Releasing the Adaptive Power of Human Systems

NASA failure history captures cumulative complexity circa 2000

Creating Safety Under Pressure

NASA in a changing environment under performance demands and resource pressures:

- Drive down the cost of launch
- Shorter, aggressive mission schedules
- New partners and relationships
- New roles
- Skill erosion
- Heightened public interest

"Risk, therefore, becomes the "fourth dimension" of project management—treated equally as important as cost and schedule."

3 Drivers of Change & Innovation

1. **Connectivity**
2. **Sensors**
3. **Automation/Autonomy**

oops, *4* Drivers

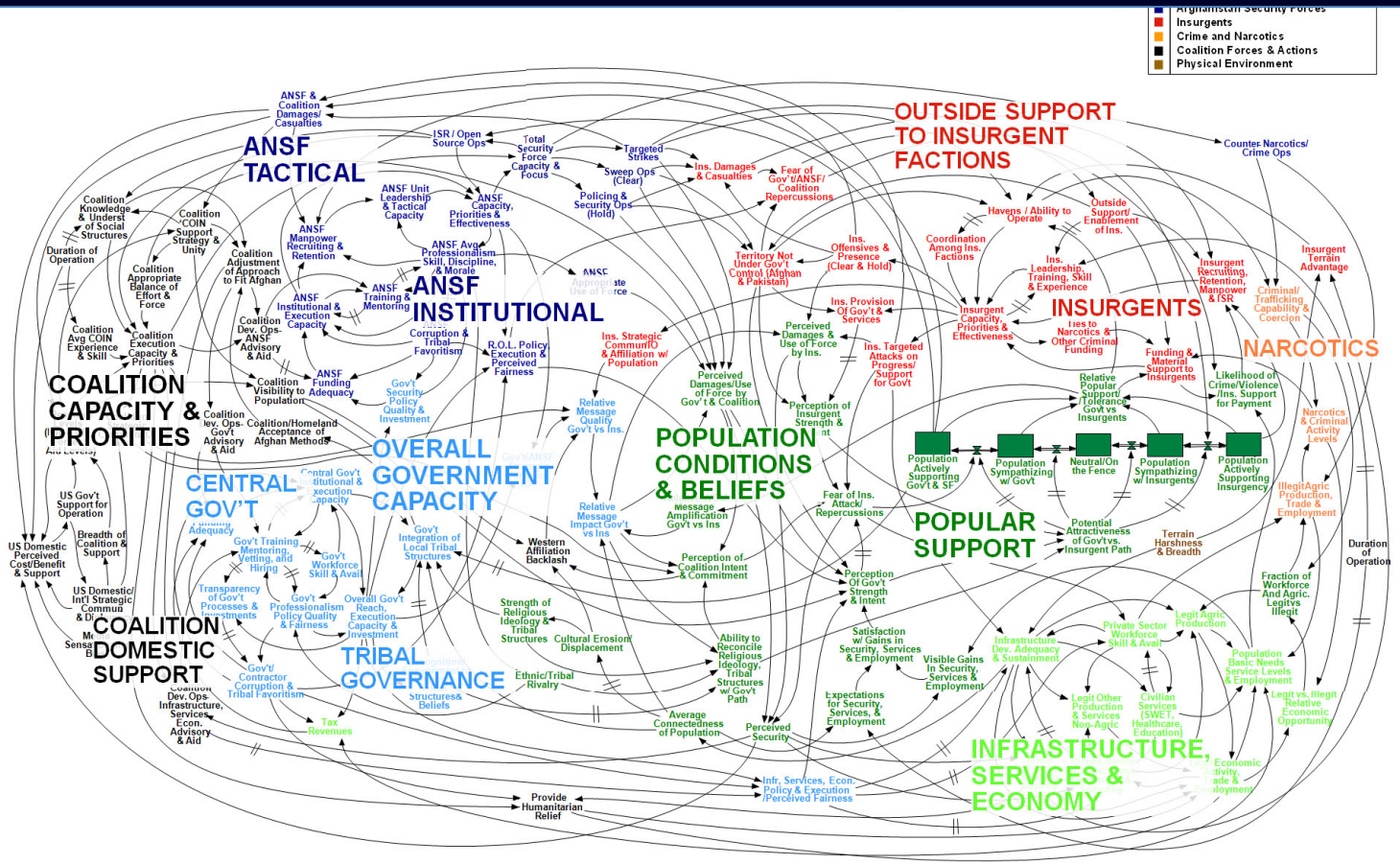
1. **Connectivity**
2. **Sensors**
3. **Automation/Autonomy**

#4. **People**

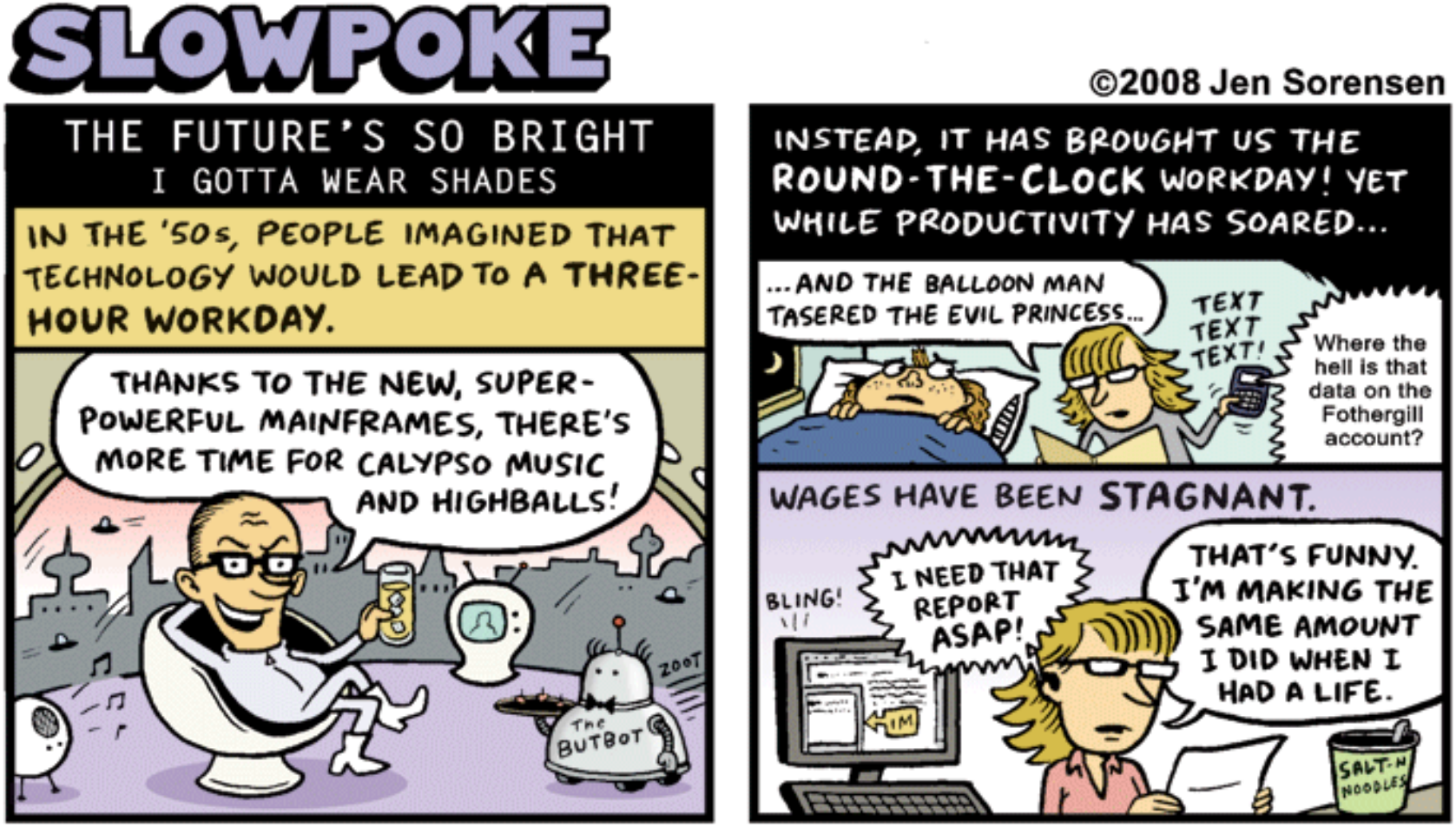
human goals and

human expertise

law of unintended consequences
surprising cascades of effects
sudden failures
linear simplifications don't work anymore

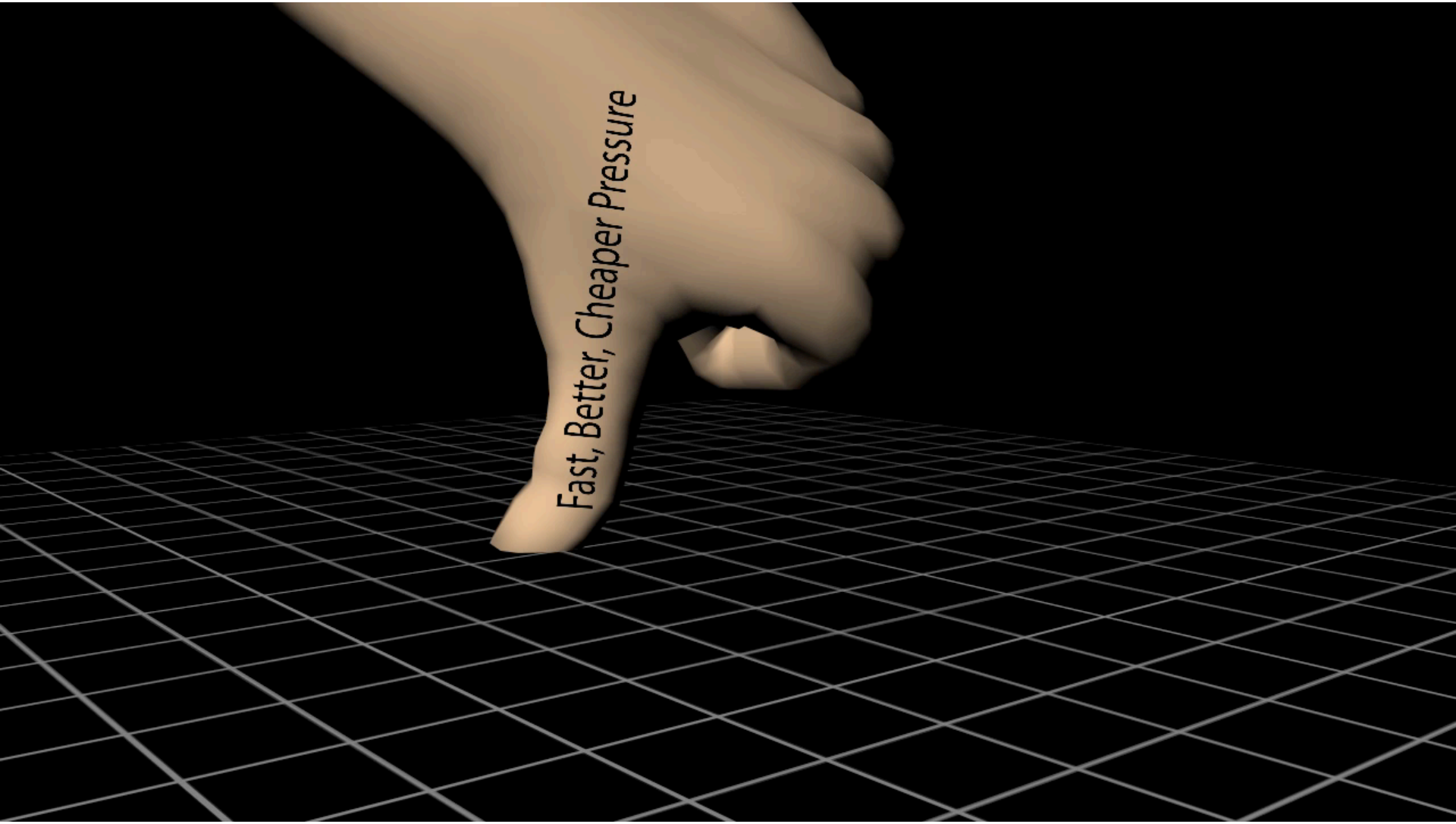


Extensive and Hidden Interdependencies



Surprising reverberations in tangled layered network

Adaptive Behavior Consumes Success



FBC: faster, better, cheaper pressure

Drivers

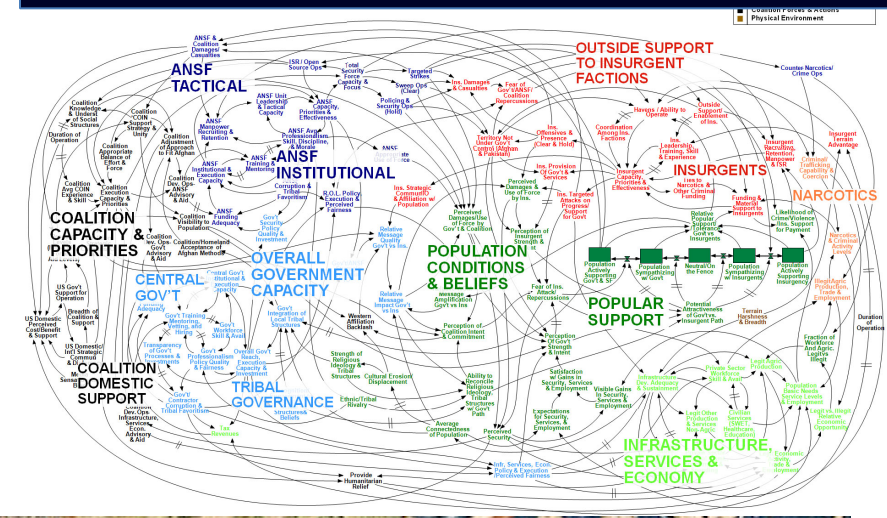
Technology advances: People Adapt to seize opportunities

Scale: Connectivity / Sensing require more Automation/Autonomy

Pressure: People searching for advantage on their goals

Brittleness appears: People Adapt to Fill Gaps

Adaptive universe: You live in it, you power 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

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

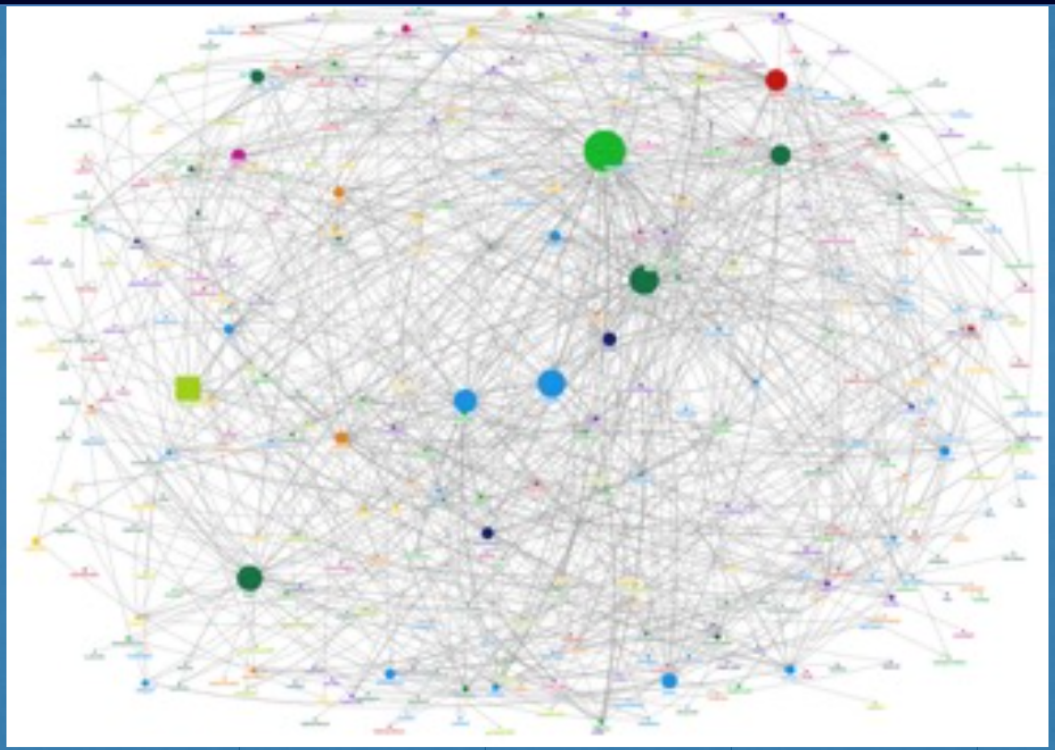
Business-critical digital services

- High-frequency trading; regular “flash crashes”

…

law of unintended consequences
surprising cascades of effects
sudden failures
linear simplifications don't work anymore

Flash Crash (2010)

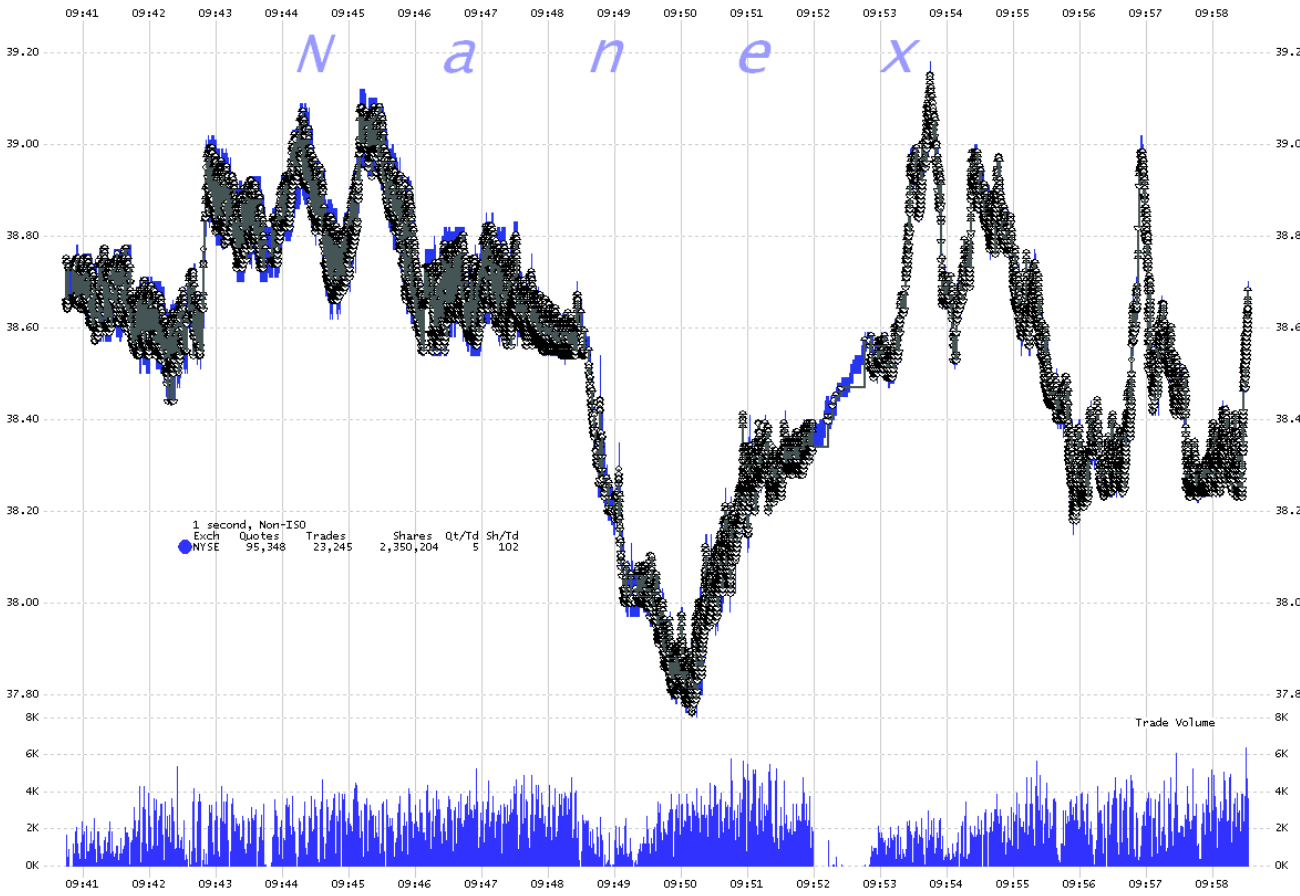


Mornings political/economic news increases volatility. A trader trying to safeguard position puts in sell order. in 4 mins. futures dropped by 3% triggering cascading effects across all markets: 2B shares, $56B, some stocks at a penny/others at $100K.

Extensive and Hidden Interdependencies

Knight Capital runaway automation

in 45 mins.:
212 events spawned
4 million events,
154 different stocks,
KP owned 397 million shares, valued at $6.65 billion, lost $484 million, out of business



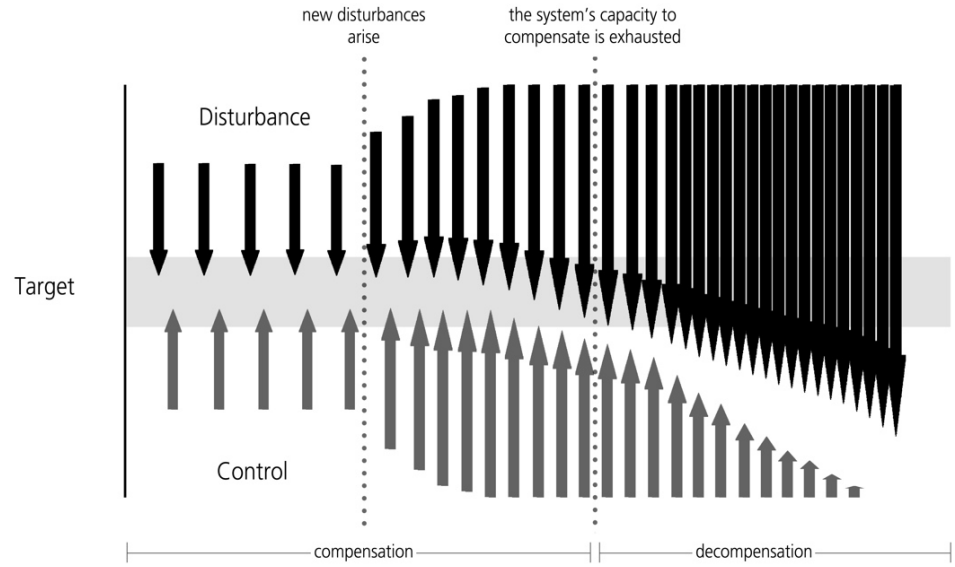
Can't keep pace with cascade

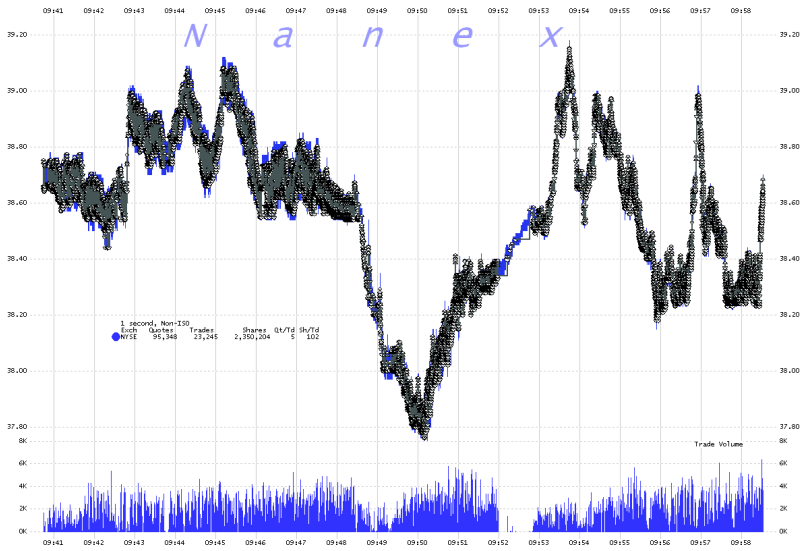
slow and stale reaction to anomalous behavior

in context

Decompensation /Anticipation

failing to keep up with the pace and tempo of events / adapt in anticipation of crunches ahead

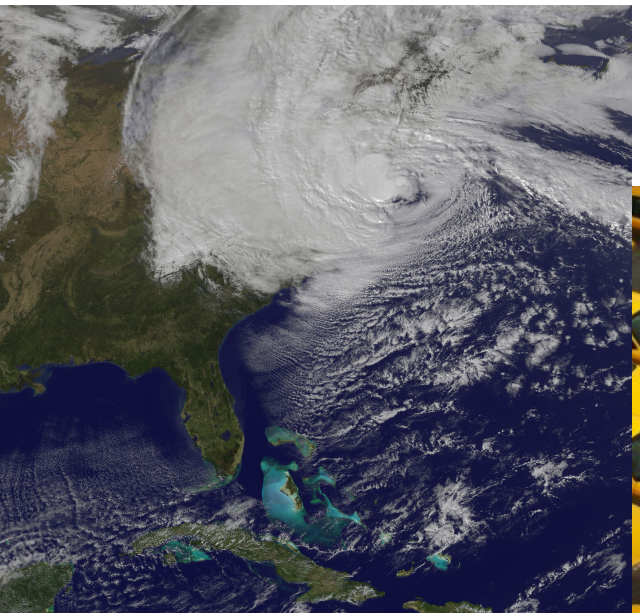


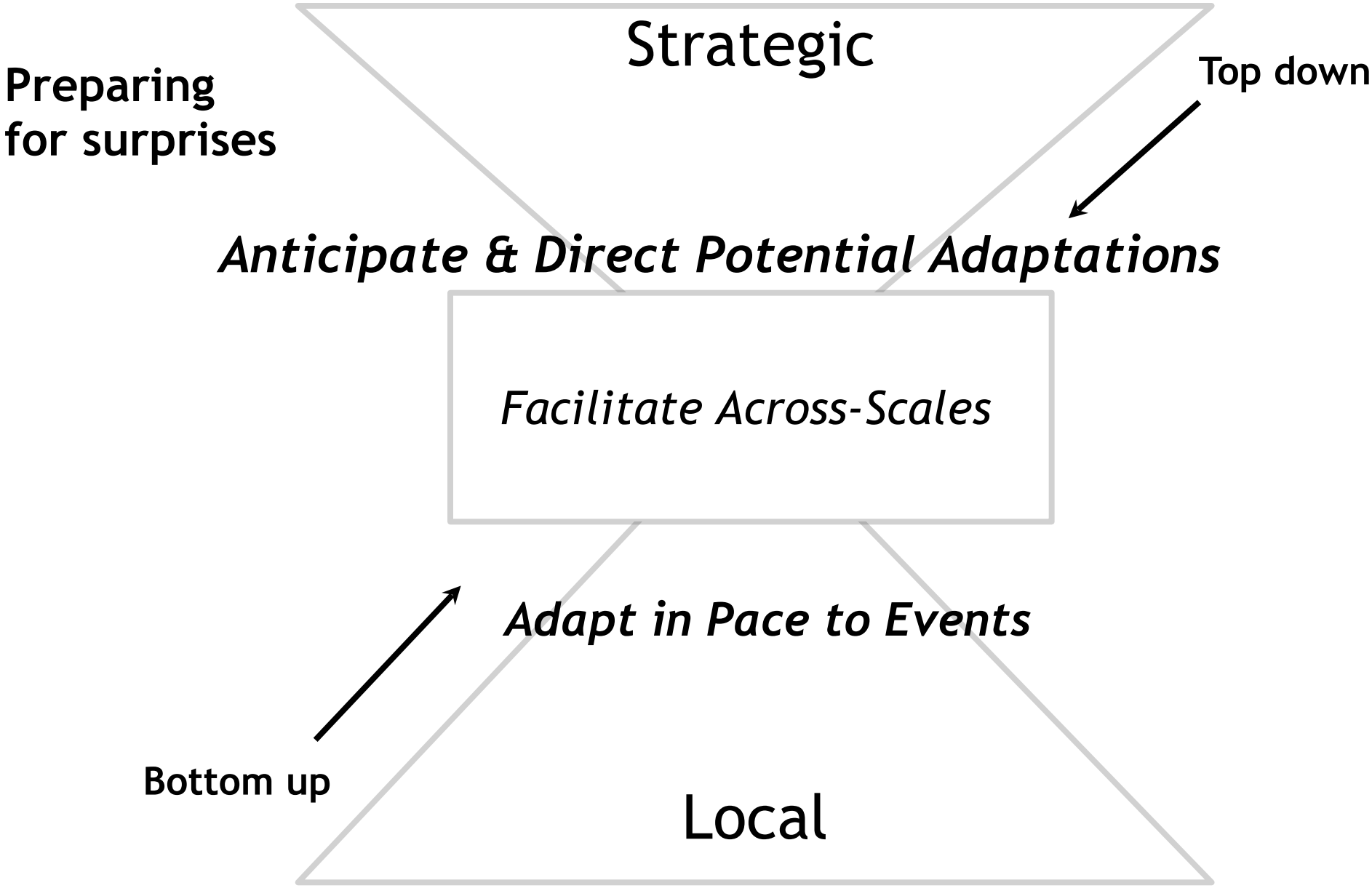


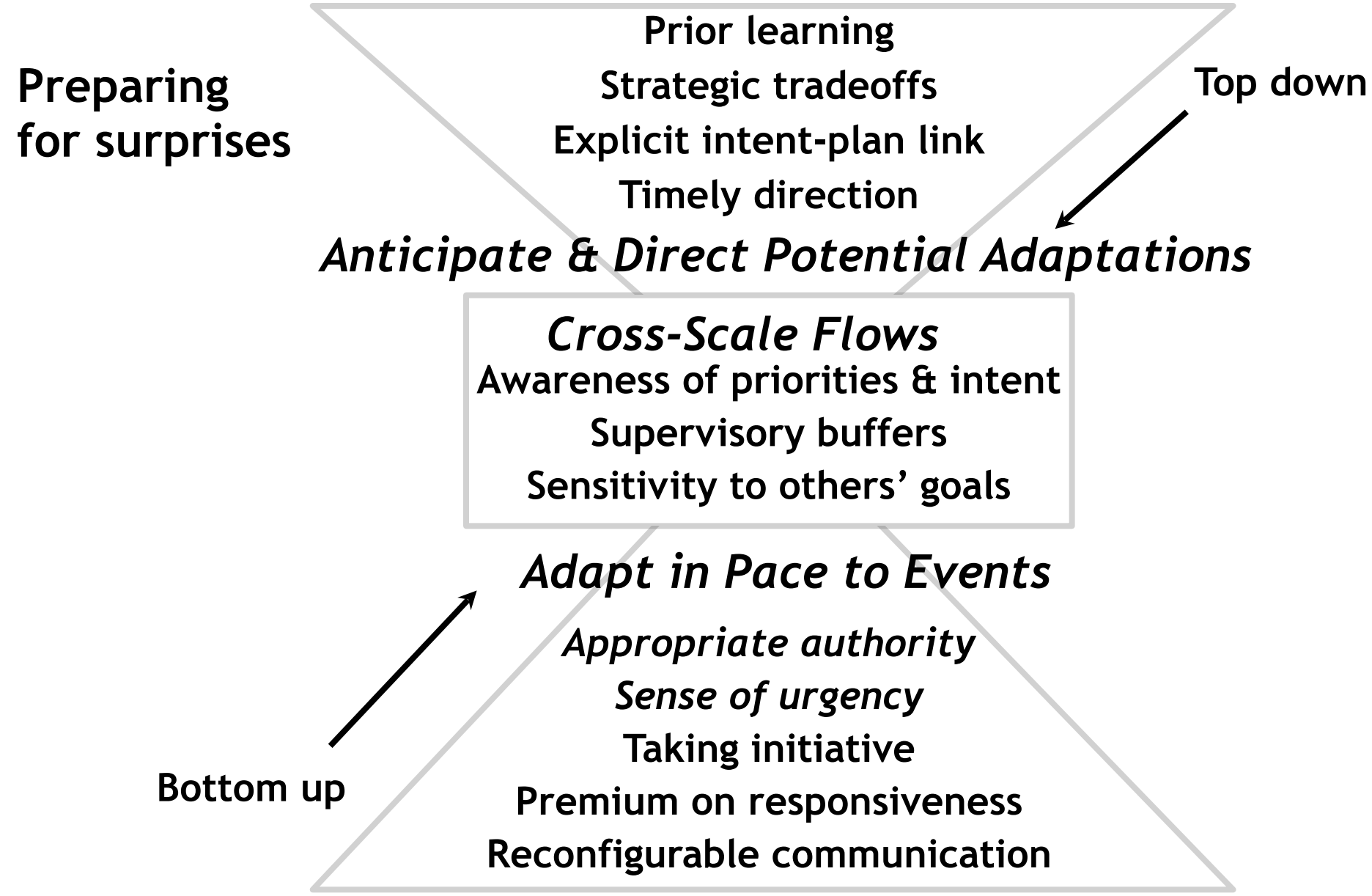
Decompensation Form of Breakdown

Adapting to Hurricane Sandy

- Natural laboratory for observing resilience in face of cascades
- Highly adaptive transportation firm
- Hundreds of movements a day
- Short notice requests
- High schedule variability




Strategic
Preparing
for surprises
Top down
Anticipate & Direct Potential Adaptations
Facilitate Across-Scales
Adapt in Pace to Events
Bottom up
Local


Preparing for surprises
Prior learning
Strategic tradeoffs
Explicit intent-plan link
Timely direction
Top down
Anticipate & Direct Potential Adaptations
Cross-Scale Flows
Awareness of priorities & intent
Supervisory buffers
Sensitivity to others' goals
Adapt in Pace to Events
Appropriate authority
Sense of urgency
Taking initiative
Premium on responsiveness
Reconfigurable communication
Bottom up

Adaptive Universe:

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

results from contrast of success/failure at managing complexity

Graceful Extensibility

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

Graceful Extensibility in Action

places where surprise is tangible

10 Theorems: Perspective and Miscalibration

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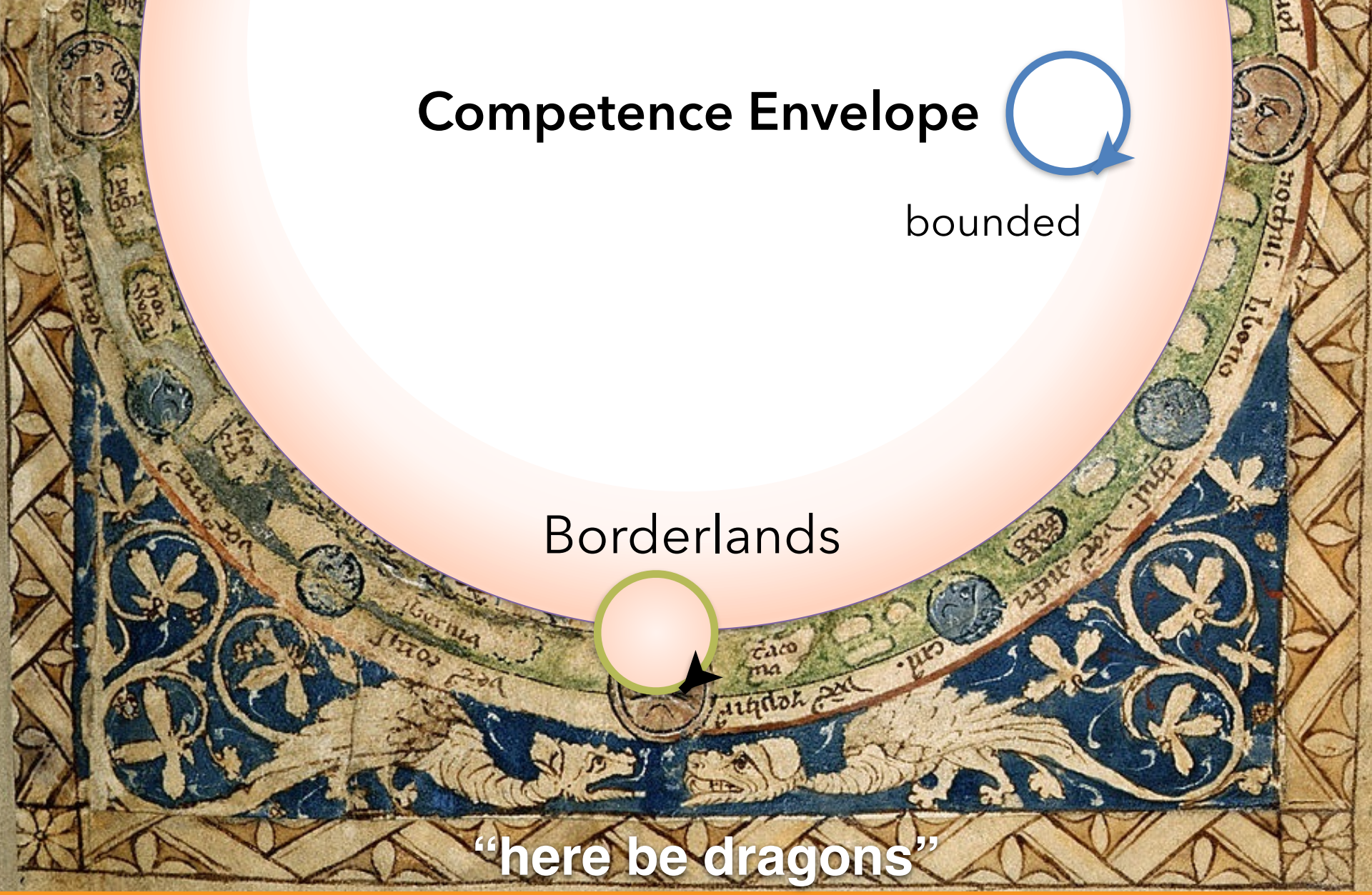
10 Theorems: Perspective and Miscalibration

Surprise: there be dragons



Surprise at boundaries

Surprise at boundaries

Borderlands

What adaptations produce Graceful Extensibility?

(descriptive) **Brittleness**

what Dragons lurking
near, at and beyond boundary?

Anticipating crunches ahead
generating/sustaining a readiness to respond

Competence (Base) Envelope

***P/R* ratio far from boundary**

Trade off

***P/R* ratio near boundary**

Graceful Extensibility

Borderlands

Cascades, Friction, changing Tempos

Surprise at boundaries

Borderlands

Graceful Extensibility

- adaptive units UABs must have some, non-zero graceful extensibility when risk of saturation is high; otherwise too brittle to survive.
- no single unit can have sufficient graceful extensibility *by themselves*; subject to finite resources and FBC pressure

strong constraint on algorithms/automation

Borderlands

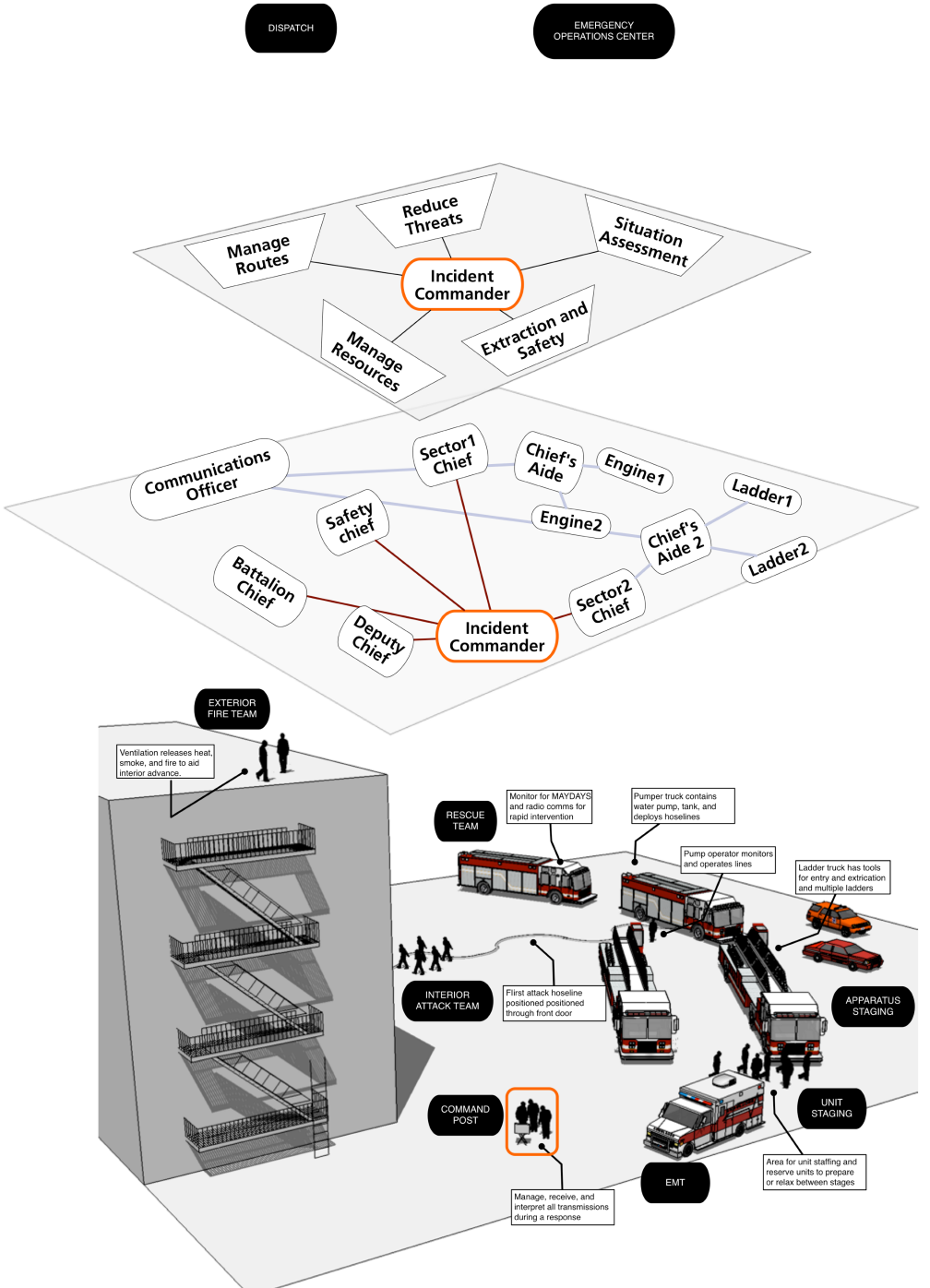
How Adaptive Systems Fail. *Resilience Engineering in Practice*. Ashgate, pp. 127-143

Decompensation /Anticipation

failing to keep up with the pace and tempo of events / adapt in anticipation of crunches ahead

Decompensation in Urban Firefighting

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



Borderlands

How Adaptive Systems Fail. *Resilience Engineering in Practice*. Ashgate, pp. 127-143

Working at cross purposes / Synchronizing over units

locally adaptive – globally maladaptive

nearby UABs expand/constrict *CfM* for a unit whose risk of saturation is high and increasing

Constrict or Expand?

Competence Envelope

Far from

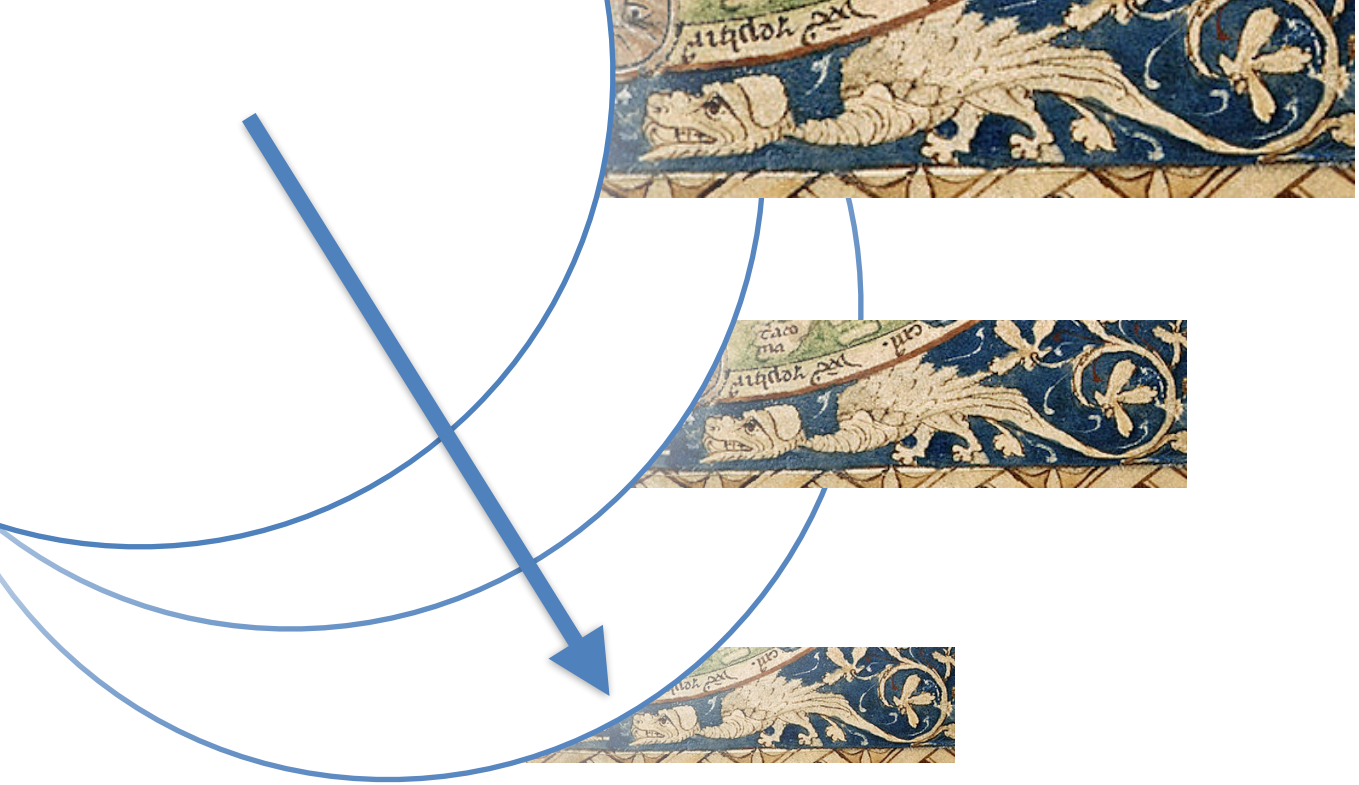
Near to **Borderlands**

Pursuit of optimality under FBC pressure

Adapt to sustain graceful extensibility

Net adaptive value

Balance of two P/R ratios



competence envelope expands to encompass more specific factors/events/disturbances,
dragons of surprise recede

Violates the Rules of the Adaptive Universe

Competence Envelope

Borderlands

challenges to
handle Surprises

steepness of transition

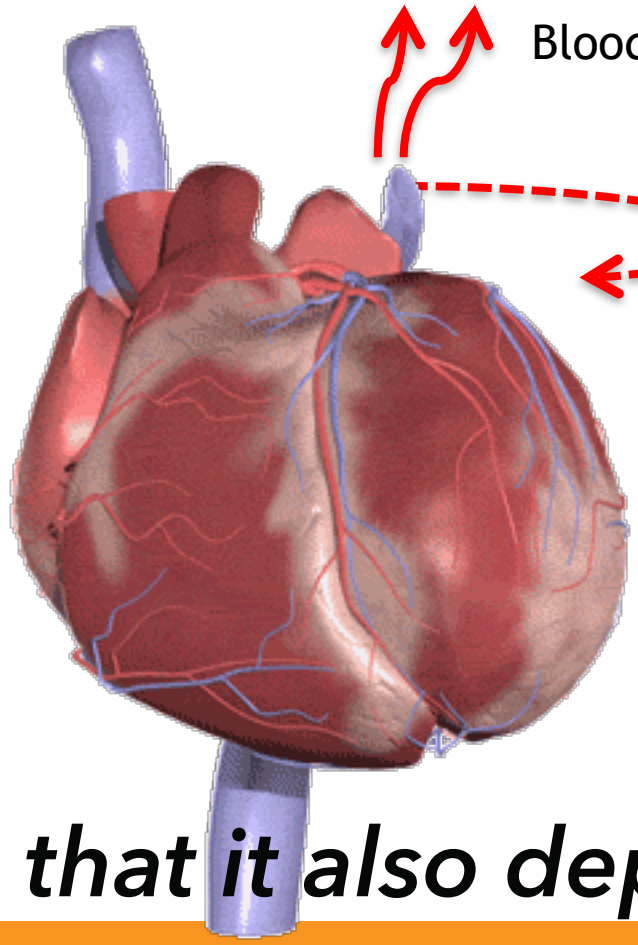
Smooth effortless

Steep Gradient

with faults / load, goal conflict / cascades

keep work **low** to reduce stress

keep work **high** to supply O2



provides function that it also depends on

Strange Loops

as systems become more optimal under FBC pressure, new forms of complexity and fragility emerge

paradoxical result:

- 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

Steep gradient

Borderlands

How Adaptive Systems Fail. *Resilience Engineering in Practice*. Ashgate, pp. 127-143

Stuck in Stale / Proactive Learning

Model Revision

Competence Envelope

Borderlands

Perspective 1:
Work to rule/role

Perspective 2:
Handling Surprises
Regularly

Distant views miss the dragons regularly tamed because others provide graceful extensibility

Competence Envelope

Borderland

change in dragons
handled **poorly**

Distant Perspective?
more rigidity

Up Close Perspective?
adjust taming of dragons

Competence Envelope

Borderland

change in dragons handled **well**

Distant Perspective?
normal

Up Close Perspective?
normal

Fluency Law

Competence Envelope

Borderland

work to tame dragons

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

Distant Perspective
misses

Up Close Perspective
disregards as normal

adaptive cycles

1. Machine Transactions: people develop new speed/ scale of machine transactions

3. Pursue Advantage: people searching for how to use the advances to gain advantage

2. Overcoming Brittleness: people growing and deploying expertise to keep these things working as they constantly change - moving target - as a result of success

Adaptive Cycles/Histories

- empirical, general patterns
- collect, share, synthesize stories of resilience & brittleness in action
- map cycles of [co-]adaptive reverberations across network

Precarious Present

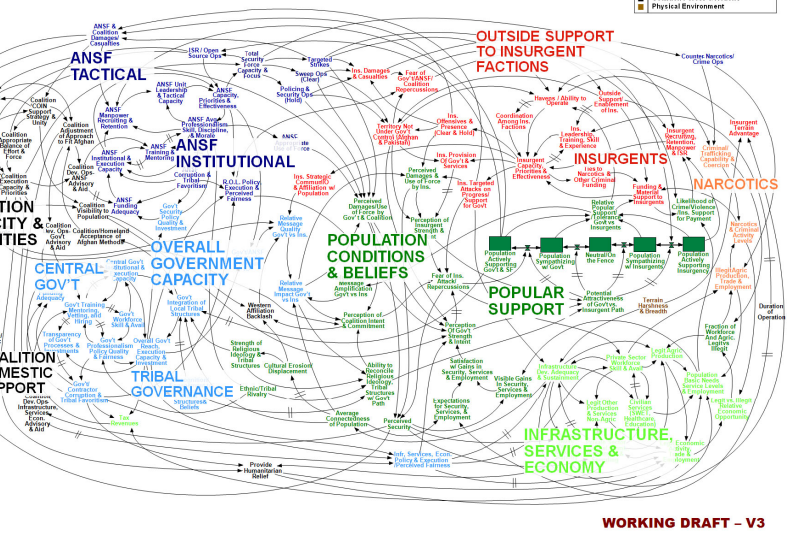
- graceful extensibility in the face of surprise
- risk of 3 patterns of adaptive breakdown
- project how change produces unintended consequences

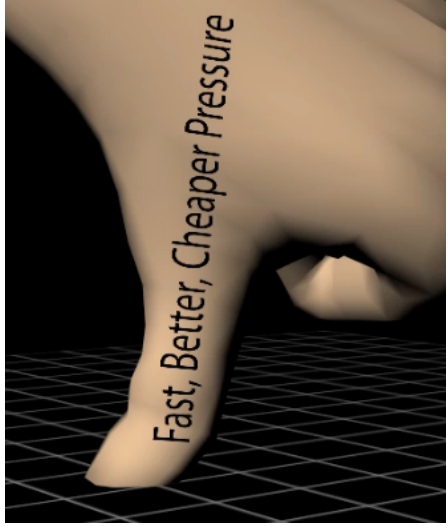
Resilient Future?

- how to engineer in graceful extensibility given trade-offs and change?

Tame complexity? *Build Graceful Extensibility*

- tangible experience with ***surprise***
- unease - our systems are ***precarious***
- human talent – ***initiative***: decentralized, coordinated
- invest resources toward ***net adaptive value*** – not only FBC pressure
- build ***reciprocity*** across roles, and units, and levels.





we are all in the Adaptive Universe and subject to its rules

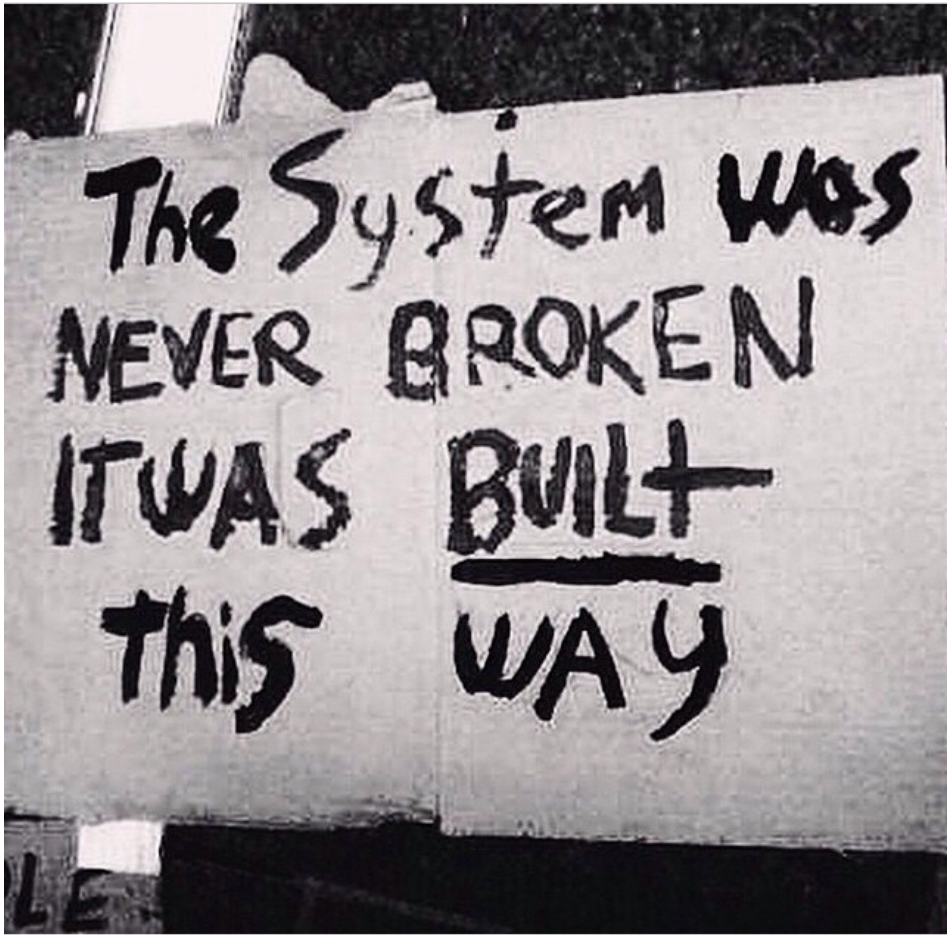
linear simplifications are no longer sufficient

Graceful Extensibility in the face of Surprise ?

to know what generates and what undermines it,

to know how much is needed when

"there will be dragons"



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

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http://csel.org.ohio-state.edu/ResilienceEngineering.html