A Pattern:

• “Computer technology capabilities advance in an organization.

• Stakeholders take advantage of this capability to introduce new services that perform new functions to gain value.

• But these same people know very little about how the service is supplied, what sorts of demands it will not be able to process efficiently, how it is interdependent on other services.”
Pattern, continued:

• “When the service was built it was imagined that it would be used in a certain way, even though the service as provided permitted much wider range of uses.

• Developers wrote code that exploited the new service in ways that generated new forms of failure that were unexpected by the authors and for which no defenses existed.

• These uses brought the system to its knees.”
Pattern, continued:

• “After gaining experience with these forms of failure it became clear that the developers who were using the service to run their jobs lacked a deep appreciation of what they were asking the service to do.

• They had no real opportunity to anticipate this, however, because the service was arcane, hidden, and the contextual assumptions about how it would be used were left unstated.”
Rise of High Frequency Trading / 
Emergence of IEX as a ‘Neutral’ Exchange

To begin, Requires reference to previous adaptive cycles, to chart ongoing process of adaptation with unseen/mis-seen reverberations:

• Some people seeking advantage begin to recognize and act to expand opportunities.
• Increased scale of operations: finer and multiple time scales; scale of transactions; more variability, more players; and cross-scale interactions matter.
• Complexity Penalties increase that produce new forms of gaps, anomalies, conflicts, and surprises.
• New roles arise at multiple levels.
• Partial, incomplete models fragmented over roles. Understanding the changes afoot lags the changes; old models persist long after they no longer apply.
• New goal conflicts arise – value for some comes at costs for others.
• Anomaly recognition: Many anomalous behaviors appear which fall outside previous models/experience.
• Discounting of anomalies that conflict with past models.
Theory is when you know everything but nothing works. Practice is when everything works but no one knows why. In my lab, theory and practice are combined: nothing works and nobody knows why.
Outmaneuvering Complexity in Worlds of Surprise

How adaptive capacities in human-technology systems are built, extended, sustained, degraded, and collapse

Adaptive universe: we all live in it, always pressures, capabilities, conflicts & successes drive it it has a kind of rules it doesn’t work the way most think it does breaking the rules has consequences
Biological Root:

“Life is a Verb.”

“Life developed by networking not combat.” Lynn Margulis

- no role/title is exempt from the rules of the adaptive universe.
- exemplified by multiple levels: cells (glycolysis); bone remodeling, healthy heart; sick heart, neurobiology, joint cognitive systems, socio-technical systems, organizations, social systems
- all lines of inquiry contribute but are partial, incomplete and off axis to the new emergent synthesis
- special character of control laws, for tangled layered networks
Poised to Adapt
Responding to surprise requires preparatory investments that provide the potential for future adaptive action. Model surprise is ubiquitous.

Empirical Laws in Adaptive Cycles
Patterns from studies of people adapt to cope with complexity

Discoveries
Fundamentals that explain the phenomena – Graceful Extensibility

Capabilities
Different paths for pragmatic action – New Architectures
Outmaneuver complexity penalties
Definition:
Adaptive capacity is the potential for adjusting patterns of activities to handle future changes in the kinds of events, opportunities, and disruptions experienced, therefore, adaptive capacities exist before changes and disruptions call upon those capacities.

Range of adaptive behavior: adaptive capacity generates a range of behavior that is adapted to the patterns of change ongoing and upcoming; as a range adaptive capacity has limits or a boundary.

Saturation: Exhausting a unit’s range of adaptive behavior or capacity for maneuver as that unit responds to changing and increasing demands.

Risk of saturation: Inverse of remaining range or capacity for maneuver given ongoing and upcoming demands.

Examples of architectures in biology that facilitate future adaptability continue to be uncovered.
Operating in Seas of Complexity

places where surprise is tangible
Adaptive Cycles/Histories extract general patterns from corpus of stories of brittleness and adaptation across natural laboratories

e.g., Critical Care
- Being Bumpable - Intensive Care Units (ICUs)
- Patient Boarding in Emergency Rooms
- Underground adaptations /anticipating bottlenecks ahead

Strong Silent Automation
- Asymmetric lift incidents and accidents in aviation

Business-critical digital services
- High-frequency trading
- regular “flash crashes”
Systems are Messy

(some) people provide resilient performance to overcome brittle systems

Finite Resources / Change Pressures
SNAFU is normal
Poised to Adapt

The System was never broken. It was built this way.

SNAFU is the natural state of systems
Failure is due to **brittle** systems, not erratic people. Systems operate successfully due to people providing extra adaptive capacity, usually hidden or under-appreciated.

**Law of Fluency:**
“Well”-adapted activity occurs with a facility that hides the difficulty of the demands resolved and the dilemmas balanced.
Messy Systems

RyF: systems “which are robust to perturbations they were designed to handle, yet fragile to unexpected perturbations and design flaws” (Carlson and Doyle 2000, p. 2529).

• 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

Given the pursuit of optimality increases brittleness, why don’t more failures occur?

SNAFU Catching

Adapting to handle the regular occurrence of SNAFUs makes the work of SNAFU Catching almost invisible
Messy Systems
Unintended reverberations of change as success is hijacked by others adapting to seek advantage produce new forms of congestion, conflict and cascade.

Malware
WannaCry, Petya, NotPetya: how ransomware hit the big time in 2017

Most first encountered ransomware after an outbreak shut down hospital computers and diverted ambulances this year. Is it here to stay?
Pause

Verbs, not Nouns

Brittle

SNAFU is natural state (finite resources & change

Competence Envelope

Model Surprise

Adaptive Capacity (future oriented)

SNAFU Catching is essential

(some) People are the ad hoc source of SNAFU Catching
Perspective and Miscalibration
Perspective and Miscalibration
Perspective and Miscalibration
Discovery of 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

Viability, over cycles of change, requires Extensibility

places where model surprise is tangible
No plan survives first contact with a disaster-in-the-making.

"perfect" software

production traffic
No plan survives first contact with a disaster-in-the-making.

"perfect" software

production traffic

British Airways' latest Total Inability To Support Upwardness of Planes* caused by Amadeus system outage

Stuck on the ground awaiting a load sheet? Here's why (100 kB)
Viability crushing events?

MX, TSX, TSX V, and Alpha all down 4-27-18

troubles persist 4-30-18

TSB online banking meltdown drags into second week

Customers still facing problems with internet and business services after bungled IT upgrade

New forms of congestion, conflict & cascade
Patterns of Adaptive Breakdown - How Control Saturates

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

**Working at cross-purposes**: behavior that is locally adaptive, but globally maladaptive
inability to coordinate across roles, units, & echelons as goals conflict.

**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.
Cognitive Work as Imagined

Comics created by Robert Hoffman
Cognitive Work as Done

Comics created by Robert Hoffman
Cognitive Work as Done

Work as Imagined vs Work as Done

joint systems perspective

Comics created by Robert Hoffman
NASA failure history captures creeping complexity

1999: 3 space exploration failures

Report on Project Management in NASA

by the Mars Climate Orbiter Mishap Investigation Board

March 13, 2000

increasingly brittle systems under faster, better, cheaper (FBC) pressure

2003: Run up to Columbia accident

NASA FBC circa 00
Urban Firefighting
- distributed roles
- multiple echelons
- disrupting factors
- multiple goals
- interdependencies
Urban Firefighting Critical Incidents reveal

**Working at cross-purposes** (both horizontal and vertical)
Actions of one group increase threats to other groups (opposing fire hoses; rendering escape routes or protected areas unaccessible)

**Decompensation**
- If request resources when need is definitive, it is already too late
- Regulate additional adaptive capacity (tactical reserves)
  ~ maintain **capacity for maneuver** (ability to handle next surprise)
  ~ “avoid all hands situations” (incident command)
Poised to Adapt or Brittle?

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

ability to adapt to signals about future surprises
as conditions continue to evolve
Fundamentals
Theory of Graceful Extensibility

first comprehensive / formal account of how human adaptive systems, at all scales, succeed and fail as the complexity of modern systems continues to grow.

(1) explains empirical regularities and phenomena,
(2) reveals new fundamentals that drive how all adaptive systems work, requires abandoning linear oversimplifications,
(3) predicts the impact of proposed changes to uncover unanticipated consequences that arise as people ‘hijack’ new capabilities for their own purposes,
(4) directs innovative pragmatic action paths to outmaneuver complexity and create proactive safety.