Robuste und resiliente Gestaltung von Infrastruktursystemen

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Singapore CREATE Initiative

Vision

Bring world-class research organizations together in one SIN site to internationalize and increase the vibrancy of Singapore's R&D system

Goals

- Establish a strong pipeline of ideas, talent and research capabilities to accelerate SIN capability building
- Make researchers from diverse backgrounds and disciplines interact with SIN's research ecosystem

Established

- 2007 SMART Infectious Disease

CREATE Research Centres

Massachusetts Institute of Technology

University of California, Berkeley

Technische Universität München

University of Cambridge

Hebrew University of Jerusalem

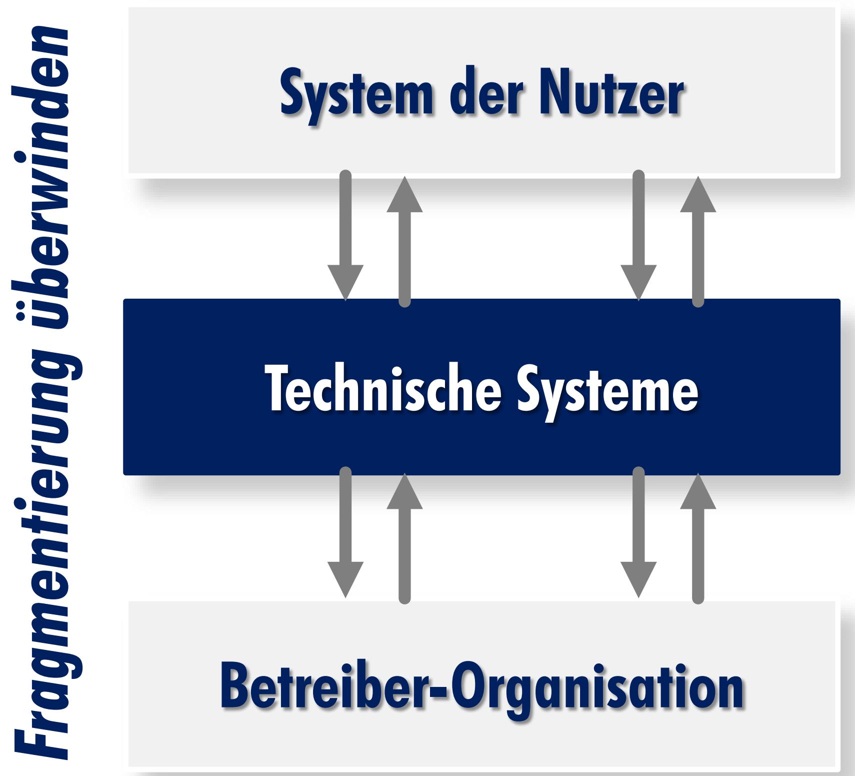
上海交通大學 Shanghai Jiao Tong University

ETH zürich

NUS National University of Singapore

Nanyang Technological University

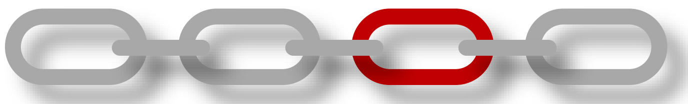
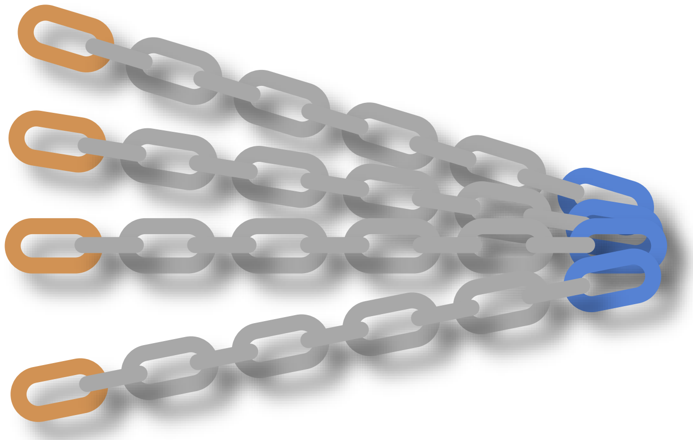
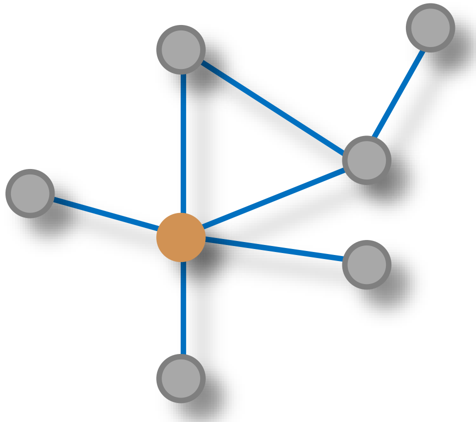
Sozio-Technische Systembetrachtung



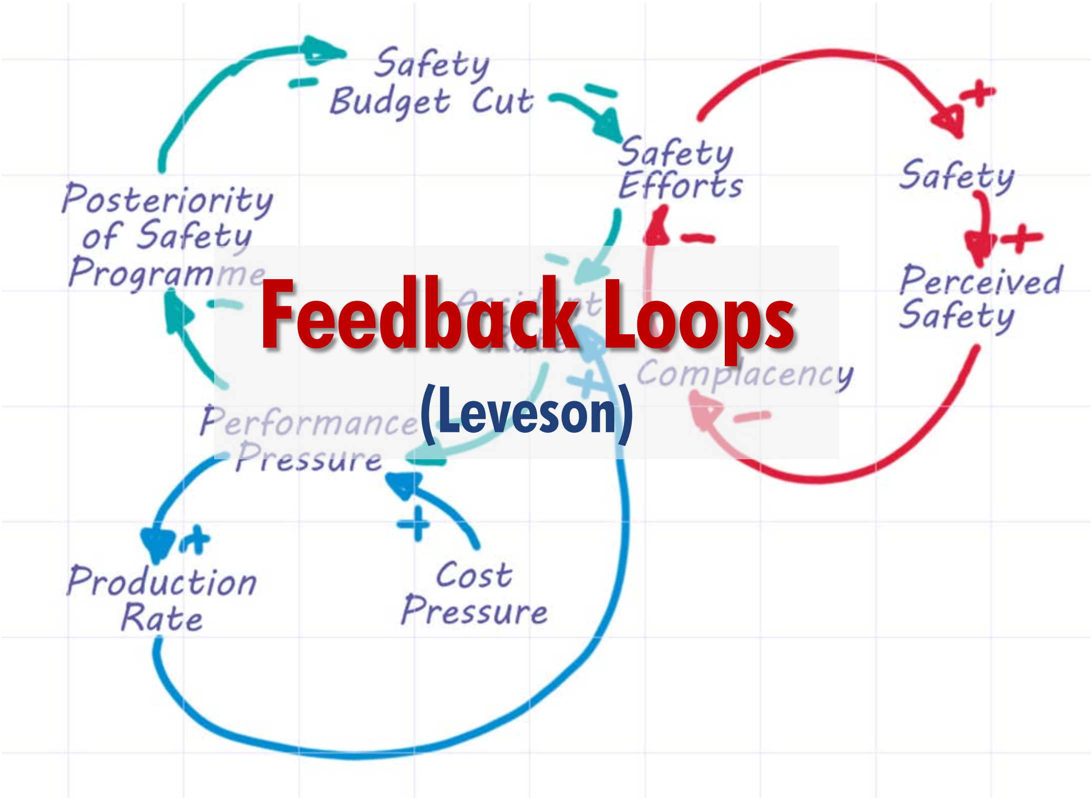
Outline

1. Challenges calling for a new approach
2. Resilience, emerging paradigm
3. Resilience metrics
4. Building Resilience
   - Robust Design
   - "Informed" Recovery
   - Social Resilience

Paradigms to Cope with Uncertainty

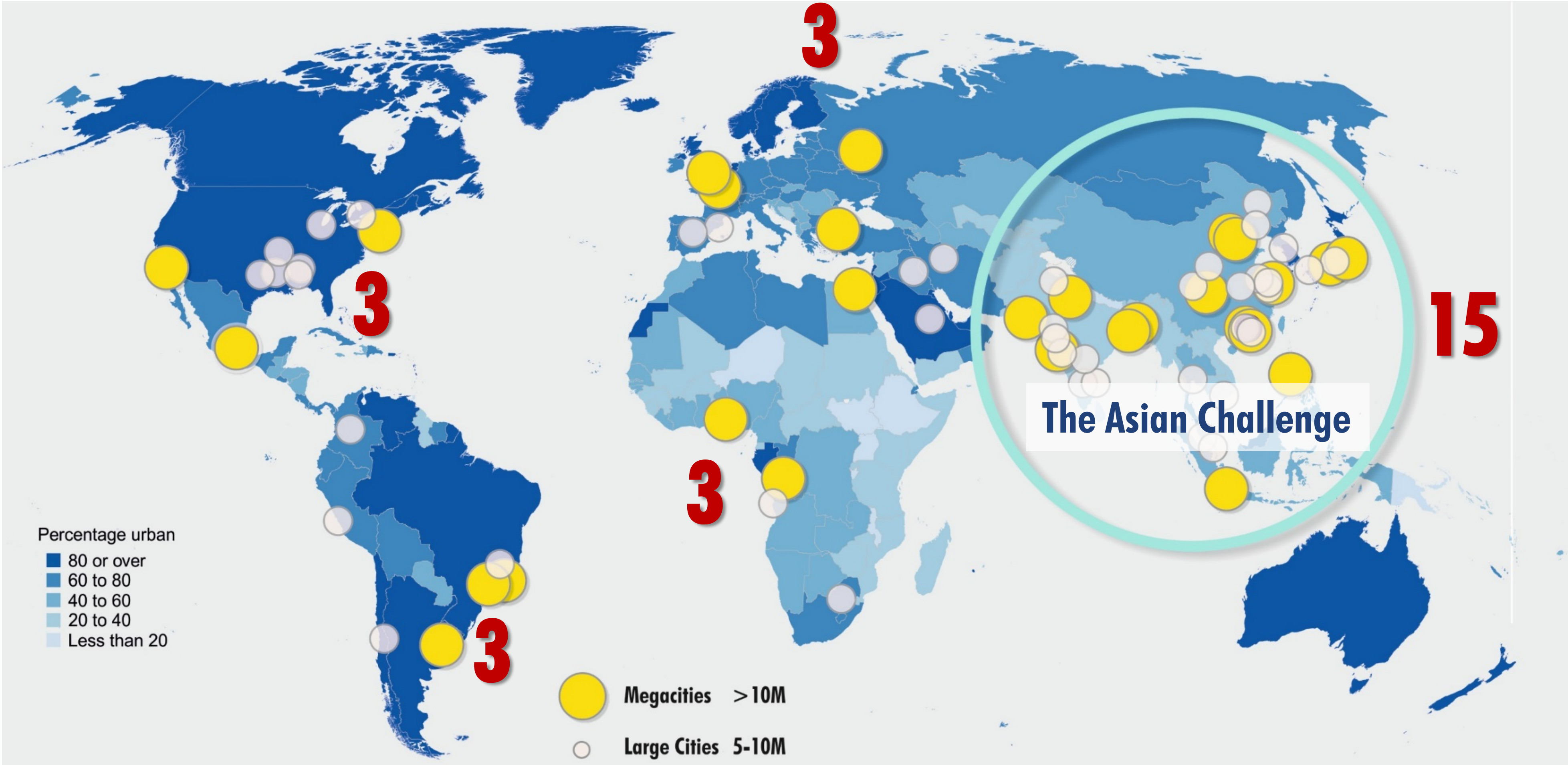
Reliability Engineering	Risk Management	Robustness / Resilience
weakest link	chain of events	network-centric
		
Pre-event Probabilistic	Pre-event Probabilistic F/C-diagrams	Pre+Post-event Probabilistic F/C-diagrams

Challenges



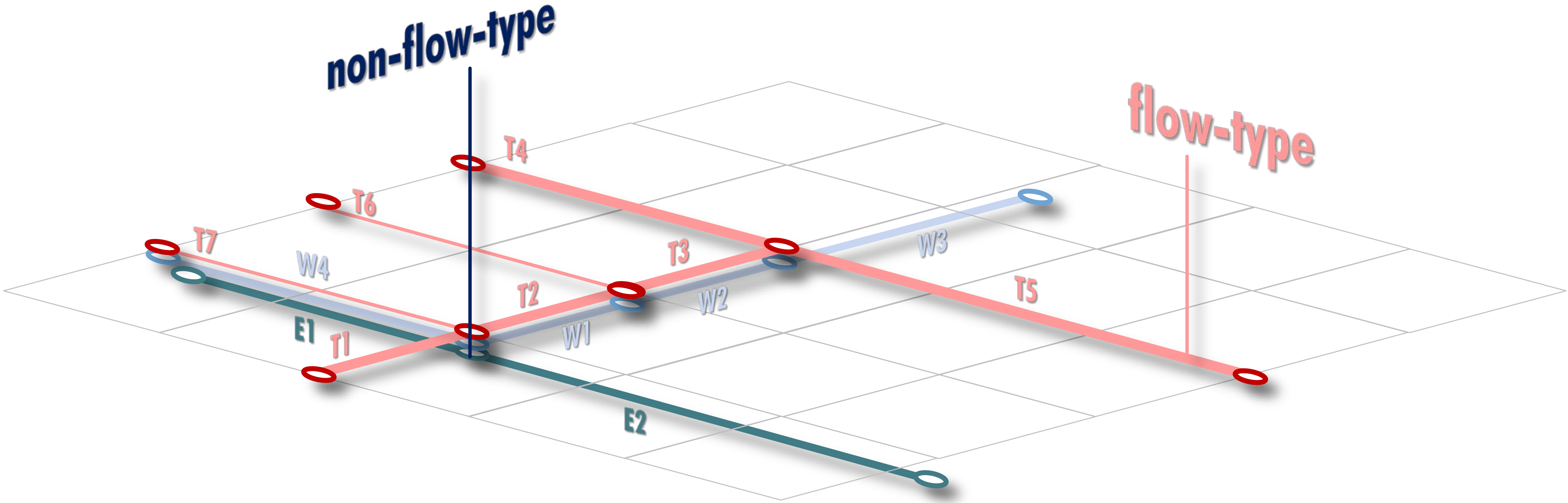
- Failures often statistically interdependent
- Cascading failures
- Postive Feedback
- Emerging phenomena (Dragon Kings)

[C1] Increasing Value@Risk + Coupling

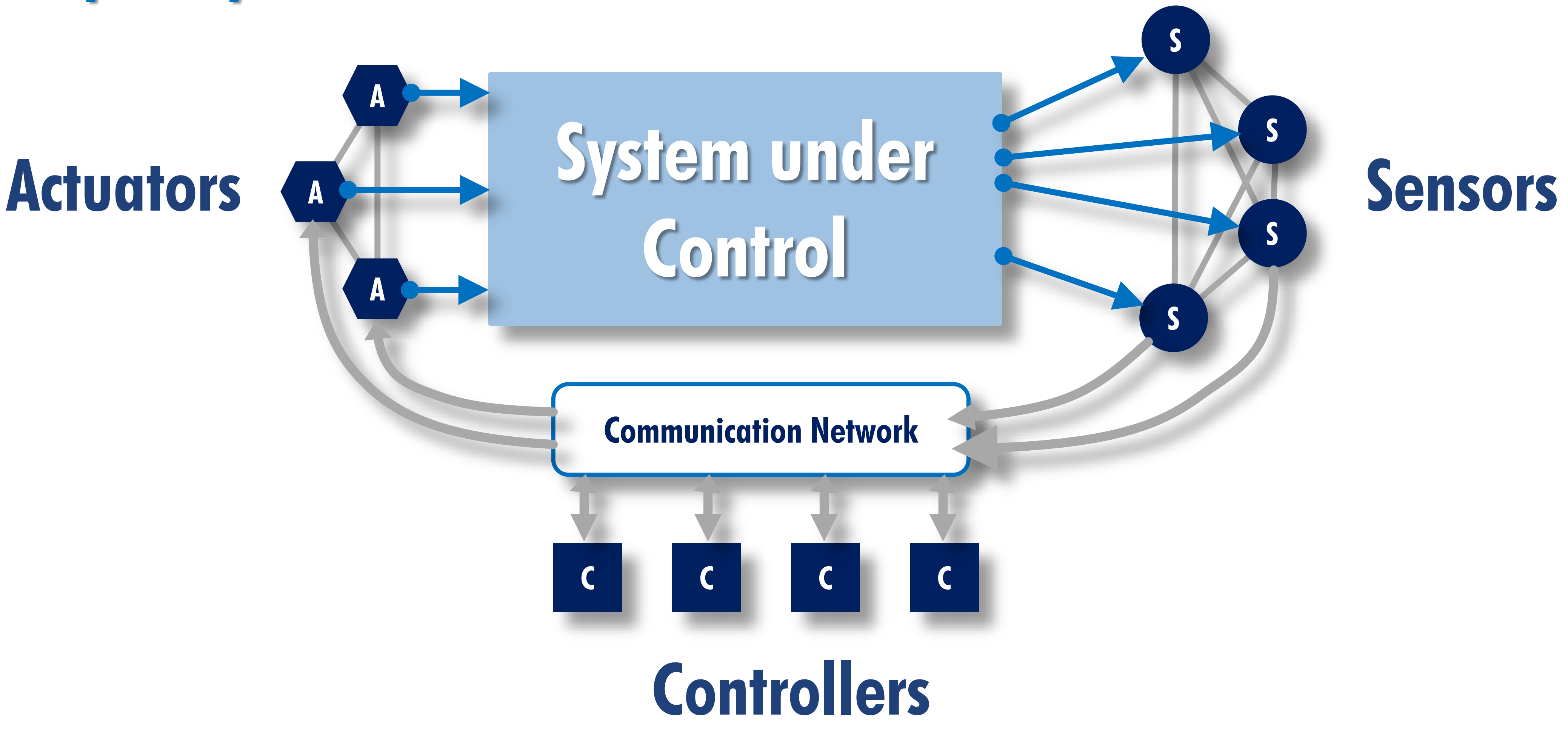


UN (2014). World Urbanization Prospects The 2014 Revision. Highlights. 27 p.

[C2] Interdependencies



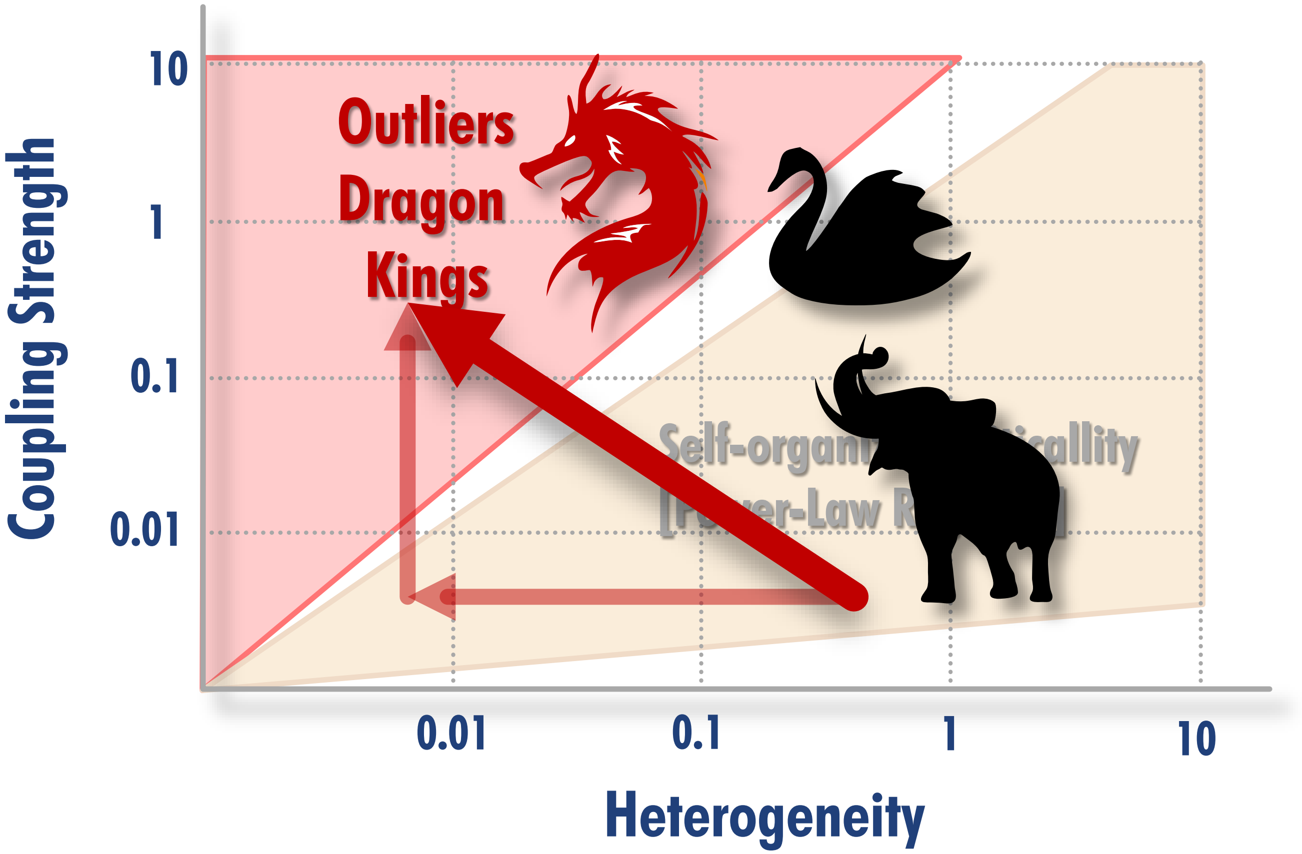
Cyber-Physical Systems



Complexity

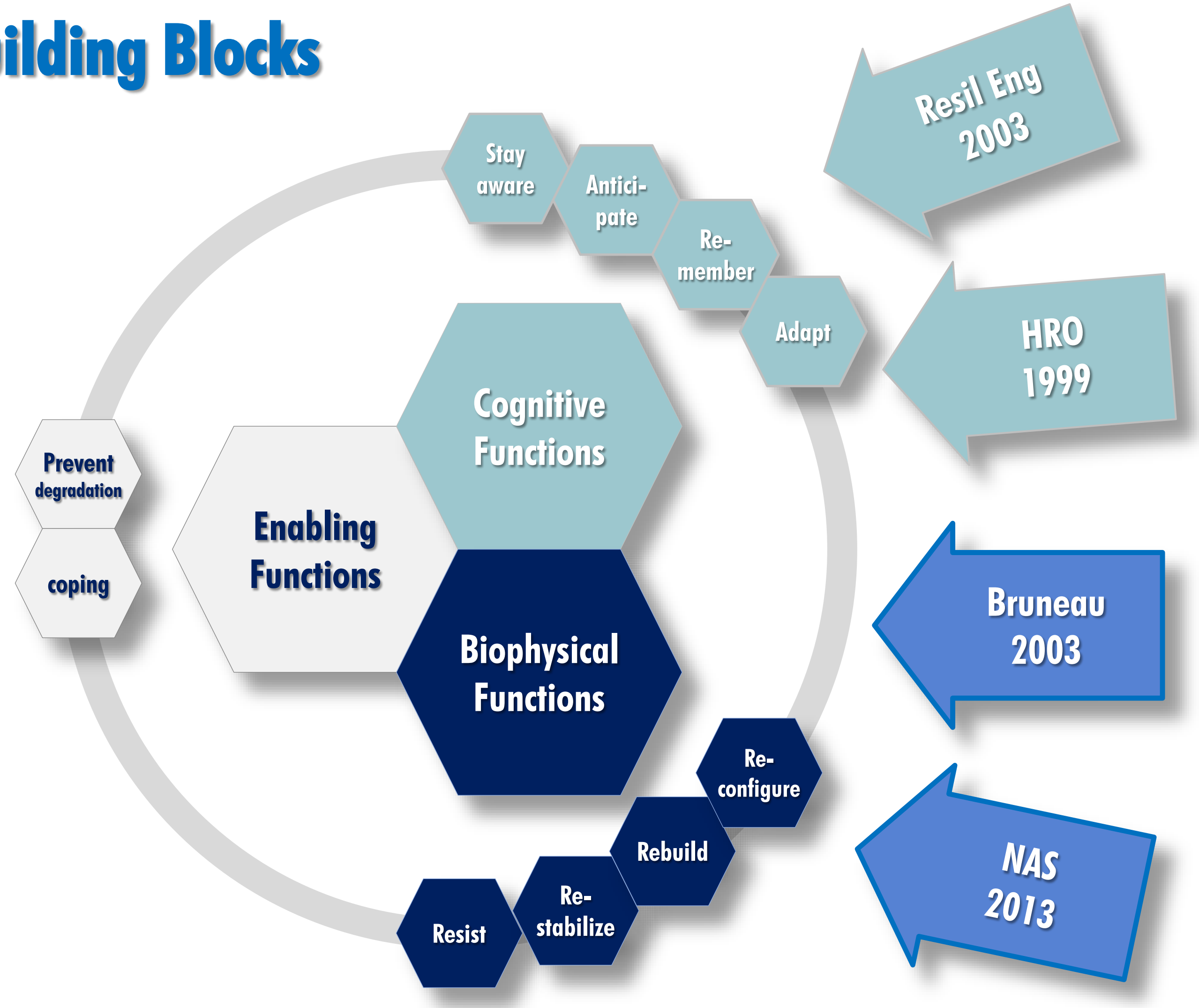
Sugiyama, Y. Fukui, M., Kikuchi, M., Hasabe, K., Nakayama, A., Nishinari, K., Tadaki, S., Yukawa, S. (2008): Traffic Jam without Bottleneck. https://youtu.be/7wm-pZp_miΟ

[C3] – Regime Shifts (Osorio et al. 2010)

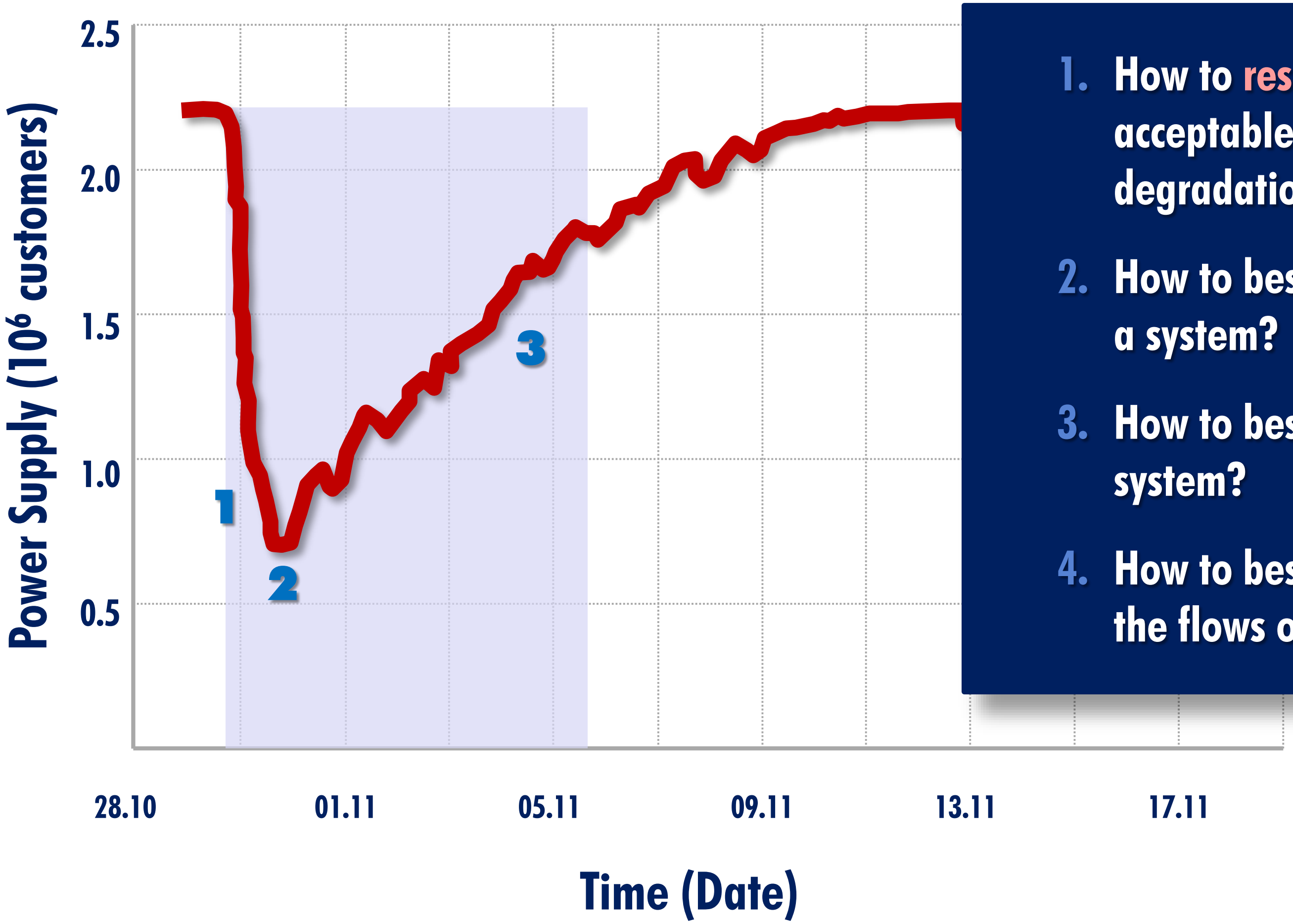


Need for a new approach

Resilience – Building Blocks



Hurricane Sandy – Power Grid Disruption



1. How to **resist** within acceptable degradation?
2. How to best **re-stabilize** a system?
3. How to best **rebuild** a system?
4. How to best **reconfigure** the flows of a system?

Key Questions to Be Answered

Pre-Event (Risk-M)

1. What can go wrong?
2. What is the probability that it will go wrong?
3. What are the consequences?

From the Triplet Question Set

INTERNATIONAL STANDARD ISO 31000

First edition 2009-11-15

Risk management — Principles and guidelines

Management du risque — Principes et lignes directrices

Pre/Post-Event (Resilience)

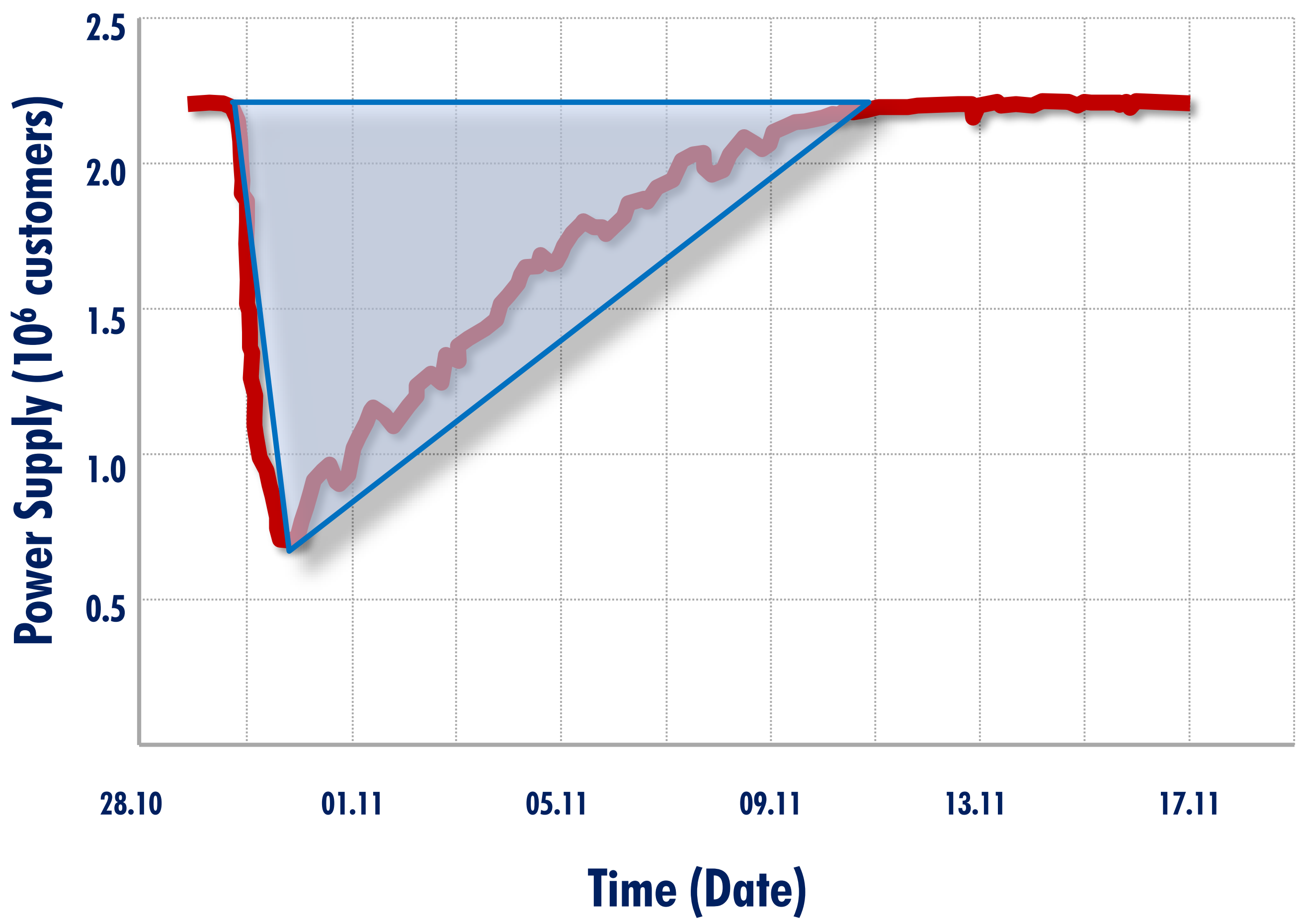
1. How to resist within acceptable degradation?
2. How to best re-stabilize a system?
3. How to best rebuild a system up to a sufficient level of service?
4. How to best reconfigure a system?

1. How to keep awareness high?
2. How to anticipate critical events?
3. How to remember successful past responses?
4. How to speed up orga-nizational adaptation?

1. How to increase the coping capability?
2. How to reduce degradation with smart responses?

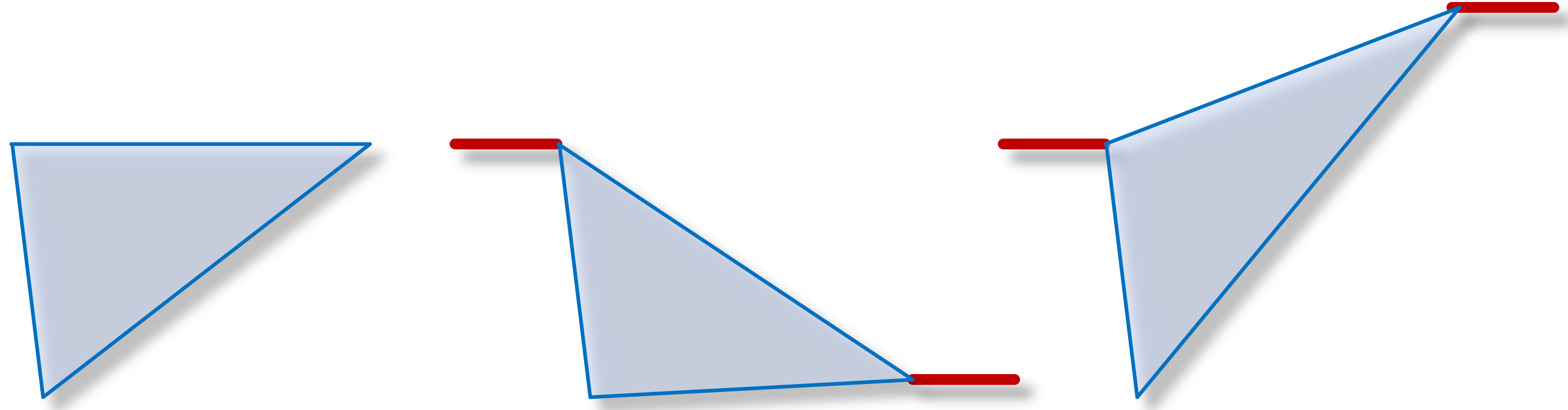
To the Deca-Tuple Question Set

Resilience Metric [Bruneau et al 2003]



$$R = \int_{t_{post}}^{t_{pre}} P_{pre} - P(t)\,dt$$

Problems with Bruneau's Assumptions

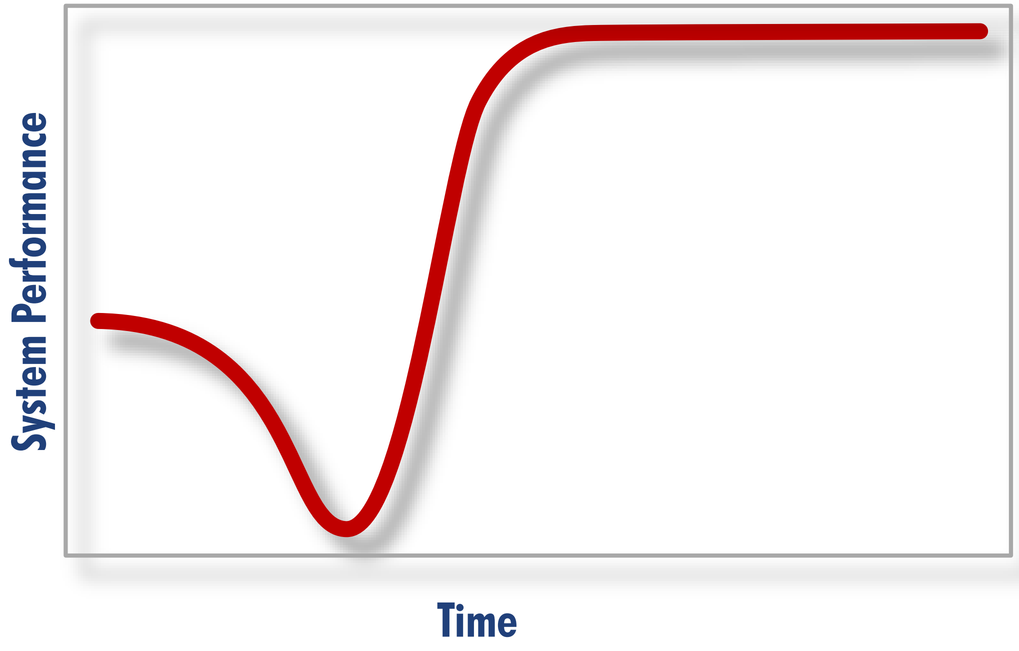


Bruneau Assumptions

Decrese in Resilience

Increase in Resilience

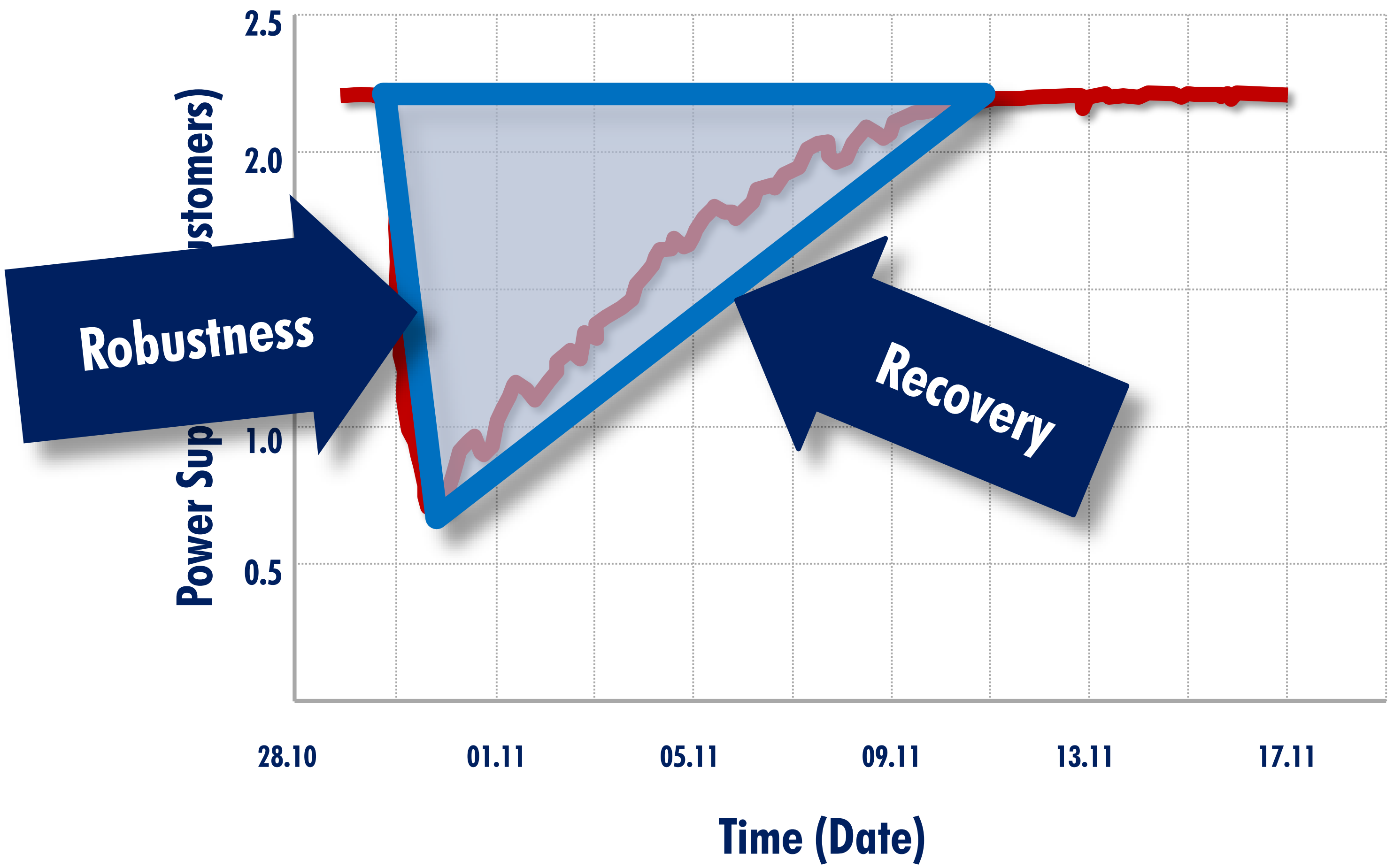
Recovery Functions



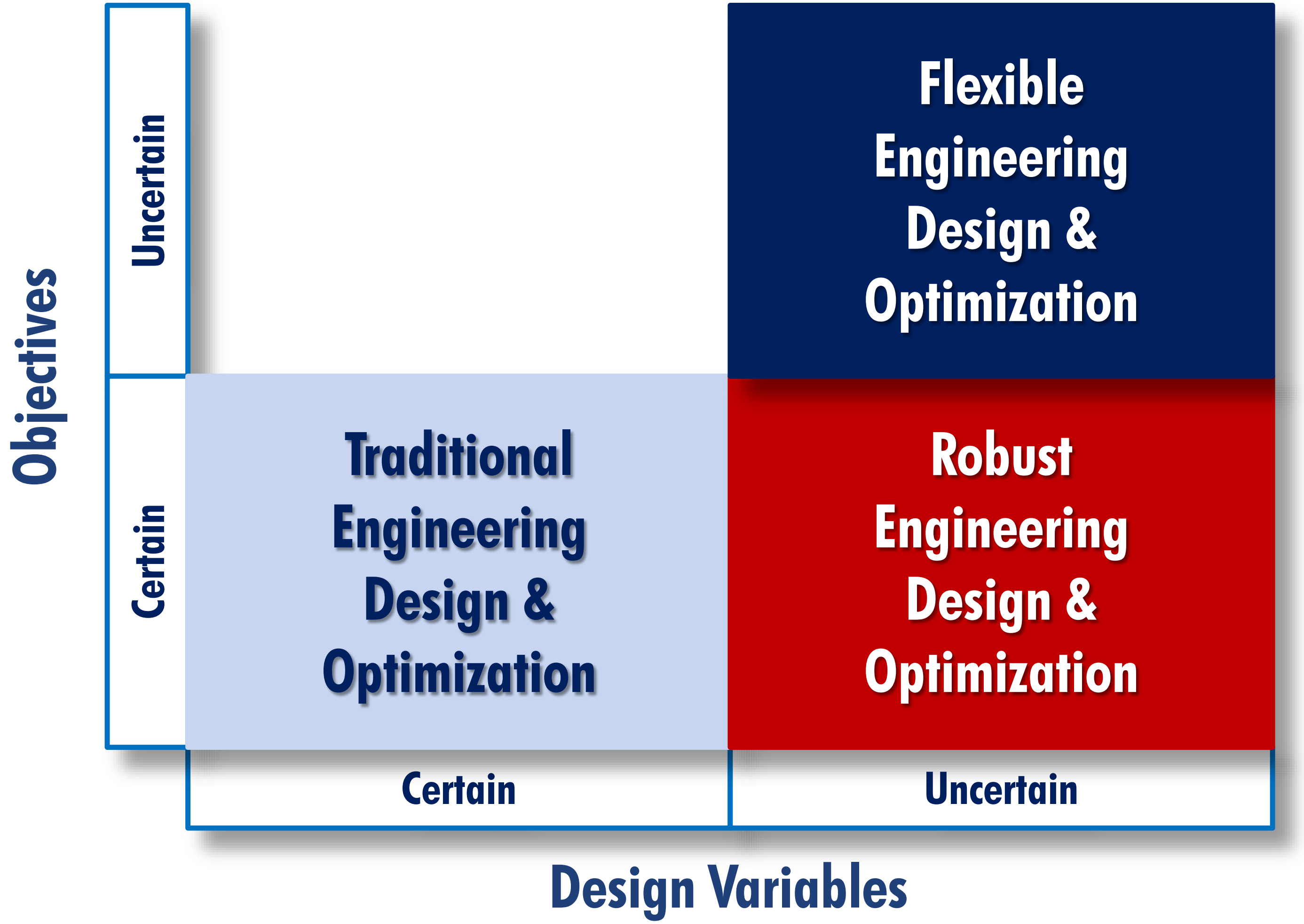
1. Robustness
2. Reliability
3. Recovery
4. Reconfigurability

Function parameters Represent Intrinsic system properties

Building Resilience



Robust Design



Building Resilience Through Design

Robustness

Property of a system which allows it

- to satisfy a fixed set of requirements,
- despite changes occurring after the system has entered service,
  1. in the environment or
  2. within the system itself,
  3. from the nominal or expected environment or
  4. the system design parameters.

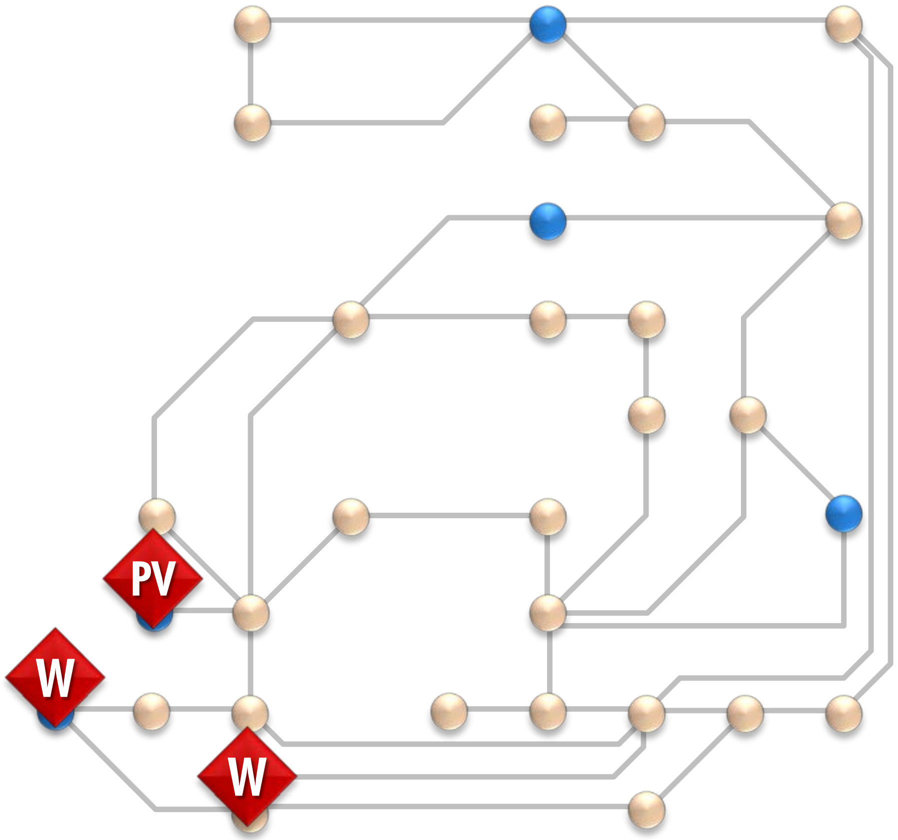
Flexibility

implies the ability of a design

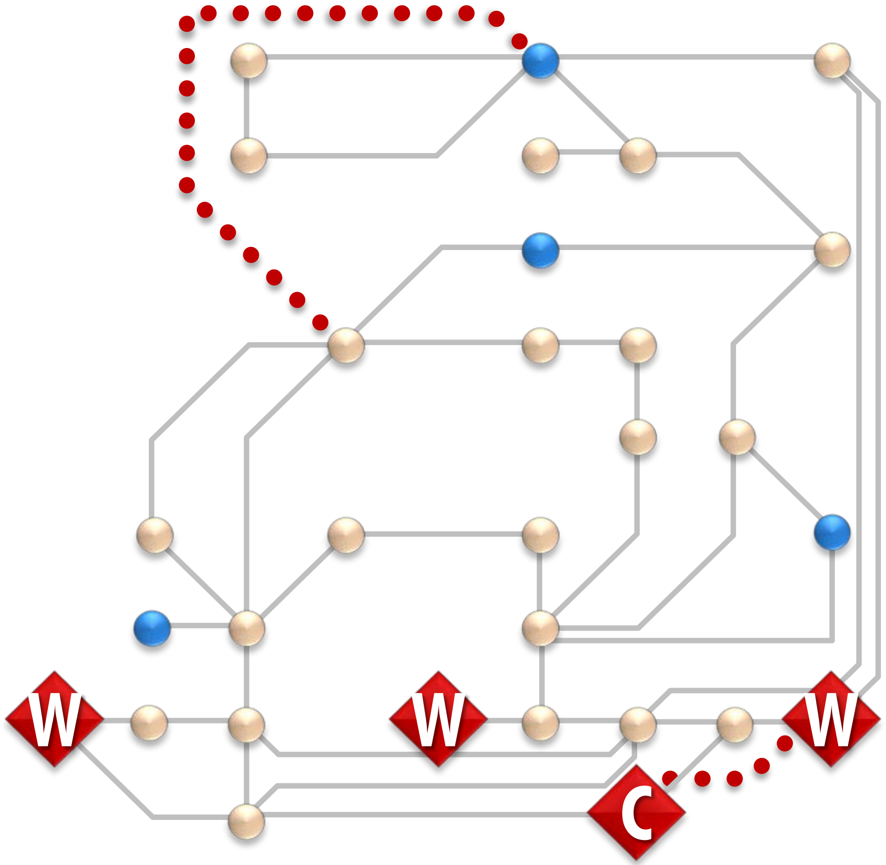
- to satisfy changing requirements
- after the system has been fielded

Saleh, J. H., Hastings, D. E., & Newman, D. J. (2003). Flexibility in system design and implications for aerospace systems. Acta astronautica, 53(12), 927-944.

Robust Design – Key to Resilience IEEE-30

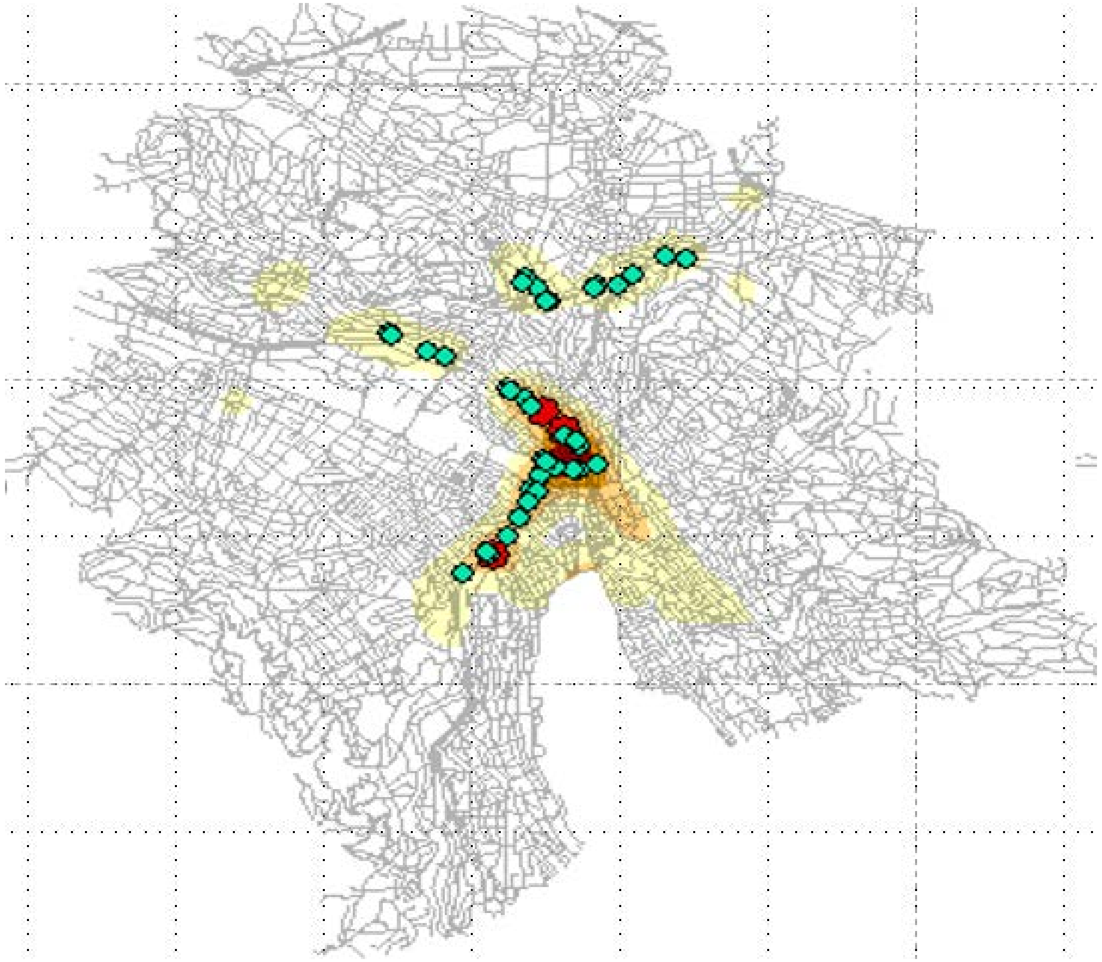


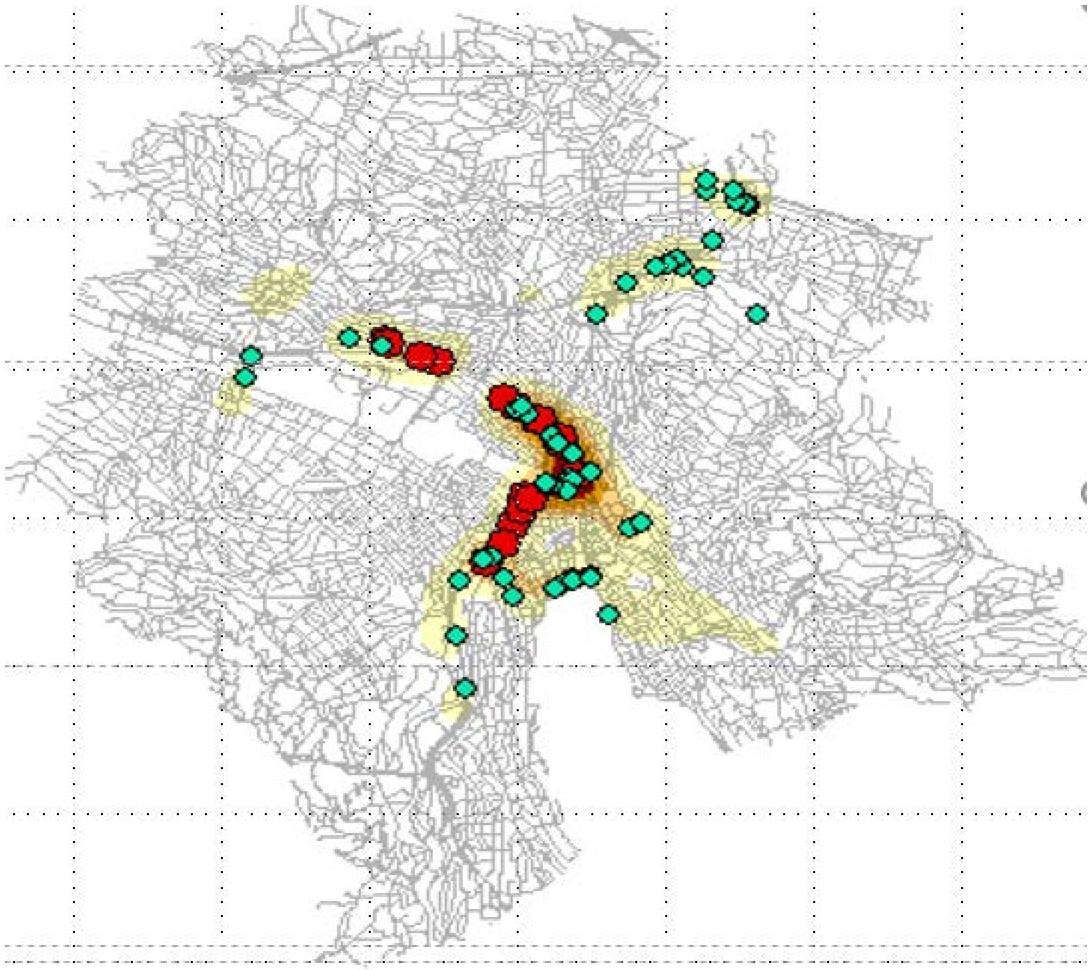
Traditional Optimization



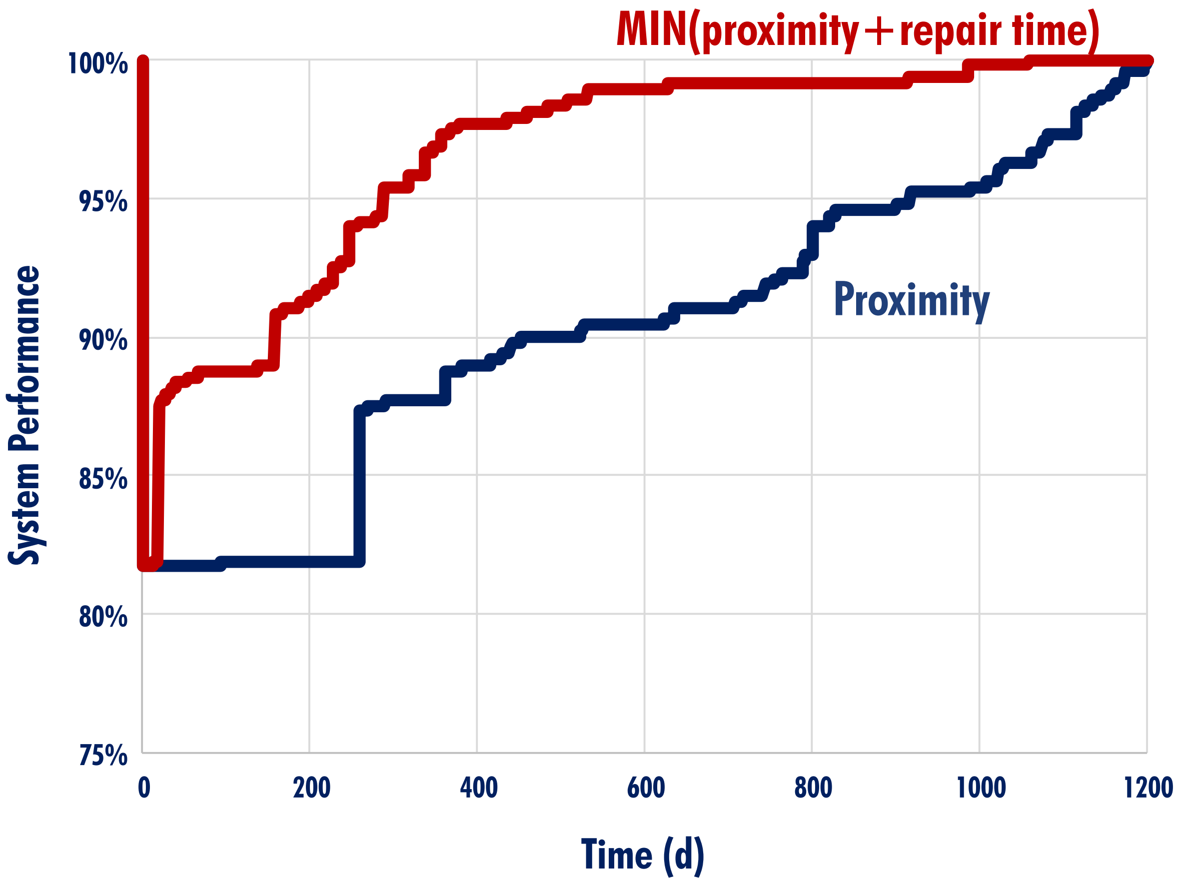
Robust Optimization

Recovery -Topology Management



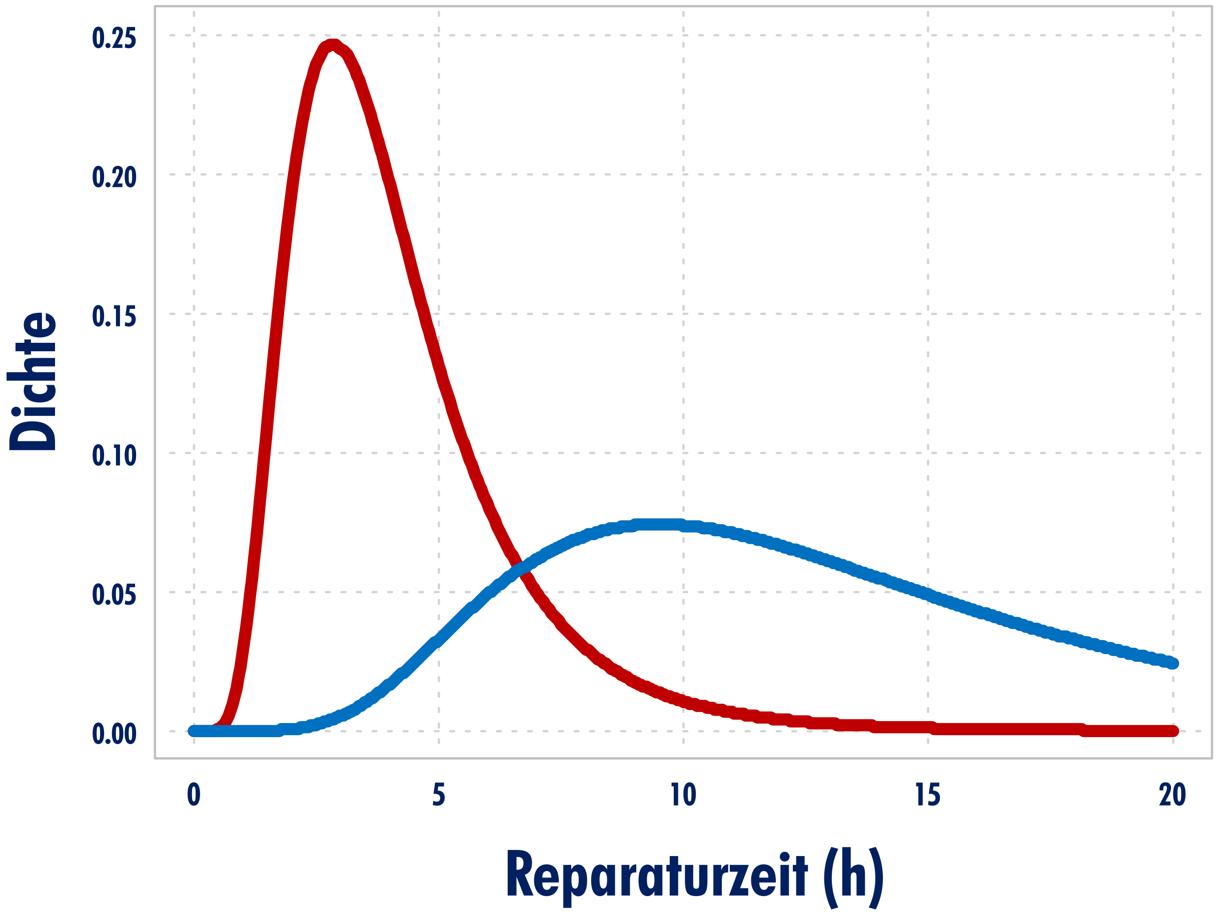


Recovery - Influence of Repair



Nazli Yonca Aydinl, H. Sebnem Duzgun, Hans Rudolf Heinimann, Friedemann Wenzel , Kaushal Raj Gnyawali (forthcoming): Evaluation of operational resilience enhancement strategies for rural transport networks und geohazards

Recovery - MTTR - Repairability



Social Resilience

Problem Framing

Decision Making

Action

Capture cues → make sense → develop options → choice → act

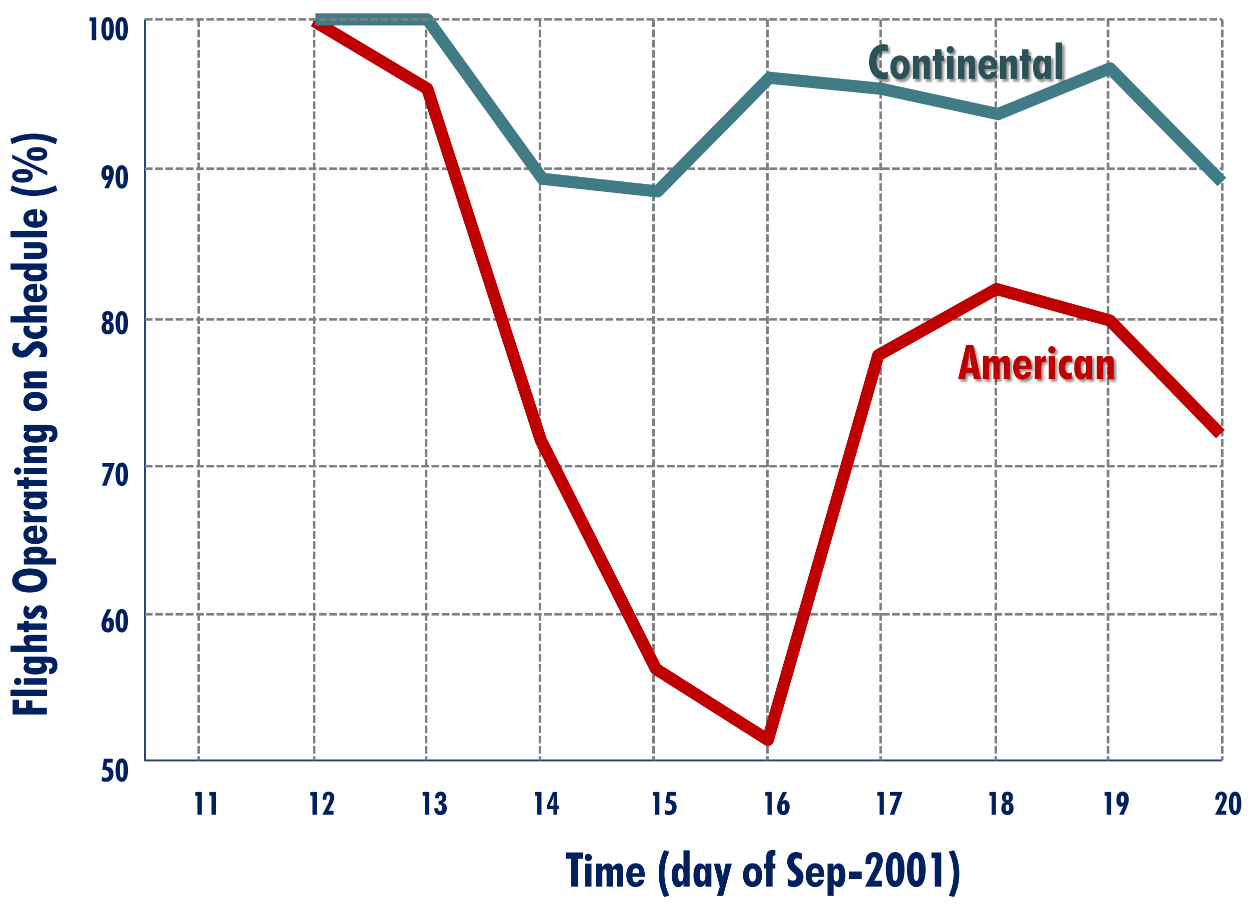
Intelligence | **Design** | **Act**

- Update memory
- Reconfigure
- Rebuild
- Re-stabilize
- resist

Sensing, anticipating, sensemaking and the identification of purposeful action options are crucial to cope with ambiguous, unexpected events.

Resilience-building actions comprise of resistance, re-stabilizing critical social functions, recovery of social functions and reconfiguration of social interactions

Organisational Resilience – Recovery after 9/11 Grounding



YU, G. and X. QI. 2004. *Disruption management : framework, models and applications. Singapore ; River Edge, NJ. World Scientific. 294 p.*

To Sum Up…

- Systems are getting
  - More interconnected
  - More cyber-physical
- Ambiguity and unexpectedness as main challenges
- Resilience extends reliability and risks, not replaces thems
- Resilience metric: still searching for better approaches
- Robust and flexible design + "Informed recovery" key to build resilience
- Social resilience – distributed cognitive function view