Resilience in Energy Systems

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- While FPL has invested nearly $3 billion to build a stronger, smarter energy grid, with this powerful of a storm, customers should prepare for potentially prolonged power outages

Sep 5, 2017

JUNO BEACH, Fla., Sept. 5, 2017 /PRNewswire/ -- Florida Power & Light Company (FPL) today announced that it is closely monitoring the path of Hurricane Irma and preparing to respond safely and as quickly as possible should the storm impact its service area.

More Than 10 Million People Lost Power in Florida

Thanks to Hurricane Irma, the southwest of the state's electrical grid will need a "wholesale rebuild."

L | SEP 11, 2017 | TECHNOLOGY

ERDC

Innovative solutions for a safer, better world

FPL spent $3 billion preparing for a storm. So why did Irma knock out the lights?

BY NICHOLAS NEHAMAS AND NANCY DAHLBERG
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SEPTEMBER 21, 2017 8:00 AM

An electrical worker repairs stoplights the morning after Hurricane Irma swept through Naples, Florida.

The Slatest YOUR NEWS COMPANION SEPT. 11 2017 4:56 PM

After Irma, Florida's Smart Grid Needs the Longest and Most Complex Restoration in U.S. History

BUILDING STRONG®

Risk -- “a situation involving exposure to danger [threat].”

Security -- “the state of being free from danger or threat.”

Resilience -- “the capacity to recover quickly from difficulties.”

Definitions by Oxford Dictionary

30 | NATURE | VOL 555 | 1 MARCH 2018

Don’t conflate risk and resilience

‘Risk’ and ‘resilience’ are fundamentally different concepts that are often conflated. Yet maintaining the distinction is a policy necessity. Applying a risk-based approach to a problem that requires a resilience-based solution, or vice versa, can lead to investment in systems that do not produce the changes that

Igor Linkov, Benjamin D. Trump *US Army Corps of Engineers, Concord, Massachusetts, USA.* **Jeffrey Keisler** *University of Massachusetts Boston, USA.* *igor.linkov@usace.army.mil*

Environmental Science & Technology

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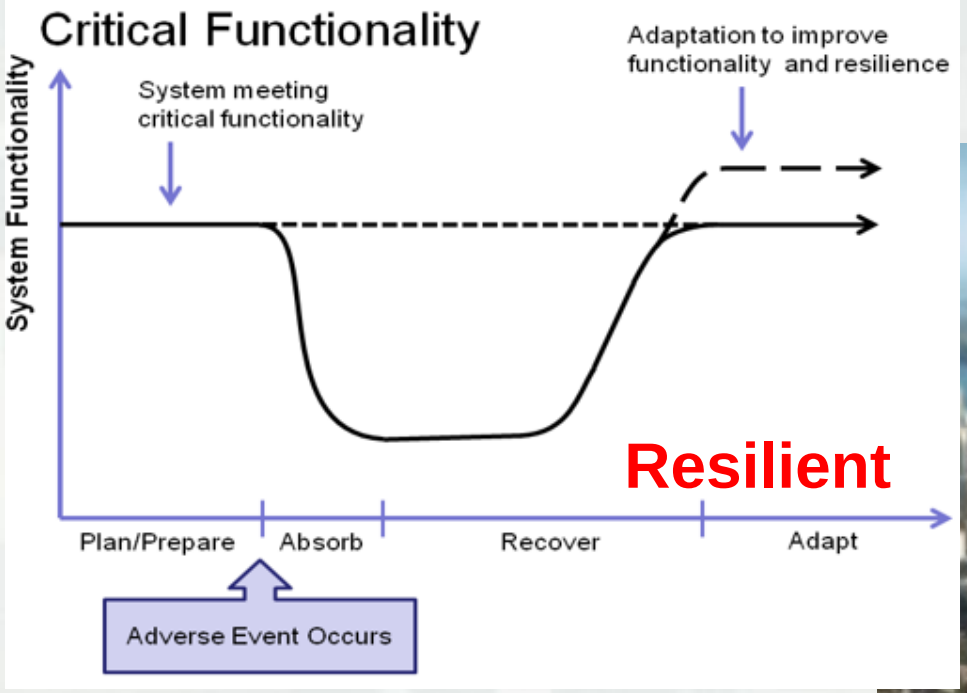
Can You Be Smart and Resilient at the Same Time?

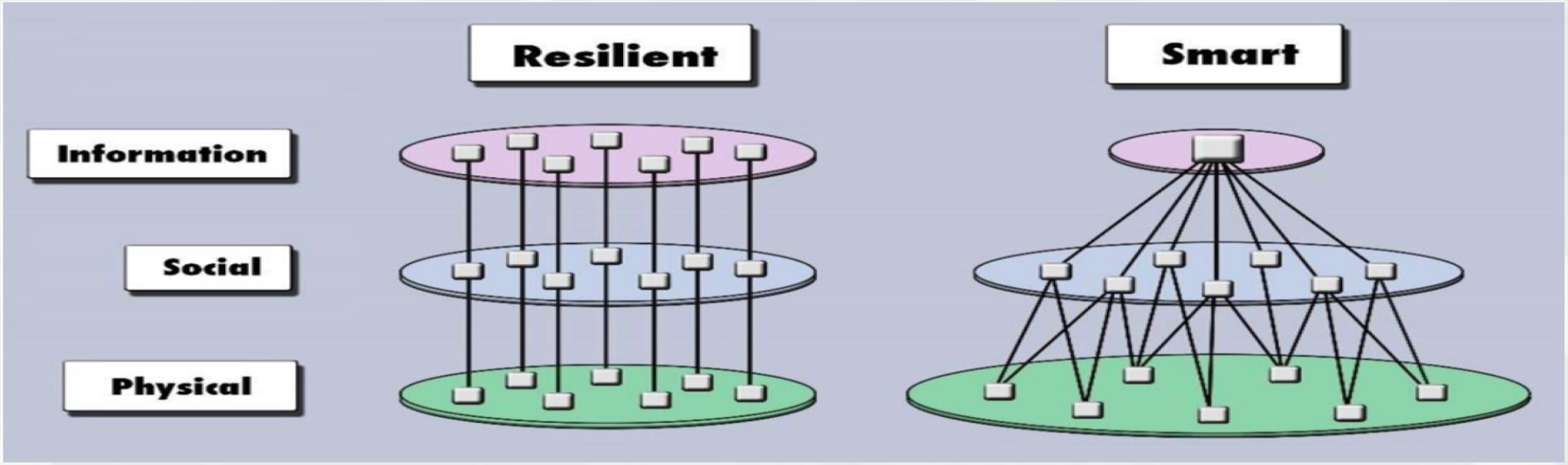
Dayton Marchese and Igor Linkov*

DOI: 10.1021/acs.est.7b01912
Environ. Sci. Technol. 2017, 51, 5867−5868



Smart

Difference in Efficiency and Resilience



- Fully Redundant
- Greater maintenance requirements
- Functional during disruption
- **Less efficient during random attacks**

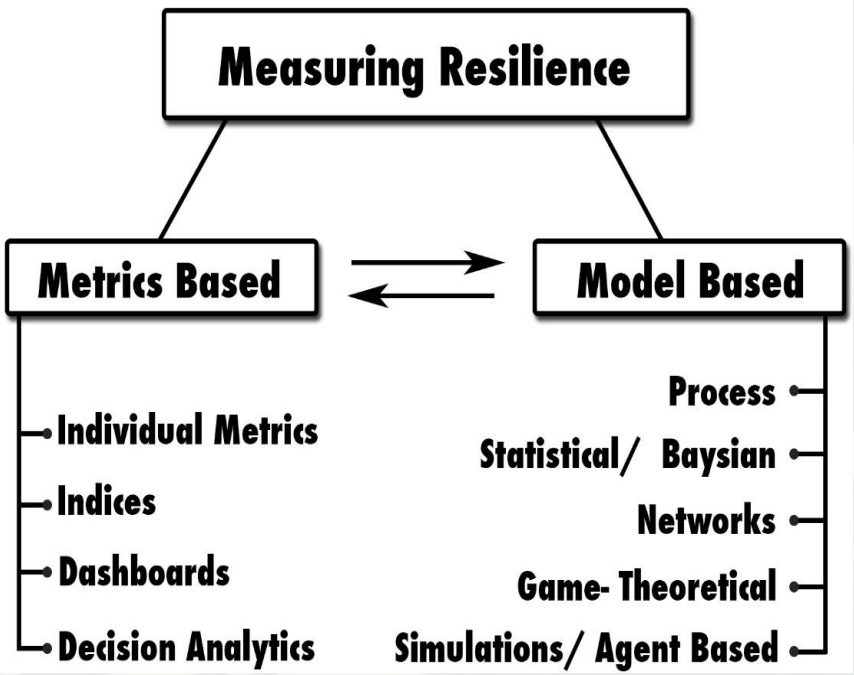
- Observe emergent patterns
- Centralized decision making
- No redundancy
- **Prone to targeted attacks**

How to Quantify Resilience and do Tradeoffs?

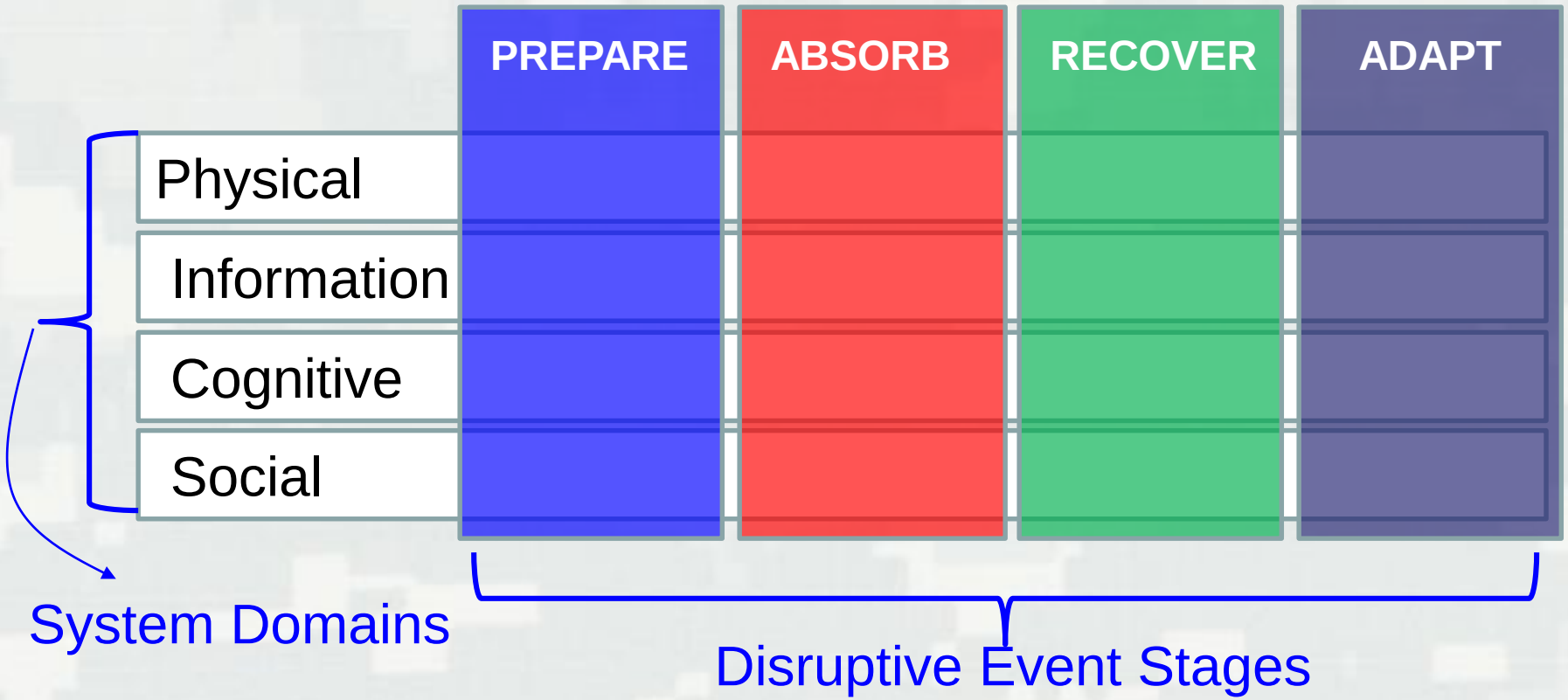
Marchese and Linkov, 2017

Measuring Resilience

- Resilience Matrix
  - *Metrics Based*
  - Coupled with decision analysis comparative assessment
- Network Resilience Theory
  - *Model Based*
  - Widely applicable to networked systems
- Energy Resilience Analysis Tool (DoD & MIT-Lincoln Lab)
  - *Model Based*
  - Predicts annual unserved energy and life cycle cost of alternative energy infrastructure investments



Present: Metrics-Based Resilience Approaches



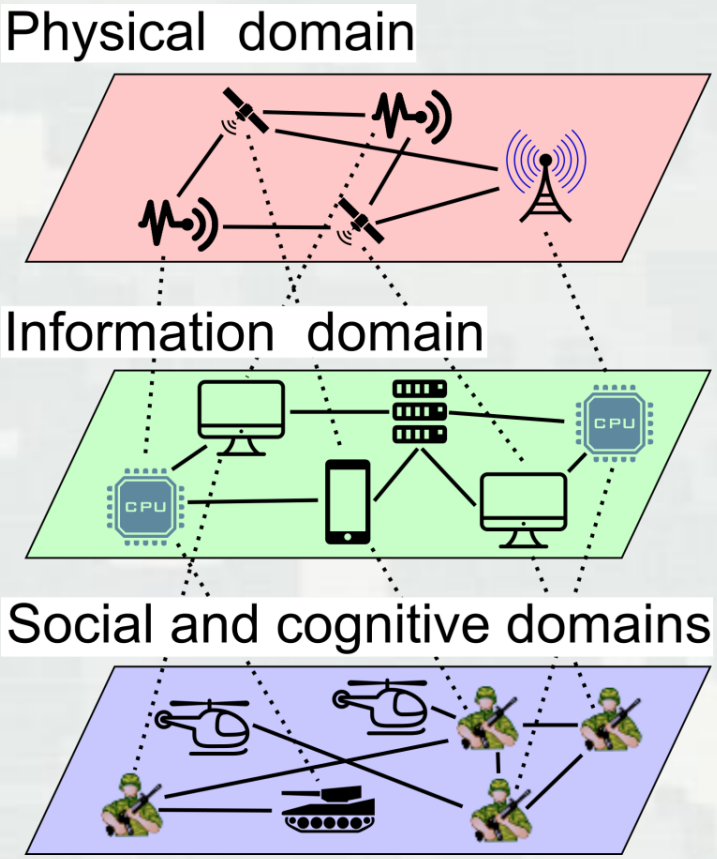
Linkov et al., 2013

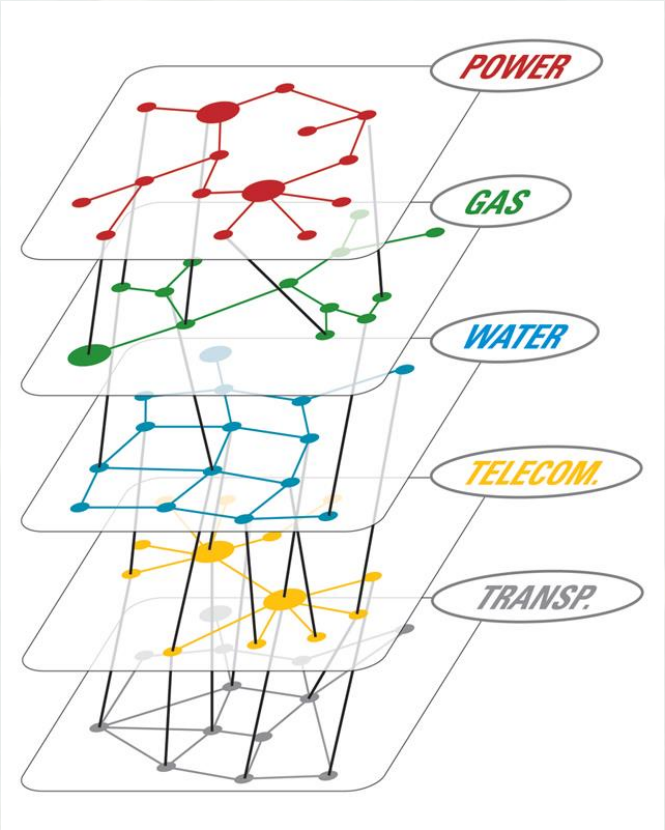
Scale

Home | Neighborhood | Town | County | Region | State | Country

Future: Network-based Approaches

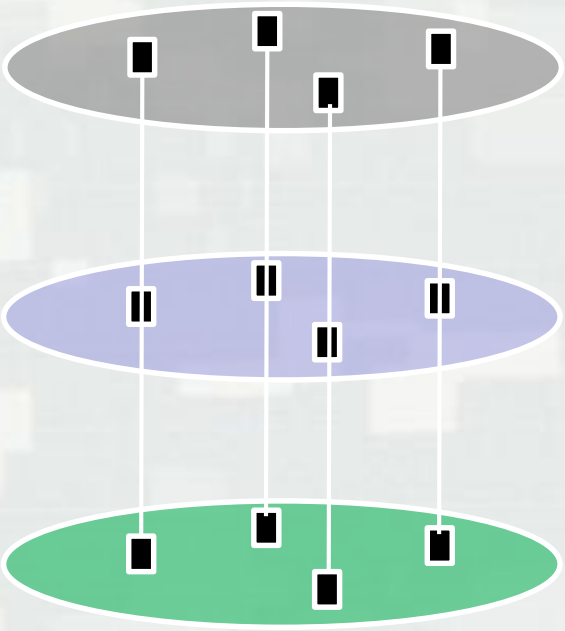
We quantify resilience by using network science approach by considering the different domains as interdependent multiplex networks.



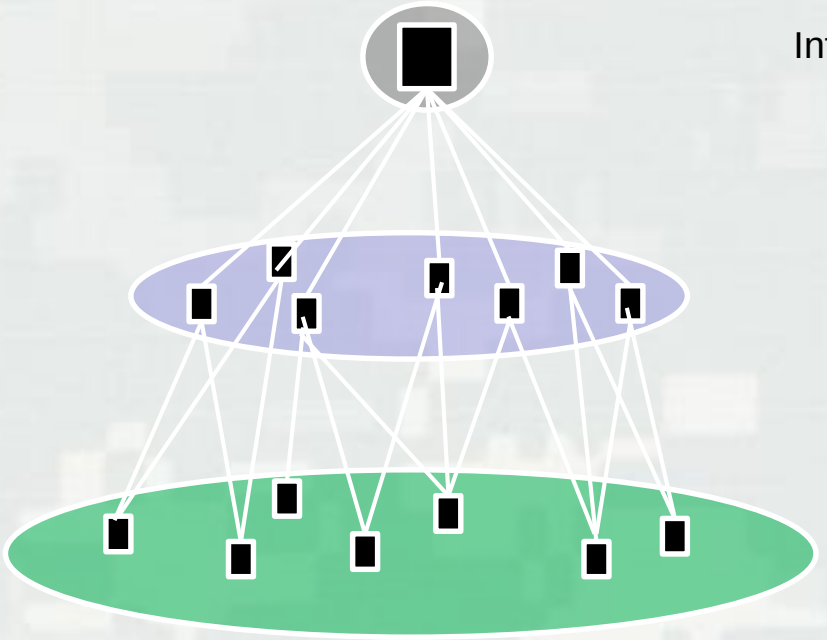


Smart vs Resilient: Network View

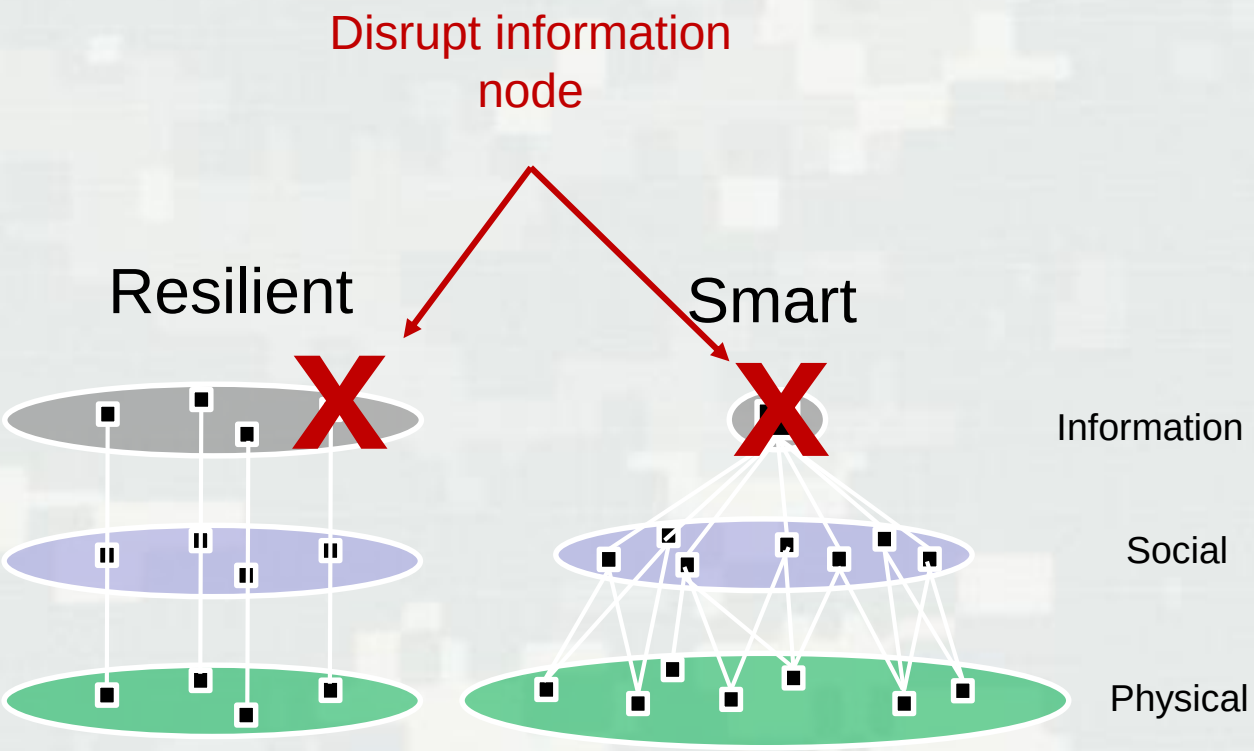
Resilient

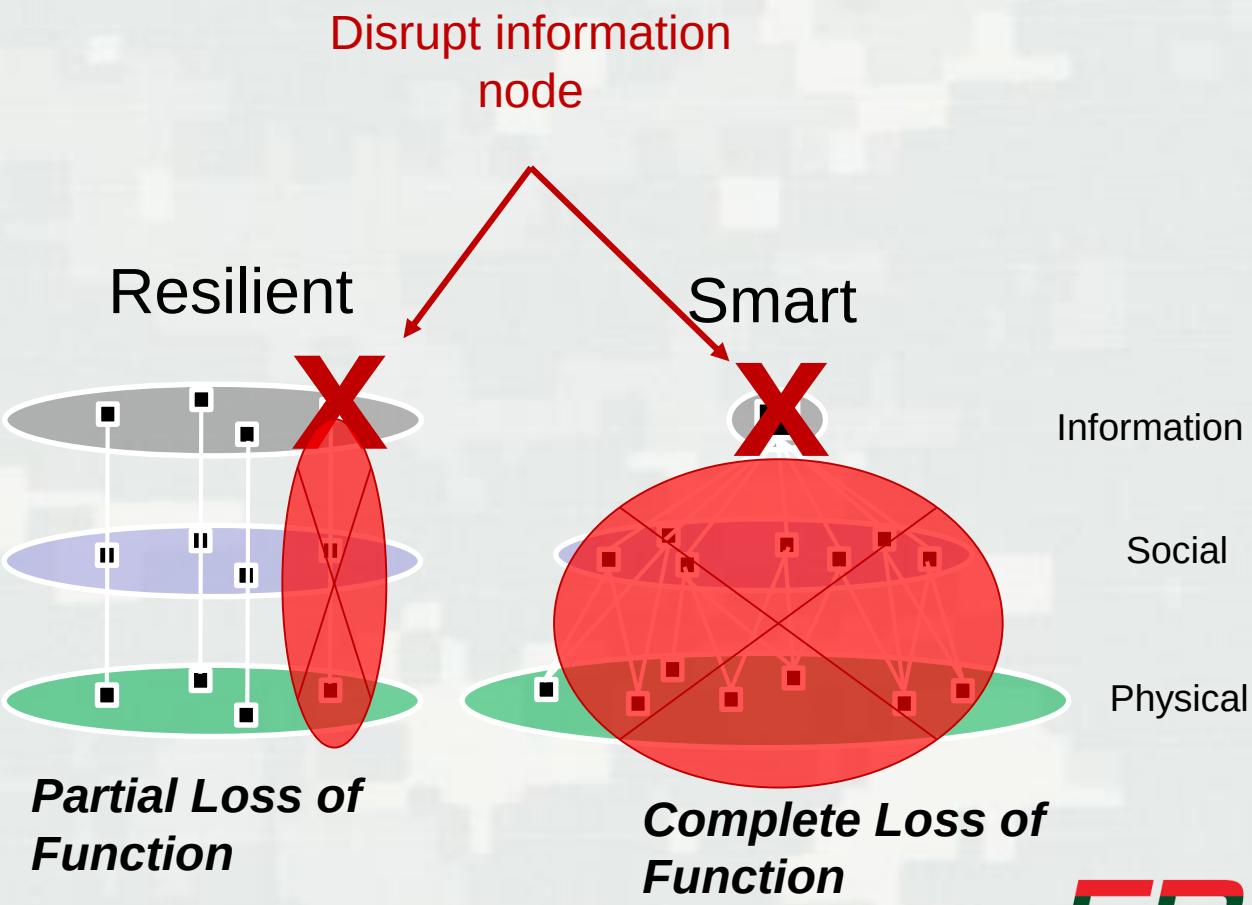


Smart

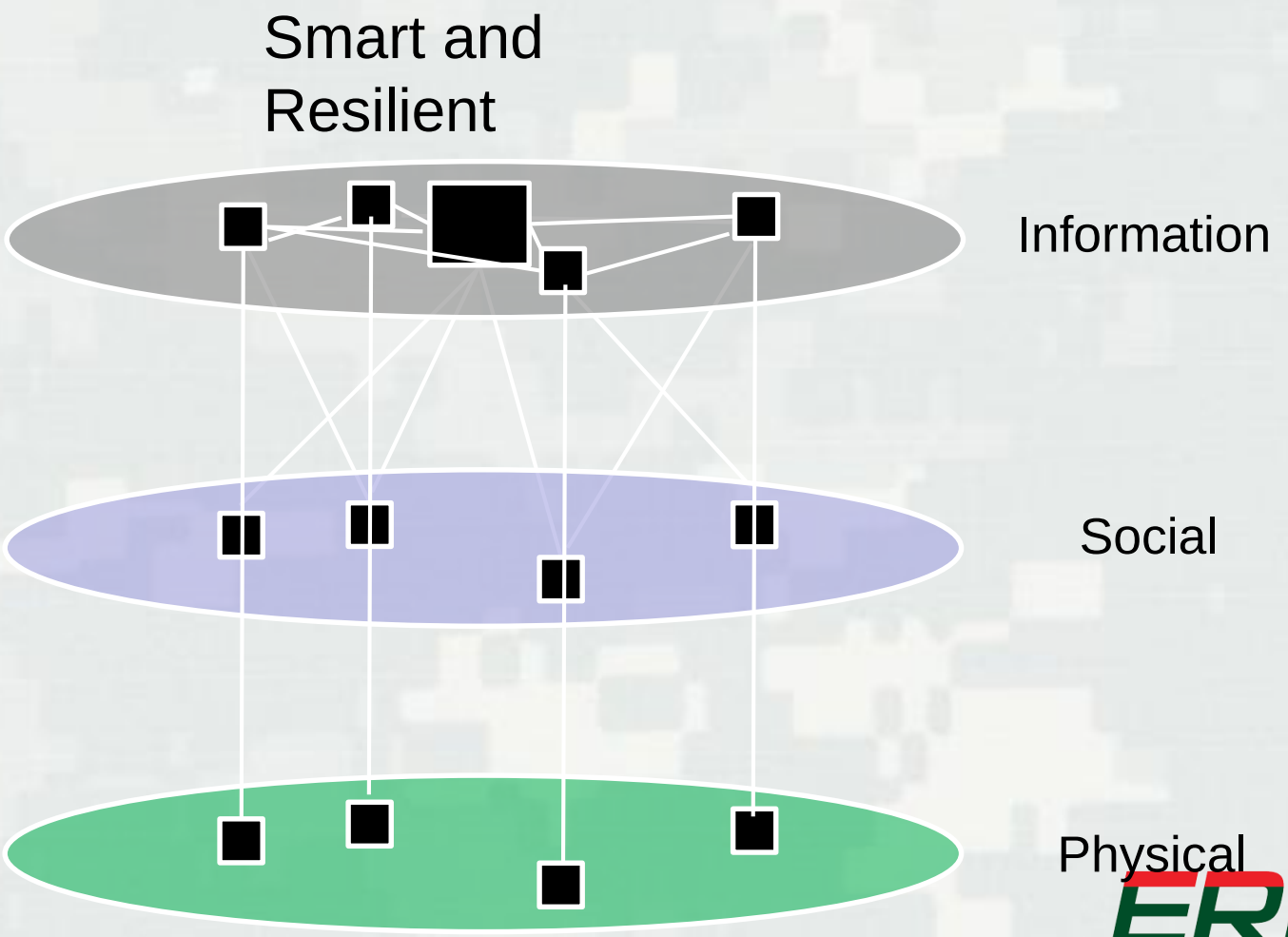


Smart vs Resilient under Attack




Disrupt information node
Resilient
Smart
Information
Social
Physical
Partial Loss of Function
Complete Loss of Function

How can we be Smart AND Resilient?



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