

# Trends and New Directions in Software Architecture

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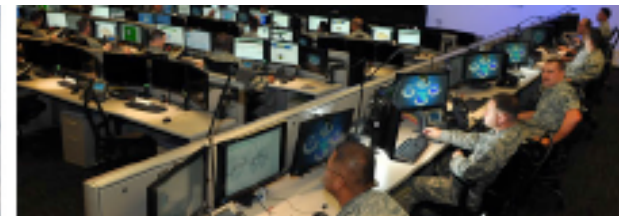
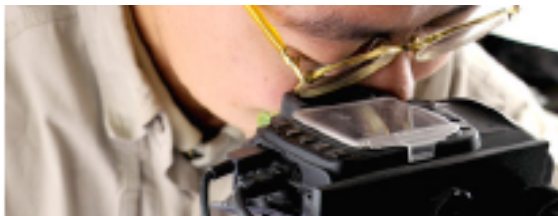
Team Software Process<sup>SM</sup> and TSP<sup>SM</sup> are service marks of Carnegie Mellon University.

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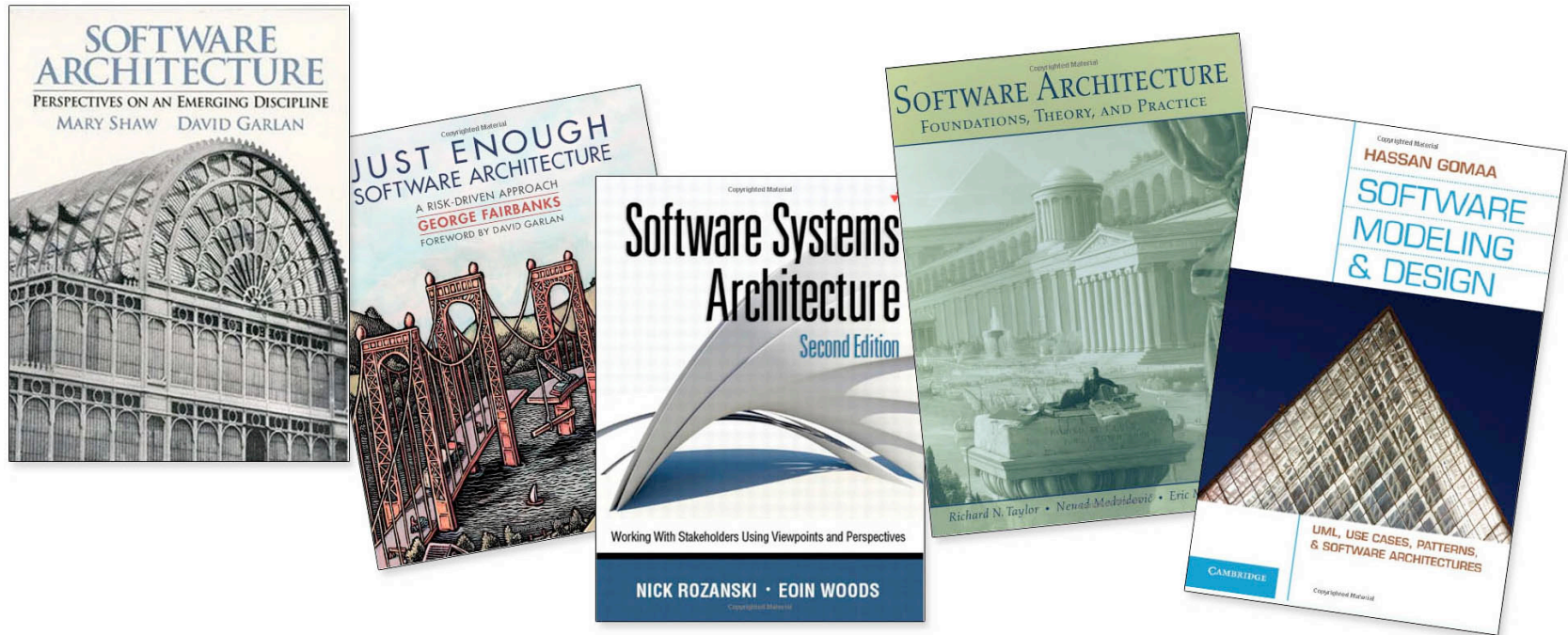
# Software Architecture

- The quality and longevity of a software-reliant system is largely determined by its architecture.
- Recent US studies identify architectural issues as a systemic cause of software problems in government systems (OSD, NASA, NDIA, National Research Council).

**Architecture is of enduring importance because it is the right abstraction for performing ongoing analyses throughout a system's lifetime.**



# Software Architecture Thinking



- High-level system design providing system-level structural abstractions and quality attributes, which help in managing complexity
- Makes engineering tradeoffs explicit



# Quality Attributes

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## Quality attributes

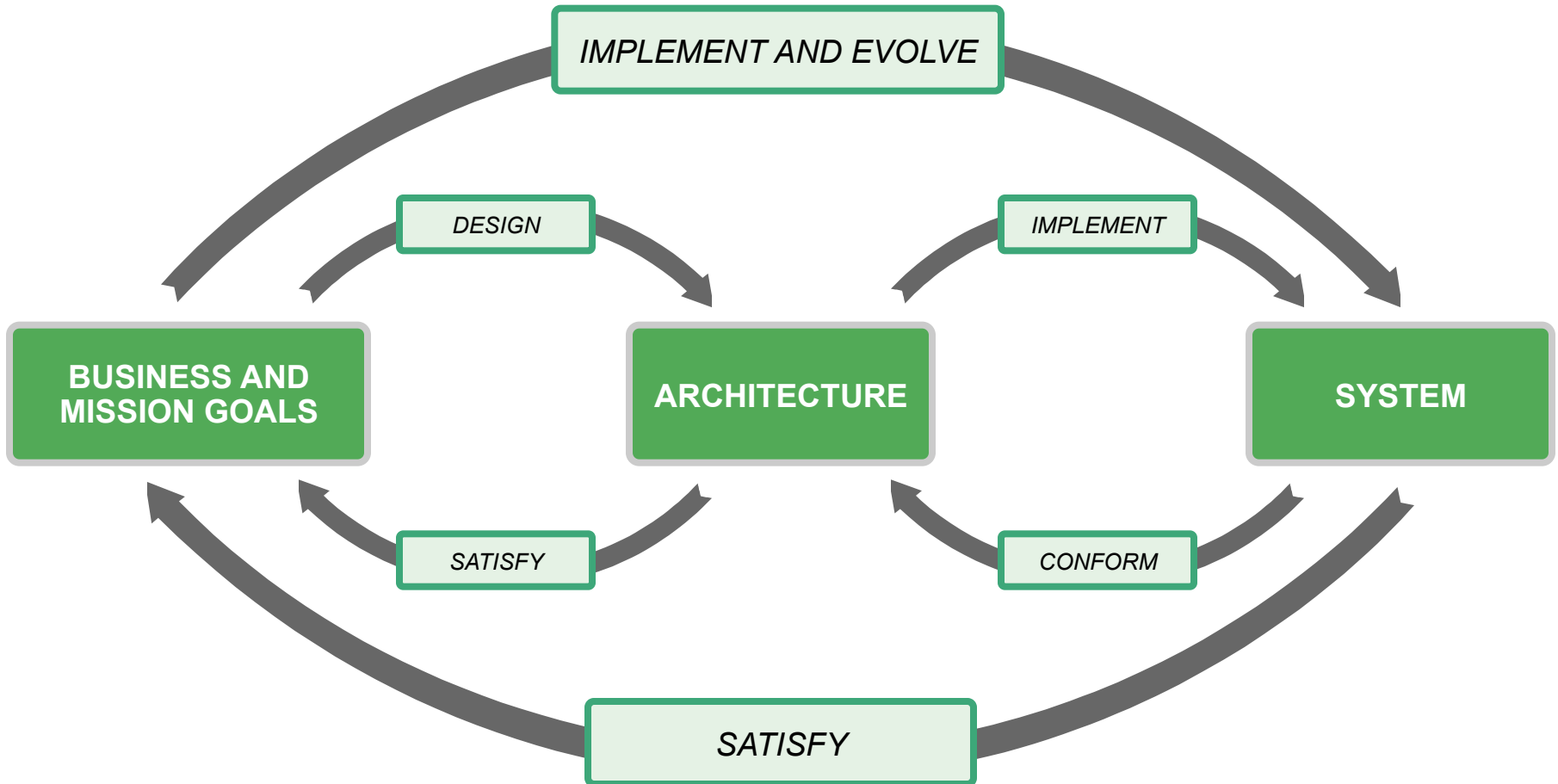
- properties of work products or goods by which stakeholders judge their quality
- stem from business and mission goals.
- need to be characterized in a system-specific way

## Quality attributes include

- Performance
- Availability
- Interoperability
- Modifiability
- Usability
- Security
- Etc.

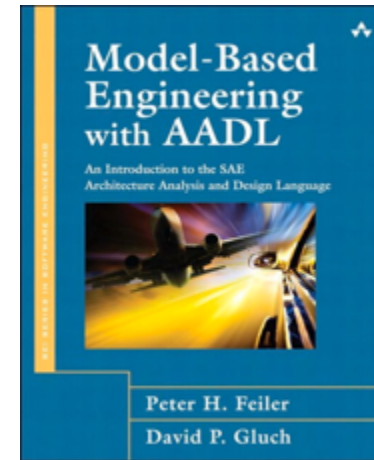
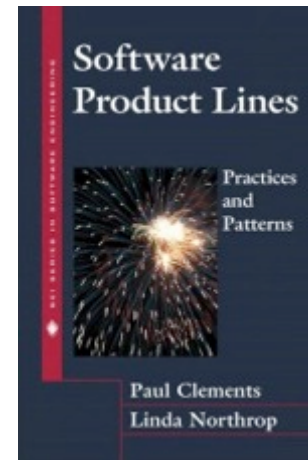
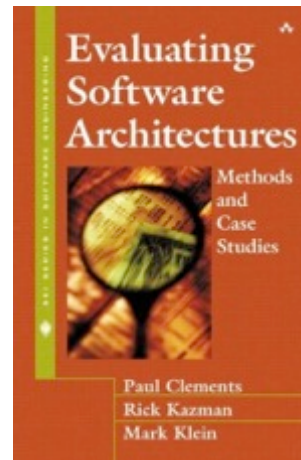
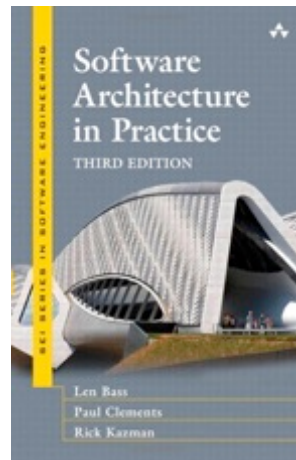


# Central Role of Architecture





# Our View: Architecture-Centric Engineering



- *explicitly focus on quality attributes*
- *directly link to business and mission goals*
- *explicitly involve system stakeholders*
- *be grounded in state-of-the-art quality attribute models and reasoning frameworks*



# Advancements Over the Years

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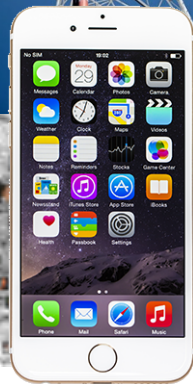
- Architectural patterns
- Component-based approaches
- Company specific product lines
- Model-based approaches
- Frameworks and platforms
- Standard interfaces



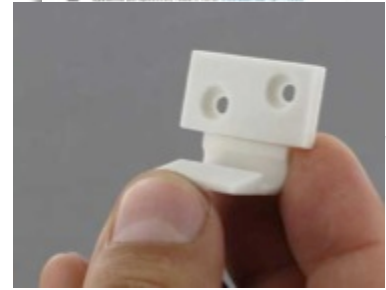
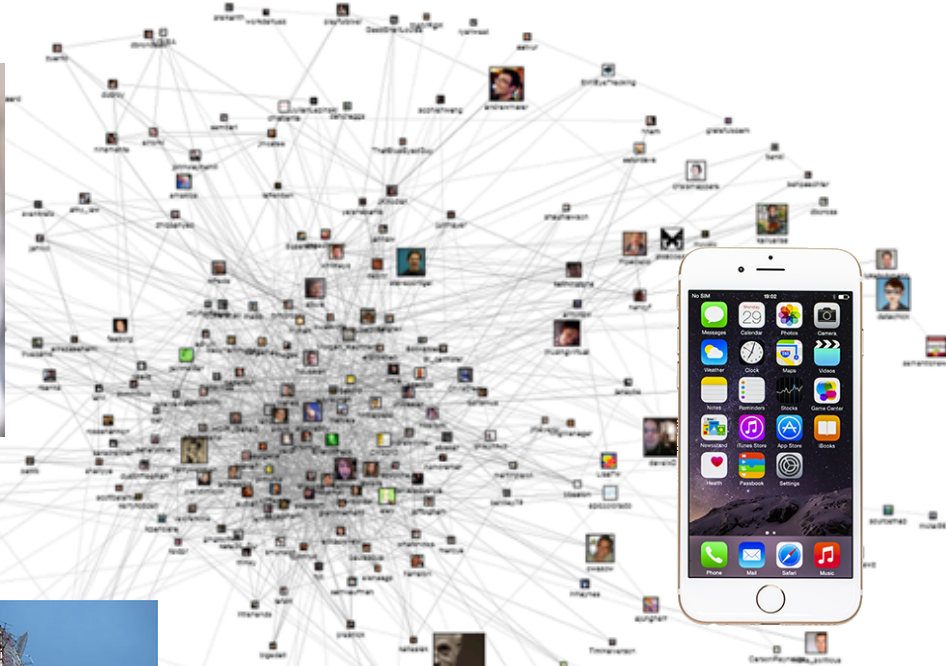


# What HAS Changed?

- Increased connectivity
- Scale and complexity
  - decentralization and distribution
  - “big data”
  - increased operational tempo
  - inter-reliant ecosystems
  - vulnerability
  - collective action
- Disruptive and emerging technologies

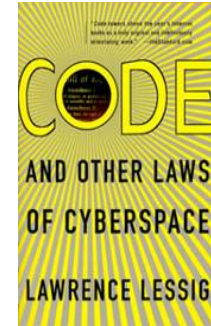


# Technology Trends



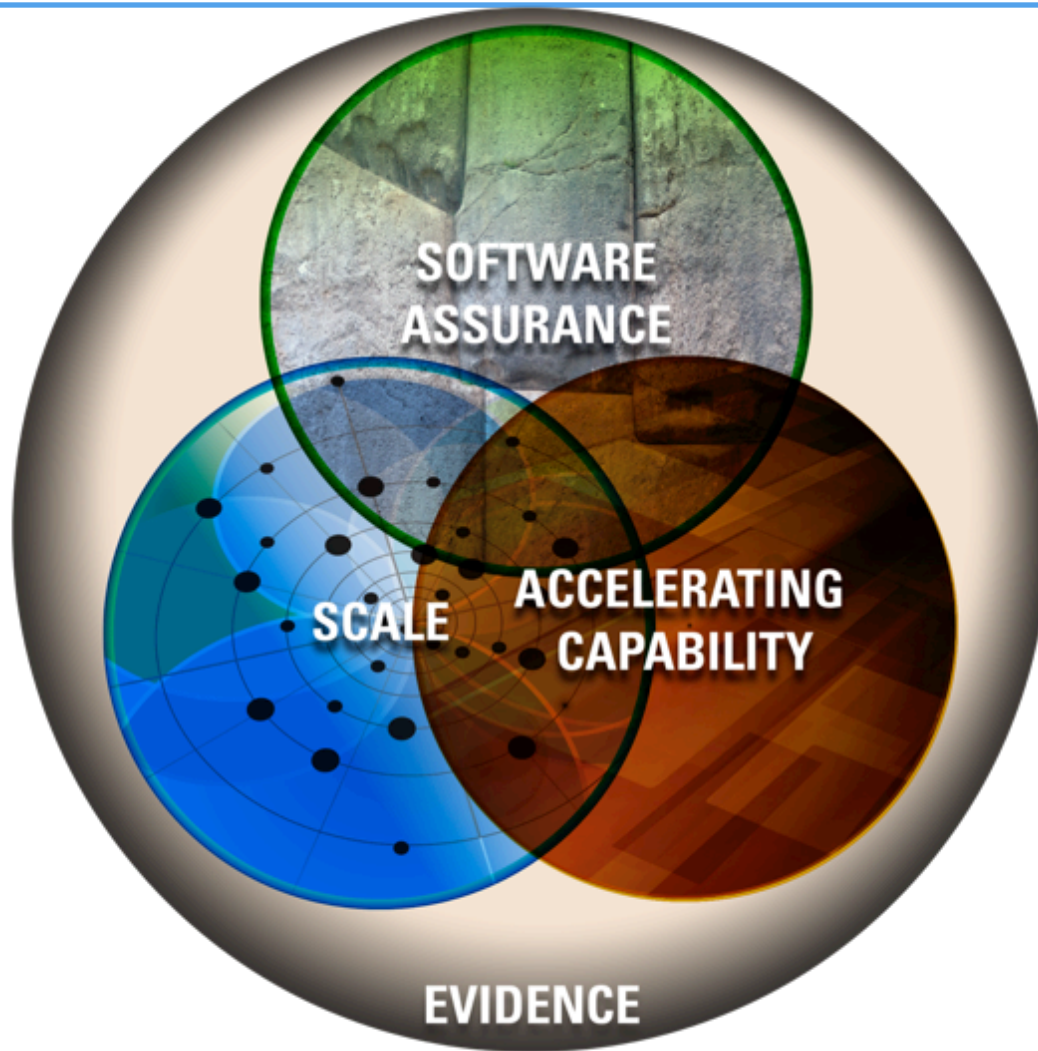
# Software Development Trends

- Application frameworks
- Open source
- Cloud strategies
- NoSQL
- Machine Learning
- MDD
- Incremental approaches
- Dashboards
- Distributed development environments
- DevOps



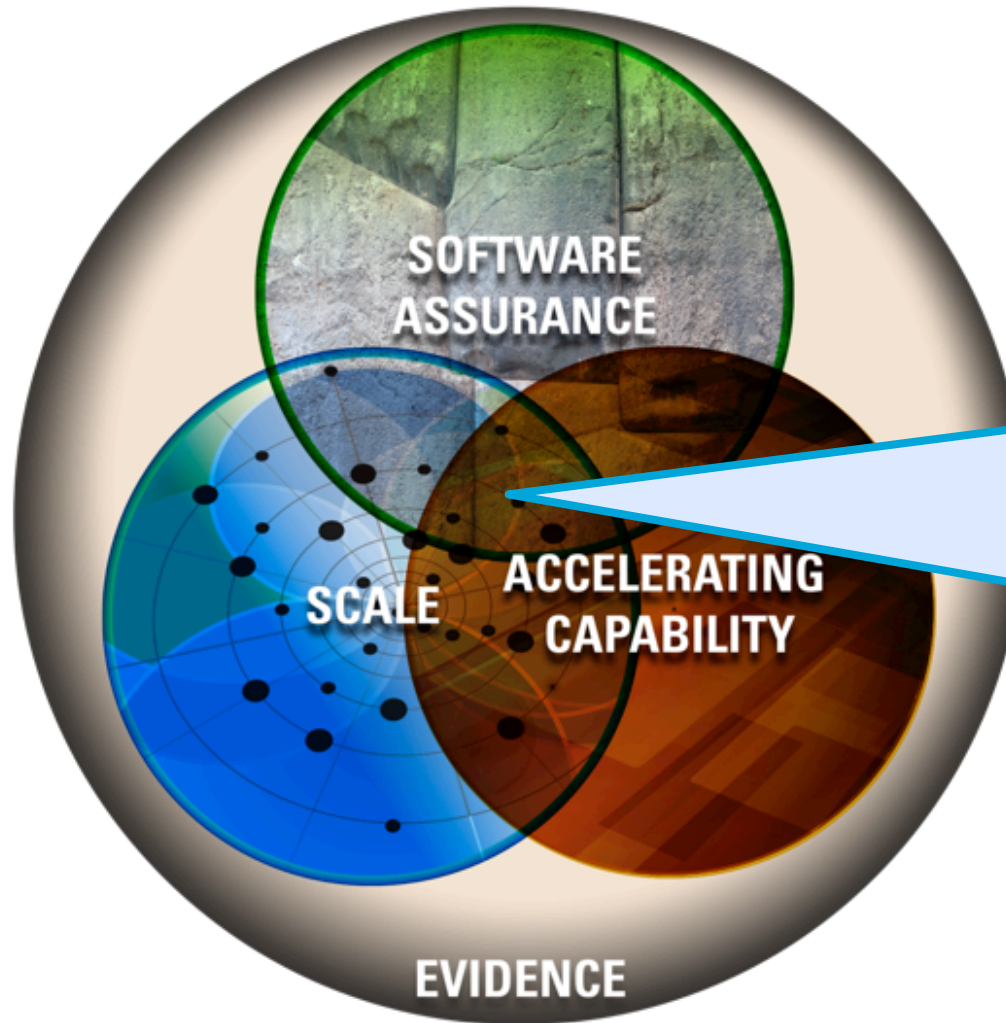
# Technical Challenges

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# The Intersection and Architecture



At the intersections there are difficult tradeoffs to be made in structure, process, time, and cost.

**Architecture is the enabler for tradeoff analyses.**



# Architecture and Accelerated Capability

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How much architecture design is enough?

Can architecture design be done incrementally?

There is a difference between being agile and doing agile.

Agility is enabled by architecture – not stifled by it.

Managing technical debt is key.





# Managing Technical Debt\*

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A design or construction approach that's expedient in the short term but that creates a technical context that increases complexity and cost in the long term.

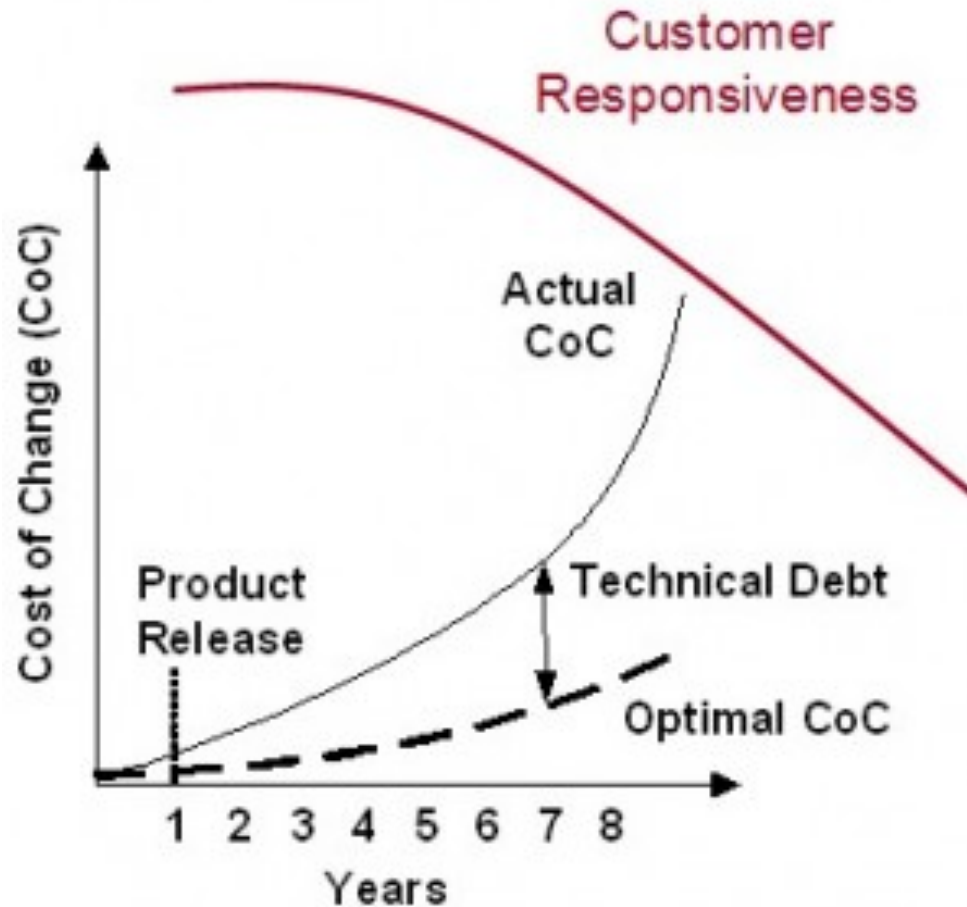
Some examples include:

- continuing to build on a foundation of poor quality legacy code
- prototype that turns into production code
- increasing use of "bad patches," which increases number of related systems that must be changed in parallel

\* Term first used by Cunningham, W. 1992. *The WyCash Portfolio Management System*. OOPSLA '92 Experience Report. <http://c2.com/doc/oopsla92.html>.



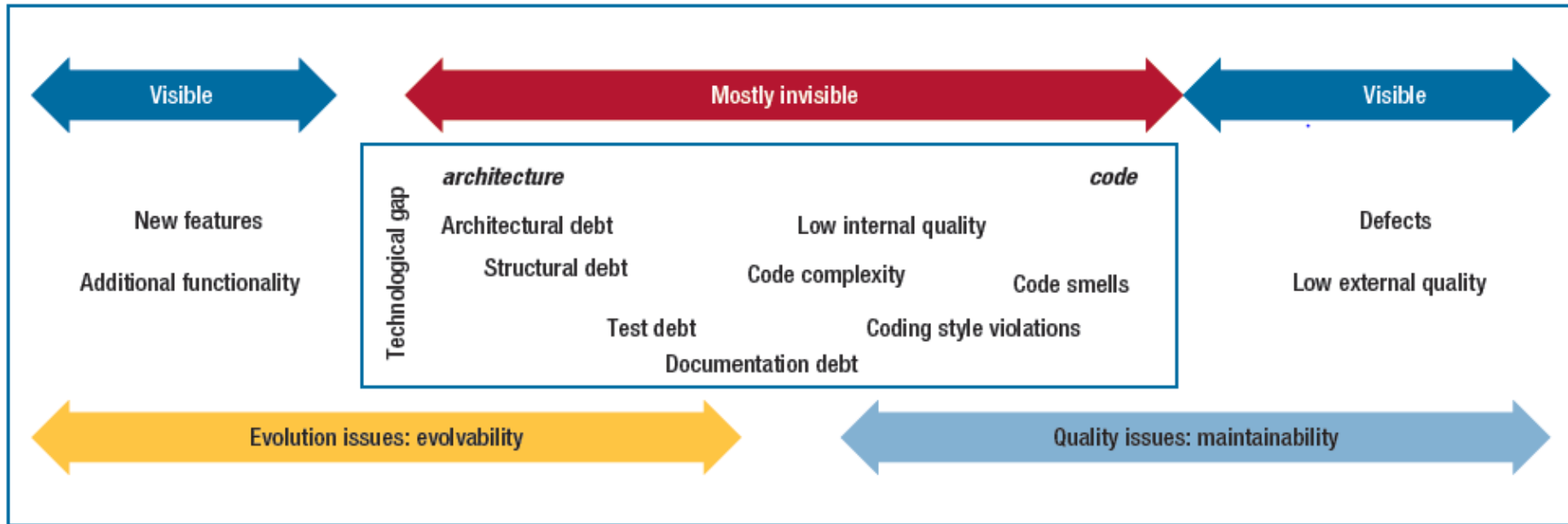
# Technical Debt Impact



From:  
Jim Highsmith  
2010



# Technical Debt Landscape



**FIGURE 1.** The technical debt landscape. On the left, evolution or its challenges; on the right, quality issues, both internal and external.

“invisible results of past decisions about software that negatively affect its future...deferred investment opportunities or poorly managed risks”

Kruchten, P. Nord, R.L., Ozkaya, I. 2012. Technical Debt: From Metaphor to Theory and Practice, IEEE Software, 29(6), Nov/Dec 2012.



# Making Hard Choices About Technical Debt

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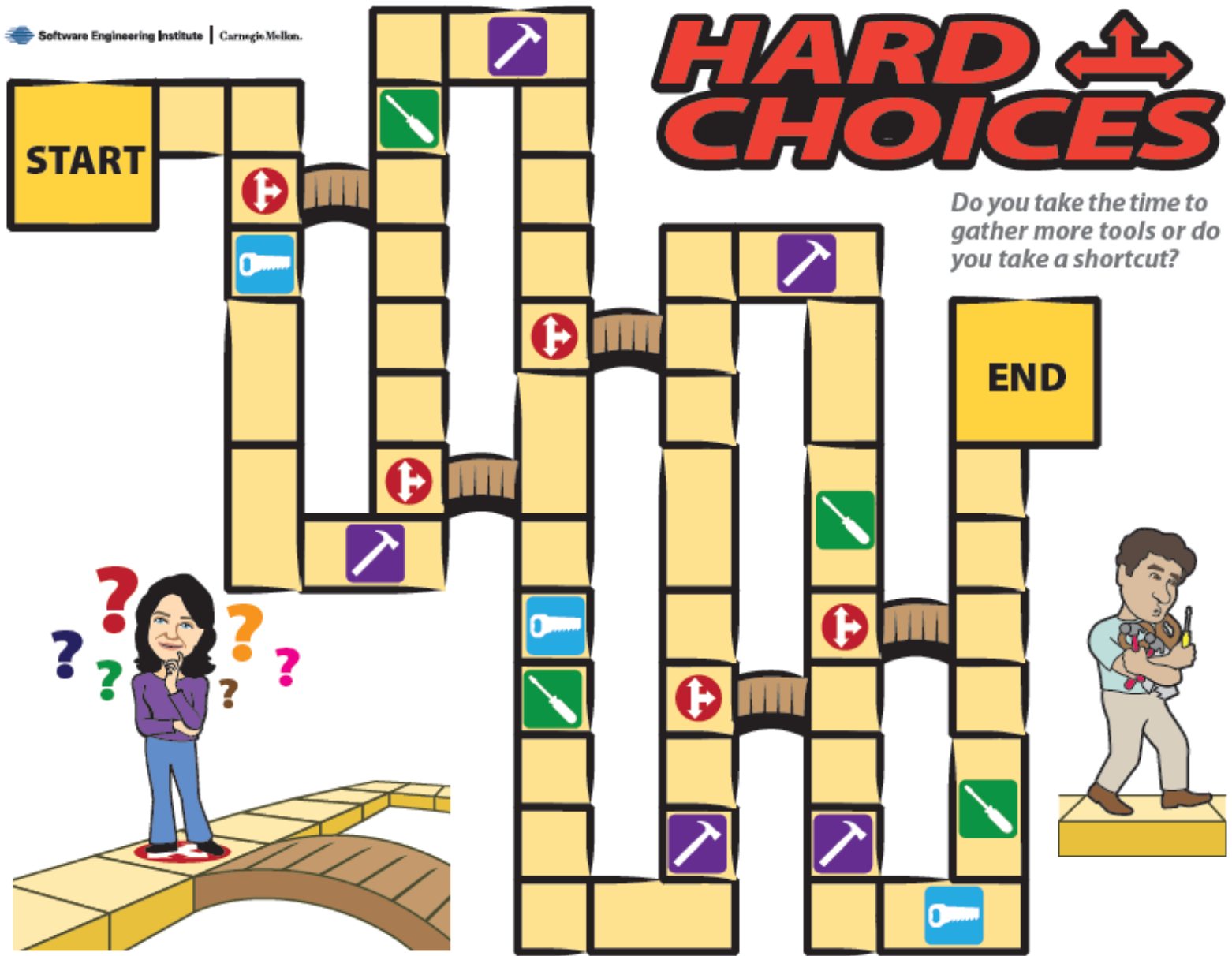
In the quest to become market leader, players race to release a quality product to the marketplace.

The Hard Choices game is a simulation of the software development cycle meant to communicate the concepts of uncertainty, risk, options, and technical debt.



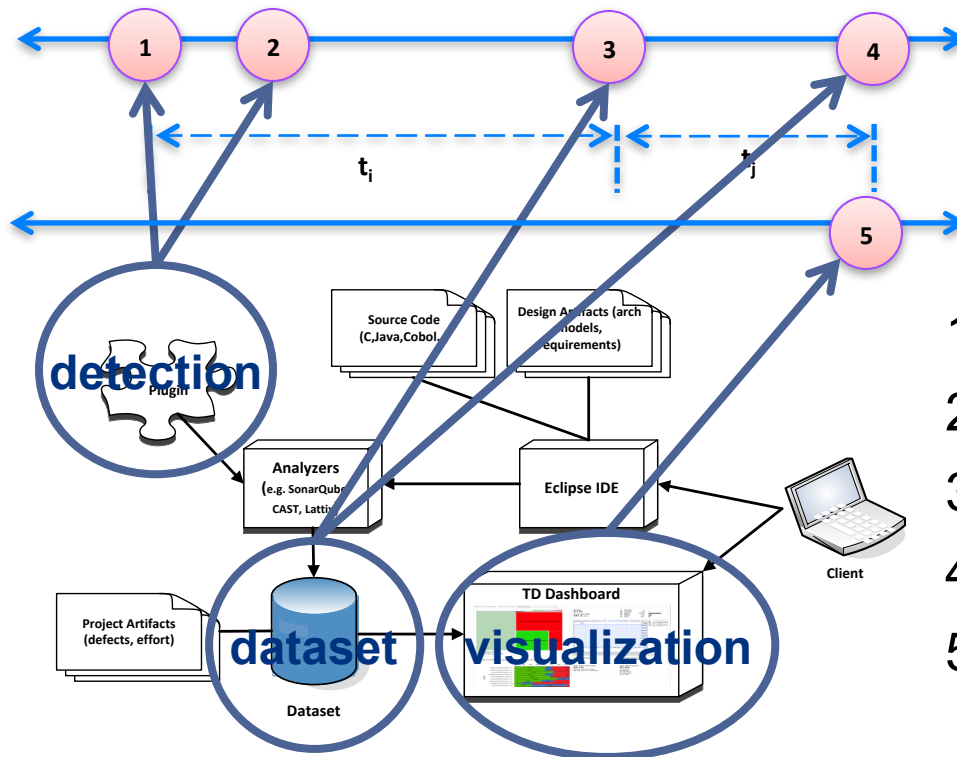
Hard Choices Strategy Game to Communicate Value of Architecture Thinking game downloadable from <http://www.sei.cmu.edu/architecture/tools/hardchoices/>.





# Our Current Research

What code and design indicators that correlate well with project measures allow us to manage technical debt?



1. time technical debt is incurred
2. time technical debt is recognized
3. time to plan and re-architect
4. time until debt is actually paid-off
5. continuous monitoring





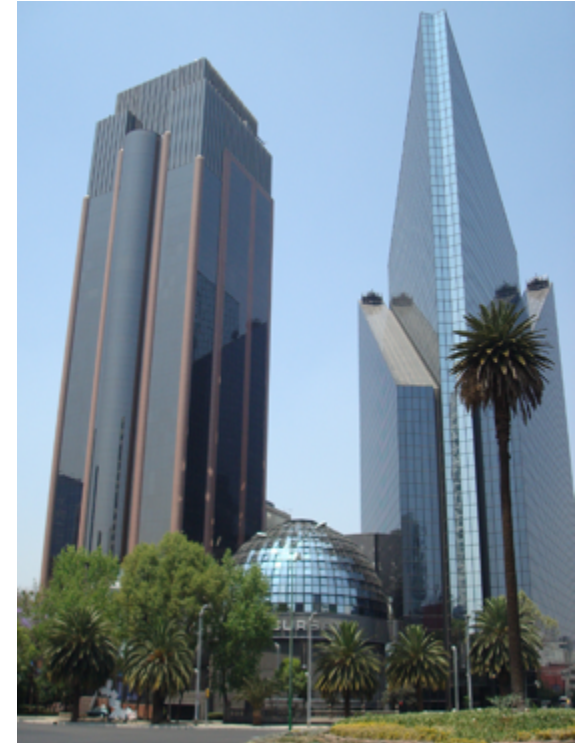
# Architecture Done Incrementally

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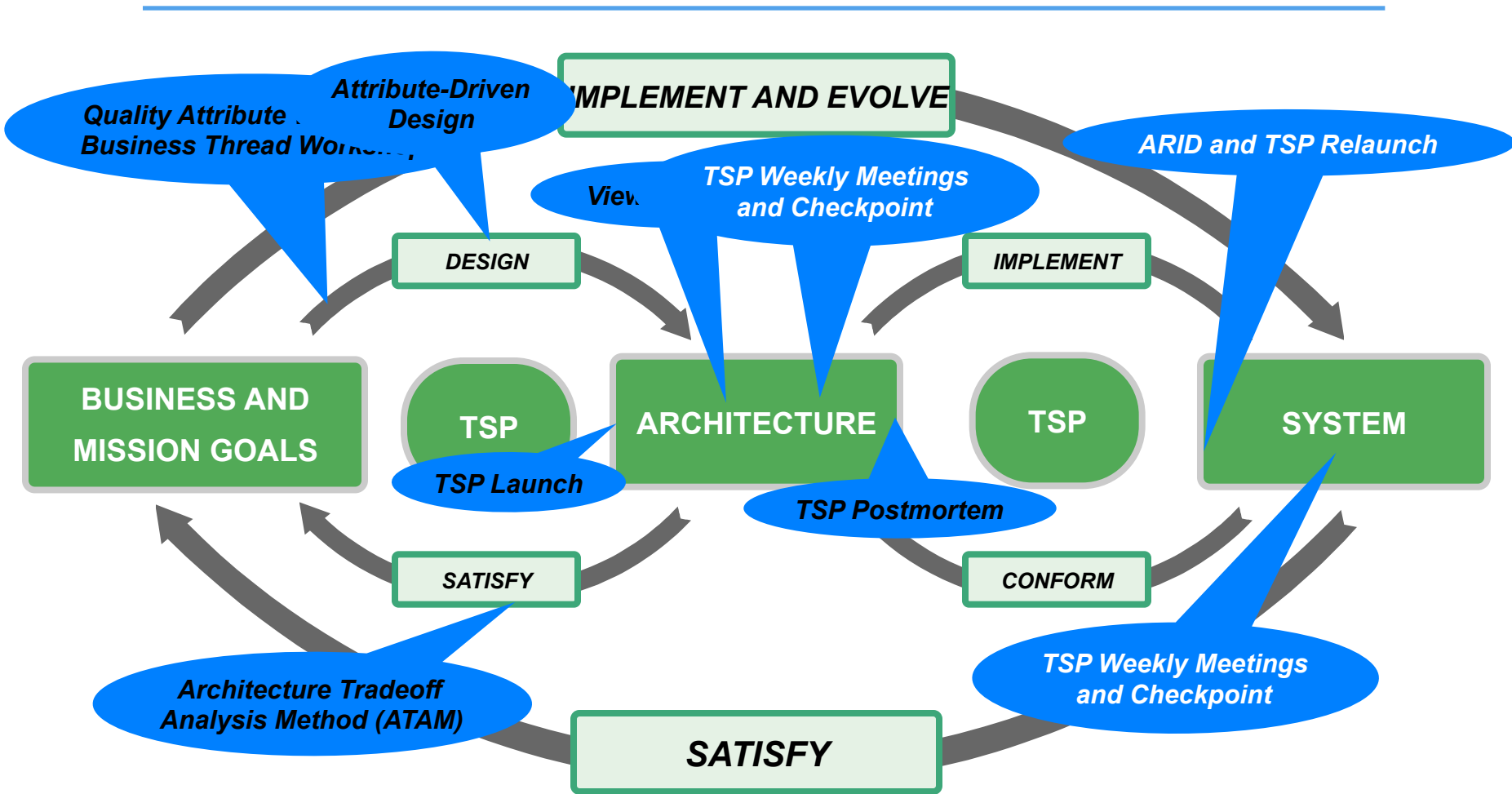
- Bolsa Mexicana de Valores (BMV) operates the Mexican Financial Markets on behalf of the Mexican government.
- Bursatec is the technology arm of the BMV.
- BMV desired a new stock trading engine to drive the market.
- BMV performed a build vs. buy analysis and determined that Bursatec would replace their three existing trading engines with one in-house developed system.

Bursatec committed to deliver a trading engine in 8-10 quarters.

- High performing
- Reliable and of high quality
- Scalable



# Approach

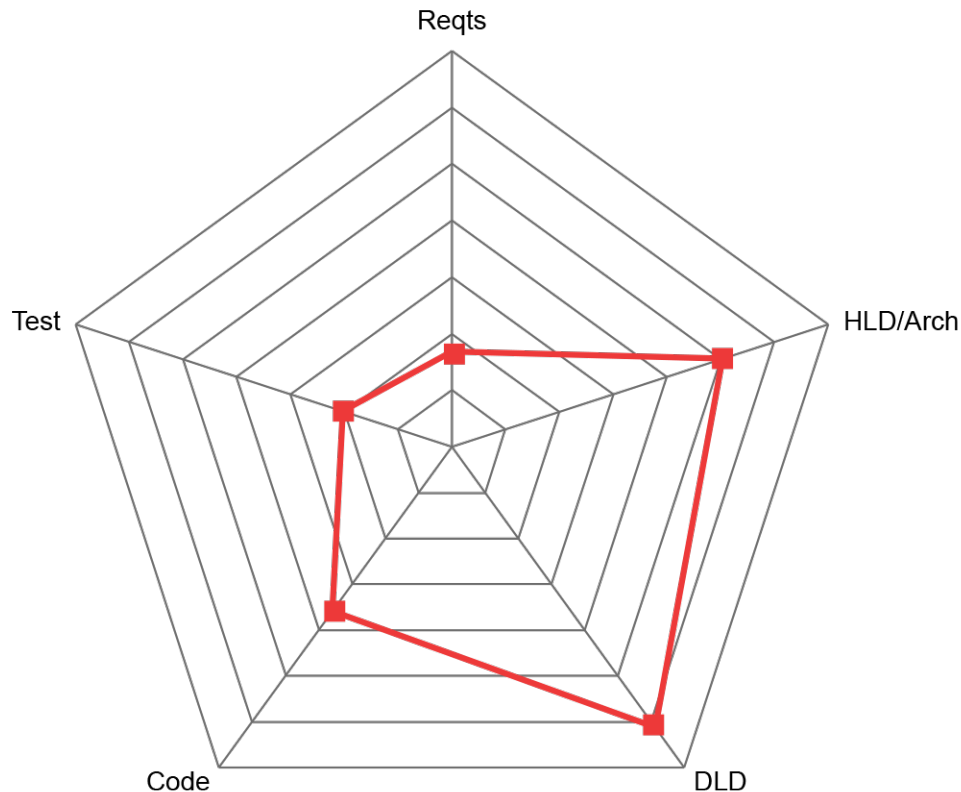


## Team Software Process (TSP) and Architecture-Centric Engineering



# Effort in Percent over Cycles – 1

## Cycle 1 – 14 Weeks

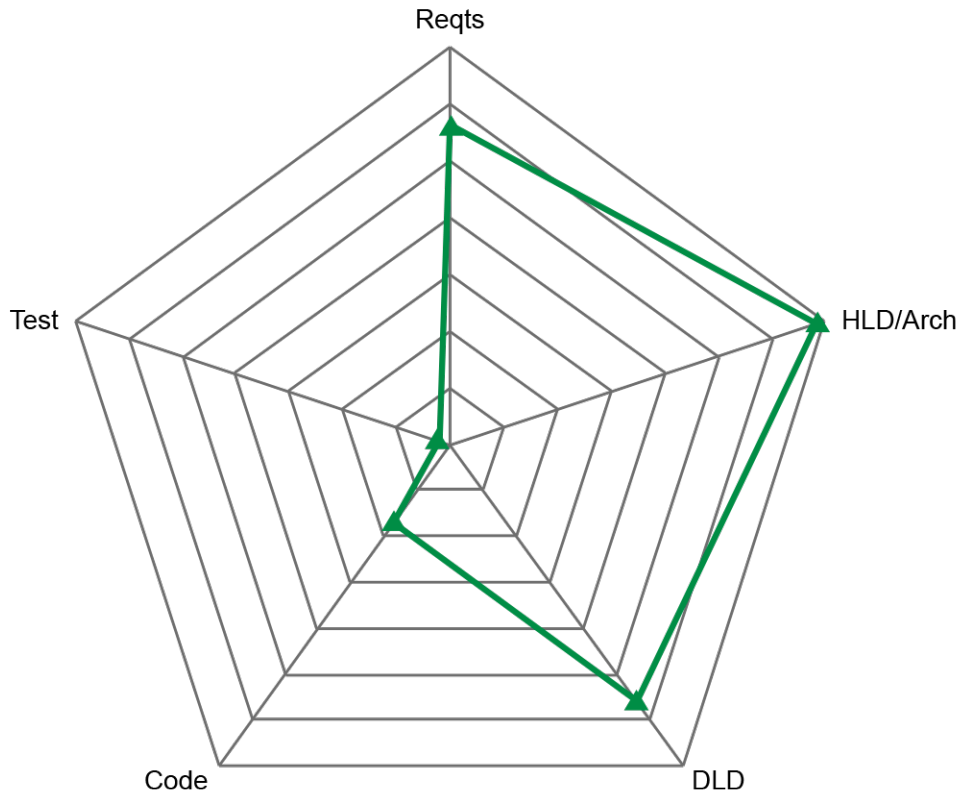


Reqs: Requirements  
HLD/Arch: High level Design / Architecture  
DLD: Detailed Design (UML)  
Code: Coding (no detailed design)  
Test: Testing



# Effort in Percent over Cycles – 2

## Cycle 2 – 10 Weeks

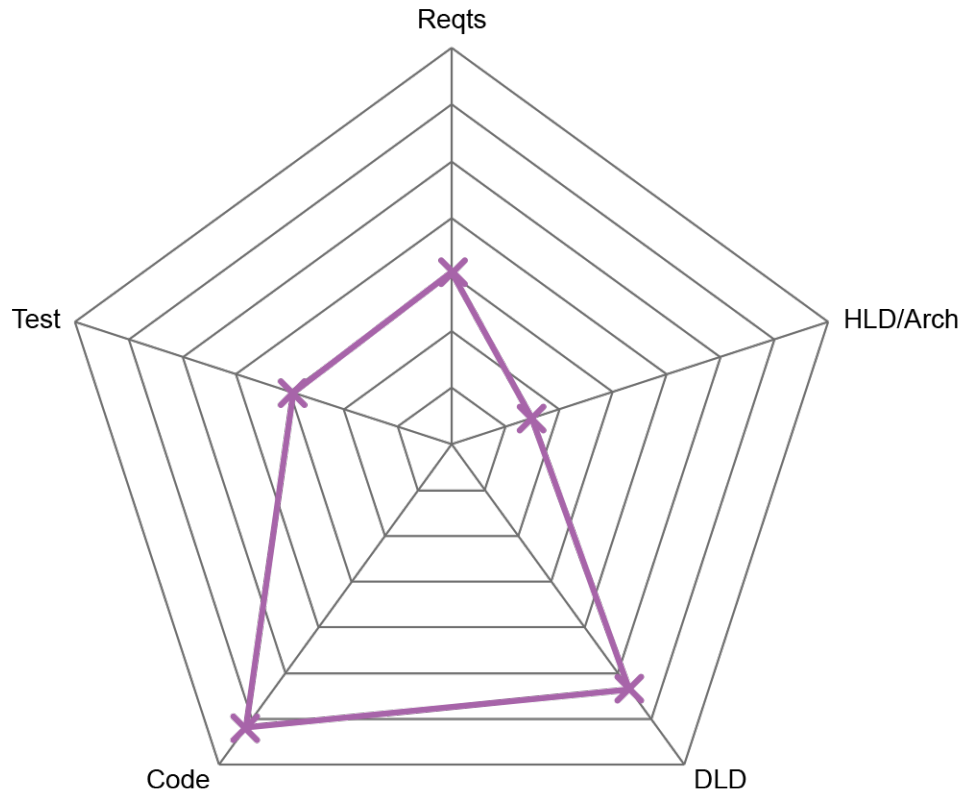


Reqs: Requirements  
HLD/Arch: High level Design / Architecture  
DLD: Detailed Design (UML)  
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Test: Testing



# Effort in Percent over Cycles – 3

## Cycle 3 – 18 Weeks

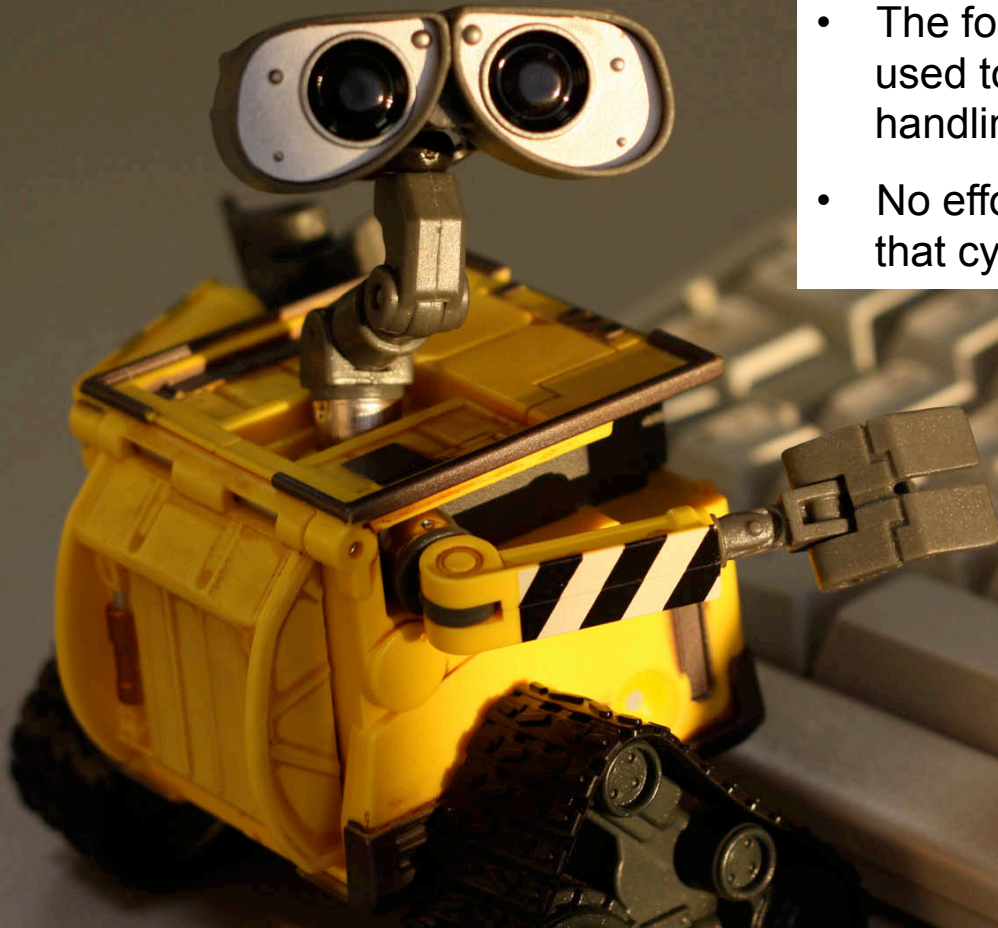


Reqs: Requirements  
HLD/Arch: High level Design / Architecture  
DLD: Detailed Design (UML)  
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Test: Testing



# Effort in Percent over Cycles – 4

- The fourth cycle of three weeks was used to rethink garbage collection handling and cleaning up.
- No effort data was collected during that cycle.



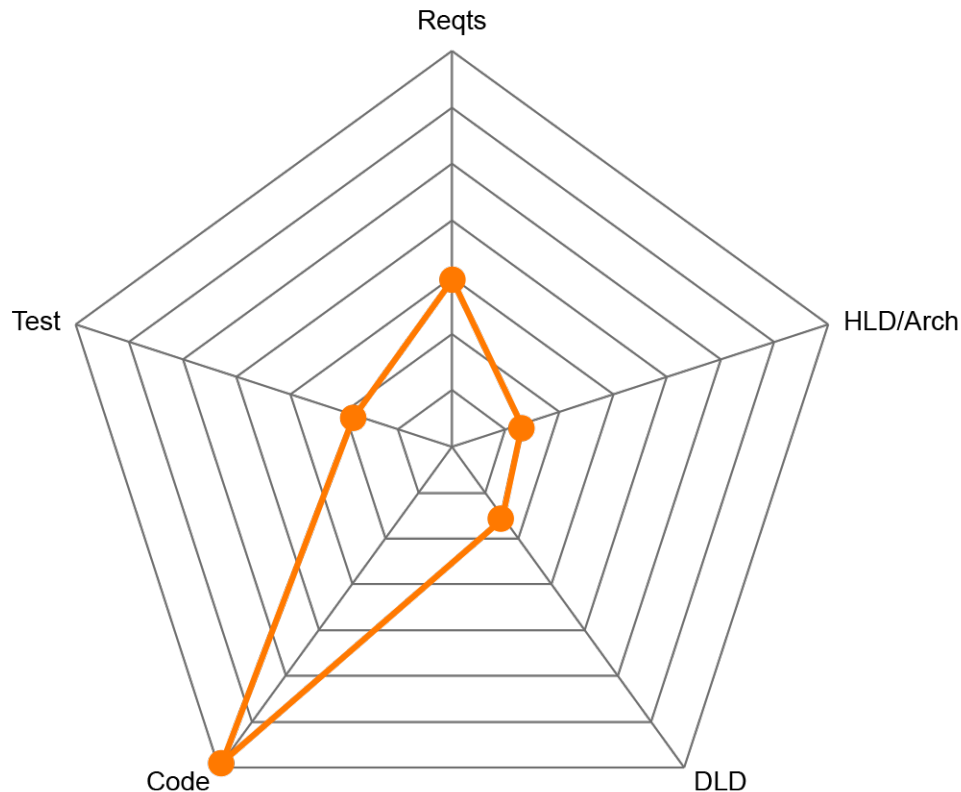
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# Effort in Percent over Cycles – 5

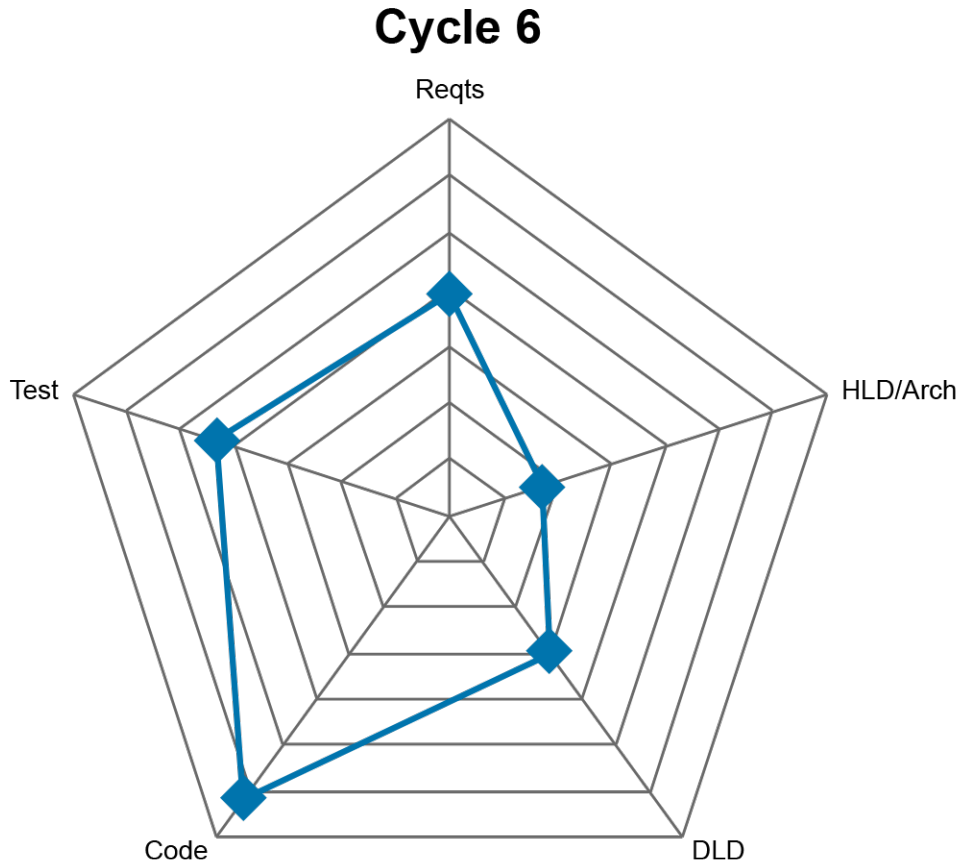
## Cycle 5 - 25 Weeks



Reqs: Requirements  
HLD/Arch: High level Design / Architecture  
DLD: Detailed Design (UML)  
Code: Coding (no detailed design)  
Test: Testing



# Effort in Percent over Cycles – 6



Reqs: Requirements  
HLD/Arch: High level Design / Architecture  
DLD: Detailed Design (UML)  
Code: Coding (no detailed design)  
Test: Testing



# Results

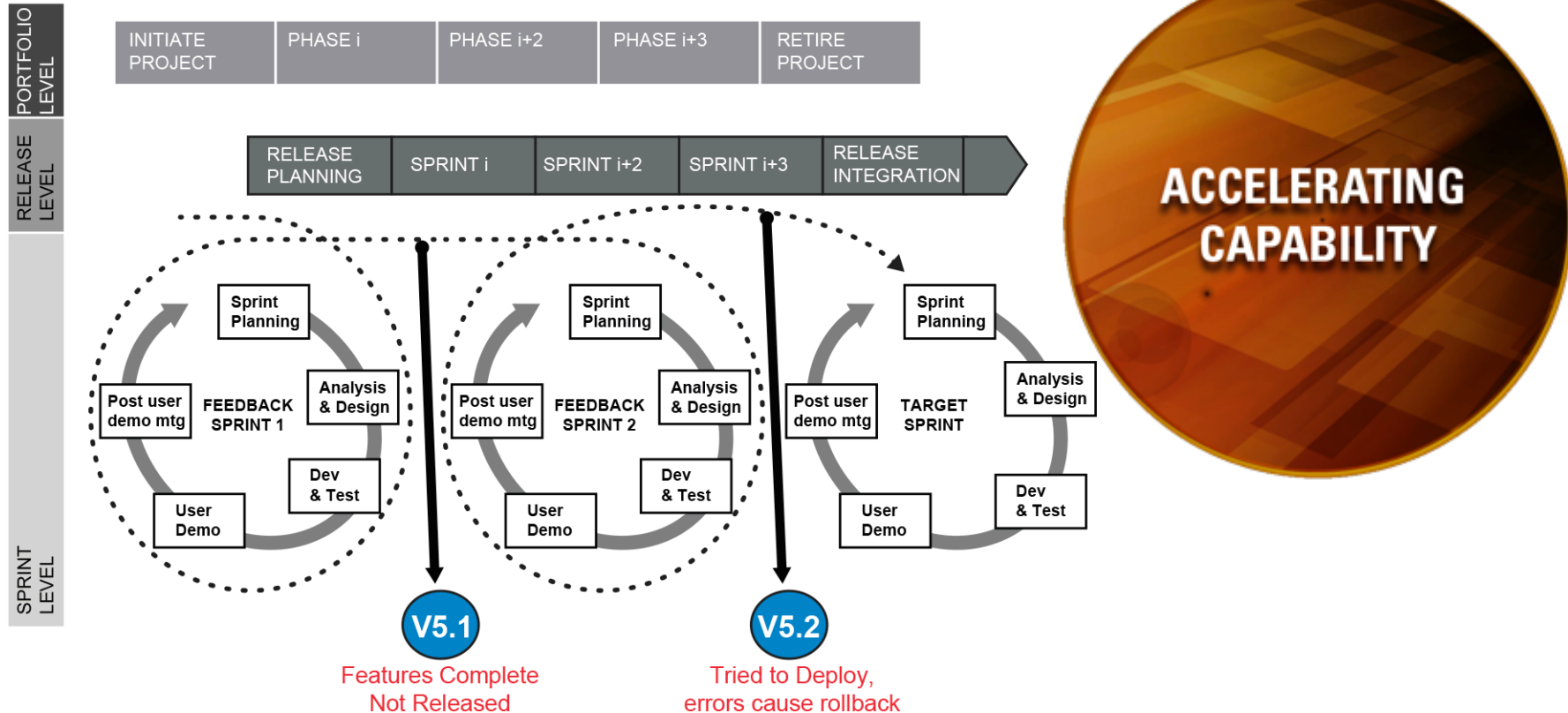
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Results	Target	Actual
Latency	1ms	0.1ms
Throughput (transactions per second)	1,000	200,000
Schedule (months)	18	17
Quality (defects/KLOC found during validation testing)	0.25	0.1



# Deployment Challenges

The **DevOps** movement continues what Agile started.



# DevOps: State of the Practice

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Focus is on

- culture and teaming
- process and practices
  - value stream mapping
  - continuous delivery practices
  - *Lean* thinking
- tooling, automation, and measurement
  - tooling to automate repetitive tasks
  - static analysis
  - automation for monitoring architectural health
  - performance dashboards



# Architecture and DevOps

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Design decisions that involve deployment-related limitations can blindside teams.





# DevOps Tips

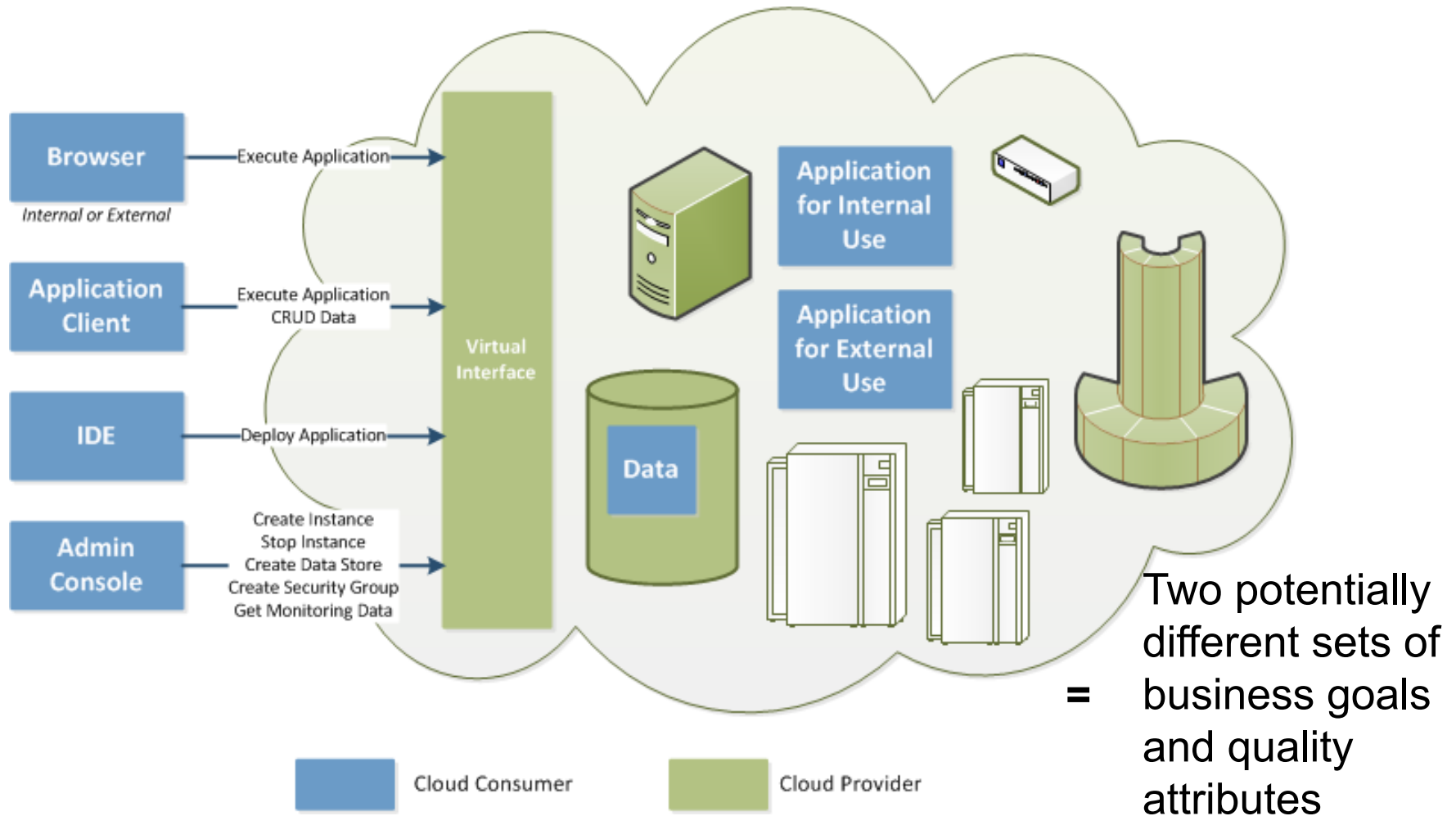
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- Don't let designing for deployability be an afterthought.
- Use measurable deployability quality attributes.
- Consider architectural tactics that promote modifiability, testability, and operational resilience.
- Use architectural abstractions to reason about deployability implications of design options and tradeoffs.
- Establish monitoring mechanisms.





# Two Perspectives of Software Architecture in Cloud Computing



# Cloud Computing and Architecting

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- SLAs cannot prevent failures.
- In cloud environments,
  - cloud consumers have to design and architect systems to account for lack of full control over important quality attributes.
  - cloud providers have to design and architect infrastructures and systems that provide the most efficient way to manage resources and keep promises made in SLAs.



# Mobile Device Trends



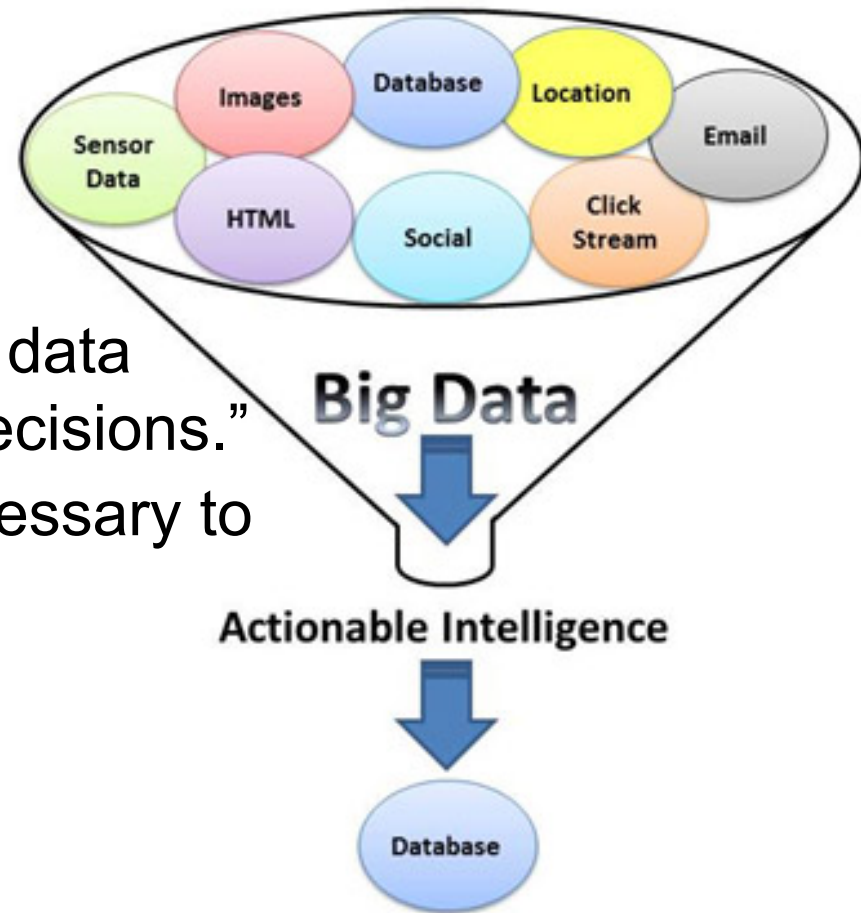
# Architecture Trends: Cyber-Foraging

- Edge Computing
- Using external resource-rich surrogates to augment the capabilities of resource-limited devices
  - code/computation offload
  - data staging
- Industry is starting to build on this concept to improve mobile user experience and decrease network traffic.
- Our research: cloudlet-based cyber-foraging
  - brings the cloud closer to the user



# Big Data Systems

- Two very distinct but related technological thrusts
  - Data analytics
  - Infrastructure
- Analytics is typically a massive data reduction exercise – “data to decisions.”
- Computation infrastructure necessary to ensure the analytics are
  - fast
  - scalable
  - secure
  - easy to use





# Big Data – State of the Practice

## “The problem is not solved”

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Building scalable, assured big data systems is hard.



Building scalable, assured big data systems is expensive.



# Big Data Survey

55%

OF BIG DATA PROJECTS  
ARE NOT COMPLETED

WHEN IT COMES TO BIG DATA PROJECTS,  
THE MOST SIGNIFICANT CHALLENGE



58%

INACCURATE SCOPE

80%

FINDING TALENT

76%

FINDING THE  
RIGHT TOOLS

73%

UNDERSTANDING

EDUCATION

## TOP REQUIREMENTS OF BIG DATA SOLUTIONS

#1

EASE OF  
MANAGEMENT

#2

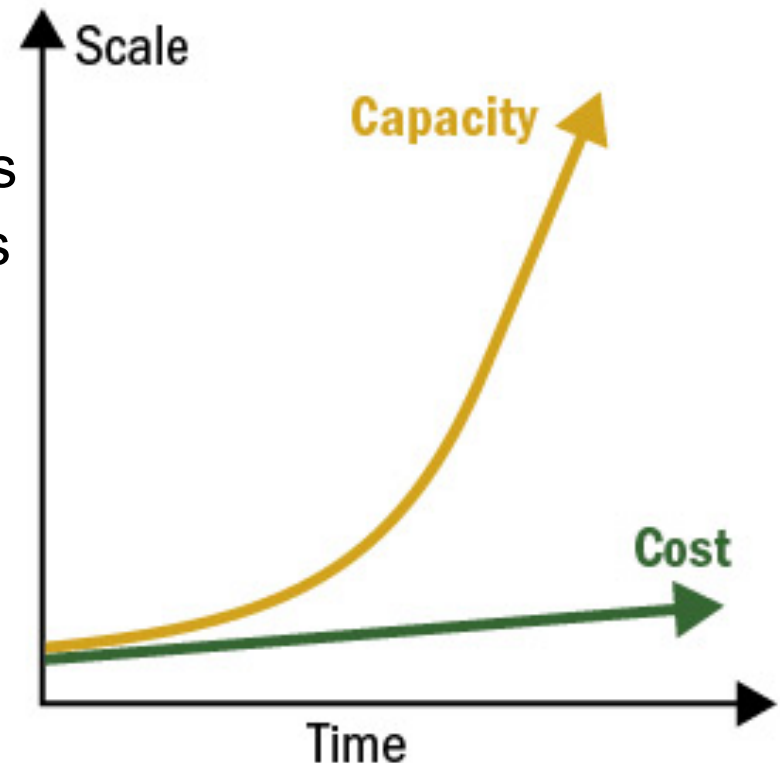
ABILITY  
TO SCALE

<http://visual.ly/cios-big-data>



# Architecture and Big Data

- System costs must grow more slowly than system capacity.
- Approaches
  - scalable software architectures
  - scalable software technologies
  - scalable execution platforms
- Scalability reduces as implementation complexity grows.
- NoSQL models are not created equal.
- You can't manage what you don't monitor.



# Our Current Research

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- Lightweight Evaluation and Architecture Prototyping for Big Data (LEAP4BD)
- QuABase: A Knowledge Base for Big Data System Design
  - semantics-based knowledge model
    - general model of software architecture knowledge
    - populated with specific big data architecture knowledge
  - dynamic, generated, and queryable content
  - knowledge visualization



# Architecture and Software Assurance

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# Architectural Models

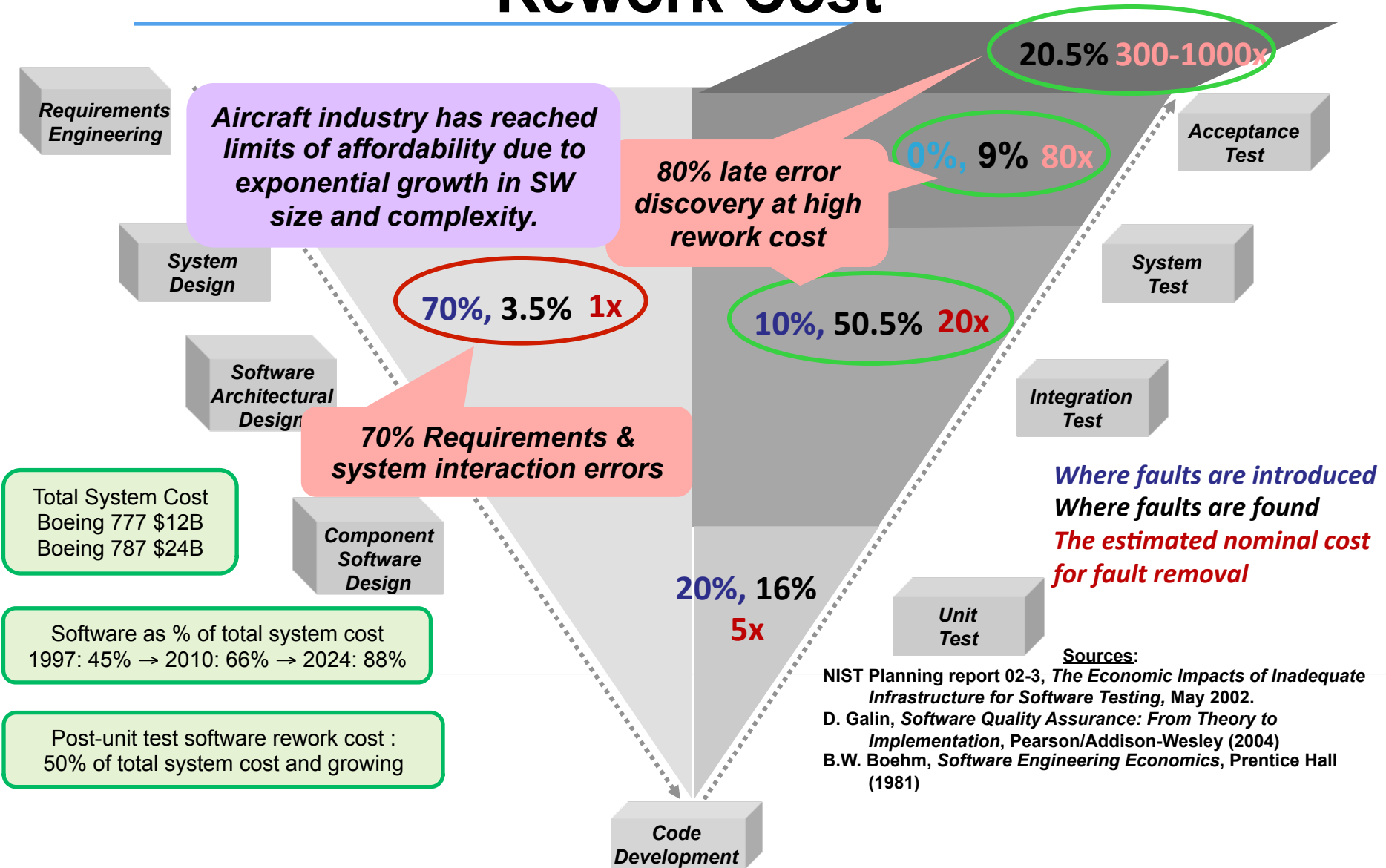
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- capture architecture in a form amenable to analysis, which contributes to assurance
- range from informal (e.g., visio diagrams) to formal (e.g., with precisely defined execution semantics)
- In safety critical systems formality is warranted.





# High Fault Leakage Drives Major Increase in Rework Cost



# SAE Architecture Analysis & Design Language (AADL) Standard Suite (AS-5506 Series)

- Core AADL language standard (V2.1-Sep 2012, V1-Nov 2004)
  - Strongly typed language with well-defined semantics
  - Textual and graphical notation
  - Standardized XML interchange format

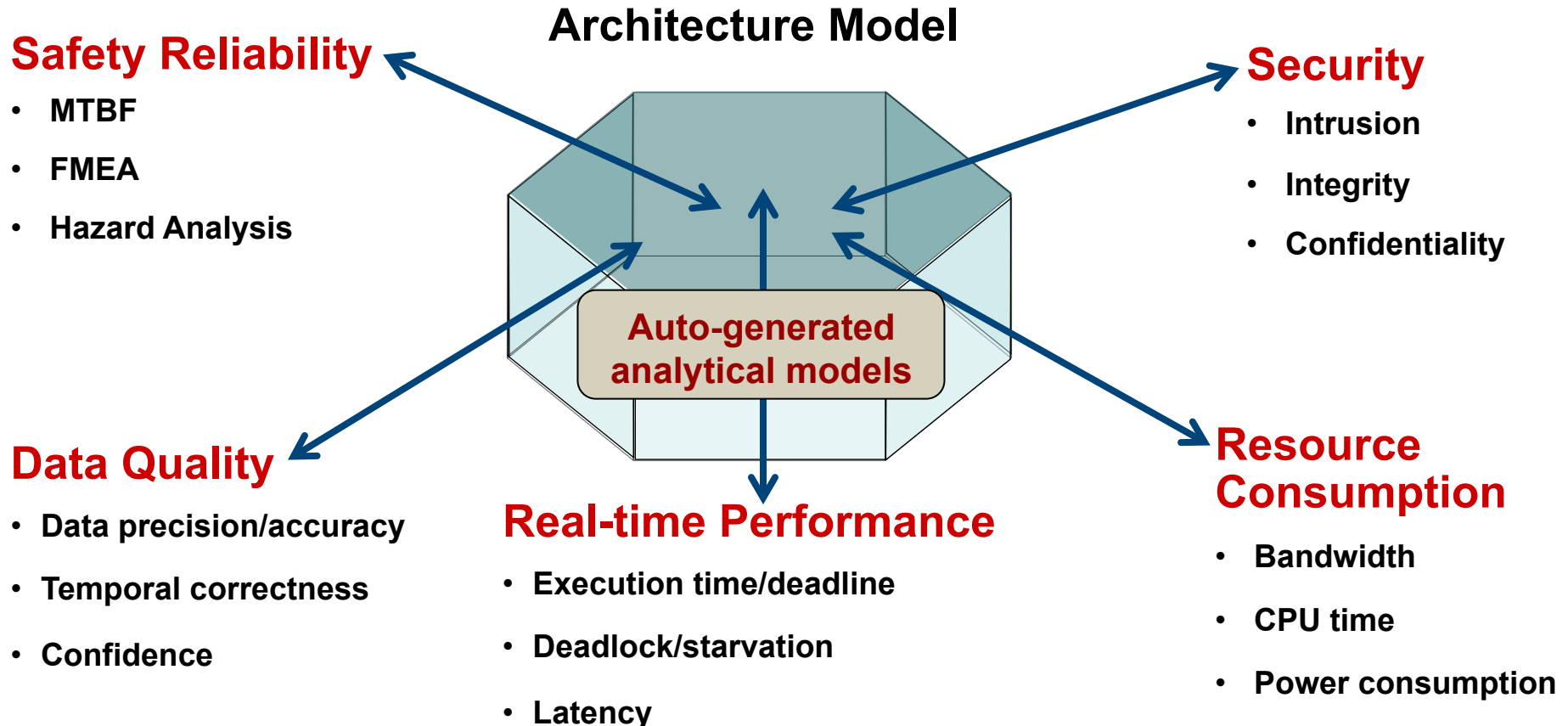
## Standardized AADL Extensions

- Error Model language for safety, reliability, security analysis
- ARINC653 extension for partitioned architectures
- Behavior Specification Language for modes and interaction behavior
- Data Modeling extension for interfacing with data models (UML, ASN.1, ...)

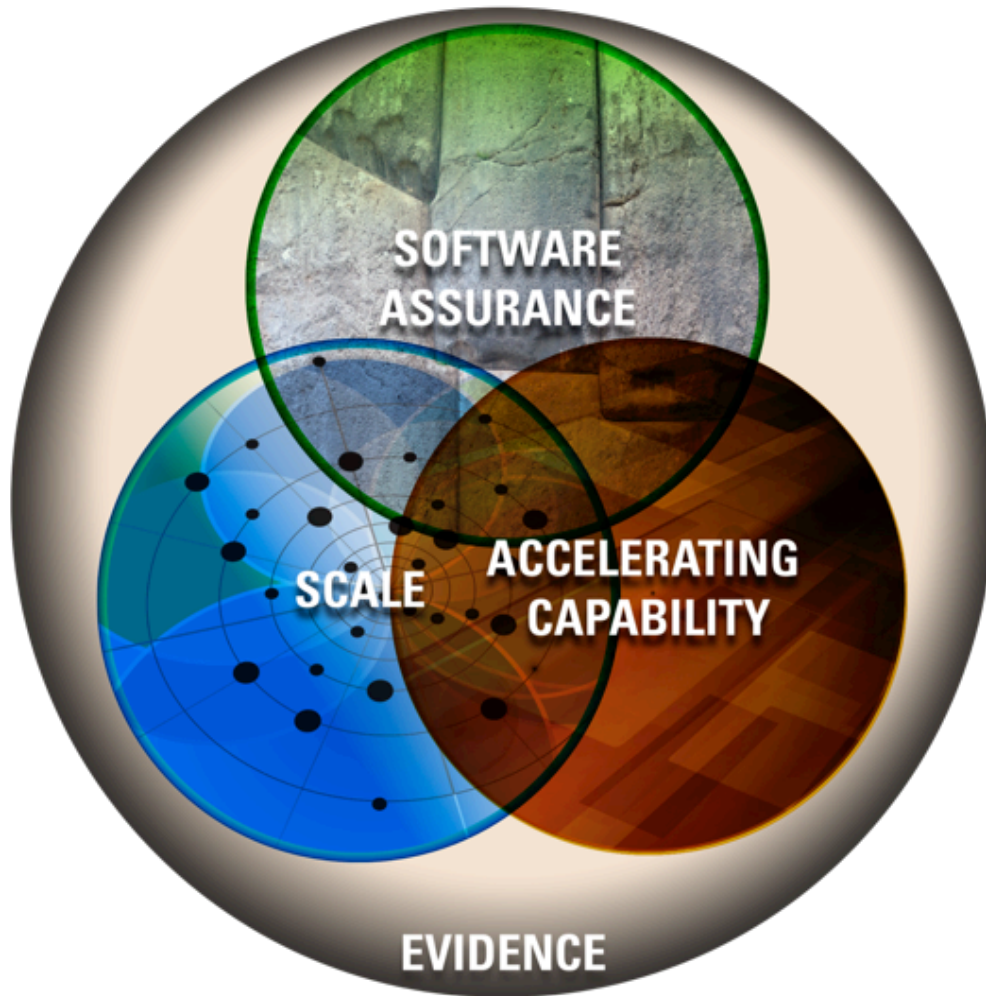


# Architecture-Centric Quality Attribute Analyses

Single Annotated Architecture Model Addresses  
Impact Across Operational Quality Attributes



# Conclusion



- Software architecture principles and their importance persist.
- Change brings new challenges.
- Software architecture practices and research are key to meeting these challenges.
- Much remains to be done.



# This Is the Work of Many

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## At the SEI

- Felix Bachmann
- Stephany Bellomo
- Peter Feiler
- Ian Gorton
- James Ivers
- Rick Kazman
- John Klein
- Mark Klein
- Grace Lewis
- Ipek Ozkaya
- Rod Nord
- and many more...



# More Information

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## **Related Blogs:**

<http://blog.sei.cmu.edu/archives.cfm/category/architecture>

## **Technical Debt:**

[http://www.sei.cmu.edu/architecture/research/arch\\_tech\\_debt/arch\\_tech\\_debt\\_library.cfm](http://www.sei.cmu.edu/architecture/research/arch_tech_debt/arch_tech_debt_library.cfm)

## **Agile Architecting:**

<https://www.sei.cmu.edu/architecture/research/agile-architecting/index.cfm>

## **Cloudlets:**

<http://www.sei.cmu.edu/mobilecomputing/research/tactical-cloudlets/index.cfm>

## **AADL and Model-Based Engineering:**

<http://www.sei.cmu.edu/architecture/research/model-based-engineering/index.cfm>





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