

Critical Infrastructure Resilience Concepts, Frameworks, & Strategies

INCOSE Chesapeake Chapter
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Cities | Roads | Railways | Transmission Lines | Pipelines | Shipping Lanes | Submarine Cables | Flight Routes

NIPP 2013

Partnering for Critical Infrastructure
Security and Resilience

Critical infrastructure

Products & services deemed
essential to public health, safety,
and well-being.



- Chemical
- Commercial Facilities
- Communications
- Critical Manufacturing
- Dams
- Defense Industrial Base
- Emergency Services
- Energy
- Financial Services
- Food and Agriculture
- Government Facilities
- Healthcare and Public Health
- Information Technology
- Nuclear Reactors, Materials, and Waste
- Transportation Systems
- Water and Wastewater Systems

16 Critical Infrastructure Sectors

Critical Infrastructures

*...essential to public health,
safety and well-being*

- 3,000+ government facilities
- 7,500+ Hospitals
- 2 billion miles of telecomm cable
- 1000s of telephone switching offices
- > 11,000 Electric power plants;
- 300,000 oil & natural gas producing sites
- > 90 nuclear power plants
- > 80,000 dams
- 5000 public airports
- > 600,000 roadway bridges
- 2 million miles of pipelines
- 300 coastal ports
- 500 major urban public transit operators

(Kennedy, 2006)

Photo: Felix Pharand Deschenes

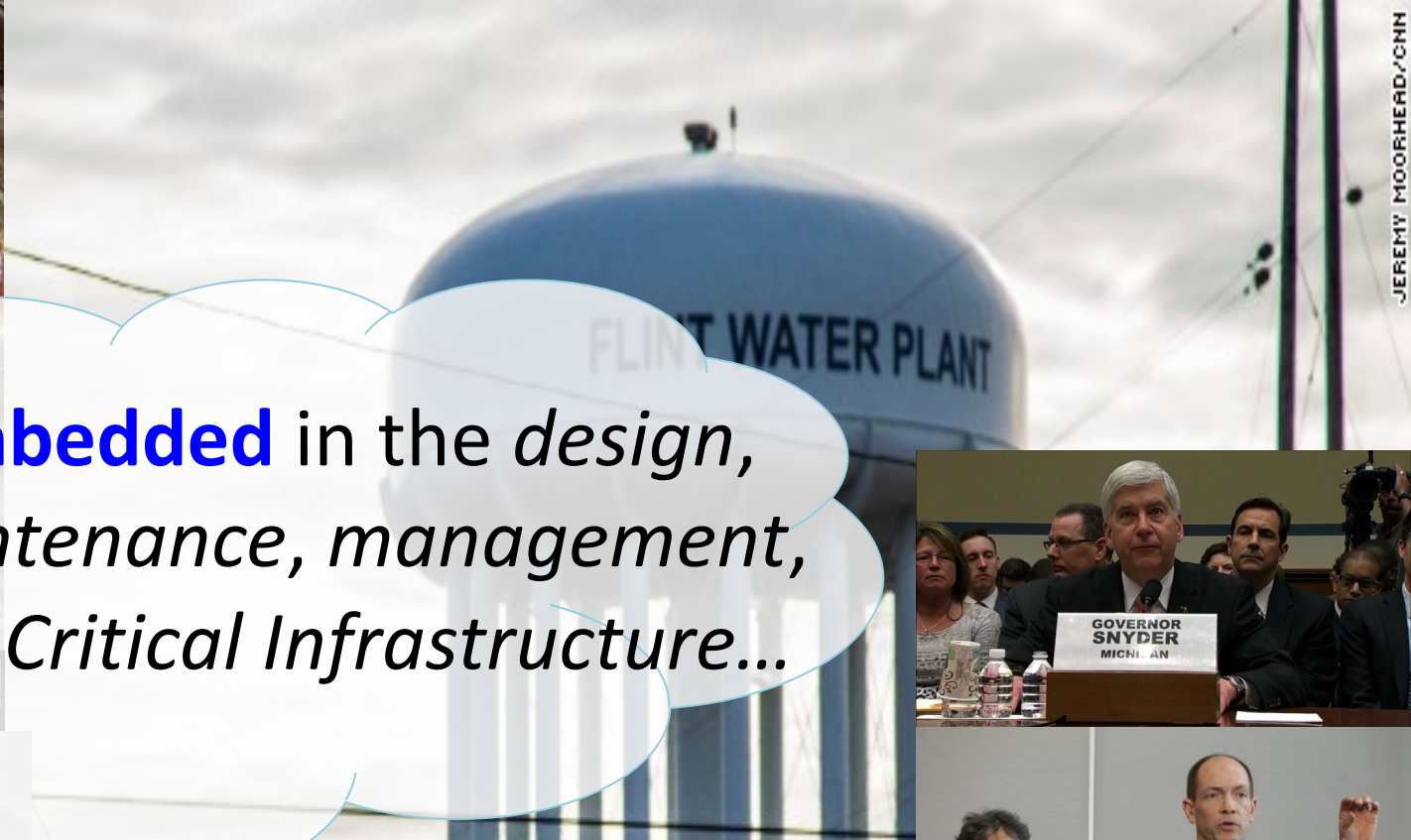


PPD-21

(The White House, 2013)



National Infrastructure
Protection Plan, 2013



JEREMY MOORHEAD/CNN

Humans are **embedded** in the *design, operation, maintenance, management, & regulation of Critical Infrastructure...*

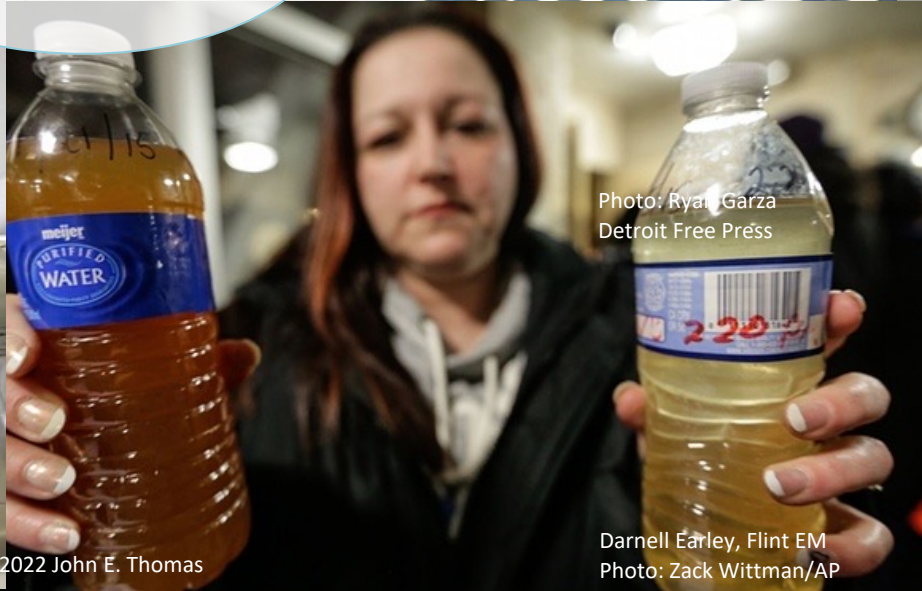


Photo: Ryan Garza Detroit Free Press



Darnell Earley, Flint EM Photo: Zack Wittman/AP

Texas Power Outage: Unprepared to be Unprepared

15 February 2021



Resilience Engineering Paradigm Shift?

Risk Management		Resilience
Fail-safe	→	Safe-to-fail
Reduction	→	Incompleteness
Definition	→	Ambiguity
Specification	→	Emergence
Reliability	→	Recovery
Centralized	→	Distributed
Probabilistic	→	Possible

(Park et al., 2013)

Resilience Engineering

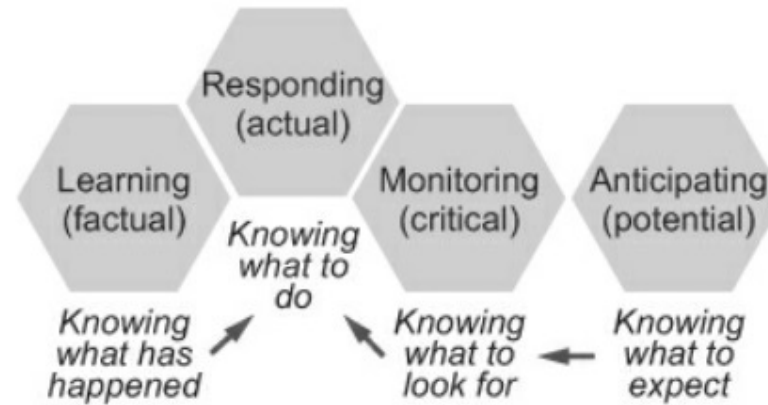
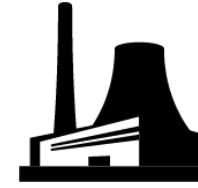


Figure P.5 The four cornerstones of resilience

The resilience of a system is defined by the abilities to respond to the actual, to monitor the critical, to anticipate the potential, and to learn from the factual.” (Hollnagel et al., 2011)

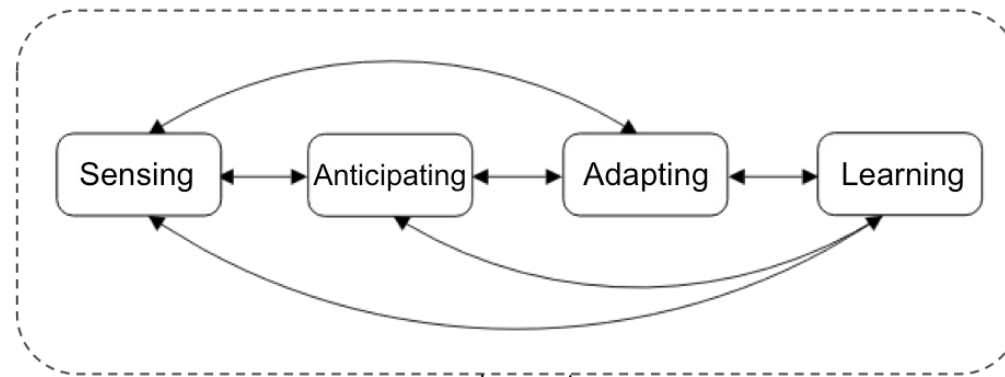
- What goes right is just as important as what goes wrong.

Resilience Enabling Processes



- **Sensing**—monitor systems state variables
- **Anticipating**—imagining possible state outcomes
- **Adapting**—changing state variables to manage performance
- **Learning**—differentiate, integrate, & create knowledge informing system behaviors

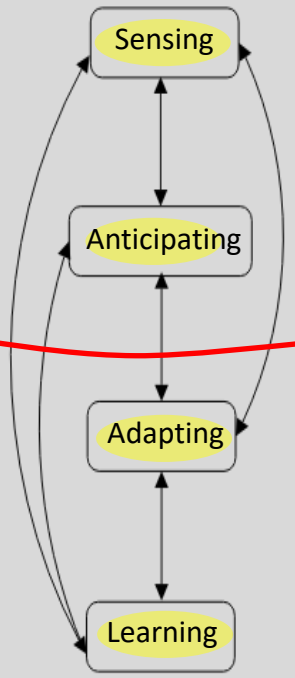
(Park et al., 2013)



Inputs and outputs at the system boundary

Individual & Group Resilience
Actions, behaviors, & artifacts

(Thomas et al., 2019)



Humans



Infrastructure

Solarwinds Cyber Security Breach

- Biggest cybersecurity breach in U.S. history
 - Supply-chain network management software
 - Russia is suspected
 - Over 18,000 hacks identified
 - Microsoft's systems used to support the hack
 - Einstein designed in 2003 to address known threats
 - Unable to respond to unknown threats
-
- Homeland Security
 - Commerce and Treasury
 - National Institutes of Health
 - Department of State



solarwinds

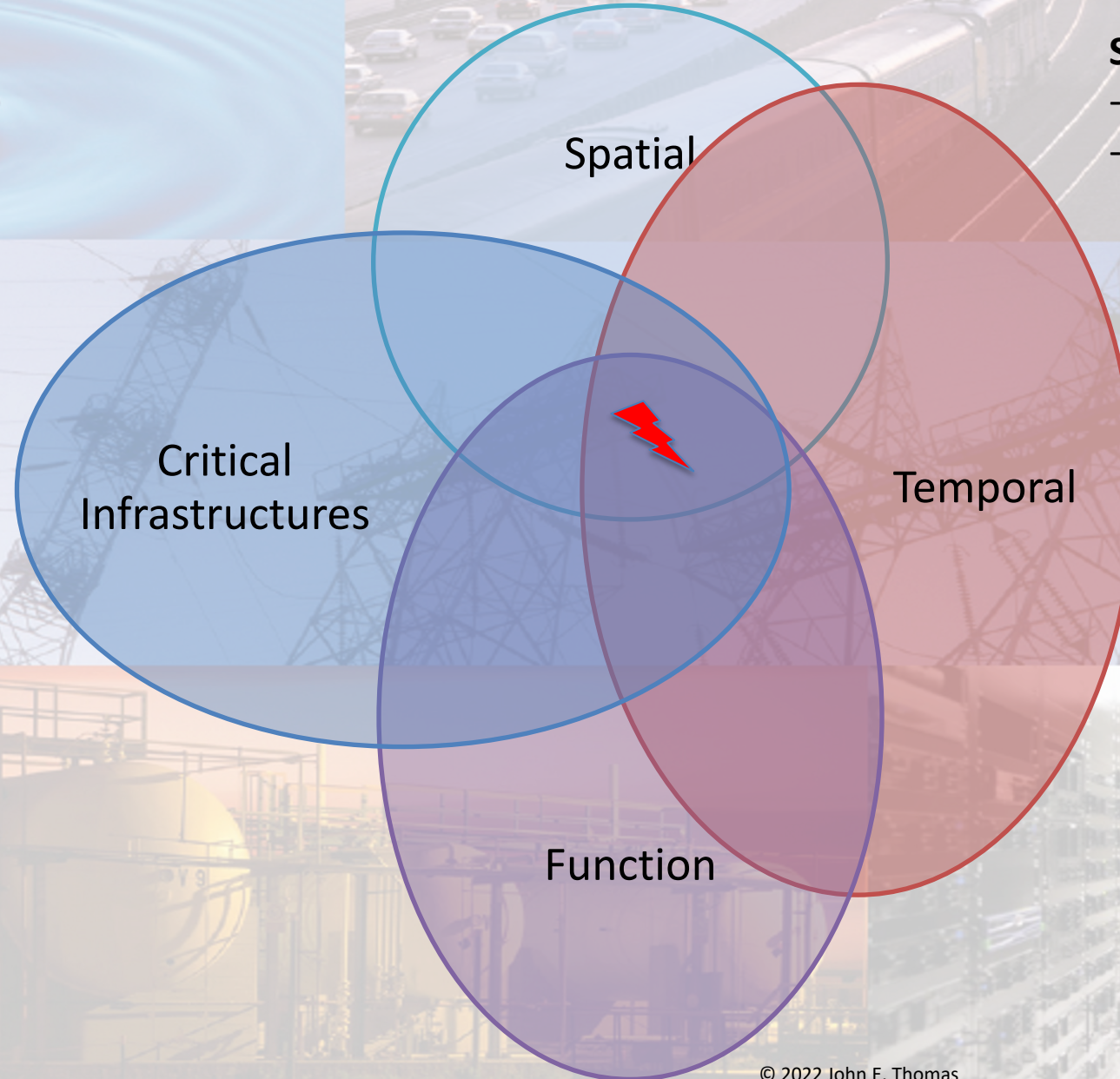
Transboundary Crises Trends

Critical Infrastructures

- Energy
- Water
- Transportation
- Communications
- Public health
- Cyber attacks
- Domestic terrorism
- Other

Functional boundaries

- Hurricane Katrina
- Social breakdowns L&O
- Cascading breakdowns
- Deep Horizon oil spill



Spatial boundaries

- 2003 Blackout in NE, Ms
- Pandemics:
 - SARS
 - Covid-19

Temporal Boundaries

- Climate change
- Oil spills
- Pandemics, Covid-19
- Social & political unrest



CORONAVIRUS PANDEMIC

Environmental Damage, Sustainability & Global Impacts

Growth

Sustainability

Conflicting agendas
Deplete resources faster than they can be replenished



complexity

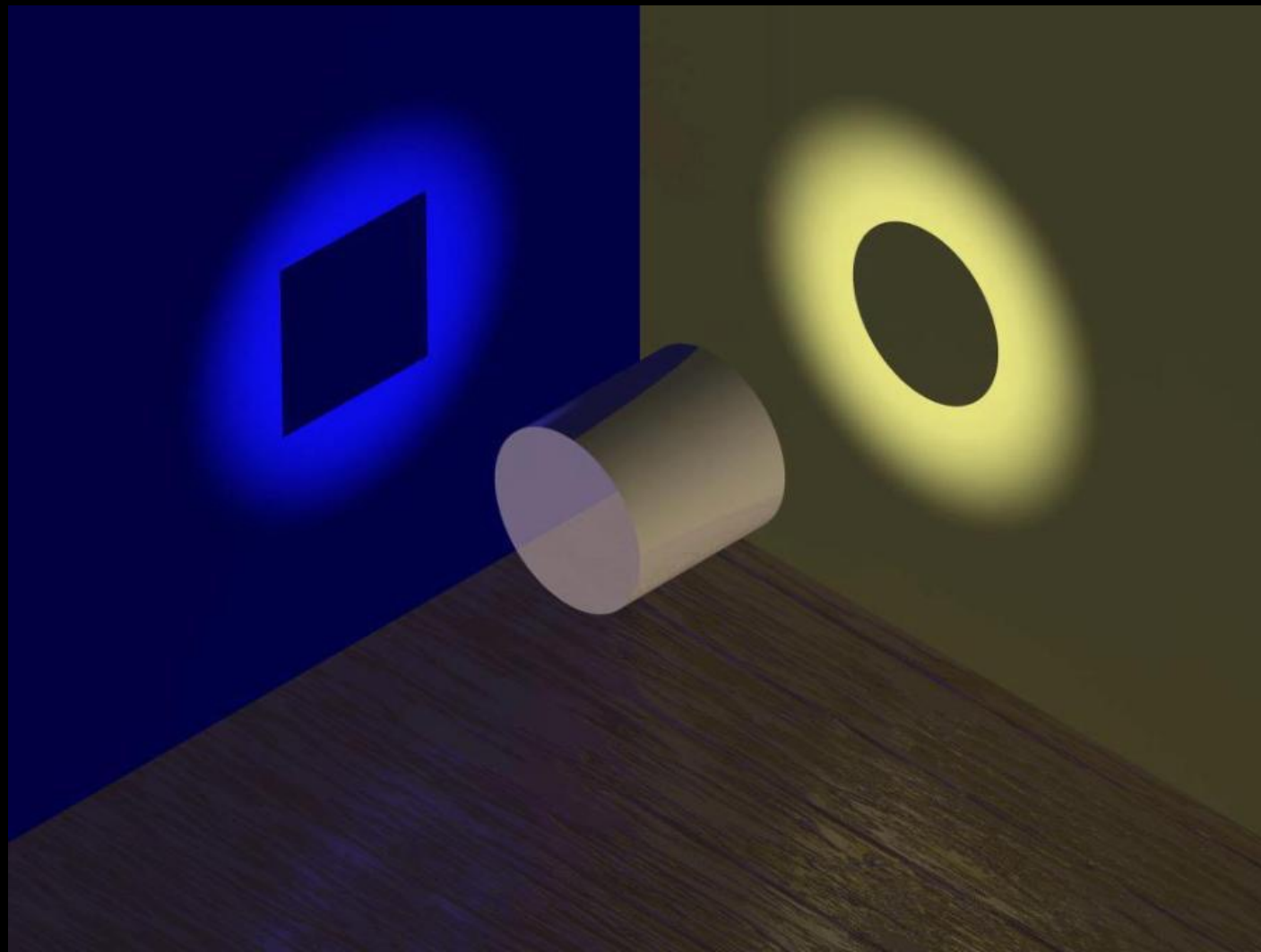
Human complexity?

Technological complexity?



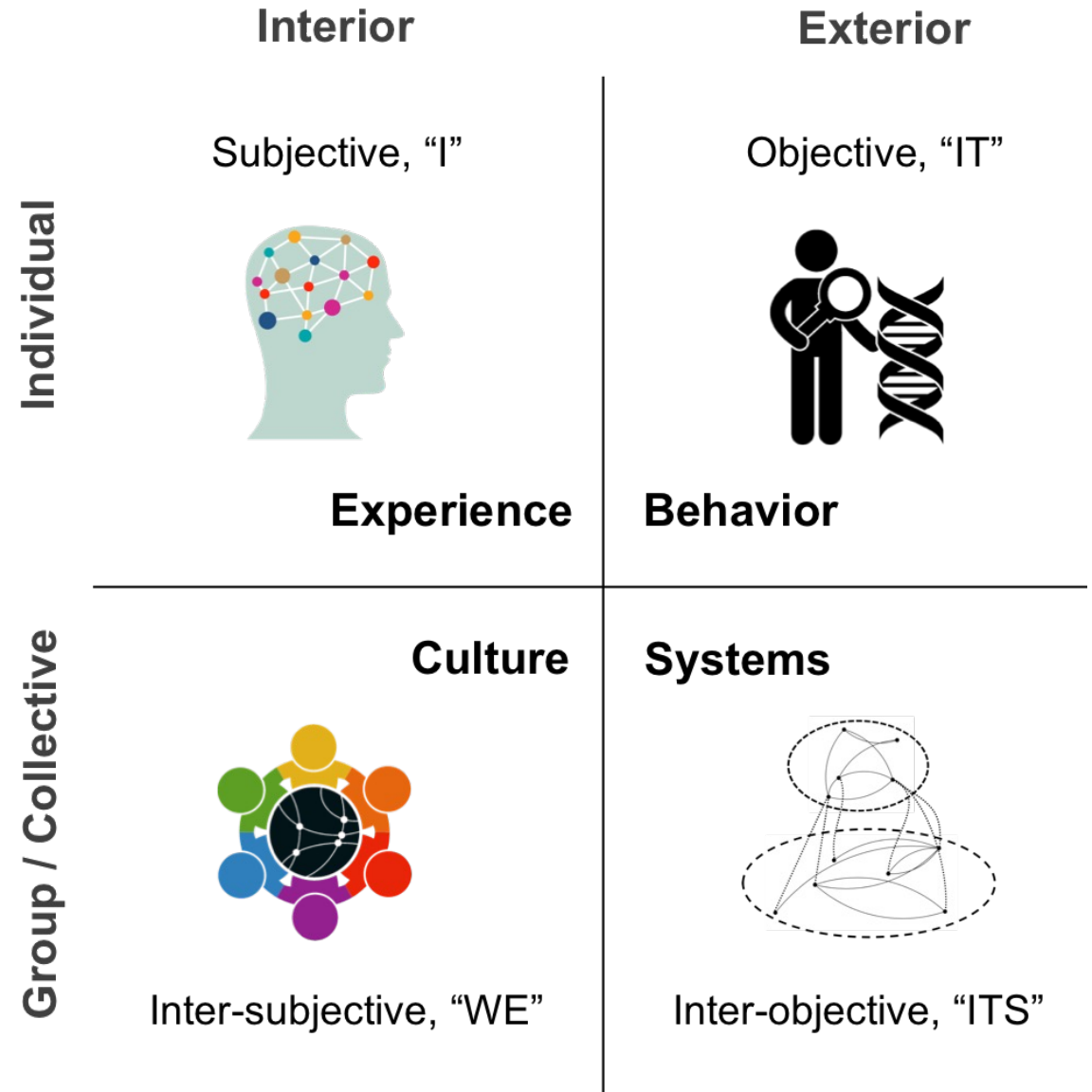
ISO New England
Holyoke, Mass

What do 'you' see?



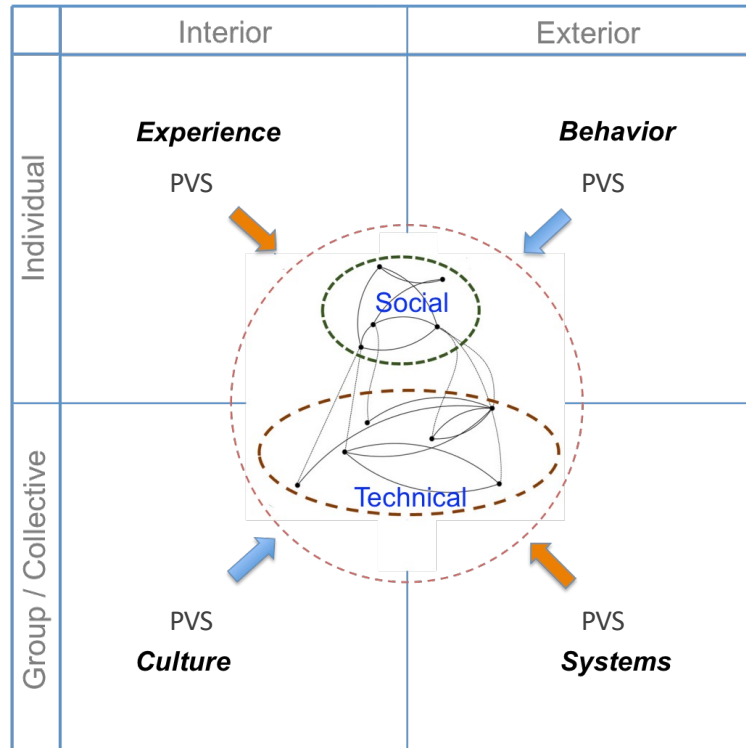
Holistic Perspectives

- Irreducible domains of information
 - Interior & exterior dimensions
 - Singular & plural dimensions
- Does not change the content
 - Frames perspectives



(Thomas, et al. 2018)

Holistic perspective of coupled social and technical systems

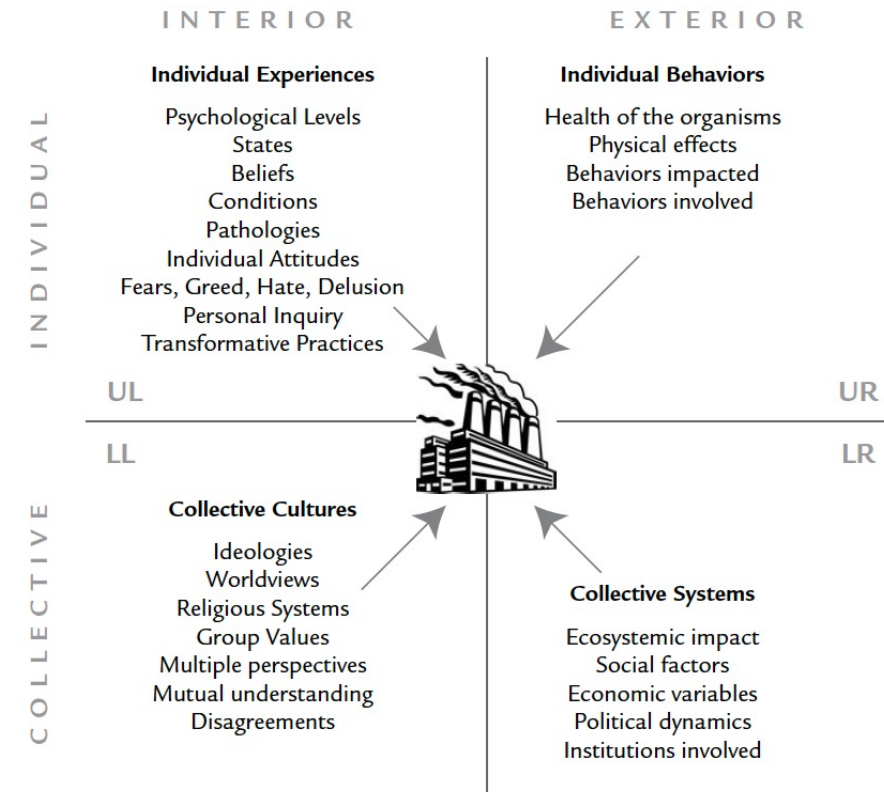


PVS

P = Protective factors

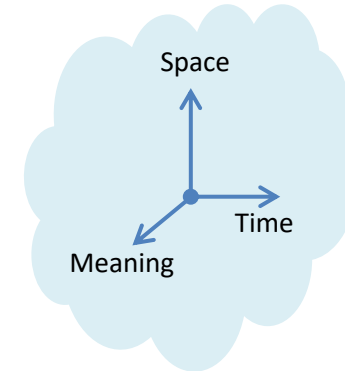
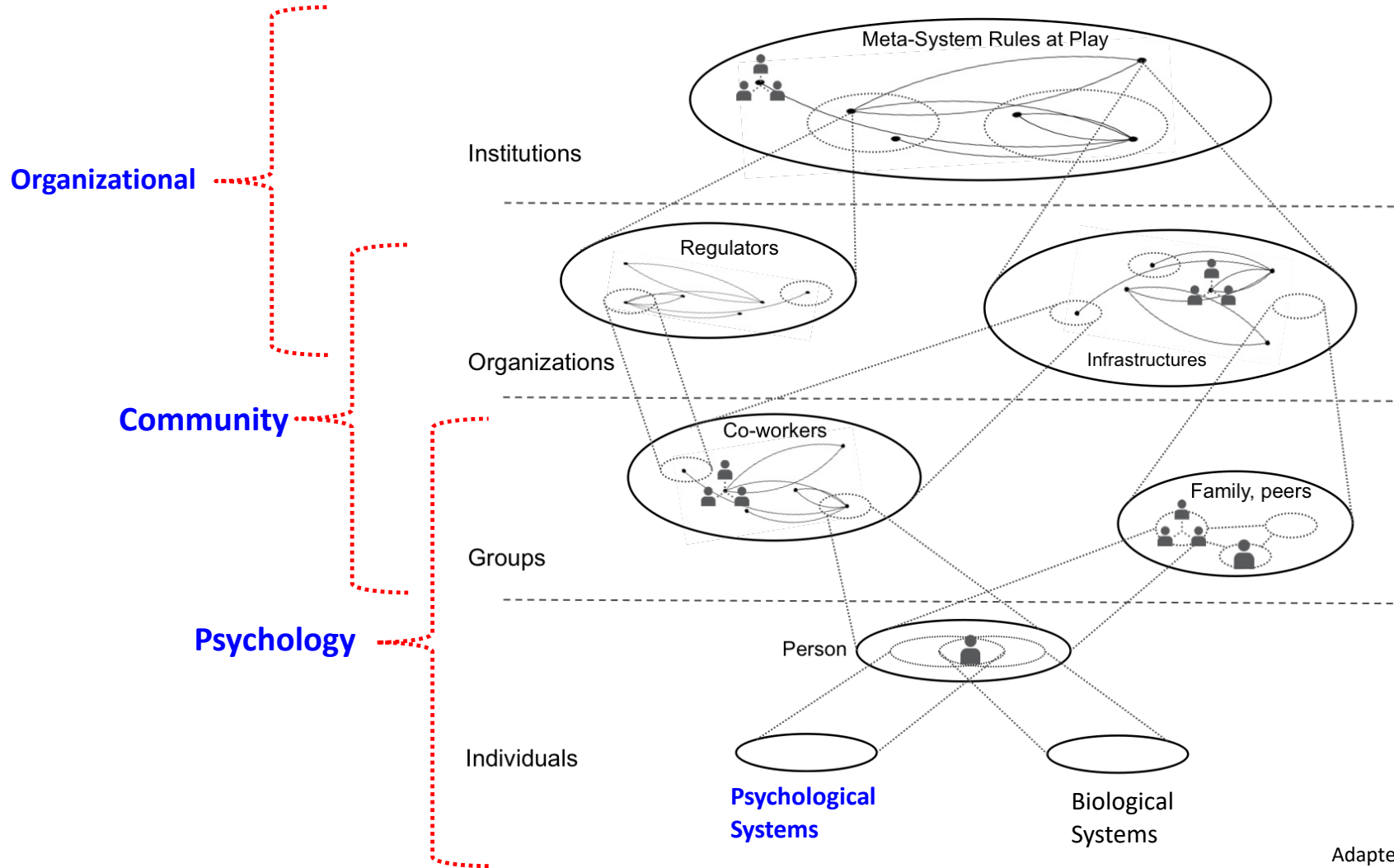
V = Vulnerability factors

S = Stressors / Shocks



Adapted: (Esbjörn-Hargens, Zimmerman, 2009)

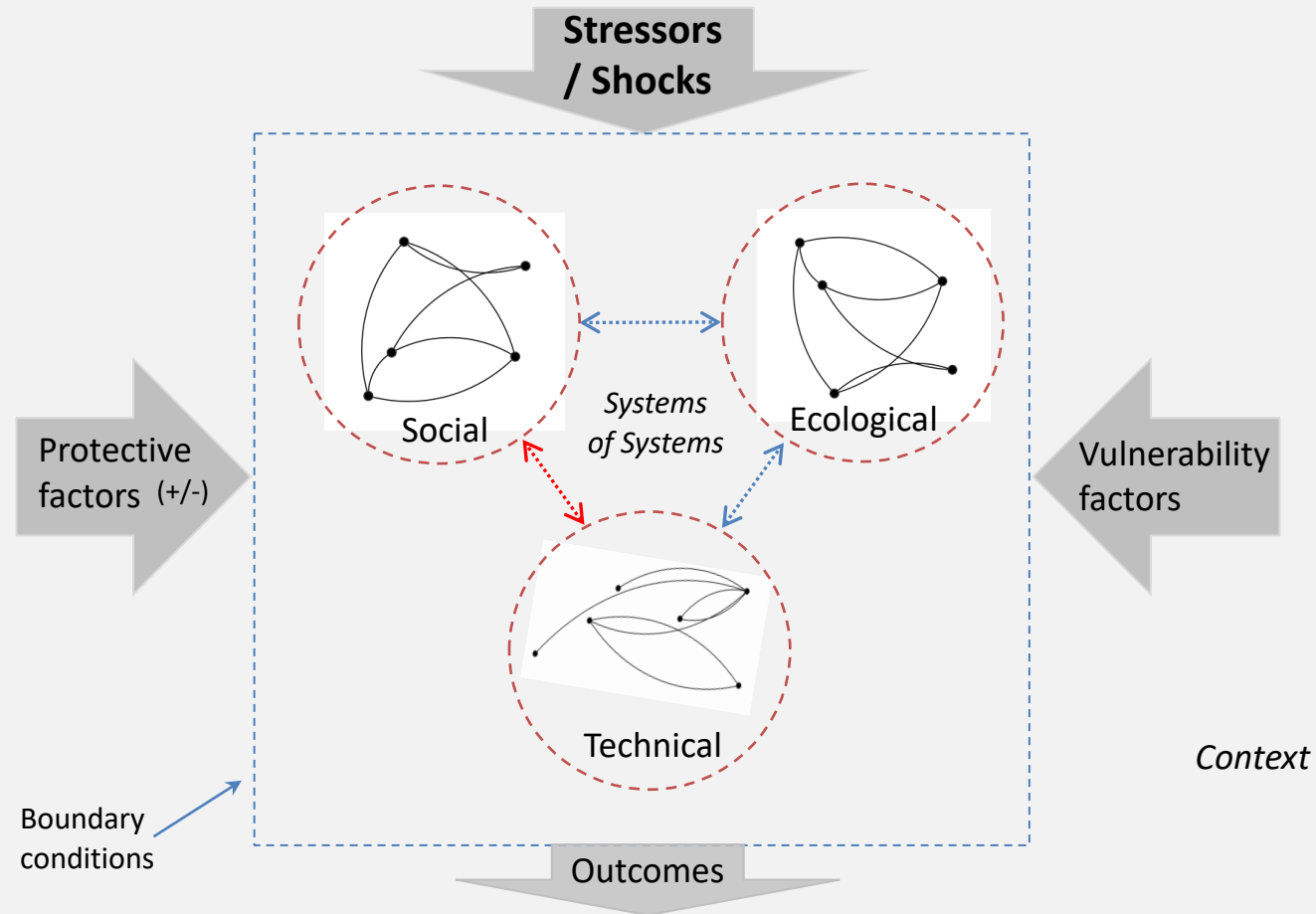
Social Ecology of Infrastructure Resilience



Adapted (Masten, 2010; Bronfenbrenner, 1979)

SETS resilience main effects model

Social
Ecological
Technological
Systems



Adapted: (Masten, 2001; Luthar, 2000)

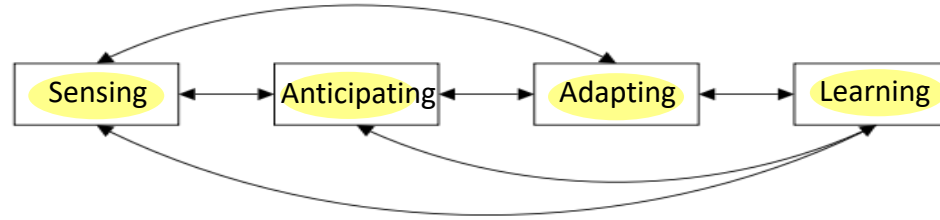
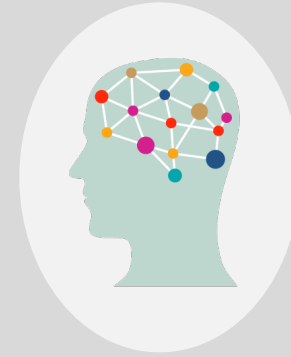
- Endogenous
- Exogenous



Psychological resilience capacities

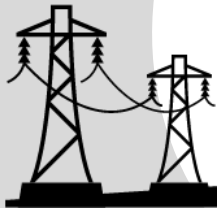


Cognitive	Affective	Behavioral / Social
<ul style="list-style-type: none"> Balanced perspective on experience Fortitude, conviction, & resolve Moral reasoning Perceive beneficial effect of stress Personal / collective goals Self-esteem View change/stress as a challenge 	<ul style="list-style-type: none"> Coping Faith, religion Hopefulness Internal locus of control Optimism Patience Self-commitment Sense of humor Meaningfulness & purpose 	<ul style="list-style-type: none"> Ability to adapt to change Ability to use past successes to confront current challenge Action-oriented approach Engaging the support of others Secure attachments to others Self-efficacy Tolerance of negative effect

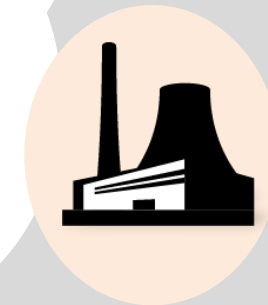


Capacities mediate processes

Technical system resilience capacities



Attributes contributing to system resilience	
<ul style="list-style-type: none"> Avoidance Buffering Control Efficiency Goals management Margin Pinging Survival Tolerance 	<ul style="list-style-type: none"> Adaptive capacity Autonomy Cohesion Compensation Coping Diversity Efficacy Flexibility Maneuverability



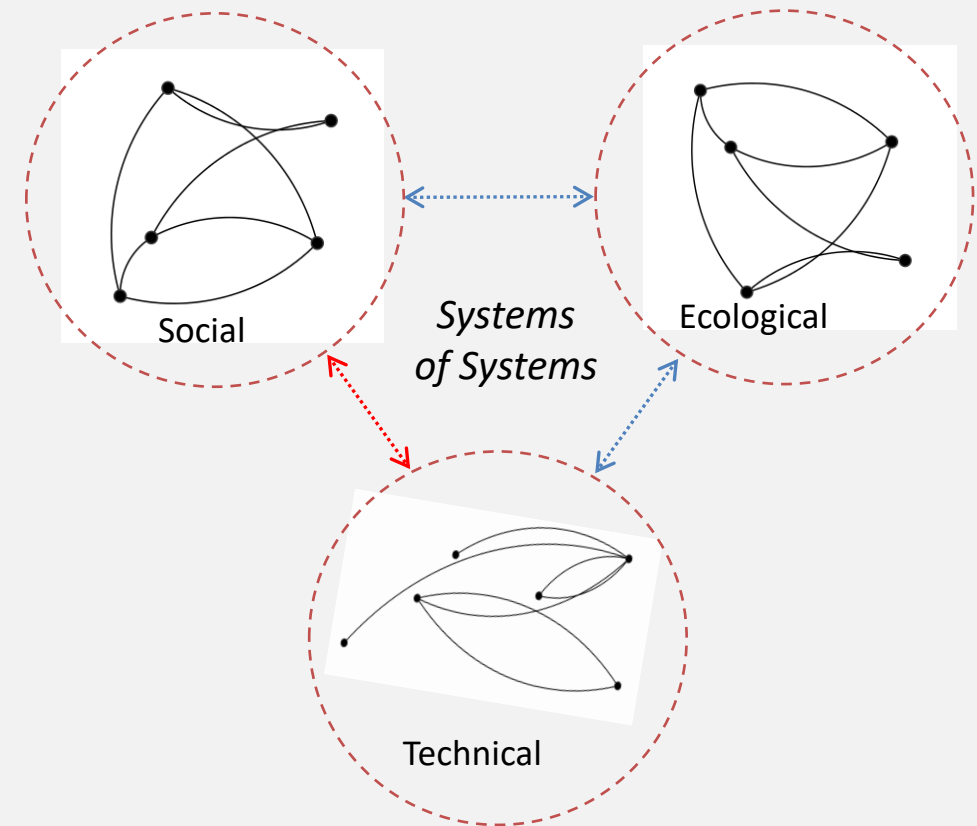
CRISIS MANAGEMENT

UNPREDICTABLE
STRATEGY

RECOVERY

Systems Perspectives

- Service systems—**management**
- Viable systems—**operational** coherence
- **Reticular** systems—network theory
- **Economic** systems—micro and macro
- **Social** systems—organizations
- Institutional systems—law and governance
- Technological systems—critical infrastructure
- Developmental systems—psychology
- **Ecosystems**—natural environment
- Integral theory
 - Alternative perspectives
 - Epistemological resolution



Management Systems

- **Relationships**—dynamic interactions among parts
 - Competitive behavior among firms
 - Relative to other viable systems
 - Ability to organize—viability
- **Adaptation**—dynamic self-adjustment
 - Realign internal and external elements
 - Navigate and negotiate the elements
 - Ability to change and learn from experience
- **Complexity**—variety, variability, and indeterminacy
 - Variance of perceptual experience
 - Variety over time
 - Ability to fully understand
 - Development



Engage systems thinking!

- Dimensional perspectives
 - Look **at** the system
 - Look **through** the system
 - Look **as** the system
- How can systems thinking **enhance learning?**



Crisis Leadership

- **Situation** assessment—accurate problem identification
 - **Decision** making—what to do?
 - **Team** coordination—coherent action
 - **Communicating**—receive & deliver relevant information
 - **Monitoring**—sensing the system & environment
 - **Delegating**—distribute workload
 - **Prioritizing**—organizing information & response
 - **Planning**—engaging process & tasks completion
-
- Admiral Thad Allen—U.S. Coast Guard
 - Hurricane Katrina



As Ukraine Resists Russian Invasion, Zelensky Demonstrates These Leadership Lessons



Edward Segal Senior Contributor ©
Leadership Strategy
I cover crisis-related news, issues and topics.

- Leadership comes from within
- ‘Grit is built through struggle. There’s no way around it.’
- Leaders come from everywhere
- Being seen & communicating effectively
- Active & engaged—modeling the way
- Authenticity—human & accessible



John Dickerson on Zelensky's leadership, and on making courage contagious



BY JOHN DICKERSON
MARCH 6, 2022 / 10:29 AM / CBS NEWS





Irony of Resilience

Be prepared,

to be unprepared!

Thank You

Resilience, Simulation for Water, Power
& Roadway Networks, NSF Grant No. 1441352

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expressed in this material are those of the authors and do
not necessarily reflect the views of the NSF.*

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IntegralResilience.org

ResilienceEngineeringInstitute.org



How adaptive systems fail & coping with uncertainty

- Resilience engineering assumes
 - Adaptive capacities can be **managed**
 - Assumes some ability to **self-monitor**

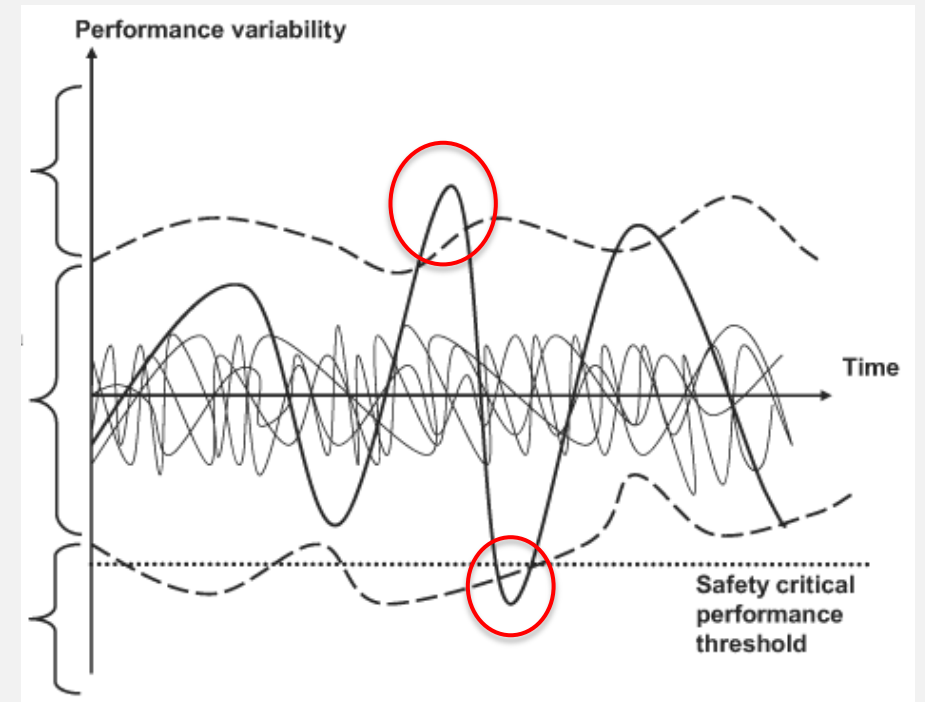
Patterns can lead to adaptive traps

- **Decompensation**
- Working at **cross purposes**
- Getting stuck in **outdated behaviors**

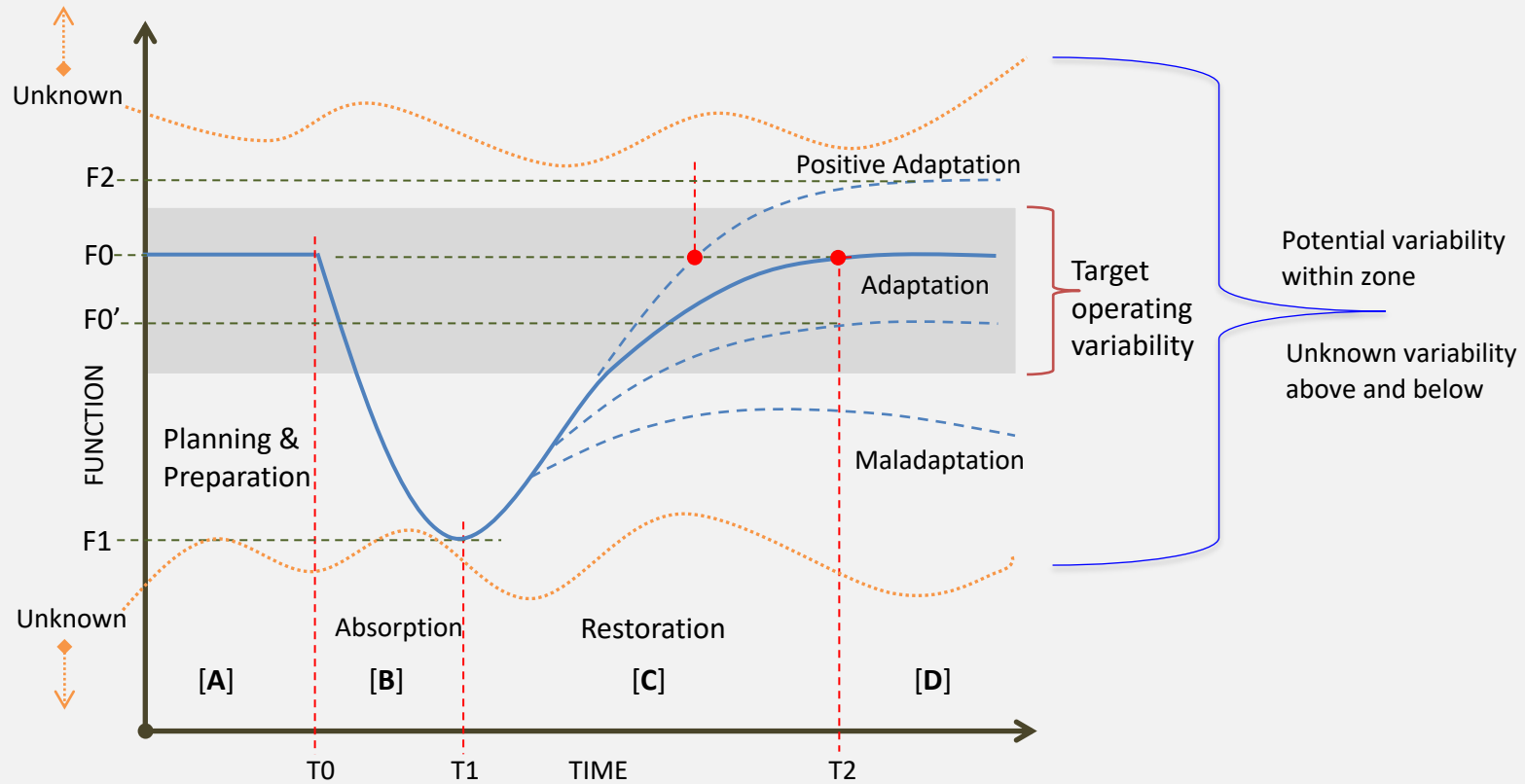
Unthought variability
Situations not envisaged

Potential variability
Situations anticipated

Unthought variability
Situations not envisaged



Resilience Time Blocks



“The ability to prepare and plan for, absorb, recover from or more successfully adapt to actual or potential adverse events.” (NAS, 2012, p14)