Class 1

The adaptive universe
- finite resources
- surprise is fundamental
- change never stops

terrain ⇒ trans-disciplinary
complexity
adaptation

biological
engineered
human

quest: to identify fundamental rules that govern the adaptive universe

blows mind of western civ
can't simplify our way out of adaptive universe

2nd aspect ⇒ engineering
can we guarantee appropriate forms of resilience: adaptive capacity

Systems that serve human purposes

Complexity, adaptation resilience

System

↳ defies definition

System of interest

"System" is a label → an act by an outside analyst to draw a boundary where there are some entities/processes/functions inside the boundary

outside → the envit, provides context

Self-driving car example

there is no omniscient view, it's a fiction

3 things that define sys perspective

1. behavior of system is function of interactions of parts/components that make up the system. (and what emerges from those) properties
   Can't be seen in parts in isolation

2. interactions across scales
   more than 1 scale

to understand:
   choose a scale
broader + narrower scales impact it

always multi-scale.

interactions occur from scales above + below

3. What is a system is a matter of perspective of the analyst who chooses the boundary

When you look at the adaptive universe, it's about stories

Complexity - can't hide from it

↳ networks with increasingly extensive + hidden interdependencies

fes. eng defin →

Every perspective reveals and obscures

Always have to shift/contrast perspectives

network: set of interacting entities, processes + functions

tangled, layered network (TLN)

↳ John Doyle

unit of adaptive behavior (UAB)

- nodes — tactics, strategies, resources, activities
- can adjust^ their ^behavior in face of variability/uncertainty

adaptive capacity

ability to adjust in the face of events to regulate processes relative to targets/constraints

skill: adapt behavior in changing circumstances to achieve goal

two varities of adaptive capacity

human system: system that serves human purposes

- people
- roles
- groups of people
- machines?

Examples

Unintended consequences offset gains

will look at stories (see quiver notes for setting, antagonists etc)

unintended consequences is not a law, it's a symptom of complexity

graceful extensibility

sustained adaptability

case: NASA Columbia
1999 NASA had 3 space exploration failure

Safety culture: independent perspective when things go wrong (safety investigation)

March 13, 2000 investigation
increasingly brittle system

acute fast/better/cheaper (FBC) pressure

FBC made system more brittle

brittleness - behavior of a system when it gets near its boundary conditions
↳ rapid performance degradation

all systems
- finite resources
- constant changes

contrast: graceful degradation

brittleness is opposite of resilience

NASA: Design for Safety program (see quiver)
↳ Need to treat risk along w/ cost + schedule

Woods said in 2000: risk won't work, it's reactive. Need pro-active: resilience.

faster, better, cheaper: it's not "pick 2", pressure for all 3 is omnipresent

thorough (vs. efficient acute)

Safety is a chronic goal

resilience: extra investment

tradeoff: building resilience vs pursuing optimality

you have to do both
→ be more and more optimal
→ handle surprise

Columbia: three things outside boundaries
1. energy magnitude of debris strikes
2. base of flight (?)
3. striking leading edge structure, not normal tiled surfaces

FBC: rationalize away outside boundary
"everything's normal"

Resilience Eng book (2006)

Tradeoffs

acute vs chronic (goals)
efficiency vs thoroughness (plans)
optimality vs ~~brittleness~~ resilience (complex systems)

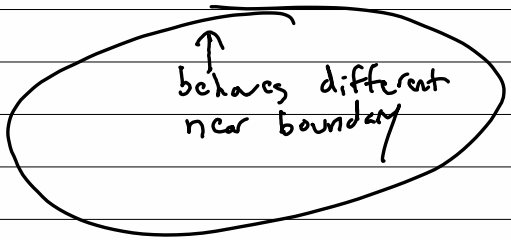
optimist: you can be better/worse in tradeoff space

adaptive capacity is the potential for future adaptive action

how well can you handle the next event when it's not the same as the last event

you see resilience in orgs w/ tangible experiences w/ surprise

Surprise has to be part of it.



Want architecture that can continue to find good tradeoffs ~~v~~ even when surprises change

sustained adaptability

this course
chart adaptive cycles based on stories

(Flash Boys book

adaptive flourescence
(sounds like punctuated equilibrium
evolution in bio happens in fits & starts

Lecture 2

Assumptions of adaptive universe
1. Finite resources
2. The world doesn't stop changing

3 different tradeoffs

1. acute ~ chronic (short run vs long run)
2. efficiency - thoroughness (Hollnagel)
3. robust - fragile
(optimality) (brittleness)

John Doyle - control theory (CalTech)
Alderson et al (robust yet fragile (including robustness)
In pursuing optimality^, increases brittleness

systems seems to be getting faster/better/cheaper,
but becomes more vulnerable to collapses

pessimist: collapses are inevitable
optimist: can outmaneuver complexity

Big picture

1. adaptive histories
2. precarious present
3. resilient future

1. empirical - what happens in adaptive cycles? regularities, patterns, descriptive, explanations

2. assess where things stand
   systems are more precarious than we think
   - different units in our tangled, layered network have models
   - those models can be wrong

3. action agenda

Images of resilience + brittleness in action

Platform drilling collapse in Brazil
- even richest orgs on earth feel pressure to cut costs

Drone failure

Emergency medical system (resilience)

Case 1: anasthesia case

Cook & Woods, anaesthesiology

surgical plan, anasthesia team

surgeon expects little blood loss
short procedure

attending asks for extra lines.
anasthesiologist

why?

attending anticipating problems ahead *
bottleneck

take action in advance directs resident to do extra work, to handle case where crisis arises in future

resident accepts surgical plan at face value

attending physician has additional context info

Expertise: ability to anticipate bottlenecks ahead & take actions to prepare

players: anasthesia team — resident, attending
surgical team
patient conditions

opportunities for variation to occur

units, levels in TLN

What's the { unit ?
network ?

Competence envelope

graceful extensibility - how to handle surprise at the boundaries of the plan

not about frequency

noting what kind of surprise could arise?

ideas + principles have to work at different scales

Case 2: anasthesia case

(resilience in action: anticipating trouble ahead)

- anesthesiology gotten much safer over last 15 yrs
- production + financial pressures
- moving more surgeries to outpatient

Setting: operating in a network w/ extensive, hidden deps

Antagonist: linear thinking

Story: Escaping & failing to escape Simplifications

Driver: Surprises & Cascades

Tensions: Dramatic failures in Brittle Systems

Dead Ends: Unintended Consequences

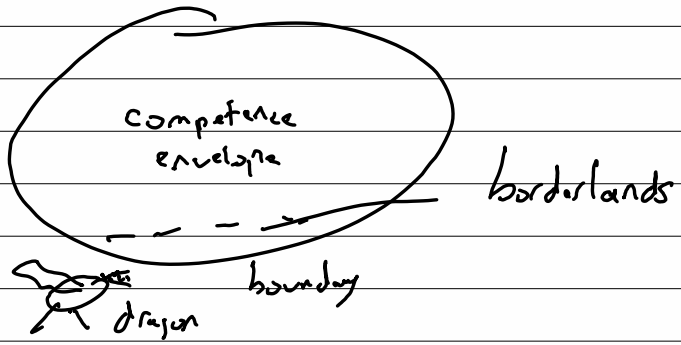
Hope: Where People Stretch to Outmaneuver Complexity

Forward: Graceful Extensibility and Sustained Adaptability

Class 3

Charting adaptive cycles

competence envelope



Surprise

1. anticipating how we might get Crunched/squeezed
2. generating readiness to respond

preparing to be surprised

Competence envelope
Perspective 1: work to rule/role

borderlands
Perspective 2: handling surprises regularly

fluency law: "well"-adapted activity occurs with a facility that belies the difficulty of the demands resolved and the dilemmas balanced.

adaptations hide what was adapted

competence envelope continually expands

model surprise is always possible

optimizing within the competence envelope always makes you more brittle in the borderlands

- it is necessary/good to pursue optimality
- brittleness is separate, at the boundary

Net adaptive value: joint fn of
- graceful extensibility
- optimality
- trade-off

Change leads to shortfalls
responsible ppl make up for shortfalls

4 senses paper
- rebound
- robust
- graceful extensibility (prepare to be surprised) vs brittleness
- sustained adaptability
  - search for architectures that adapt in the trade-off space

Adaptive cycles: studies of resilience in action
charting how changes reverberate thru multi-role, multi-echelon networks
each response to change by some unit triggers adaptive responses across other units

stalls <—(reverb)—> florescence
- change in one unit opens up new possibilities in other units

reverberation across a Tangled Layered Network of interdependent units:
the degree that changes in one area tend to recruit or open up beneficial changes in many other aspects of the network; which opens up new opportunities across the network

59:30
L3

pressing need intersects w/ (apparently) powerful capability

→ point of change reverberates thru network
→ experience of adaptive shortfall (brittleness)
→ responsible ppl act as generic adaptive + learning stop-gap to fill shortfall
→ resulting in kludges (workaround costs)
→ new opportunities for innovation
→ adaptive florescence

Underground adaptations paper
- look at points of change (new tech, org change)
shadow chart - invent new artifacts
- unofficial
- supportive work tool
- more value than official tool
- new artifact failed to support flexibility

- another case:
  underestimated coordination demands

mismatch: computerization { helps @ low workloads
                          { hurts @ high workloads

tradeoffs intensify with load

Case: Being Bumpable ((cook)
  short story incident w/ICU

we need to do charts (charting adaptive cycles)

ICU as crossroads
  can be overloaded
  have to move patients out

resource (saturation)
varying & fluctuating demand

regulate system w/buffer to avoid saturation
  capacity to maneuver

Class 4

Adaptive cycles

anticipating crunches
3 ways that adaptive systems break down
fail
how do systems stretch at boundaries?

Surprise is normal

Saturation - run out of capacity
Capacity for maneuver (CFM)
risk of saturation of CFM

Case: urban firefighting
tangled, layered network
- variety of roles
- distributed in space & time
- tangible experience w/ surprise
- multiple goals
- interdependencies

(See quiver notes for slides)

Decompensation (discuss later)
→ exhaust capacity to adapt

Desynchronization
- teams are no longer coordinated

3 breakdowns
1. Decompensation
2. Working at cross purposes
3. Getting stuck in outdated behaviors

risks
1. complexities in time → decompensation
2. complexities over scales → working at cross purposes
3. complexities in learning → getting stuck

challenges grow + cascade faster than we can respond

pacing / tempo

practice crises

→ locally adaptive, globally maladaptive

Cross purposes
- fragmentation (silos)
- missing side effects of change (temporal)

complexities in learning
every good controller is a model of the system being controlled

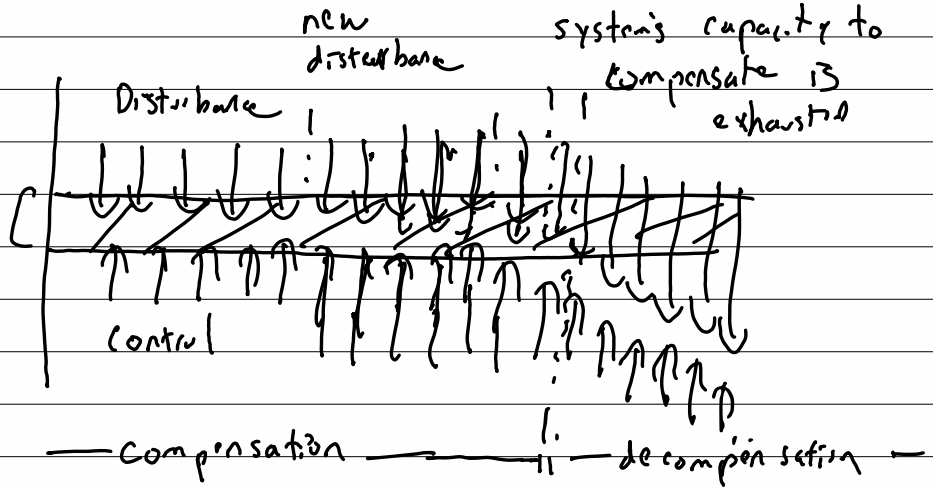
- pursuing targets in the face of variation
- there are limits on the model
- model surprise
- learning loops

world changes, but system stuck in what were previously adoptive strategies.

proactive learning vs getting stuck
-oversimplification
-fixation

Decompensation
-going solid
breakdown occurs when challenges grow + cascade faster than responses can be decided on + deployed to effect

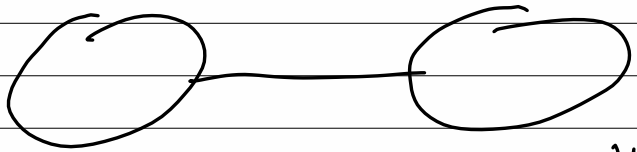
time → how do things cascade



monitor: how hard we are working to stay in control

oversimplifications

*** Capacity for Maneuver (CfM)
- cushion of potential actions + additional resources that allows system to continue functioning despite unexpected demands



one unit increasing its CfM might decrease another unit's CfM

CfM: controlling risk of saturation
critical parameter for control
anticipation

good control being able to anticipate
borderlands

there are regularities of what happens at ^
- Cascades

CfM: can measure that now

Sustained adaptability

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

Ten theorems of adaptive universe

1. Adaptive capacity is finite (boundaries are universal)

Corollary 1.1 The boundaries on the range of adaptive behavior can be fixed or elastic

1.2 A variety of concepts about adaptive capacity can be collapsed into the single parameter Capacity for Maneuver (CfM)

2. Events will produce demands that challenge boundaries on the adaptive capacity of any UAS

2.1 The location of boundaries relative to demands is uncertain

2.2 There are recurring patterns about surprise

2.3 Brittleness is operationally defined as the risk of saturating CfM

3. Adaptive capacities are regulated to manage the risk of saturing CfM

4.

Class 5

1. Boundaries are universal
2. Surprise occurs

multiple goals, and they conflict
- how to align?

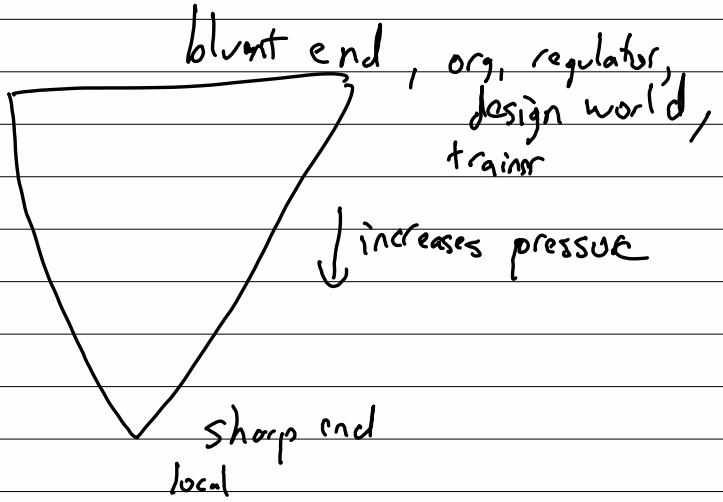
Adaptive units
↳ uses its knowledge + capabilities to adjust its behavior in changing circumstances in pursuit of goals

human systems are:
- intentional (have goals) themselves
- reflective (have a model of how they work)

how goals interact + conflict
seeking alignment

Today: working at cross-purposes

UABs responsible for goals
experience consequences of success/failure



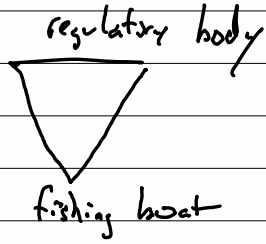
polycentric governance

tragedy of the commons ('68)

- common pool resource (e.g. fishery)
- individual unit behavior affects global system
- pressure on individual agents to fish more
- feedback loop: fish decline, individuals have pressure to fish harder
- fish decompensate: collapse (tipping point)

Ostrom: ppl generally find a different way out of the tragedy

polycentric governance



- multiple centers
- each partial authority / autonomy
- partial responsibility
- command structure → flows down
  - increases risk of decompensation
  - tends not to work (gaming)
- limits on going fully flat
- polycentric in between { command hierarchy / fully decentalized
- polycentrism range
- good architecture is a dynamic control mechanism
- Balinese water temple example
  unintended consequences of western intervention post outbreaks

- military doctrine (Napolean)
  - flexible polycentric architecture

58:49

Van Klausworth - polycentric
adapt plan to fit the situation

initiative, coordination across levels critical

polycentric governance
- network of interdependent units operating over different ranges
- strategy for
  - empower decentralized initiative
  - coordinate over emerging trends to meet priorities
  - dynamic interplay as situations evolve + as other units adapt

emergency informatics: social media, fires in SoCal

patterns from patient boarding study
- hoarding resources → ~~trust breakdown~~ misnamagement of TLN

Ostrom's reciprocity - need repicoprocity in TEN
"I will help you when you're crunched"

work to role undermines ~~synchronization~~ coordination
globally maladaptive

need to incentivize working across roles

responsibility to achieve local goals
that's what you want
adaptive simultaneously
all systems are well-adapted
and
all are mal-adapted
under-adapted

bio: can select for adaptability, potential for future adaptive action when the world changes

Class 6

precarious present-assessment
3 forms of ~~a~~ breakdown
decomposition — anticipate
cross purposes — locally adaptive
tragedy of commons — polycentric governance
~~Stuck~~ eco

coordinate synchronize
learn proactive

stuck in stale models

net adaptive value: how we do
- far from boundary
- near boundary crisis, starvation
high

charting adaptive cycles

1. pick a trigger
   acute, immediate, slowly building
   anomalous?
   opportunity?
   bottleneck

2. who does trigger affect? (what units)
   ~~what does it~~
   who reacts to it?
   who notices it?
   what does it mean for that role/UAB?
   role/org

how did they change?

Treat each adaptive unit response as a trigger. How does that look?

looking at waves of change

foreground/background

↳ unit

eventually stalls out, stops triggering change

analysis pattern

3 panel poster
1. initial adaptive cycle
2. reverberations triggered by that
3. what does that lead to?

(could have subplots)

adaptive landscapes

basics in theorems

3* adaptive capacities can be regulated
- recognize risk of saturation
- adjust capacity to maneuver
- how hard is it to stay in control?
- struggle for fitness is ongoing

4. No UAS can have sufficient range of adaptive behavior to regulate risk of saturation by itself

- have to look at network

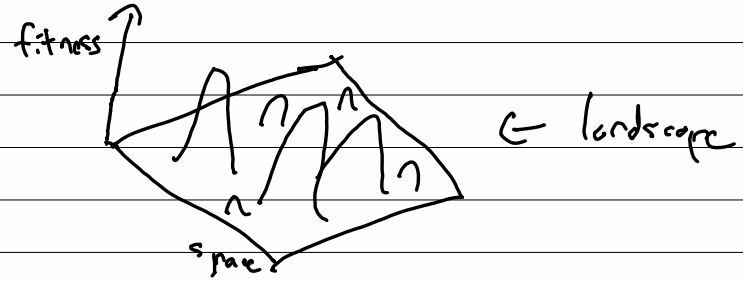
Example: heart as adaptive unit (UAB)

5. Some UABs can monitor + regulate CFM of other UABs in response to changes in the risk of saturation

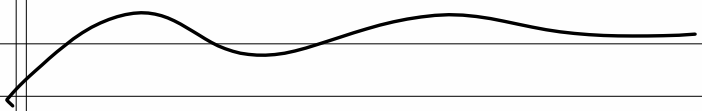
Sewall Wright, 1932, adaptive landscape (this paper?)
2D topology w/ height → fitness
"adaptive value"

genetics talk Sixth Int'l Congress of genetics

Darwin's finches – beaks adapted to food on local island



← landscape



Decompensation

fitness: ability to stay on target

all units have bounds, can saturate

can I keep up w/change?
how much margin is left?

mutuality
- changing demands in envit
- units have capabilities to respond to demands

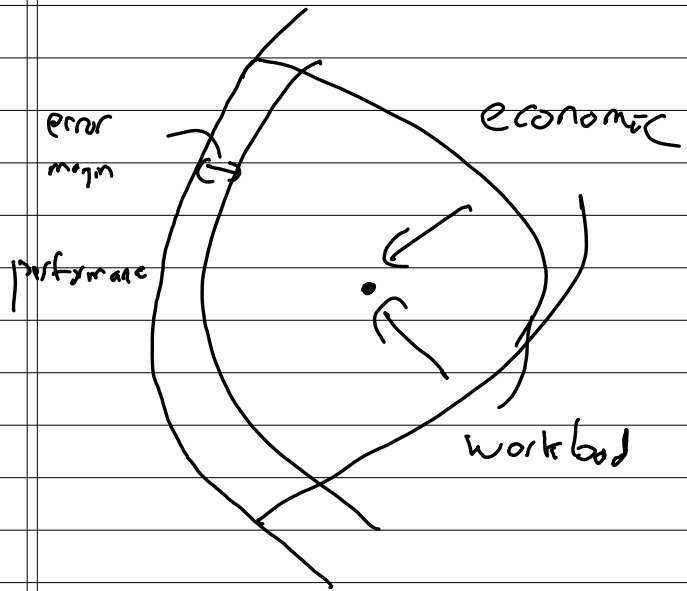
relationship

Readiness to:
- Deploy existing
- Mobilize new
- Generate new (the future)

getting stuck + stale

2 kinds of learning
- change your base envelope/fitness
- how graceful extensibility is created
  how do we stretch at boundary

Safety margin- boundary diagram



metaphor (turns out it's wrong)

not correct (don't have "surprise is normal")

tend to think competence envelope bigger than really is
overconfident
miscalibrated

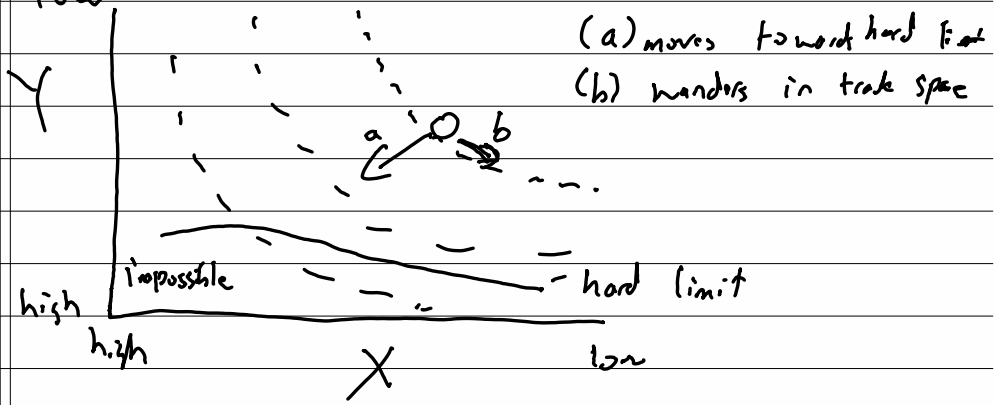
Class 7

Key concept of today: tradeoffs

will go over adaptive cycle example

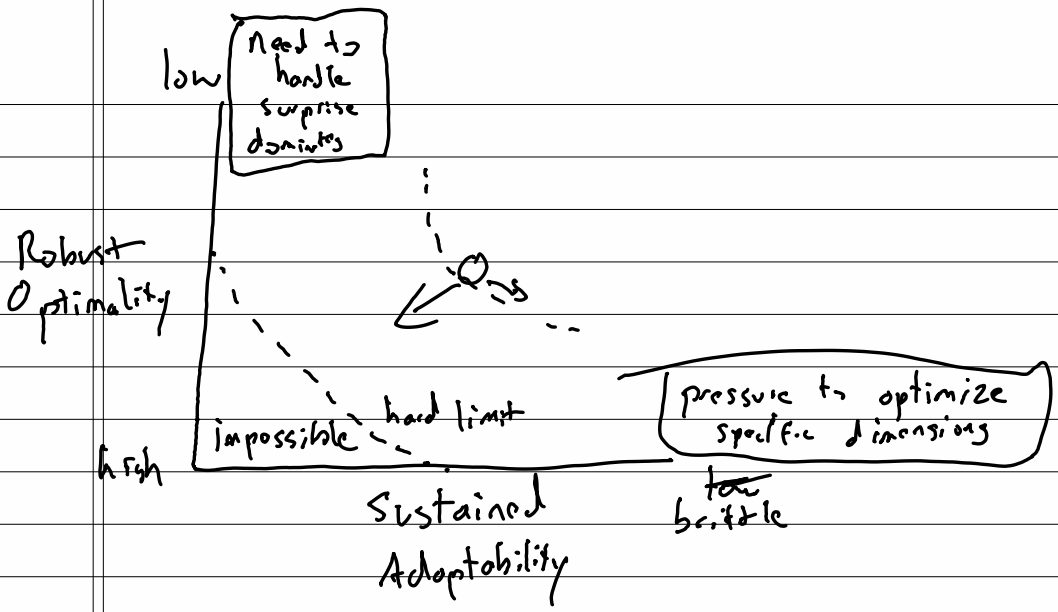
Key data: actual adaptive cycles

how to draw trade-offs



Fundamental tradeoffs

- optimality - brittleness (Doyle)
- acute - chronic, FRC pressure (Woods)
- efficiency - thoroughness (Hollnagel)
- bounds on perspective (Woods)



Many refs to Doyle here
he is looking for architecture

5 tradeoffs

fitness plans effectivity

optimality vs resilience
efficiency vs thoroughness
concentrated vs distributed
local vs distant views
acute vs chronic goals

when pressure/load is low, lots of good operating points, easy to find them

As load goes up, harder to find good operating points.

Case of drones

1. adaptive flexibility - extending human reach
2. experience of adaptive shortfall (need 170 ppl per drone in 90s)
3. responsible ppl act as adaptive + learning stop-gap largest work-arounds in history of computer technologies (extreme kludges)

Law of stretched systems

every system is continuously stretched to operate at capacity

Lecture 9

Thm 10: you ~~overes~~ think your model is better than it is

Thm 9: individual perspectives are limited

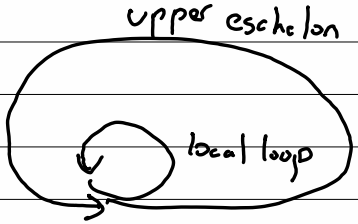
If we can stand down the service, then we can temporarily relax constraints (block dragons of surprise)

planes → don't let fly when weather bad
hospital → can't stand down
(e.r.)

humans: we adapt how we adapt

Confidence that we have no confidence

you can monitor how hard you're working to stay in control



monitor successes & difficulties on staying in control

.

Thm 6. adopting how you adapt

.

∴ (didn't capture all these)

Algorithm cannot be a unit of adaptive behavior
- until it's connected to the world
- unless it has graceful extensibility

people are unmodelled, generic reserve of graceful extensibility

automation → autonomy

ML won't save us

actuator saturation

Places where this works

1. tangible experience w/surprise ^
   * recognizes decomp is a risk
2. unease about how precarious they are

3. push initiative down (units help each other) be heir
   empower local
4. reciprocity ⇒ sync work across units of adaptation
5. work to align goals across multiple units

1:28:24

Rules of the architecture
polycentric governance

Lecture 10

John Doyle

graceful extensibility
sustained adaptability

architecture

key point: surprise is about preparation

there are regularities about surprise

systems can be adapted to those regularities about surprise

need capabilities in advance

we can get better at building adaptive capacity

life cycle architectures
sustain adaptability over life cycles

context of use will change
b/c you are successful!

what arch will sustainability to change?
sources of adaptability

universal laws + architectures

universal "conservation laws"

graceful extensibility →

"constraints that deconstrain"
- critical things in arch

(going over Doyle slides)

case study: transportation firm adapts
to Hurricane Sandy

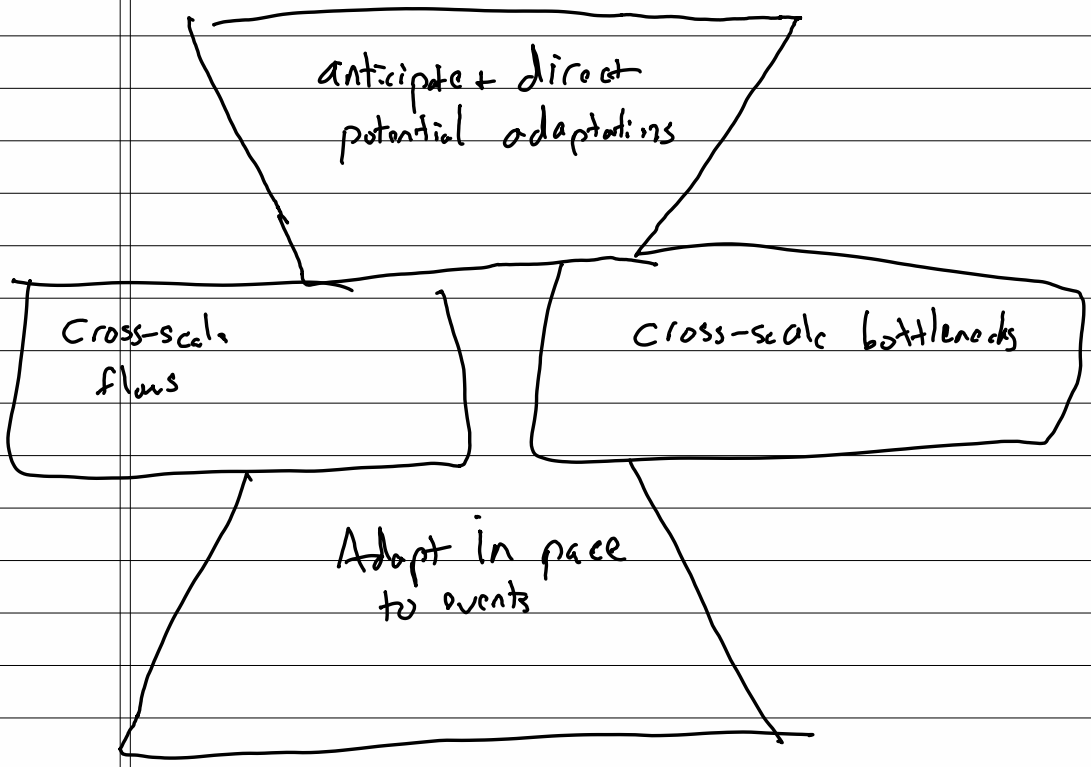
prepping for storm

value responsiveness over cost

no initiative → not a UAB

time matters

communication bottleneck



class 12

Reaching resilience: releasing the adaptive power of human systems

telling a story of basic rules of adaptive universe

4 drivers of change & innovation

1. connectivity
2. sensors
3. automation/autonomy
4. people
   human goals + expertise

law of unintended consequences
regulatory change

tangled, layer networks

hidden interdependencies

surprising cascade of effects

Brad surprised by how other units reacted to introduction of IEX

adaptive behavior consume success

everything keeps changing

17:52 & pressure points
surprising reverberations

All about load/pressure

how they change under pressure

faster/better/cheaper (only) → more brittle

not adaptive value

anticipating bottlenecks ahead

the world will surprise you

can you recognize dragons?

rebound

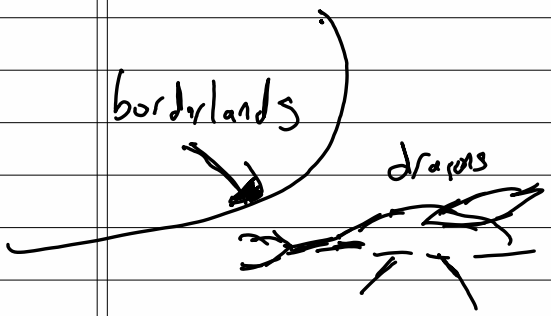
linear
simplifications

robust

adaptive
universe

graceful extensibility

sustained adaptability



Decompensation
working at cross purposes
stuck in stuck

Anticipation
Synchronizing over units
proactive learning

cascades, frictions, changing temps

optimality ⟷ graceful extensibility

net adaptive value

Charting cycles of adaptations

adaptive cycles: charting how changes reverberate thru networks

- each response to change by some unit triggers adaptive responses across other units

stall ⟵ revrb ⟶ florescence

innovation as florescence

law of stretched systems

10 theorems

bio sphere: they draw adaptive landscapes

1:26:20 Matching process

2 regions

deploy / mobilize / generate

Brad builds team w/ generative qualities
- high initiative
- strong personalities — complementary
- diverse set of experiences + backgrounds
- open to exchanging info + adjusting model
-

had to generate adaptive capacity

equilibrium
- temporary state
- doesn't mean anything

2 kinds of learning
1. adjust competence envelope
2. graceful extensibility
   ↳ tilting toward flourescence

heuristics: tilting toward flourescence

1. when surprise is normal
   - practice + simulation when don't see dragons that often

Otto von Bismarck: I prefer to learn from other's experience

2. unease precarious

3. human talent - empower local initiative
   circumscribed.
   coordinated
   upper echelons:
   - monitor how well handling things
   - reinforcing ~~error~~ areas of success
   - filling in gaps in order to achieve higher-level goals

4. invest in graceful extensibility

- jet engines in air hardly ever fail vs engines on the ground

reserve needs to be effective force

5. reciprocity - you will help me out when I'm in trouble

Is it safe to simplify?

Can pretend world is linear, but it's pretending

opposite of complexity is not simplicity

→ need to be able to maneuver
- graceful extensibility

4 drivers of TLNs

1. connectivity
2. sensors
3. automation/autonomy
4. people

Strange loop

discussion of digital services

heart example

faults/load, goal conflict/cascades

adaptive universe: you power it

leverage ^(adaptive) power of human systems