Complexity Revisited

6.033 Lecture 26

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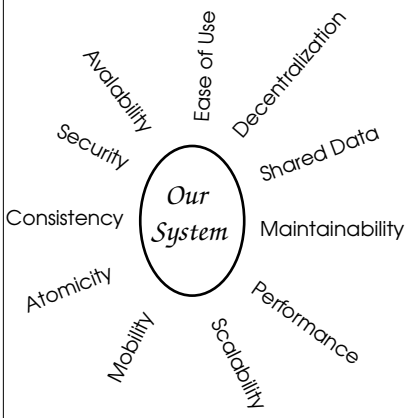
Coping with Complexity

- Sources
- Learning from failure (and success)
- Fighting back
- Admonition

Too many objectives



Not enough principles

Many objectives

+

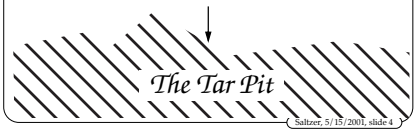
Few principles

+

High d(technology)/dt

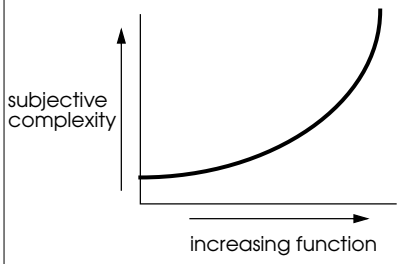
=

Very high risk



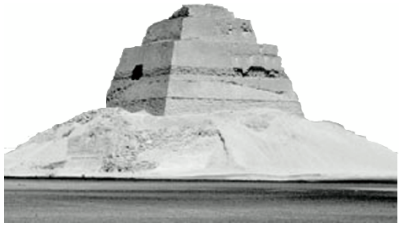
No hard–edged barrier—

it just gets worse…



Learn from failure

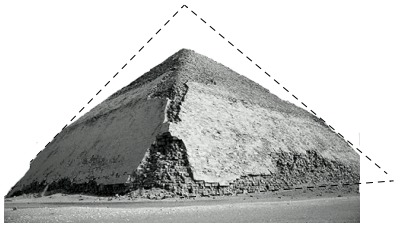
Pharaoh Sneferu's first try



Meidum pyramid

Learn from failure

Pharaoh Sneferu's second try



Bent pyramid

Learn from failure

Pharaoh Sneferu's third try

Red pyramid

Learn from failure

Complex systems fail for complex reasons

Find the cause
Find a second cause
Keep looking
Find the mind–set

(see Petroski, *Design Paradigms*)

NYC: 10,000 traffic lights

Univac, based on experience in Baltimore and Toronto with 100

started: late 1960's
scrapped: 2-3 years later
spent: ?

- second-system effect:
  - new radio control system
  - new software
  - new algorithms
- based on systems 100X smaller, incommensurate scaling

California Department of Motor Vehicles

Vehicle registration, driver's licenses

started: 1987
scrapped: 1994
spent: $44M

- Underestimated cost by factor of 3
- Slower than 1965 system
- Governor fired the whistleblower
- DMV blames Tandem
- Tandem blames DMV

United Airlines/Univac

Automated reservations, ticketing, flight scheduling, fuel delivery, kitchens, and general administration

started: late 1960's
scrapped: early 1970's
spent: $50M

- Second system: tried to automate everything, including the kitchen sink

(ditto: Burroughs/TWA)

CONFIRM

Hilton, Marriott, Budget, American Airlines

Hotel reservations with links to Wizard and Sabre

started: 1988
scrapped: 1992
spent: $125M

- Second system
- Very dull tools (machine language)
- Bad-news diode
- See CACM October 1994, for details

Advanced Logistics System

U.S. Air Force materiel and transport tracking

started: 1968
scrapped: 1975
spent: $250M

- Second system effect

SACSS(California) Statewide Automated Child–Support System

Started: 1991 ($99M)
"on hold": Sept. 1997
cost: $300M

- "Lockheed and HWDC disagree on what the system contains and which part of it isn't working."
- "Departments should not deploy a system to additional users if it is not working."
- "...should be broken into smaller, more easily managed projects..."

Taurus

British Stock Exchange

Share trading system

started: ?
scrapped: 1993
spent: £400M = $600M

- "Massive complexity of the back-end settlement systems…"
- Delays and cost overruns
- 2001: replacement is failing, exchange may close

IBM Workplace OS for PPC

Mach 3.0 + binary compatibility with Pink, AIX, DOS, OS/400 + new clock mgt + new RPC + new I/O + new CPU

started: 1991
scrapped: 1996
spent: $2B

- 400 staff on kernel, 1500 elsewhere
- "Sheer complexity of the class structure proved to be overwhelming"
- Big–endian/little–endian not solved
- Inflexibility of frozen class structure

Tax systems modernization plan

U.S. Internal Revenue Service, replaces 27 aging systems

started: 1989 (est.: $7B)
scrapped: 1997?
spent: $4B

- All–or–nothing massive upgrade
- Government procurement regulations

Advanced Automation System

U.S. Federal Aviation Administration

Replaces 1972 Air Route Traffic Control System

started: 1982
scrapped: 1994
spent: $6B

- Changing specifications
- Grandiose expectations
- Congressional meddling

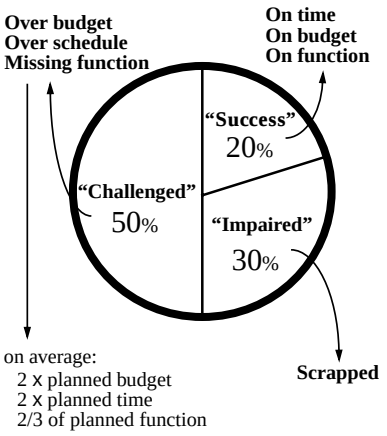
London Ambulance Service

Ambulance dispatching

started: 1991
scrapped: 1992
cost: 20 lives lost in 2 days of operation, $2.5M

- Unrealistic schedule (5 months)
- Overambitious objectives
- Unidentifiable project manager
- Low bidder had no experience
- Backup system not checked out
- No testing/overlap with old system
- Users not consulted during design

1995 Standish Group study



on average:
2 x planned budget
2 x planned time
2/3 of planned function

Recurring problems

- Incommensurate scaling

- Too many ideas

- Mythical man-month

- Bad ideas get included

- Modularity is hard

- Bad-news diode

Why aren't abstraction, modularity, hierarchy, and layers enough?

- First, you must understand what you are doing.

- It is easy to create abstractions; it is hard to discover the ***right*** abstraction.

(ditto for modularity, hierarchy, and layers)

Fighting back: Use sweeping simplifications

Some modular boundaries work better than others

By chapter…

1: Processor, memory, comm.
3: Dedicated servers
4: Best–effort network
5: Delegate administration
6: Signing *and* sealing
7: Fail–fast, pair–and–compare
8: Atomic actions, version history, whole–file caching

Fighting Back: Control Novelty

Sources of excessive novelty…

- Second–system effect
- Technology is better
- Idea worked in isolation
- Marketing pressure

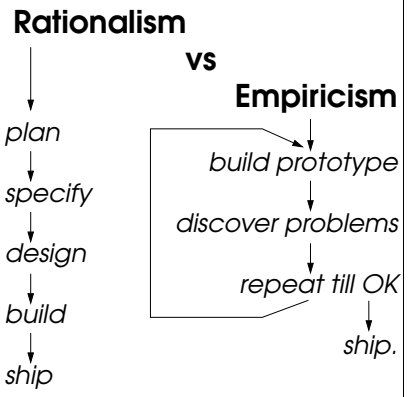
Some novelty is necessary; the hard part is figuring out when to say **No**.

Fighting back: Feedback

Design for Iteration,
Iterate the Design

- Something simple working soon
- One new problem at a time
- Find ways to find flaws early
- Use iteration-friendly design
- Bypass the bad-news diode
- General: Learn from failure

Brooks's version:



(stolen from Brooks, 1993)

Fighting back: Find bad ideas fast

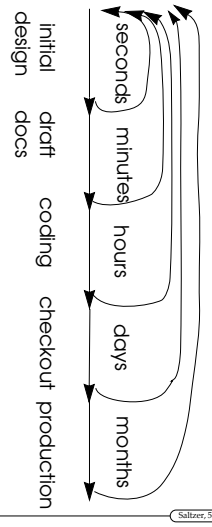
- Examine the requirements

  "and ferry itself across the Atlantic" (LHX light attack helicopter)

- Try ideas out—but don't hesitate to scrap them
- Understand the design loop

Requires strong, knowledgeable management

The design Loop



Fighting back: Find flaws fast

- Plan, plan, plan
- Simulate, simulate, simulate
- Design reviews, coding reviews, regression tests, performance measurements
- Design the feedback system e.g., alpha test + beta test, no–penalty reports, incentives & reinforcement

Use iteration–friendly design methods

- Authentication logic (Ch 6)
- Alibis (space shuttle)
- Failure tolerance models (Ch 7)

General method:

— document all assumptions
— provide feedback paths
— when feedback arrives, review assumptions

Fighting back: Conceptual integrity

- One mind controls the design
  - — *Reims cathedral*
  - — *Macintosh*
  - — *Visicalc*
  - — *Linux*
  - — *X Window System*
- Good esthetics yields more successful systems
  - — *Parsimony*
  - — *Orthogonality*
  - — *Elegance*

Obstacles

- Hard to find the right modularity
- Tension: need the best designers—but they are the hardest to manage
- The Mythical Man–Month

Fighting back: Summary

- Use sweeping simplifications
- Control novelty
- Install feedback
- Find bad ideas fast
- Use iteration–friendly design methods
- Conceptual integrity

Admonition

Make sure that none of the systems ***you*** design can be used as disaster examples in future versions of this talk.

6.033 Theme song

'Tis the gift to be simple, 'tis the gift to be free,
'Tis the gift to come down where we ought to be;
And when we find ourselves in the place just right,
'Twill be in the valley of love and delight.

When true simplicity is gained
To bow and to bend we shan't be ashamed;
To turn, turn will be our delight,
Till by turning, turning we come out right.

— *Simple Gifts*, traditional Shaker hymn