

Releasing the Adaptive Power of Human Systems

Is a Comprehensive
Theory of Resilience Possible?

[http://csel.org.ohio-state.edu/
ResilienceEngineering.html](http://csel.org.ohio-state.edu/ResilienceEngineering.html)

D. Woods, Complexity in Natural, Social and Engineered Systems

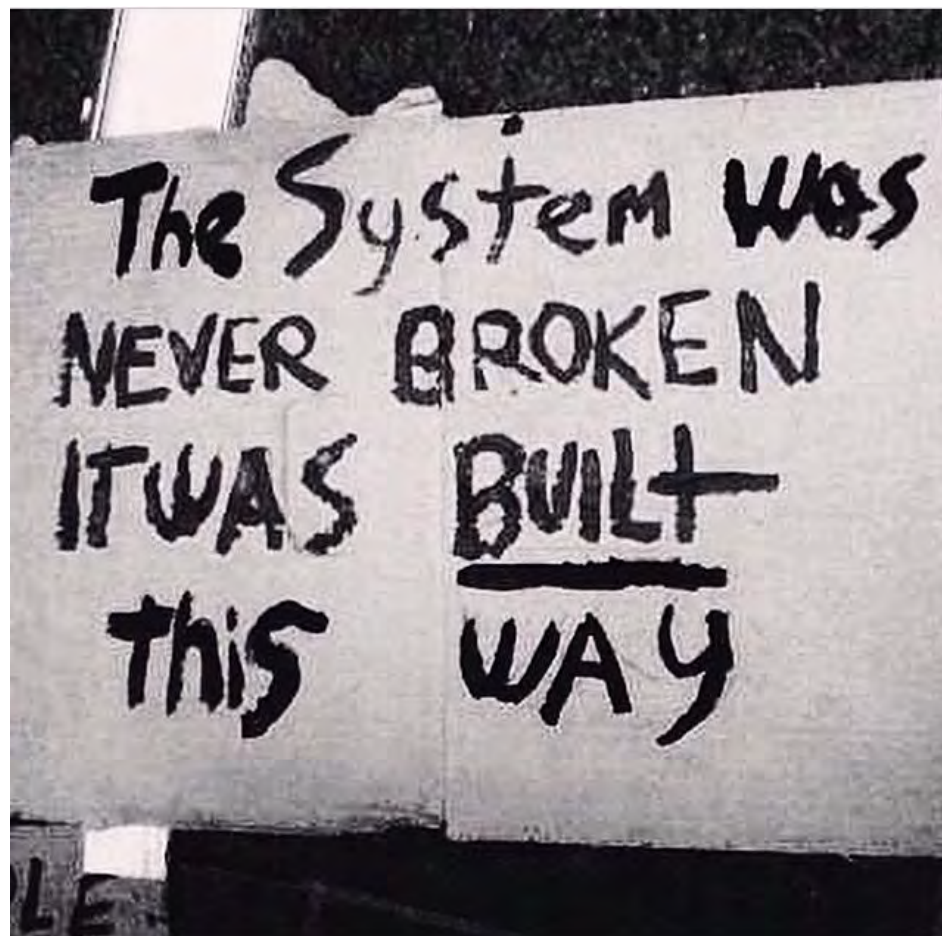
SLOWPOKE

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Surprising reverberations in tangled layered networks

Adaptive Behavior Consumes Success



A system does what it is designed to do,
except that is not what the designer intended.

SNAFU is normal



PLAN

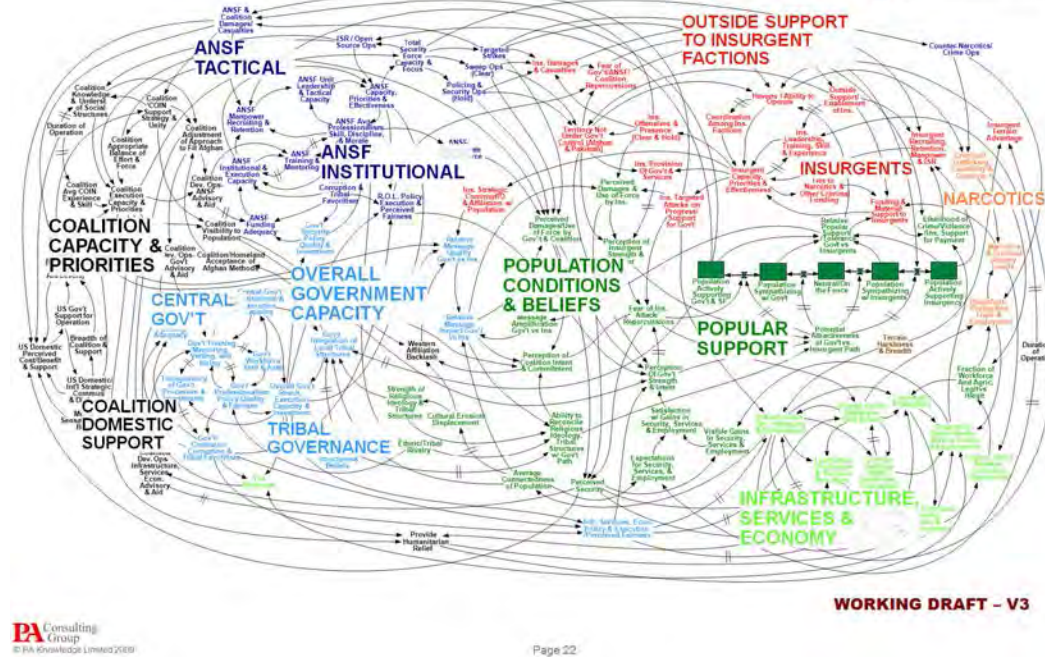
10 Theorems: Perspective and Miscalibration



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10 Theorems: Perspective and Miscalibration



Crises of Complexity in Networks with Extensive and Hidden Interdependencies

Failure is due to **brittle** systems. Systems-as-designed are more brittle than stakeholders realize, but fail less often as people in various roles adapt to fill shortfalls and **stretch** system performance in the face of smaller and larger surprises.

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Crises of Complexity



THE OHIO STATE UNIVERSITY

Complexity in Natural, Social and Engineered Systems

Adaptive Cycles/Histories

empirical, general patterns

from collecting, sharing, analyzing *stories* of resilience & brittleness in action

cycles of [co-]adaptive reverberations across networks and scales

Precarious Present

assess where and how system is brittle/resilient in the face of surprise

risk of 3 patterns of adaptive breakdown

project how change produces unintended consequences

Resilient Future?

how to build in graceful extensibility and sustained adaptability given pressures, trade-offs and change?

3 areas of progress



Adaptive Cycles/Histories

- stories of resilience and brittleness in action
- extract general patterns

Critical Care

- Being Bumpable - Intensive Care Units (ICUs)
- Patient Boarding in Emergency Rooms

Strong Silent Automation

- Asymmetric lift incidents and accidents in aviation

Business-critical digital services

- High-frequency trading;
regular “flash crashes”

...



Settings that develop Resilient Performance

- tangible experience with ***surprise***
- unease - our systems are ***precarious***
- human talent – ***initiative***: decentralized, coordinated
- build ***reciprocity*** across roles, and units, and levels
- invest resources to toward ***resilience as graceful extensibility*** – not only to meet FBC pressure

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Critical Phenomenon

as systems become more optimal under FBC pressure,
brittleness grows

paradoxical finding:

- highly competent when events fall within the envelope of designed-for-uncertainties
- sudden, large failures occur in the face of events that challenge or go beyond the envelope
- brittle, insufficient graceful extensibility



Dragons of Surprise are normal



Adaptive universe: You live in it,
pressures and technologies tempt you in,
you (and they) are trapped by its rules
it doesn't work the way you think it does

Tangled Layered Networks

Brittleness

Decompensation

Graceful Extensibility

Fluency Law

Law of Stretched Systems

Adaptive Cycles

Polycentric Governance

Initiative / Reciprocity

Net Adaptive Value

Range of Future Adaptive Action

Risk of Saturation

Patterns of Cascades

Capacity for Maneuver

Fundamental Trade-offs

Acute-Chronic Trade-off

Optimality - Brittleness Trade-off

Sacrifice Judgment

Oversimplification Fallacies

Concepts about the Adaptive Universe

Fluency Law:

'Well'-adapted activity occurs with a facility that belies the difficulty of the demands resolved and the dilemmas balanced.

Law of Stretched Systems

With change, every system is continuously stretched to operate at its new capacity.

People as problem holders exploit 'improvements' to better achieve goals by pushing the system out to operate near the edge of its new capacity boundaries. The process of adapting to exploit the improvement results in a new intensity, complexity, and tempo of activity.

Concepts about the Adaptive Universe



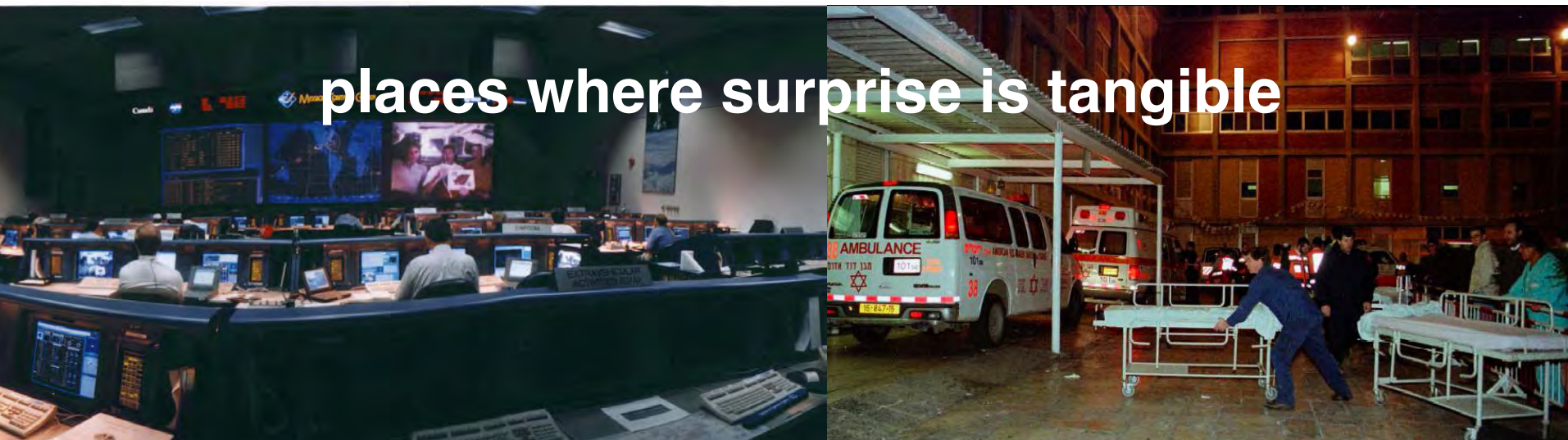
Graceful Extensibility

- graceful extensibility is a positive capability to stretch near and beyond boundaries when surprise occurs.
- opposite of brittleness
- graceful extensibility trades off with optimality

See *Reliability Engineering and Systems Safety*, doi:10.1016/j.ress.2015.03.018

http://www.skybrary.aero/index.php/Portal:Human_Factors_and_System_Safety_Seminar

Graceful Extensibility in Action



Patterns of Adaptive Breakdown - Mal-Adapted

Decompensation: exhausting capacity to adapt as disturbances/challenges cascade.

breakdown occurs when challenges grow and cascade faster than responses can be decided on and deployed to effect.

Working at cross-purposes: behavior that is locally adaptive, but globally maladaptive

inability to coordinate different groups at different echelons as goals conflict.

- Fragmentation (stuck in silos)
- Missing side effects of change (temporal)

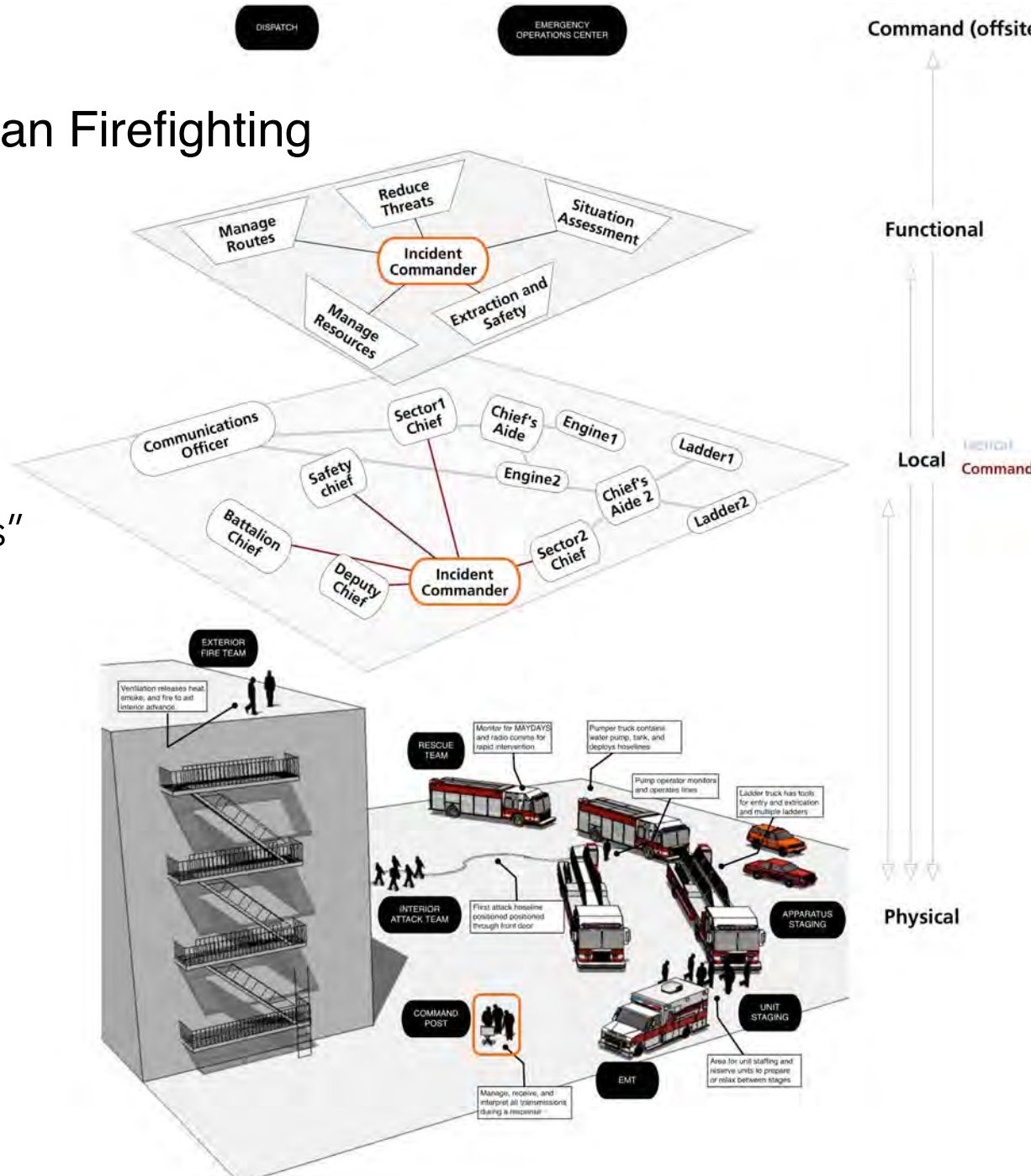
Getting stuck in outdated behaviors: the world changes but the system remains stuck in what were previously adaptive strategies.

- Oversimplifications
- Fixation

Patterns in how adaptive systems fail

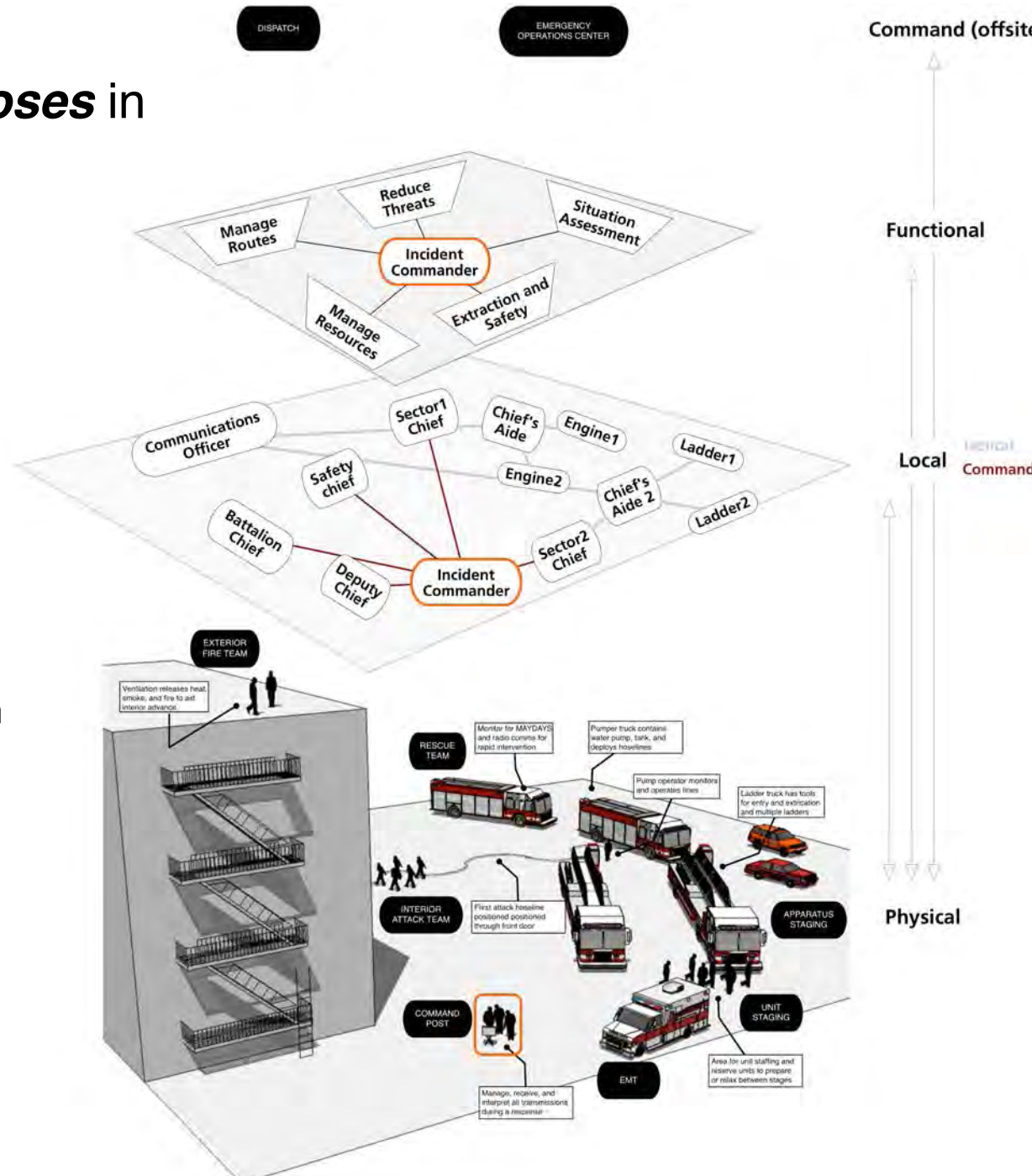
Decompensation in Urban Firefighting

- If request resources when need is definitive, it is already too late
- Maintain tactical reserves, "avoid all hands situations"



Working at Cross-Purposes in Urban Firefighting

- Actions of one group increase threats to other groups (opposing fire hoses; rendering escape routes or protected areas inaccessible)
- Failure to resynchronize
- Goal priorities/conflicts in response to distressed firefighter



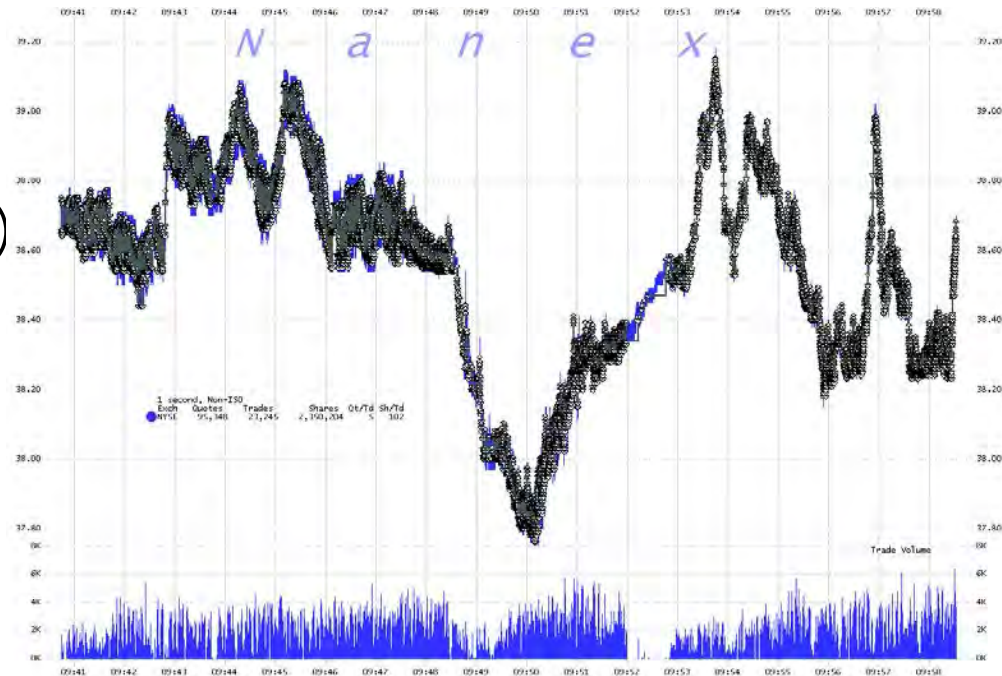
Decompensation

breakdown occurs when challenges grow and cascade faster than responses can be decided on and deployed to effect.

- Starling curve cardiology
- cardiovascular anesthesiology
- asymmetric lift in aviation
- automation (Sarter & Woods)
- 'surge' capacity & patient boarding in ER (Wears / Stephens)
- ICU bed crunches (Cook)
- high frequency trading
- critical digital services (Allspaw)

Knight Capital 2012 collapse

slow and stale as events cascade



What is needed to be sufficiently adaptive & resilient as challenges change?

ability to develop/sustain key abilities that build a readiness to respond:

anticipate	vs	decompensate,
synchronize across units, roles, levels	vs	work at cross purposes
proactive learning before failures	vs	stuck in stale behaviors

**ability to adapt to signals about future surprises
as conditions continue to evolve**

Adaptive Cycles/Histories

- how to reinforce search for general patterns?
- how to map cycles of [co-]adaptive reverberations across networks and scales?

Precarious Present

- assess where and how system is brittle/resilient in the face of surprises
- risk of 3 patterns of adaptive breakdown
- how to size and direct resources for graceful extensibility
- tools to identify unintended consequences of change

Resilient Future?

- build/modify capacity for graceful extensibility given trade-offs, pressure, limited resources and change?

Risk of what?



In adaptive systems,
yesterdays's solutions
produce today's surprises
that become tomorrow's challenges



[http://csel.org.ohio-state.edu/
ResilienceEngineering.html](http://csel.org.ohio-state.edu/ResilienceEngineering.html)

[https://www.youtube.com/watch?
v=7STcaWjJoww&index=7&list=PL055Epbe6d5YDU6sikjqcd_YM9XT4OehD](https://www.youtube.com/watch?v=7STcaWjJoww&index=7&list=PL055Epbe6d5YDU6sikjqcd_YM9XT4OehD)

[https://www.youtube.com/watch?v=zHJdDMQJXiw&index=8&list=PL7_JAXDeVTvIZ_Y-
ddqCiGF-ZKxtM5MLe](https://www.youtube.com/watch?v=zHJdDMQJXiw&index=8&list=PL7_JAXDeVTvIZ_Y-ddqCiGF-ZKxtM5MLe)

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