system design & management

Designing Software Platforms for Innovation and Profitability

MITsdm

results from 2 pilot projects
- driving design quality
- managerial decision-making

Martin Jouvenot
Software Architect
Amadeus
(& MIT SDM '17)

Dan Sturtevant
CEO
Silverthread, Inc.
(& MIT SDM Alum)

Rashesh Jethi
Head of R&D - Americas
Amadeus

1. Introducing Amadeus
2. Challenges faced by the software enterprise
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4. Case 1: Driving software platform design quality
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amadeus
30
YEARS

amadeus®

14,000
people

195
countries

€ 4.47B
2016 revenue

Among the world's top
10 software companies
Forbes 2016 global rankings

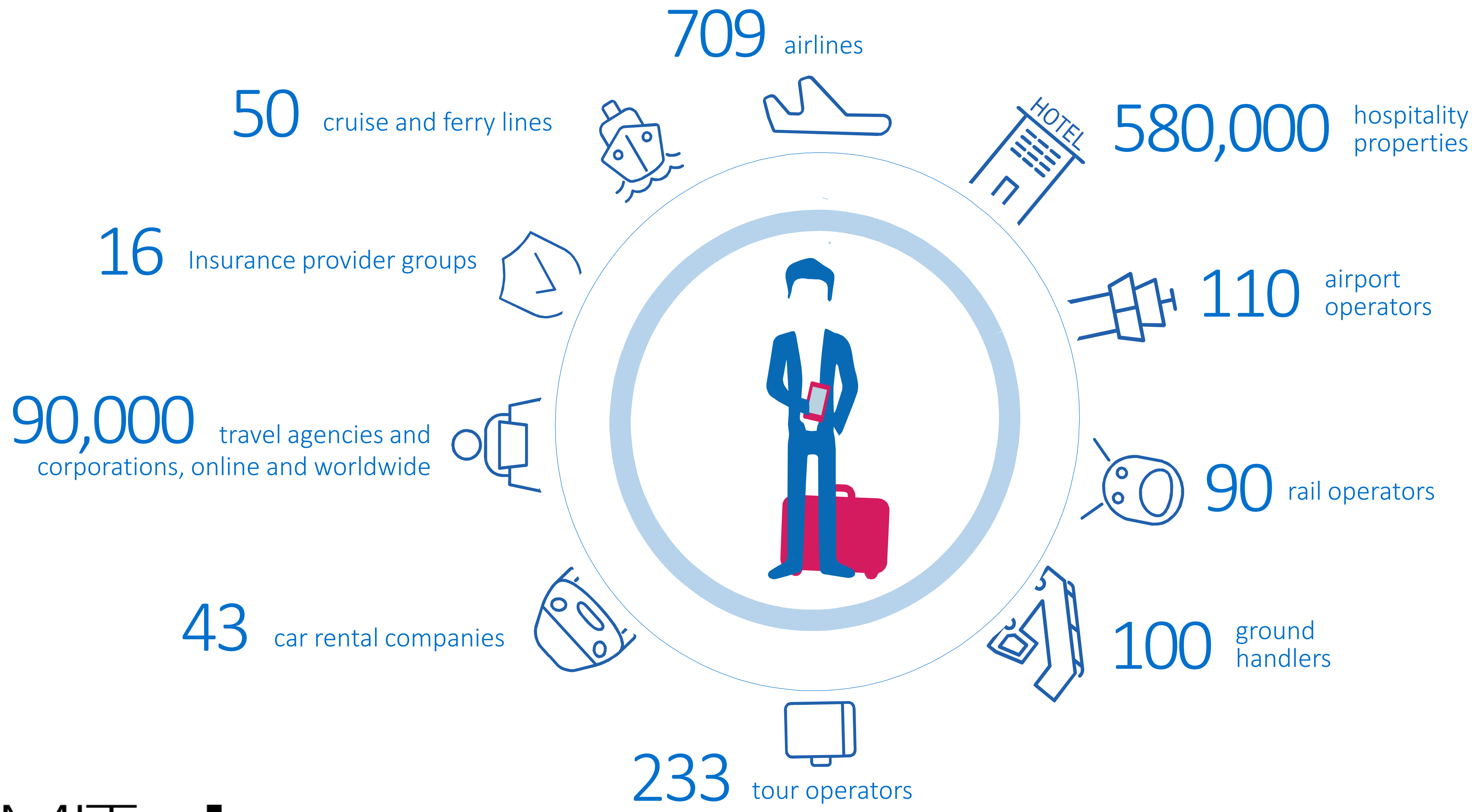
Powering the biggest names in travel in North America…

Expedia
American Express Global Business Travel
Atlas Travel
Balboa Travel
BCD travel
Carlson Wagonlit Travel
cheapOair
Travel the world for less.
EGENCIA

KAYAK
ORBITZ
G Adventures
Maupin Travel
a branch of Tzell Travel Group
merit
OMEGA WORLD TRAVEL
TRAVEL LEADERS GROUP
UNIGLOBE

American Airlines
DELTA
AIR CANADA
FRONTIER AIRLINES
spirit airlines
UNITED
SOUTHWEST
IHG
InterContinental Hotels Group

...and Globally !

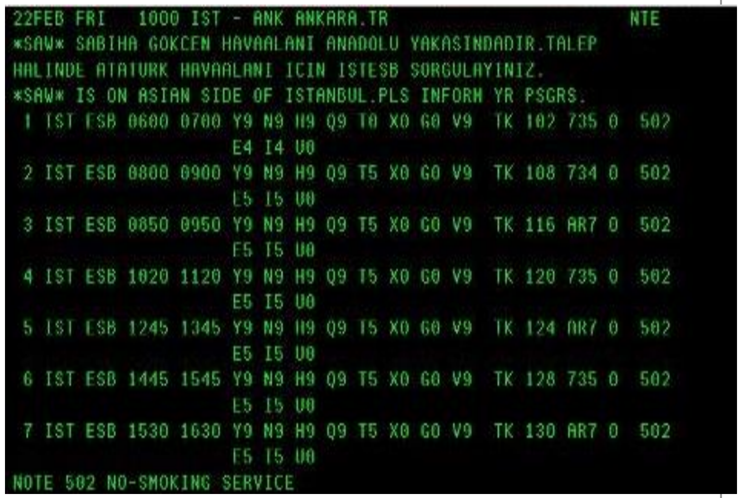


Research & Development

Leading
The travel technology industry

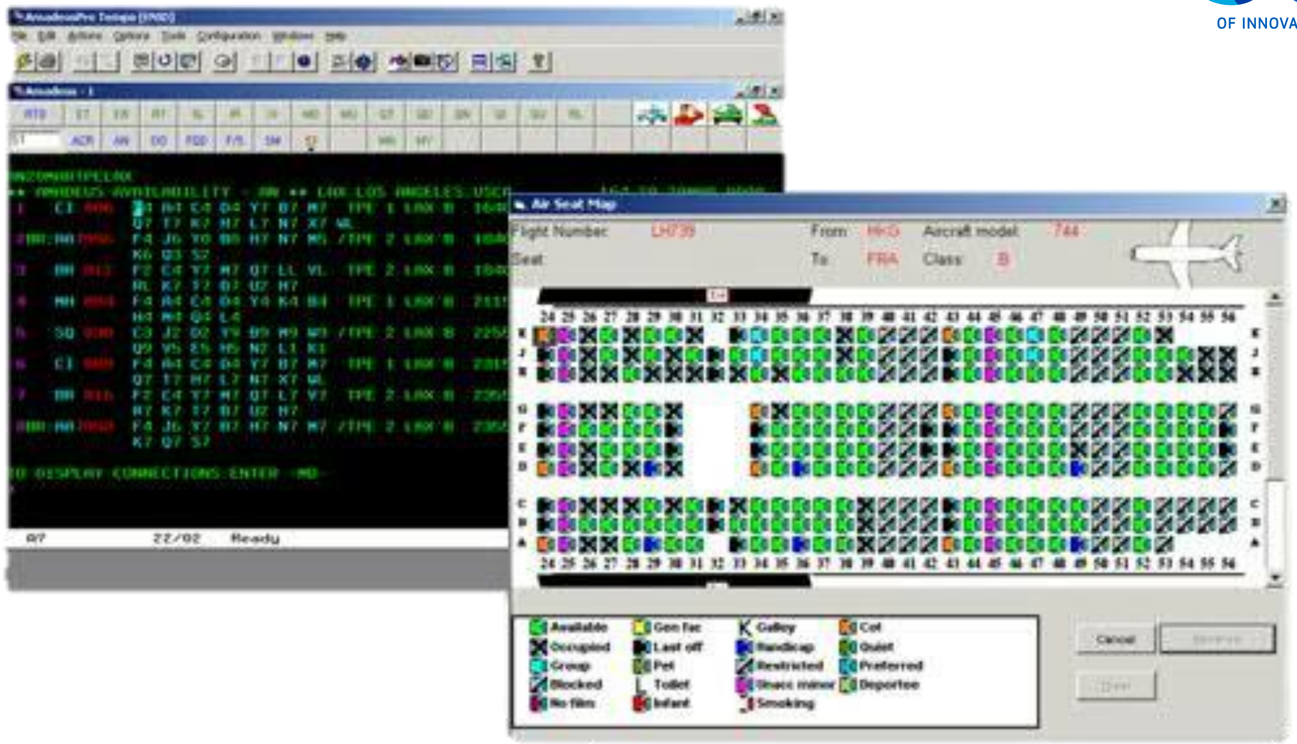
20
R&D centers

€ 4B+
Invested since 2004



1987

1990 1995 2000 2005 2010 2017



1994

1987 1990 1995 2000 2005 2010 2017

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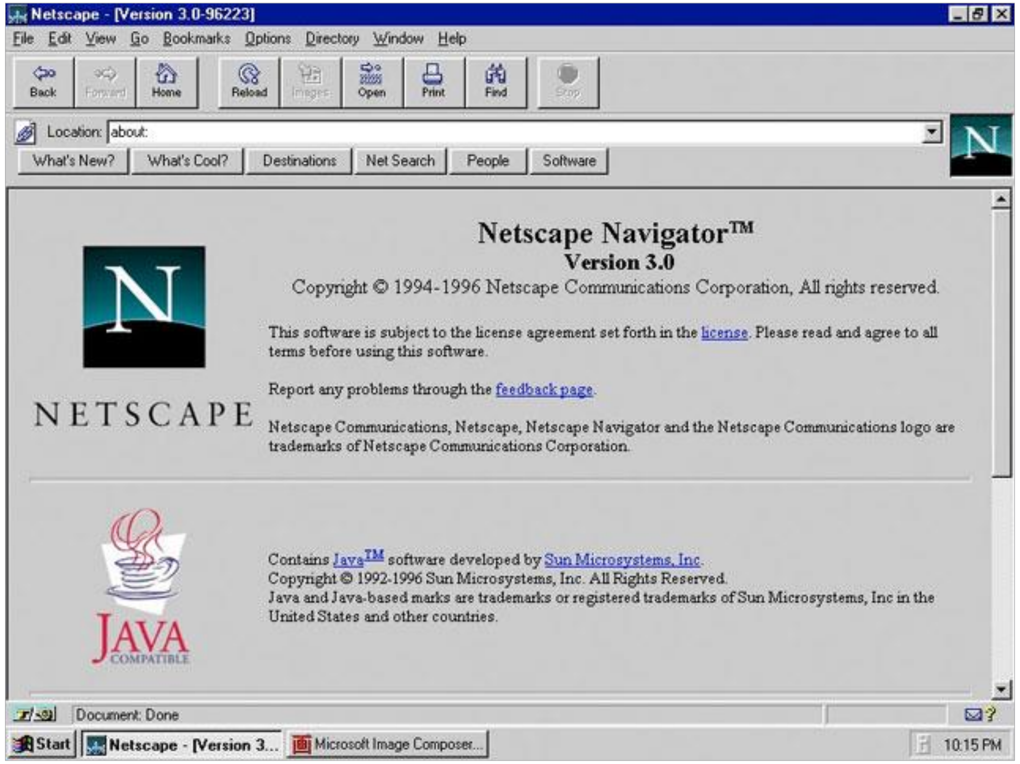

1997

1987 1990 1995 2000 2005 2010 2017

30 YEARS OF INNOVATION

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2007

1987 1990 1995 2000 2005 2010 2017

30 YEARS OF INNOVATION

2010

1987 1990 1995 2000 2005 2010 2017

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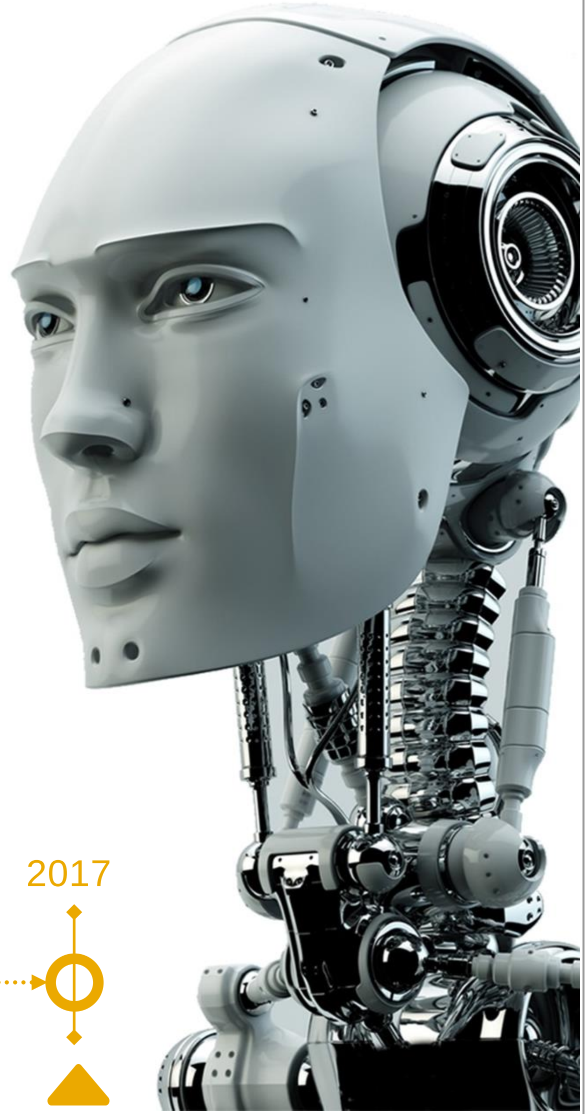
30 YEARS OF INNOVATION



1987 1990 1995 2000 2005 2010 2017

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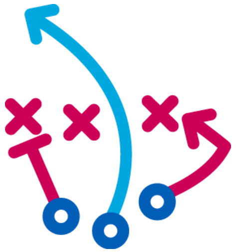
Maintaining Industry Leadership

Improved Agility



Cloud-enabled Platforms

Data-driven Technology Investments

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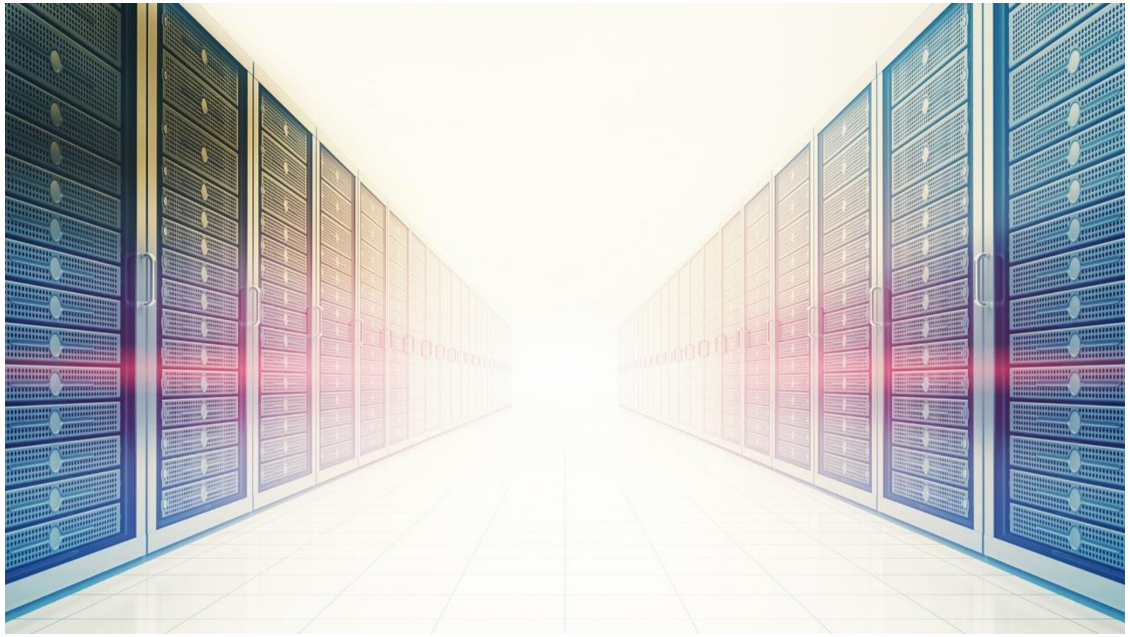
A large portfolio of services



5000+ services

2000+ components

145K queries/second

Impacting a lot of people

595M
bookings in 2016

2M
bookings every day

1.4B
passengers boarded in 2016

~2,600
passengers boarded **every minute**

Large and complex software codebases

“Writing code is like writing poetry: every word, each placement counts. Except that software is harder, because digital poems can have millions of lines which are all somehow **interconnected**… So far, nobody has found a silver bullet to kill the beast of complexity.”

- Stuart Feldman, IBM Institute for Advanced Commerce (2001)

Useful Metaphor:
Software Development =
Community Poetry
Writing at *Massive* Scale!

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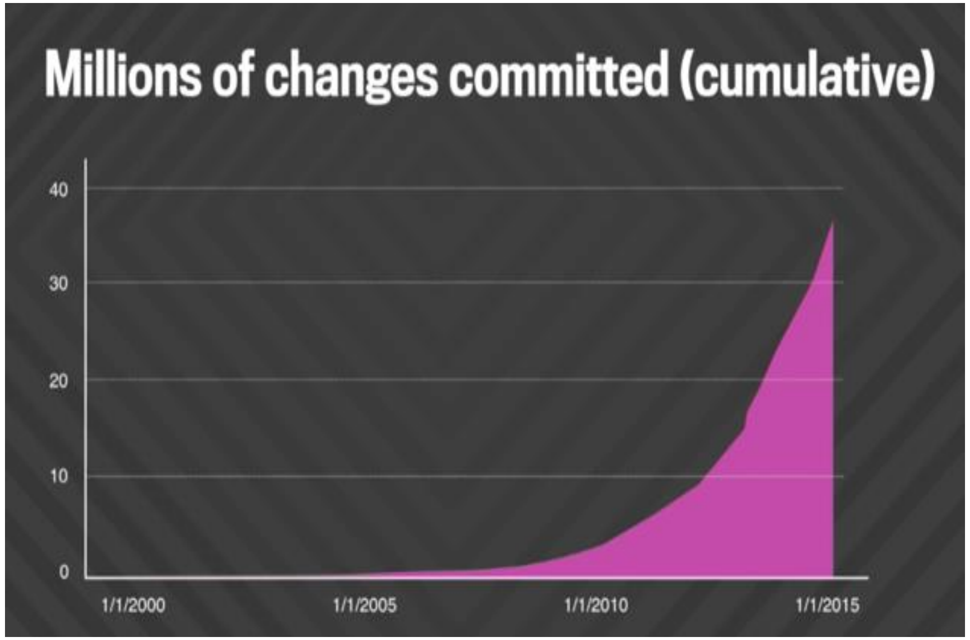
Code lives forever and scales exponentially

Google's 25,000 Engineers commit 15 million LOC/day - Equivalent to Linux; every day

Google repository statistics

As of Jan 2015

Total number of files*	1 billion
Number of source files	9 million
Lines of code	2 billion
Depth of history	35 million commits
Size of content	86 terabytes
Commits per workday	45 thousand



Software systems rarely die; we build on *legacy code*. Hence today's designers inherit *past* design decisions

Source: https://www.youtube.com/watch?v=W71BTkUbdqE

We deal with multiple, often competing business goals

Enhance existing solutions

Build new products

Sign new customers

Improve deadlines

Maximize growth

while also

Investing in the platform

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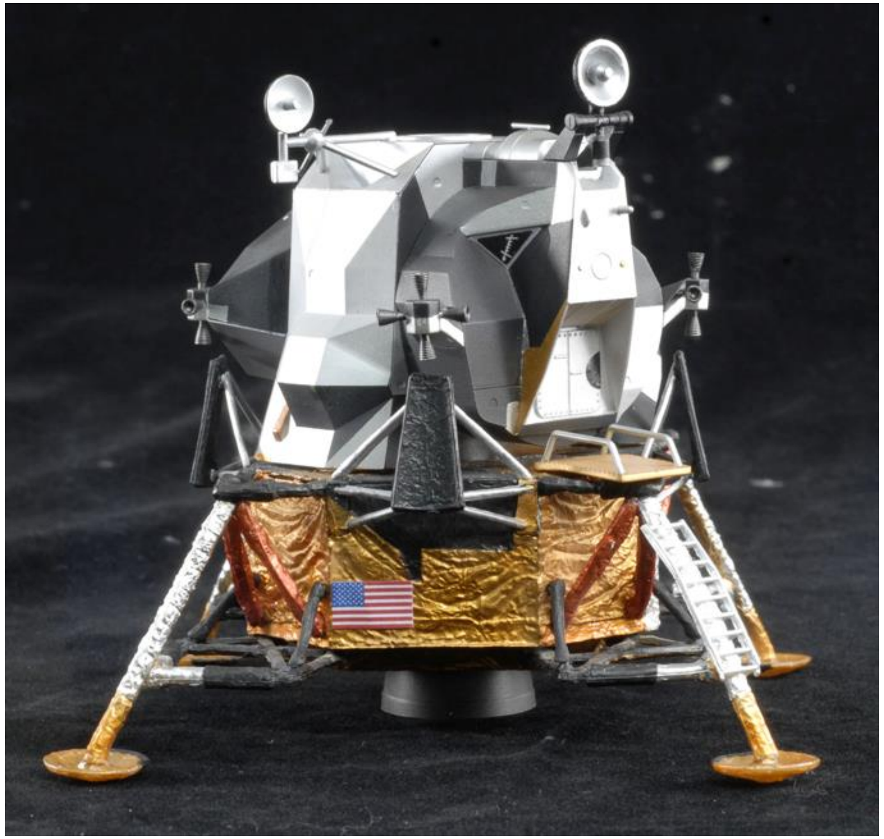
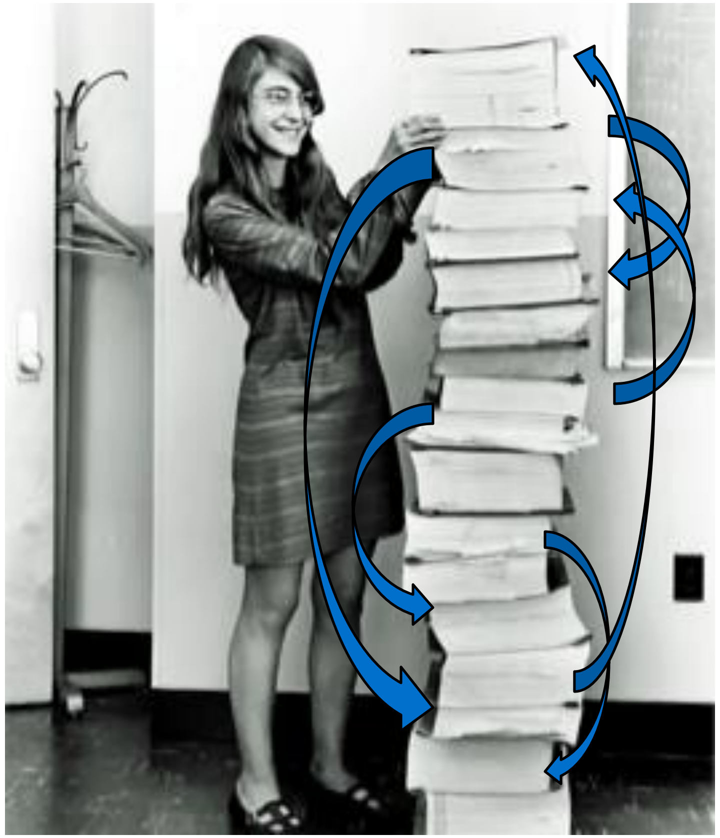
Engineers have little visibility into the design structure of code

Apollo 11 Lander



Apollo 11 Software (Printed!)



Margaret H. Hamilton

structure is hidden to the human eye

And the scale of that challenge continues to multiply

Apollo 11: 65kLOC)

Launched July 16, 1969

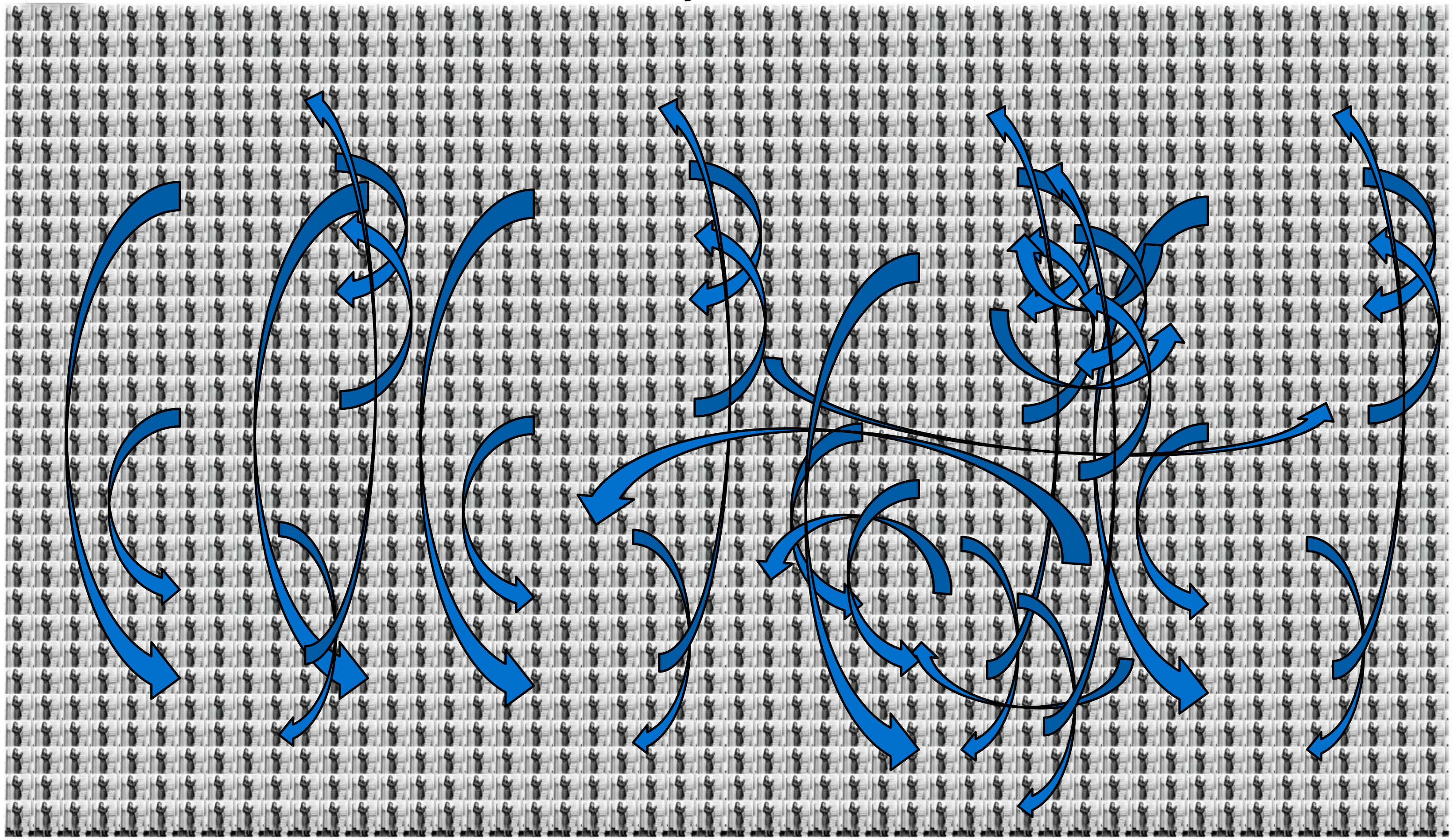
Margaret H. Hamilton

x

1500

=

Amadeus Today: ~100 Million LOC



Stack of printed paper would be 1.5 miles or 2.4 KM high

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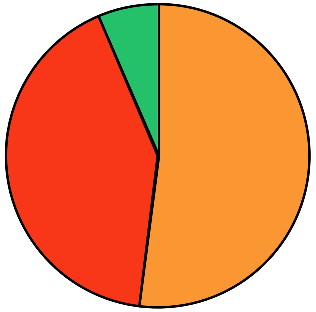
As a discipline, software development is very challenging

6.4% of large projects successful



41.4% failures

- Abandoned
- Started again from scratch

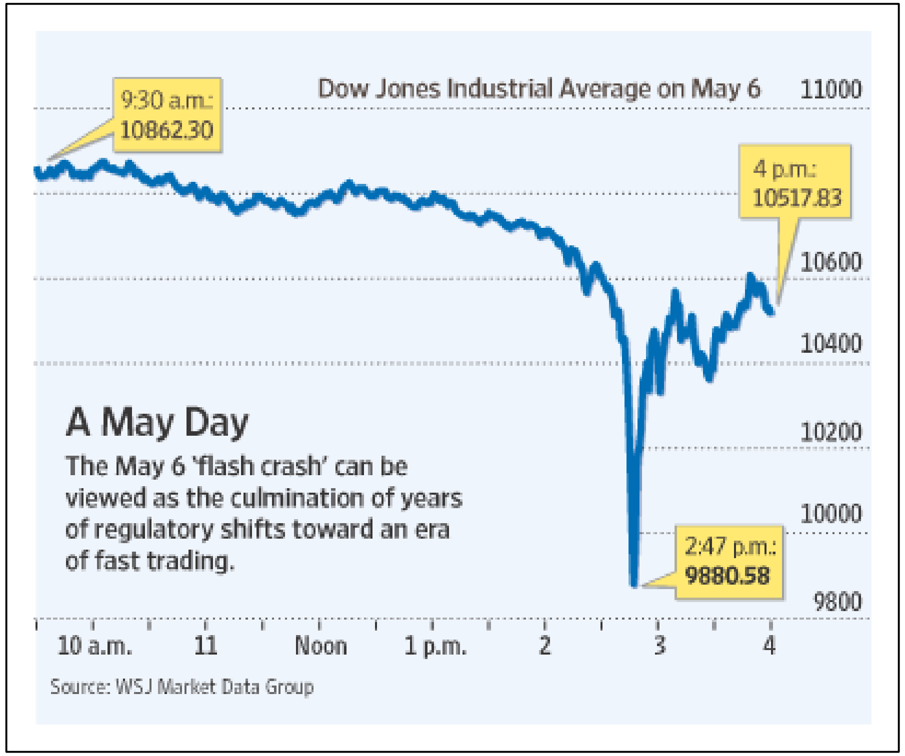
52% challenged

- Budget overrun
- Schedule overrun
- Bad functionality

The Standish Group,
with a database of 50,000 development projects
http://www.computerworld.com/s/article/9243396/
Healthcare.gov_website_didn_t_have_a_chance_in_hell_

In our world complexity can make things to go very wrong

October 24, 2013, a jury ruled against Toyota and found that unintended acceleration could have been caused due to deficiencies in the drive-by-wire throttle system or Electronic Throttle Control System (ETCS



July 8th 2015 May 6th 2010

2013 Cambridge University Study Found Software Bugs Cost (Global) Economy $312 Billion Per Year (just cost to fix defects)

Given all of these challenges, our talk today is about 2 pilot projects led by Amadeus & Silverthread aiming to:

Efficient engineering

Enable agility

1. Help technology leaders confidently evolve the software platform

2. Help business leaders optimize business outcomes with analytics

Help both communicate and collaborate more effectively

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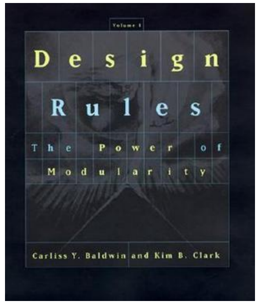
Who is Silverthread?

Massachusetts Institute of Technology

HARVARD UNIVERSITY







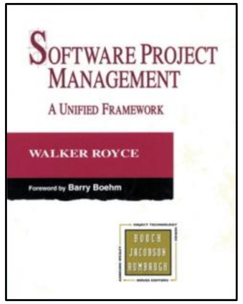
Dan Sturtevant
Founder and CEO

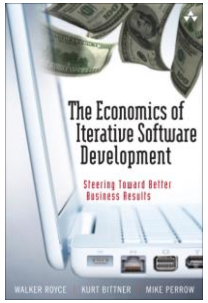
Michael Davies
Founder & Chairman
MIT tech strategy faculty

Alan MacCormack
Founder & Board Member
Harvard business faculty

Carliss Baldwin
Founder & Board Member
Harvard finance faculty







Sean Gilliland
Director of SW Dev

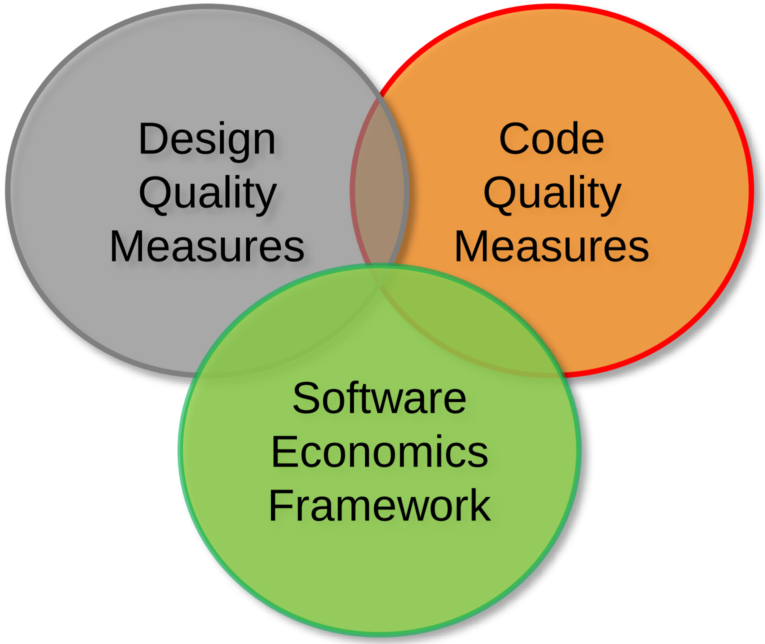
Walker Royce
Chief Software Economist

Silverthread drives results in software products and portfolios

Our Customers

Software Enterprise	Government & Defense	Due Diligence

Areas of Focus

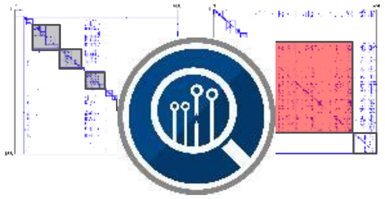


Key Questions

Diagnose	How complex is my system? Where are potential tumors? Where will we struggle with cloud transition?
Assess	Is architectural integrity getting better or worse? How does we compare with similar systems? Where does the as-coded system diverge from design intent?
Recommend	Where should we invest in highest priority improvements? Should we refactor, redesign or continue with maintenance? How can we capture more persuasive business cases?

Silverthread: More honest measurement and steering

CodeMRI® Reports & Tools



Descriptive analytics
➔ for architects

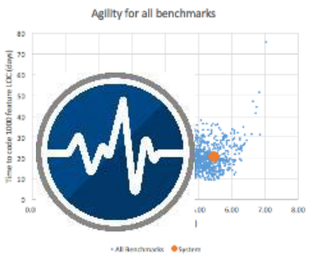
- Visuals of potential tumors
- Benchmarking
- Correlation of quality hotspots and defect trends
- Correlation between as-coded baseline and intended design

Predictive analytics
➔ for leaders

- Maintainability, security, quality, productivity improvements
- Quantify technical debt
- Predict estimated ROI of targeted refactoring

CodeEKG™ and Zoo

(Under development)



Empirical platform
➔ For enterprises

- Always-on DevOps CodeMRI®
- Context relevant benchmarking
- Refactoring insight
- Preventive health for development

Professional Services

Change catalysts
➔ For projects

- Ramp-up training
- Customized reports or insights
- Custom integration with other tools
- Expert testimony for corroboration
- Executive persuasion

Two pilot projects led by Amadeus & Silverthread

1

Gain insights about the software

Allow software architects to understand the design structure of Amadeus' enterprise software platform, drive out architectural issues, and be agile at large scale

2

Get the biggest bang for the buck

Help senior leadership make data driven and financially rational choices about investments in continuous improvement efforts to optimize business outcomes.

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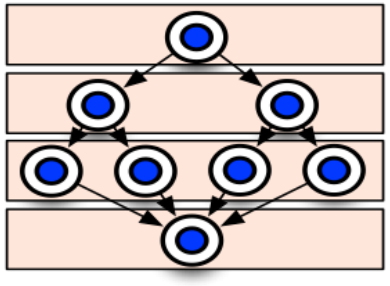
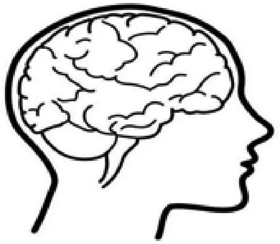
Design quality: Properties that help manage complexity

Well architected system

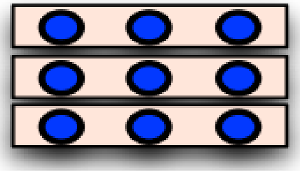
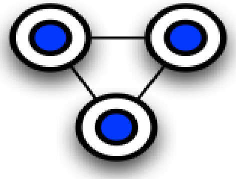
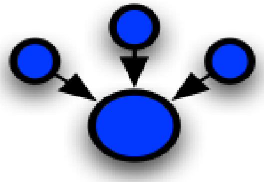
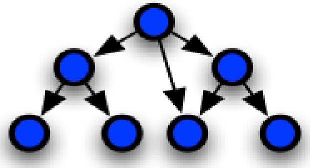
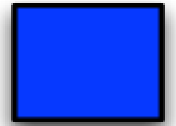


Developers understand the code, system adaptable



Development team confused and frustrated, system inflexible & brittle

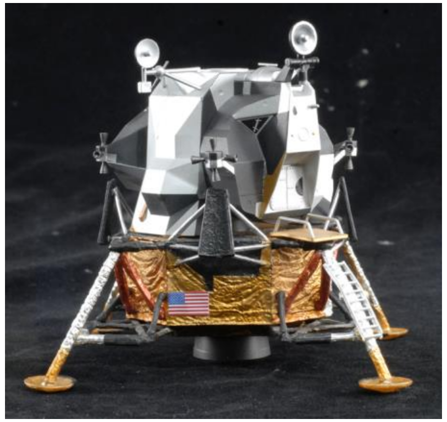
Poorly architected system

Platforms	Modularity	Reuse	Hierarchies	Comp Quality
				
Locality of change Abstraction Propagation cost	Locality of change Fan-in, Fan-out Core size	Locality of change Reuse Replication	Locality of change Cyclicality Propagation cost	Defect density Coverage tools Unit test scans

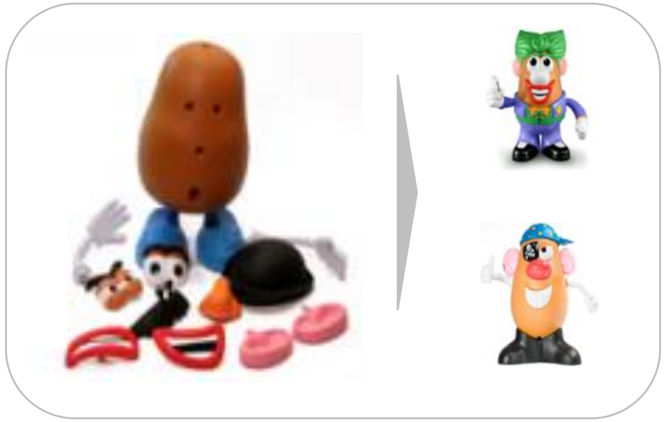
How do we quantify?

Illustrating design quality concepts with simple examples

In Hardware



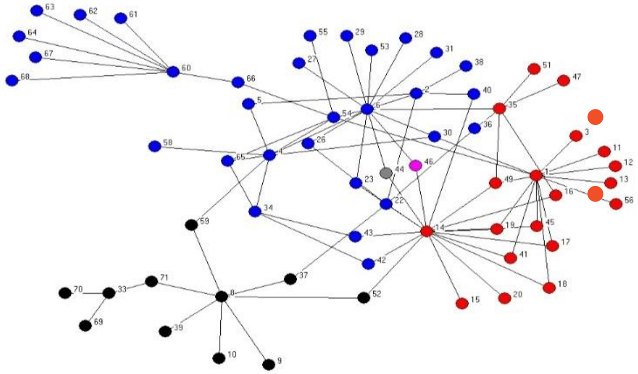
Platforms & Hierarchy



Modularity & Reuse

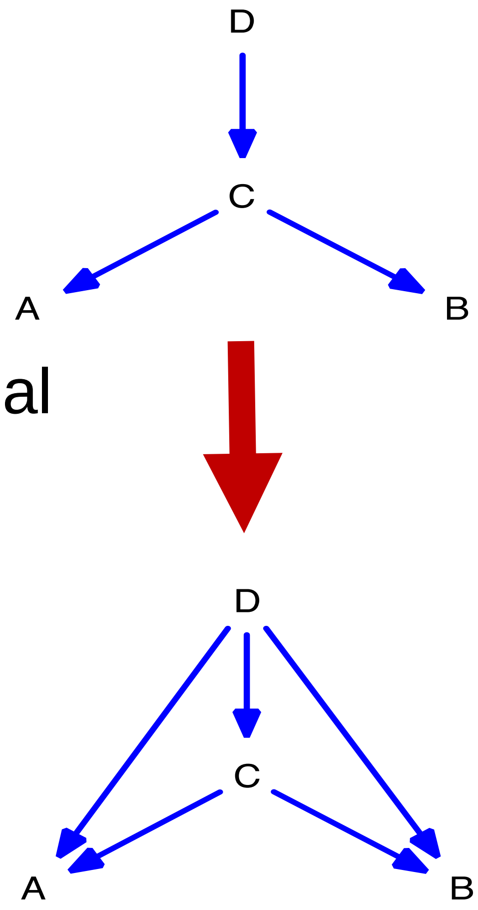
In Software

Network Diagrams?



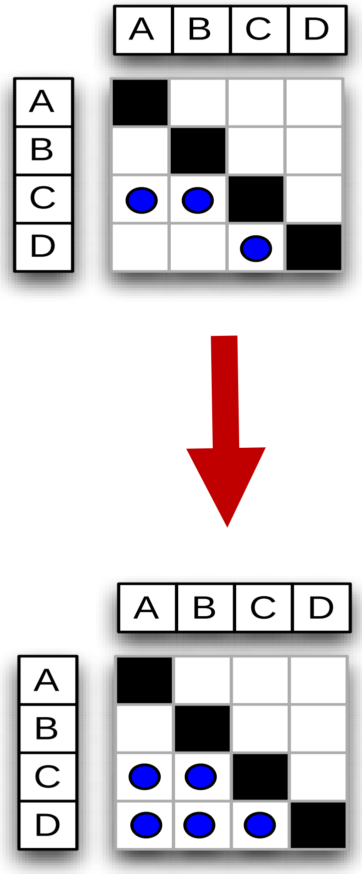
- Visually appealing
- Hard to Interpret

How else can we visualize software architecture?



Direct
Dependencies

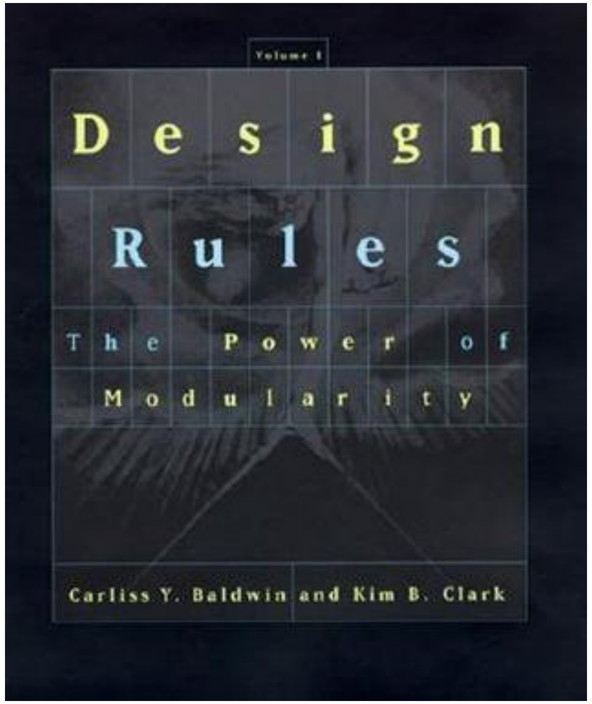
Traditional
network
view

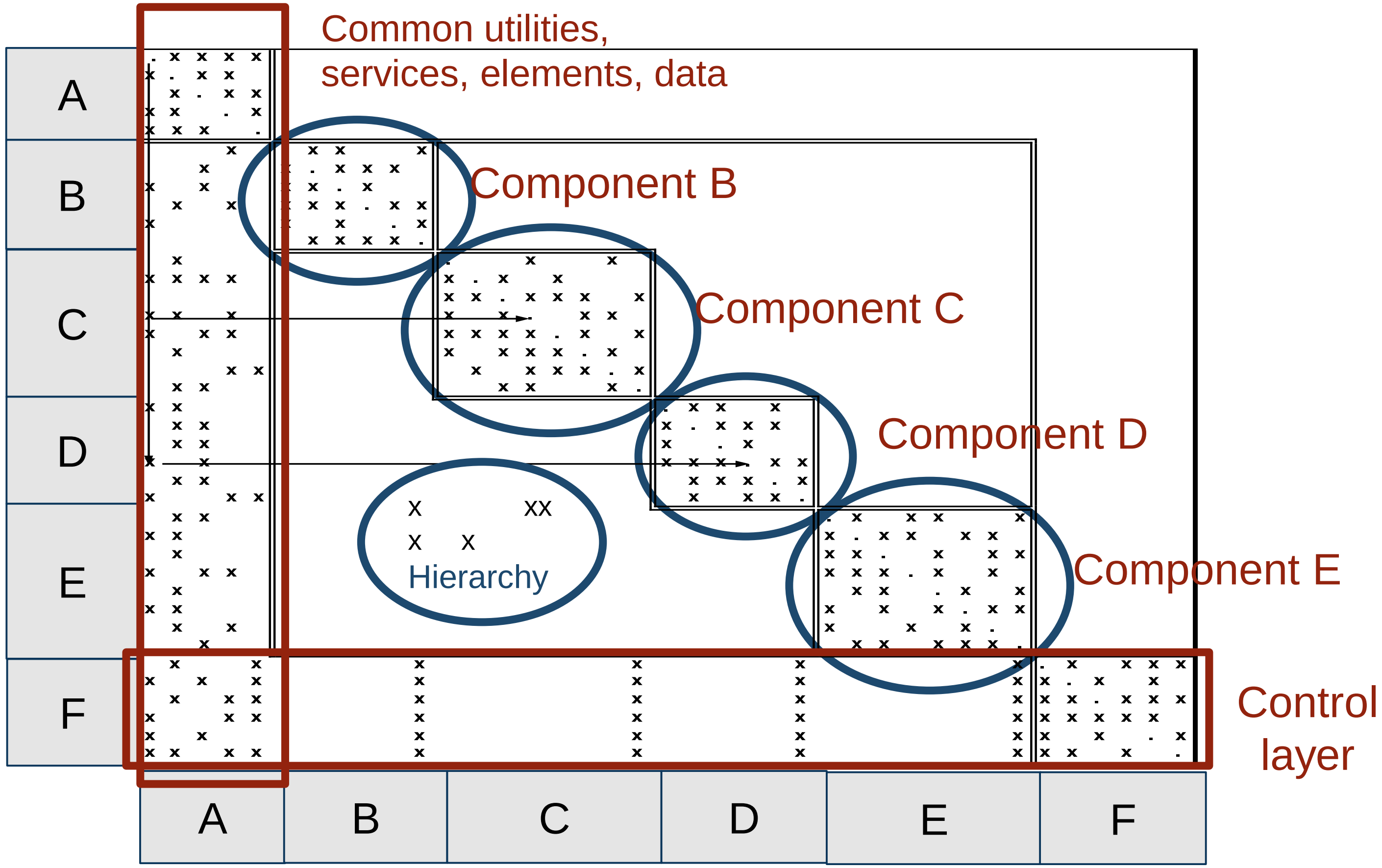


Matrix
notation

Indirect
Dependencies

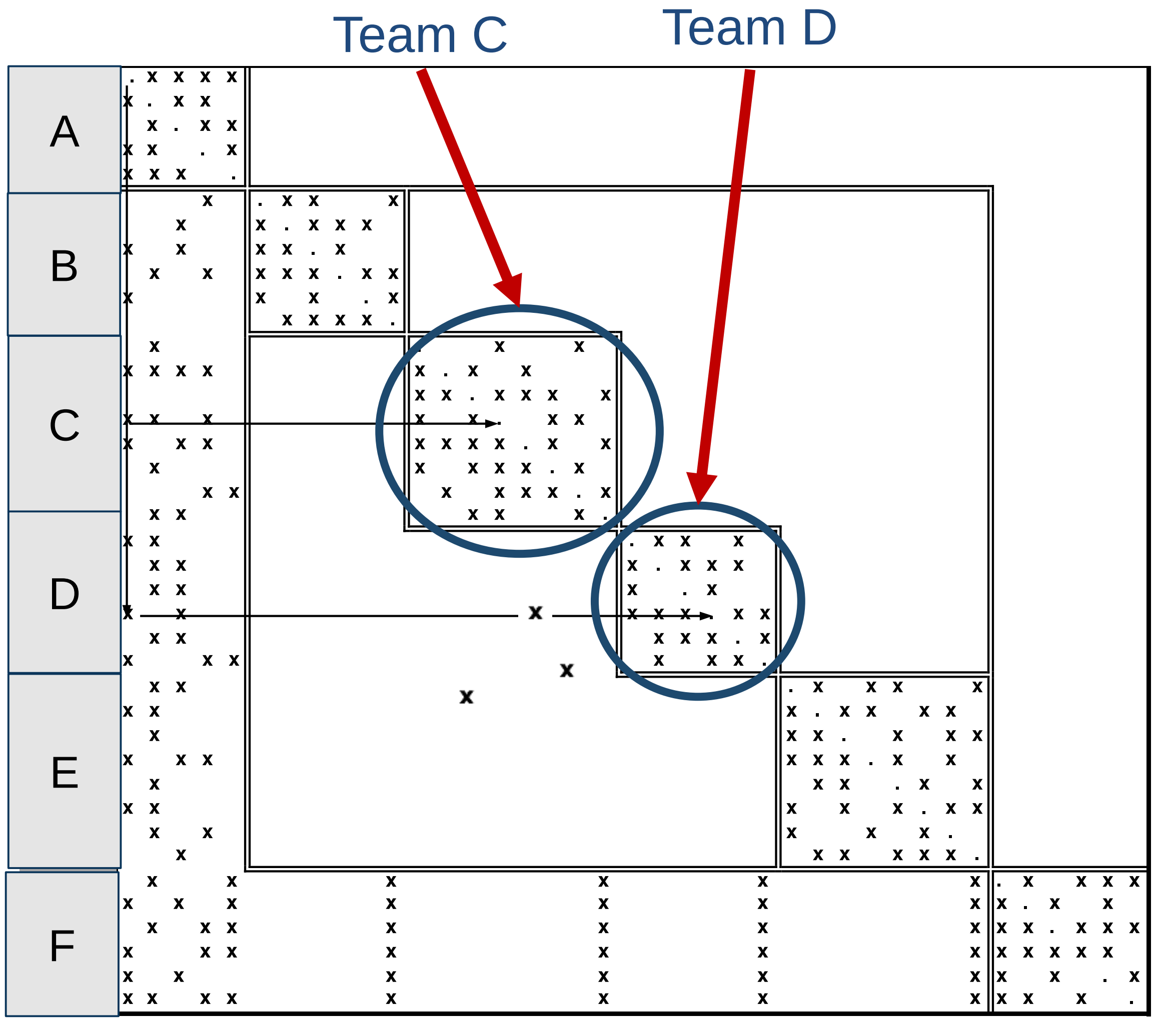
What an 'ideal' software system looks like

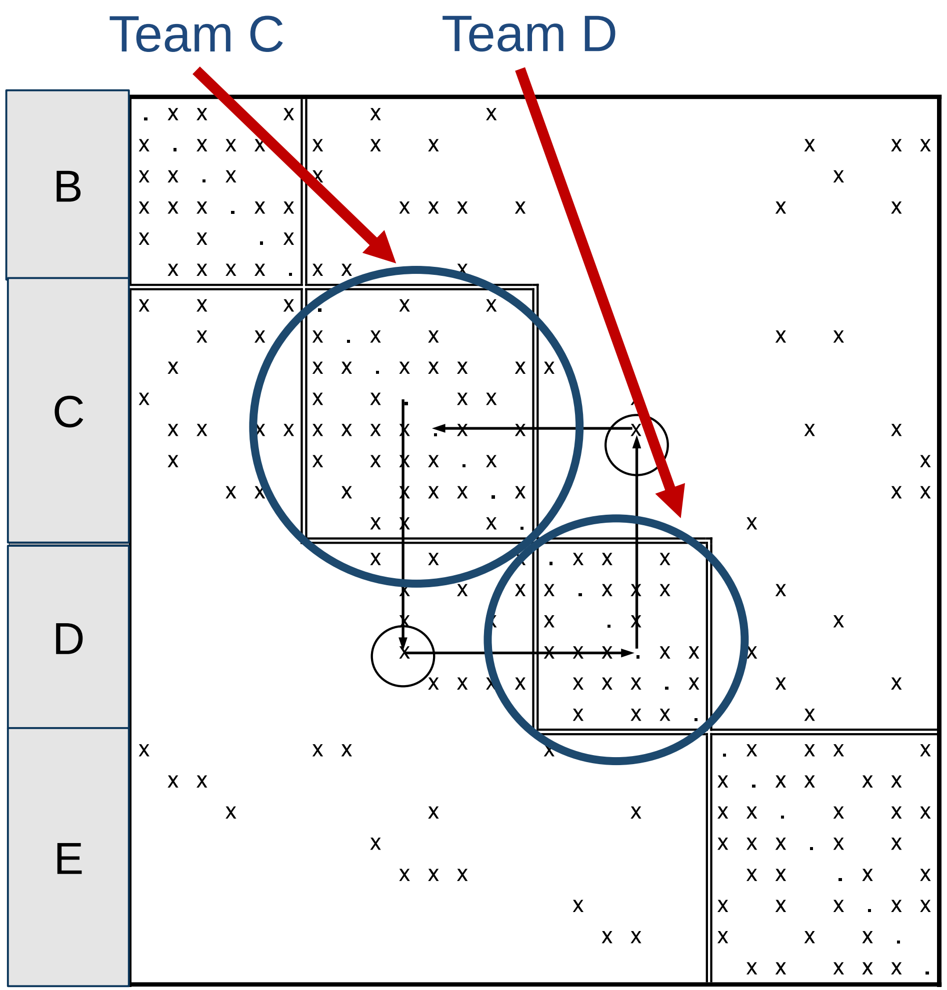




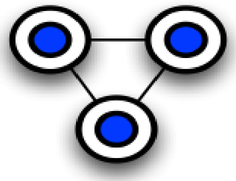
Design Structure Matrices (DSMs) are network representations of complex systems

What does it look like when design quality breaks down?

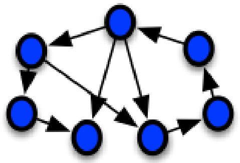




Modular System

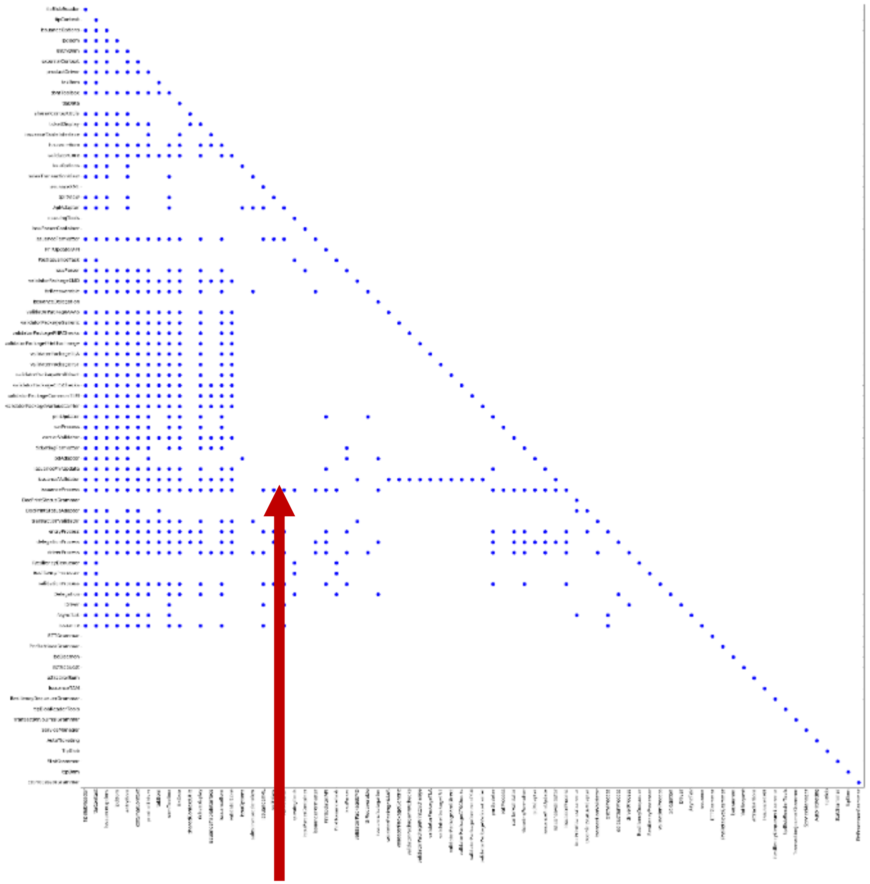


Integral System

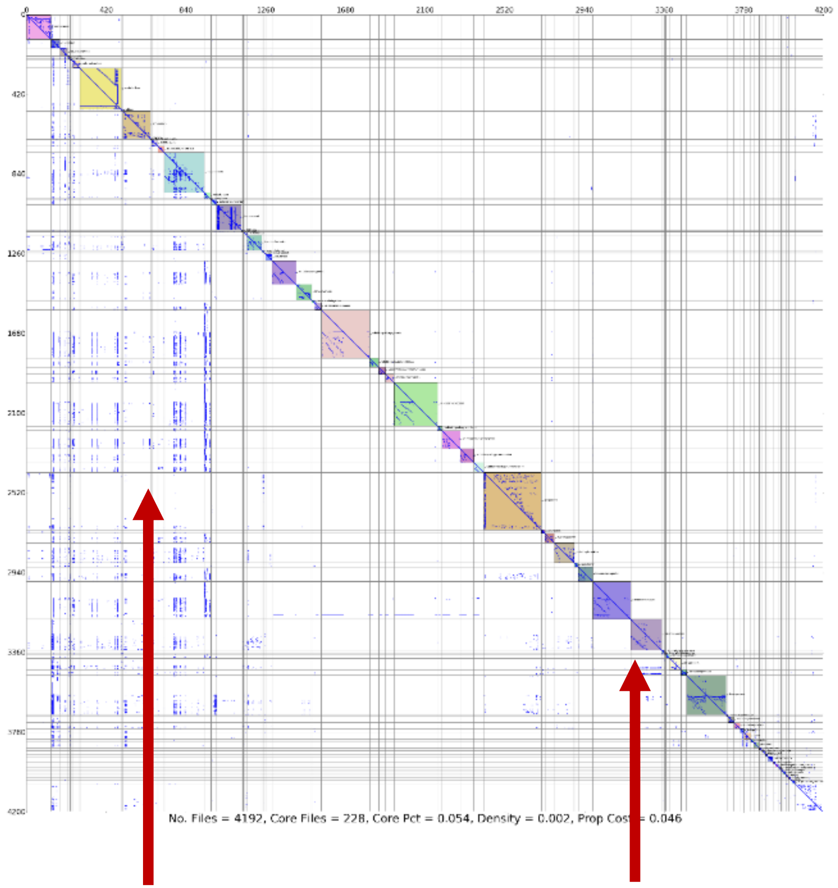


Design intent vs the coded reality

Declared relationships extracted from the build files

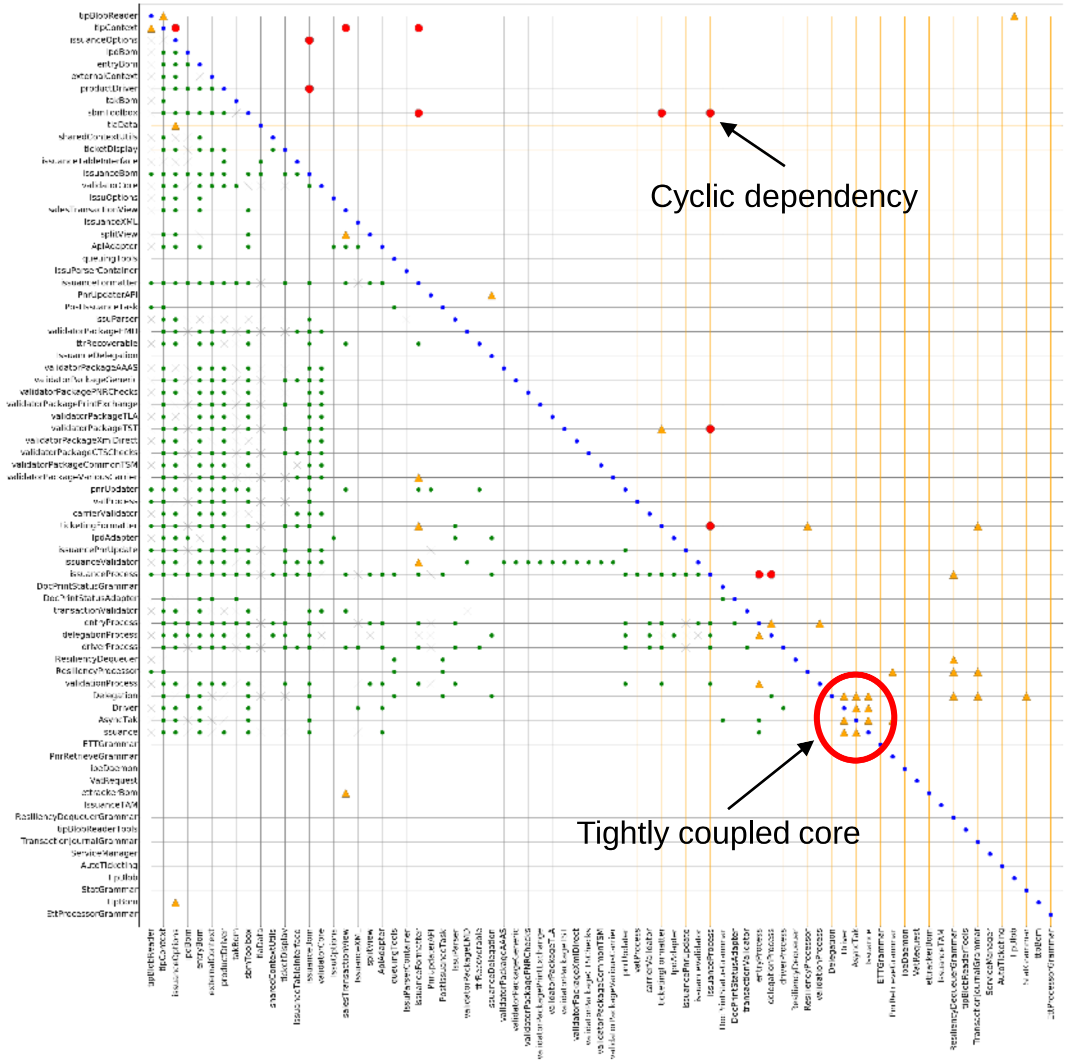


Actual relationships extracted from inter-file dependencies



Structural analysis to spot irregularities and risks

- ❑ Unexpected dependencies
  - Hidden complexity
- ❑ Cyclic dependencies
  - Tight coupling
  - Unintended consequences
- ❑ Tightly coupled core
  - Area of high complexity
  - Difficult to debug



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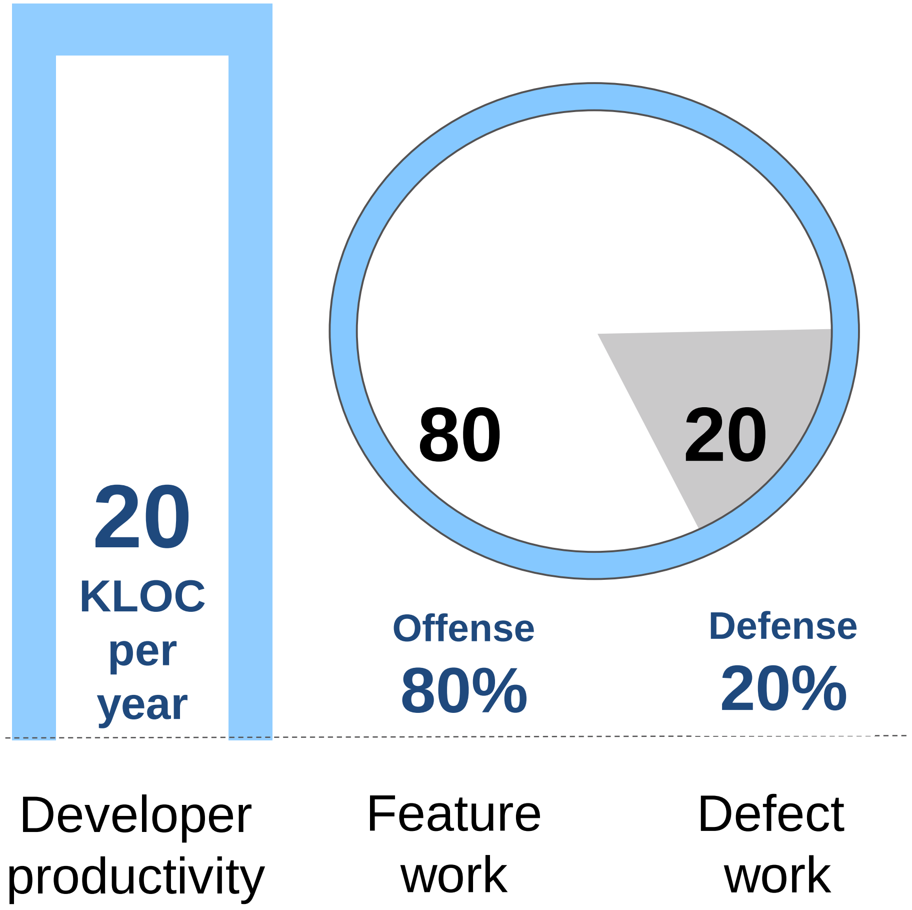
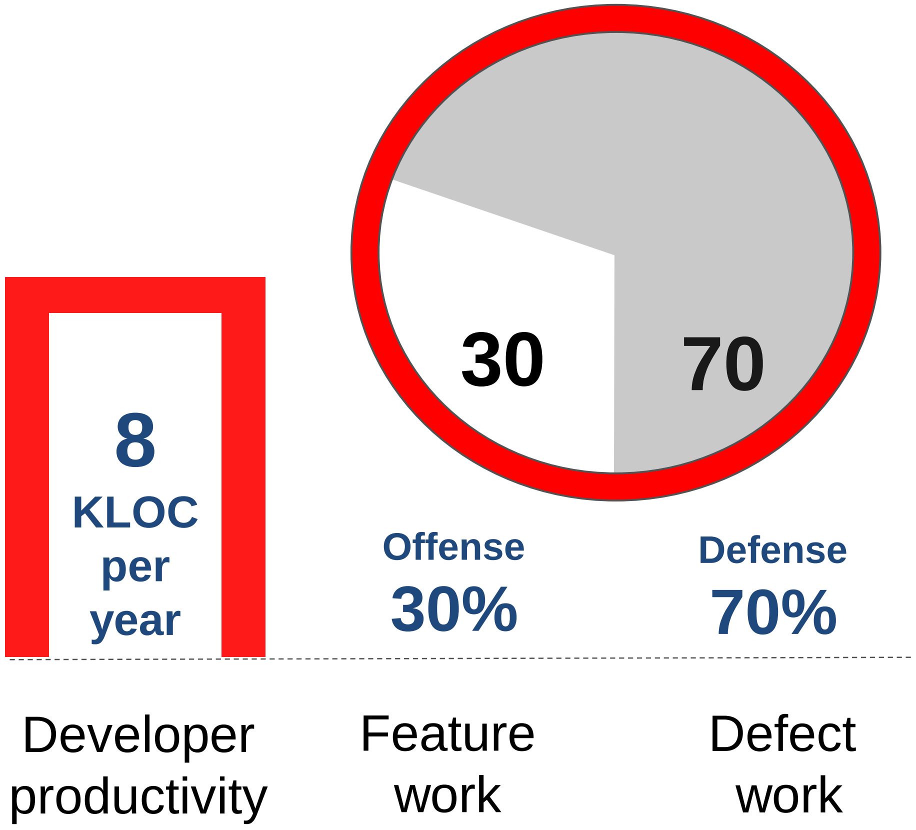
Studies: Quality has a big impact on productivity & quality



Parts with higher design quality



Parts with lower design quality

Studies: Quality has a big impact on <u>safety</u> and <u>security</u>

System safety

Fortune 100 engineering conglomerate

Design quality degradation increased defects found <u>after</u> a safety-critical system went live

	High quality design	Design quality degraded
% of fielded system with critical bugs	0.63%	13.00%
Dollars spent fixing critical defects	12 cents per LOC	81 cents per LOC

Security threat

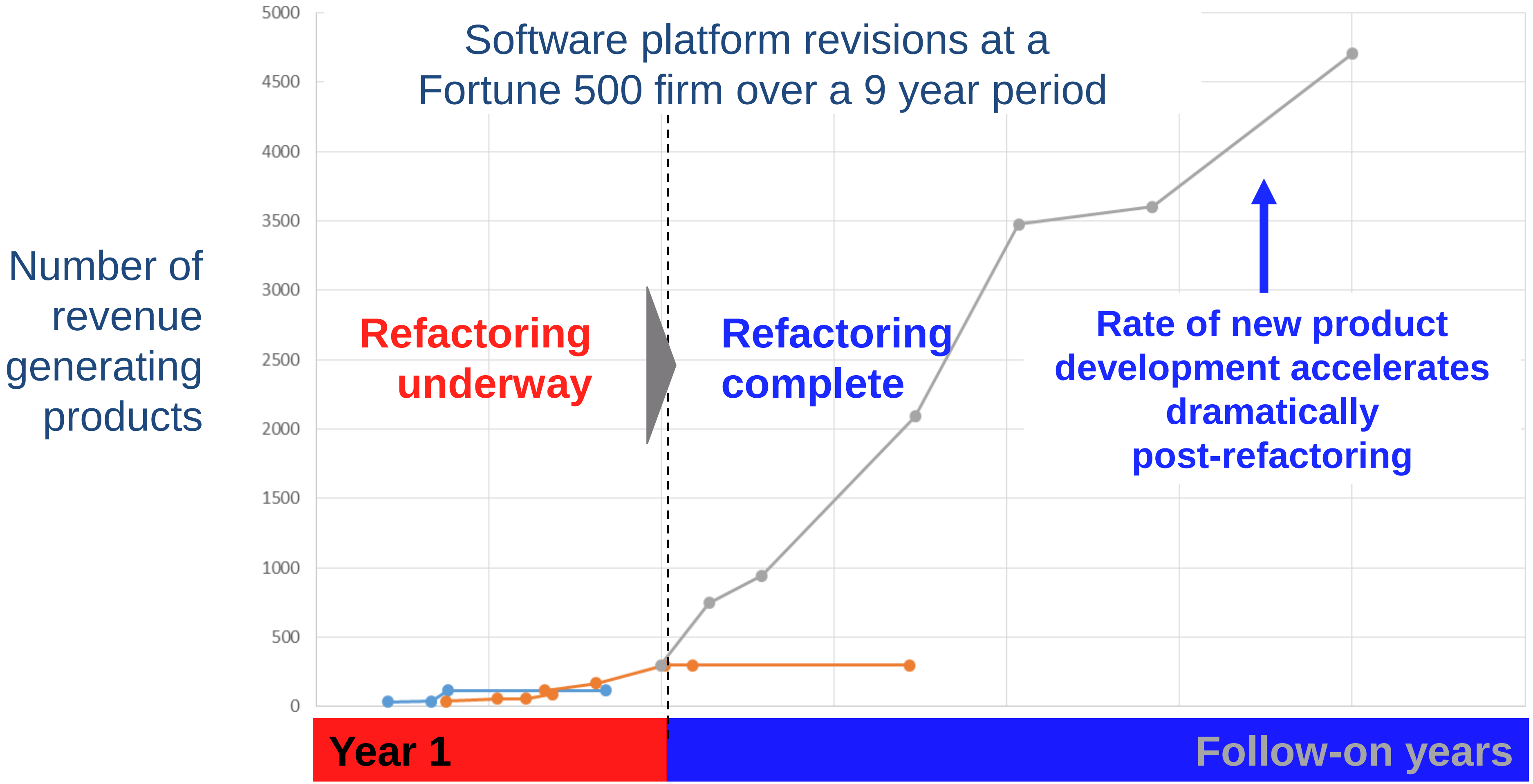
Fortune 50 consumer software firm

Design quality degradation responsible for security vulnerabilities and higher maintenance costs

In code with a measurably better architecture:

- Fewer vulnerabilities & defects found
- 10% higher developer productivity during patch process
- 14% less time to release patches
- 25% fewer incomplete or incorrect fixes

Studies: Quality has a big impact on agility and revenue



So why do quality & refactoring efforts go unfunded?!?!?

Engineer Suggests	Market Demand	ROI	CFO Reaction
New Features	• Existing customer will buy more • New customers created • Product differentiation	$	Ecstatic
Bug Fixes	• Existing customer screaming • New customers avoiding • Reputation hit	$	Required, unfortunately
Internal Quality Improvement, Refactoring Initiatives	None		Not convinced

Mechanics: Statistically linking quality & business outcomes

	Product Attributes		Process Performance	
Data Sources	Source code	Continuous integration	Version control	Feature & bug tracking
Raw Metrics	• Code complexity metrics • Design complexity metrics • Language • File attributes • Design structure	• Unit test coverage • System test coverage • Test failure rate	• Change volume • Change timestamp • Change locality • File age • Developer ID	• Bug vs Feature? • Criticality • Time to close issue • Developer ID • Development effort
Stats Models	Code quality Design quality Test quality		Defect density Dev productivity Team morale	Change locality On-time delivery Cost of change

Example regression model linking quality and developer productivity

Predicting LOC produced by a developer to implement enhancements for one release. (Negative binomial panel data model)

Parameter	**Model 1: developer attributes**	**Model 2: type of work**	**Model 3: cyclomatic complexity**	**Model 4: all controls**	**Model 5: architectural complexity**	**Model 6: combined**
Lines for bug fixes	-0.000071	-0.000068	-0.000060	-0.000067	-0.000077 .	-0.000078 .
Log(years employed)	0.279600			0.492500		0.483700
Is manager?	-0.283000			-0.251600		-0.292900
Pct lines in new files		1.801000 ***		1.699000 ***		1.714000 ***
Pct lines high cyclomatic			-1.166011 ***	-0.648300 .		-0.613000 .
Pct lines in core					-0.610943 .	-0.618600 *
Residual Deviance	560.77	558.46	560.60	558.32	560.71	558.13
Degrees of Freedom	290.00	291.00	291.00	288.00	291.00	287.00
AIC	8170.66	8135.14	8162.14	8136.78	8166.87	8135.75
Theta	0.85	0.90	0.86	0.91	0.85	0.92
Std-err	0.05	0.05	0.05	0.05	0.05	0.05
2 x log-lik	-7792.66	-7759.14	-7786.14	-7754.78	-7790.87	-7751.75

N = 478 developer/releases

Dummy variables for each of 8 releases omitted. Dummy variables for each of 178 developers omitted.

*Significance codes: <0.1, *<0.05, **<0.01, ***<0.001*

How to win over your CFO in 6 easy steps!

Step 1: A hypothetical proposal

- Come up with a hypothetical proposal
  - "I think we should increase test coverage in our codebase. It will allow us to catch bugs earlier and prevent their introduction. We have some source files with no automated unit test coverage, some with 100% coverage, and many that fall somewhere in between. We should require all source files to have at least 90% coverage. An initiative should be kicked off to write more tests so that all existing source files are 90% covered."
- Come up with a plausible sounding rationale for the CFO:
  - "I think the amount of time (& therefore money) spent fixing bugs that would have been caught is significant. I think the cost of writing the tests now will be less than the money we will save in the future if those tests are added."

The CFO is now listening to you

How to win over your CFO in 6 easy steps!

Step 2: Collect data and see if a statistically significant relationship exists

- Extract raw data from:
  - source code
  - testing framework
  - version control system
  - issue tracking system, etc.
- Set up regressions:
  - Dependent variable = File-level defect count per unit time
  - Predictor variable = Test-coverage % for each file
  - A variety of control variables
- Demonstrate statistically significant correlation

The CFO is still listening to you

How to win over your CFO in 6 easy steps!

Step 3: Get predicted defect counts for the system as it currently is

- Use your calibrated model generate ‘predicted defect counts’
  - **Use model simulation or prediction algorithms**
  - **Use actual test coverage values and controls as inputs**
  - **Capture ’predicted defect counts’ for each file.**
  - **Sum all of these ‘predicted defect counts’ (per file) to get a ‘predicted defect count’ for the codebase as a whole.**

The CFO does not care about this. Do not bother.

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Step 4: Get predicted defect counts for your hypothetically improved system

- Modify the input data to set all ‘test coverage values’ to 90% or above
- Leave all other values the same
- Rerun calibrated model with new inputs to generate ‘hypothetical defect counts’

$$\boldsymbol{Defect\ Reduction = \text{‘}predicted\ defect\ count\text{’}\ (from\ step\ 3) - \text{‘}hypothetical\ defect\ count\text{’}\ (from\ step\ 4)}$$

If ‘Defect Reduction’ is big, the CFO is listening to you again

How to win over your CFO in 6 easy steps!

Steps 5: Estimate annual savings

- Construct reasonable estimates for the cost of increasing test coverage.

- **Simple example:**
  - **It will take a developer 1 day to add coverage to 100 lines**
  - **200,000 uncovered lines**
  - **200 days in a work year**
  - **10 FTE-year to complete**
  - **$100,000/yr salary**
  - **$1,000,000 dollars to achieve**

Steps 4: Estimate cost of improvement

- Construct reasonable estimates for the annual savings

- Simple Example:
  - **Hypothetical model (step 3) predicts 1000 fewer bugs/year**
  - **Average bug takes 4 days to fix**
  - **4000 days saved annually**
  - **20 FTE saved annually**
  - **Breakeven point in 6 months!**

The CFO might actually be starting to like you now

How to win over your CFO in 6 easy steps!

Step 6: Estimate the ROI of hypothetical improvement

- **Some Equations:**
  - **‘Cost to fix’ (now) = $1,000,000**
  - **‘Annual savings’ = $1,000,000**
  - **<u>PRESENT VALUE</u> of ‘annual savings’ = $3,790,258**
    - **((assuming 5 year time horizon and opportunity cost of 10%)**
  - **ROI = [PRESENT VALUE(annual savings) – ‘cost to fix’] / ‘cost to fix’**
  - **ROI = 279%**

The CFO might even respect you now.

What if you could get quality & refactoring funded?

Engineer Suggests	Market Demand	ROI	CFO Reaction
New Features	• Existing customer will buy more • New customers created • Product differentiation	$	Ecstatic
Bug Fixes	• Existing customer screaming • New customers avoiding • Reputation hit	$	Required, unfortunately
Internal Quality Improvement, Refactoring Initiatives	• Internal modeling used to compare ROI and breakeven point against other investment opportunities	$$	Tell me more

1. Introducing Amadeus
2. Challenges faced by the software enterprise
3. Introducing Silverthread, Inc.
4. Case 1: Driving software platform design quality
5. Case 2: Analytics for managerial decision-making
6. Lessons for your company

Feedback

DEVELOPERS	TECHNOLOGY LEADERS	EXECUTIVES
• Sparked architecture discussions • Helped reveal anti-patterns • Supported their overall perception with data	• Helped evaluate the reality against the design intents • Spotted risky areas • Built business case for refactoring actions	• Will provide an objective picture of the portfolio • Will allow benchmarking • Will enable arbitration and steering based on ROI

Everyone speaks the same language now

Using the concept for continuous improvement

1

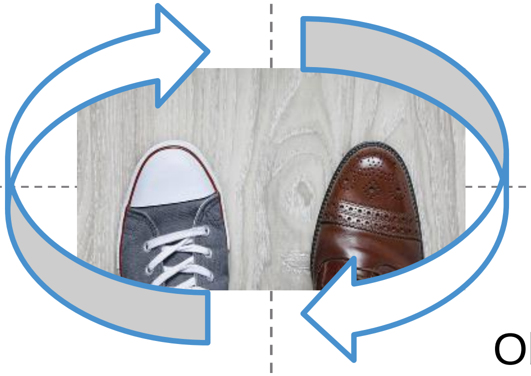
Building insight
Helping developers do their job

Understand system better:
Architecture maps
System Metrics
Project Metrics
Software economics

2

Learning
Connecting technical & economic choices

Identify and explore challenges:
Code quality
Test quality
Design quality
Software economics



3

Decision making
Objective business decisions

Explore software economics
via statistics and modeling
Model the ROI of development initiatives
Make investments in quality improvement

4

Effective steering
& management

Measure and enforce architecture rules
Set KPIs for improvement initiatives
Prioritize and manage improvement
Learn and revise models as appropriate
Propose new things to explore

Questions ??

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