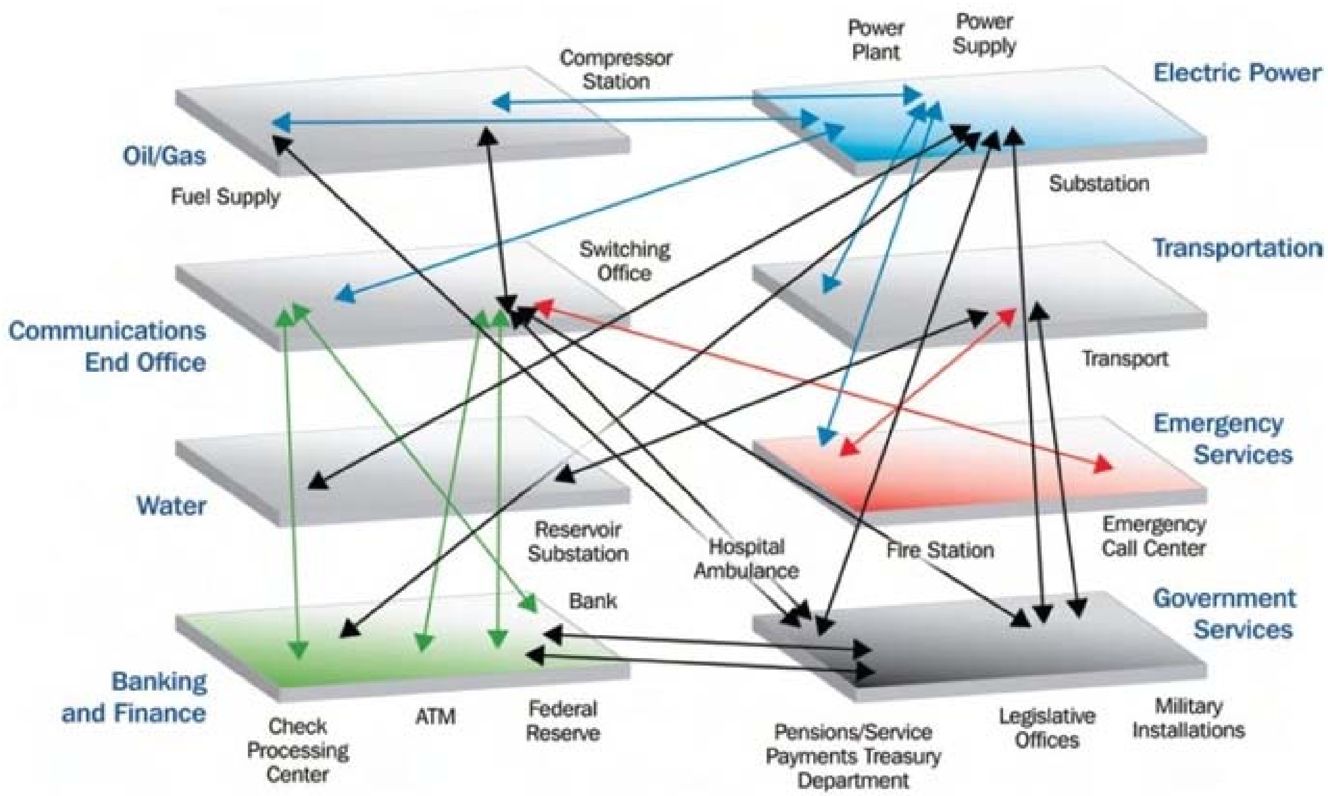

FIGURE 3.1 Connections and interdependencies across the economy. Schematic showing the interconnected infrastructures and their qualitative dependencies and interdependencies. SOURCE: Department of Homeland Security, National Infrastructure Protection Plan, available at http://www.dhs.gov/xprevprot/programs/editorial_0827.shtm.

Global System Interdependence: Complex and Increasing

- Interdependence will increase
  - Logistics, manufacturing, services, finances increasingly internationally linked
  - --> globalization
- Response coordination difficult with short warning time Ex: tsunami, Katrina responses
  - Institutional differences
  - Sensors and warning system weakness
  - Differing policies, planning
  - Variation in knowledge bases
  - Divergent economic development levels
  - Culture

Dependency Creep and Risk Migration

- Dependency creep and risk migration:
  - Electric power, transportation, and water supplies
  - GPS and logistics
  - Cell phones and telephone numbers
  - Telecommunications and diesel fuel
  - Nuclear power and chemical plant operations

- Near-term future
  - Fusion of computing, communications, biotech and nano-technologies at higher levels of complexity
  - Smaller size, greater functionality and greater societal dependence
  - Electric power, communications devices and networks, satellite-based system esp. prone to dependency creep

Space Weather and LFHCEs

- Space weather uniquely affects LTSs: electric power, communications, navigation
- Simultaneous, direct, dependent, interdependent effects of disruptions
- Individual systems work well in isolation or normal conditions...

...But overall systems almost never tested in extreme events

Efficiency-Vulnerability Trade-off

		Security Environment	
		Benign	Hostile
Economic Environment	Monopoly	Costs passed to users	Total mobilization War-time footing
	Competitive	Operations at efficiency frontier	Brittle, lack slack, vulnerable to disruption

Efficiency-Vulnerability Tradeoff

- Security externalities emerge due to:
  - Lack of knowledge
  - Lack of slack
  - Lack of trust
  - Lack of means of overcoming coordination problems

- Role for government to assist overcoming these shortcomings
  - Information sharing, trust building
  - Reserve capacity, circuit-breaker requirements

Institutions and LFHCEs

- Institutions address long-term problems
- Need time, leadership and resources to develop fully
- Need periodic provocations or existential threats to respond to challenges
- LFHCEs make risk calculations and risk management difficult

- LFHCEs frustrate social learning, preparedness and planning
- Space weather is a classic example of an LFHCE

Anticipation or Resilience?

- Normal accident theory (Perrow, 1986) suggests that it will be impossible to prevent every large system failure
- Anticipation or protection: useful strategy when threat is known and regular: applies to many technical aspects of extreme space weather (Wildavsky, 1984)
- Resilience: useful strategy when threat is unknown or inconsistent: more useful in non-technical aspects, such as dealing with the public, institutional design

Highly Reliable Operations at Risk

- LTSs essential scaffolding of modern society: highly reliable network systems of powerful/highly hazardous technologies of critical import:
  -- > Highly Reliable Organizations (HROs)
- HRO operations are essential but extraordinarily challenging to operate:
  - Taken for granted
  - Rarely accomplished
  - Not well understood
  - Hard to replicate
  - Costly to maintain
  - Involve many institutions, technologies, publics, and
  - Require specific conditions to come into being
- High reliability is both --> technical and organizational phenomenon
- Extreme space weather events threaten failure-free operation of LTSs

Complex Adaptive Systems and Anticipatory Governance

- Most learning is by trial and error, in small-scale settings, before applied at larger scales
- Extreme space weather challenges this practice: can only model or test subsets of systems, not whole systems
- How do large complex systems adapt to crises or extreme events?
- And for rare events like extreme space weather, how do organizations learn without direct experience?
- Complex adaptive systems
- Anticipatory governance

Discouraging Examples

- Three Mile Island, 1979
- Challenger/Columbia explosions, 1984, 2003
- California Blackout 2001
- 9/11 warning, prevention, 2001
- Northeast Blackout 2004
- Christmas tsunami. 2004
- Hurricanes Pam, Katrina, Rita 2004, 2005
- Mortgage and financial crisis, 2008

- Despite repeated warnings and episodic catastrophes, only weak institutional capacity to mitigate, prevent or respond to catastrophes
- Causes: competing interests, inadequate resources, poor leadership, unprepared organization culture, lack of policy attention and support
- Result: systems were non-adaptive

Encouraging Examples

- California earthquakes
- Florida hurricane response
- Dutch storm surge mitigation and response
- Cold War nuclear readiness
- Nuclear power plant operations

- All catastrophic failures, faced existential threat
- All institutionalized political constituencies, policy networks, regulatory structures
- All relatively strong technical, organizational and cultural capacities, and achieve operative or auto-adaptive response capability

Technical Change, Risk Migration and LFHC Events

- Technical systems optimized for benign environment
- New technologies introduced gradually
- Wireless communications and computing increasingly relied on for primary services; fiber optics may be mitigating factor
- Risk migrates out of view of system operators
- Digital systems do not degrade gracefully
- Complex tightly-coupled critical systems will fail "normally"
- Space weather environment changes too slowly to challenge fundamental systems designs, especially new systems

Disaster Planning & Emergency Management Institutions

- Institutions set up for familiar disasters, not extreme space weather events
  - Concentrate on the plan, not on adaptation or improvisation
  - Paralyzed by accountability requirements
- Concerns about adding a new and poorly- understood event type
- Warning time is very short, high uncertainty if wrong: Boy who cried wolf?

- Extreme space weather not typical FEMA or DHS event: lack of knowledge, experience, public trust

Space Weather: Technical Problem

- Protect devices and systems against disruptions from extreme space weather
- Rely heavily on early and precise warning from space-based and other sensors as principle strategy
- Assuring functioning of these sensors and systems is the only focus of policy and agency operations
  - Programs
  - Budgets
  - Coordination
  - Politics

Space Weather: Organizational Problem

- Technical systems at risk (electric power, communications systems, satellite operations, pipelines) may be or are likely to be aware of threats to their own systems
  - But may not be aware of (inter)dependencies among them
- System operators may not appreciate extent to which risk has migrated through the larger technical systems
  - Exploring such relationships should be a high priority
  - Very large-scale economic, communications, transportation and social system modeling may be useful, e.g. NISAC
  - But modeling cannot reveal all interdependencies with high certainty

Space Weather: Institutional Problem

- Policy and regulatory frameworks to manage extreme space weather events is job of public authorities --> anticipatory governance
- Yet inadequate understanding in policy-making community for this task to be carried out effectively
- LFHCEs thwart policy action, including space weather
  – Exception of some systems for national defense
  – Conditions under which anticipation and foresight are routinely exercised not well understood
    - Existential threat
    - Widespread public support
    - Sustaining public institutions

Space Weather: Social Problem

- Managing communications among operators and with the public is a critical function
- Yet public authorities do not now possess the capacity to carry out this task
  - Institutional trustworthiness and competence are serious issues
- Risk management and risk communications should be a priority in the coming years, and as part of a long-term strategy to heighten public sensitivity without creating undue anxiety

How could systems be designed to be inherently robust to space weather?

- Grand Engineering Challenge
- Test systems and devices, engage standards bodies
- Identify and map system dependencies and interdependencies
- Development better early warning and coordination of system monitoring, shut-down, islanding
- Encourage Highly Reliable Organization structure, practices, scaffolding
- Engage public in risk analysis and assessment: National Academies "Understanding Risk" Report 1996
- Consider radical reconfiguring systems to avoid high consequence event costs: "On Self-Reliance"

Thank you!

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