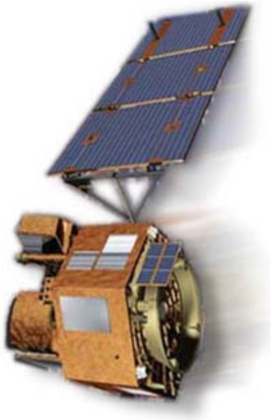
Architecting Systems to Meet Expectations - Managing Quality Attributes to Reduce Risk



Paul R. Croll
Fellow
CSC
pcroll@csc.com

Chair, NDIA Software Industry Experts Panel

Industry Co-Chair NDIA Systems Assurance Committee

Co-Chair, DoD Software in Acquisition Working Group on Software Quality Attributes

Outline

- The Systems Quality Challenge
- Architecture And Quality Defined
- Quality Attribute-Based Approaches To Architecting Systems
- Making The Case For Architectural Quality
- Customer Implications Of Quality-Attribute-Based Architectural Approaches
- Process Maturity And Product Quality
- A Current Concern: Architecting For System Assurance
- Summary

It’s About The Architecture . . .

One of the top ten emerging systemic issues, from fifty-two in-depth program reviews since March 2004, was inadequate software architectures

Source: D. Castellano. Systemic Root Cause Analysis. NDIA Systems Engineering Division Strategic Planning Meeting, December, 2007.

It's Also About Quality . . .

- The NDIA Top Software Issues Workshop examined the current most critical issues in software engineering that impact the acquisition and successful deployment of software-intensive systems
- Two issues emerged that were focused specifically on the relationship between software quality and architecture:
  - Ensure defined quality attributes . . . are addressed in requirements, architecture, and design.
  - Define software assurance quality attributes that can be addressed during architectural trade-offs

Source: G. Draper (ed.), Top Software Engineering Issues Within Department of Defense and Defense Industry. National Defense Industrial Association, Arlington, VA, August 2006.

The Systems Quality Challenge

- If we are to be successful in delivering systems that meet customer expectations, we must:
  - Start as early as possible in the design process to understand the extent to which those expectations might be achieved
  - Develop candidate system architectures and perform architecture trade-offs
  - Define and use a set of quantifiable system attributes tied to customer expectations, against which we can measure success

The Systems Quality Challenge Is A Software Quality Challenge

- Most systems we encounter today contain software elements and most depend upon those software elements for a good portion of their functionality
- Modern systems architecture issues cannot be adequately addressed without considering the implications of software architecture

Architecture Defined

- *The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.*

Source: IEEE 1471-2000, IEEE Recommended Practice for Architectural Description of Software-Intensive Systems. The Institute of Electrical and Electronics Engineers, Inc., New York, NY, 2000.

- *The set of all of the most important, pervasive, higher-level, strategic decisions, inventions, engineering trade-offs, assumptions, and their associated rationales concerning how the system meets its allocated and derived product and process requirements*

Source: D. Firesmith, P. Capell, D. Falkenthal, C. Hammons, D. Latimer, and T. Merendino. The Method-Framework for Engineering System Architectures (MFESA): Generating Effective and Efficient Project-Specific System Architecture Engineering Methods, 2008.

Quality Defined

- *Software quality: The degree to which software possesses a desired combination of attributes.*

Source: IEEE Standard 1061-1992. Standard for a Software Quality Metrics Methodology. New York: Institute of Electrical and Electronics Engineers, 1992.

- *Software product quality: The totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs.*

Source: ISO/IEC 9126-1: Information Technology - Software product quality - Part 1: Quality model. ISO, Geneva Switzerland, 2001.

Quality Attribute-Based Approaches To Architecting Systems

- *Developing systematic ways to relate the software quality attributes of a system to the system's architecture provides a sound basis for making objective decisions about design tradeoffs and enables engineers to make reasonably accurate predictions about a system's attributes that are free from bias and hidden assumptions. The ultimate goal is the ability to quantitatively evaluate and trade off multiple software quality attributes to arrive at a better overall system.*

Source: M. Barbacci, M. Klein, T. Longstaff, and C. Weinstock. Quality Attributes, CMU/SEI-95-TR-021. Software Engineering Institute, Carnegie Mellon University, December 1995.

Relationships Between Attributes

- Collaboration
  - Increasing the degree to which one attribute is realized increases the realization of another
- Damage
  - Increasing the degree to which one attribute is realized decreases the realization of another
- Dependency
  - The degree to which one attribute is realized, is dependent upon the realization of at least some sub-characteristics of another

Source: X. Franch and J. Carvallo. "Using Quality Models in Software Package Selection", IEEE Software, pp. 34-41. New York: Institute of Electrical and Electronics Engineers, 2003.

Optimization Among Quality Attributes

- Example: A large telecommunication application
  - Good optimization (Collaboration)
    - balance among multiple quality attributes, such as maintainability, performance and availability
  - Poor optimization (Damage)
    - Focusing solely on maintainability often results in poor system performance
    - Focusing on performance and availability alone may result in result in poor maintainability
- Explicit architectural decisions can facilitate optimization among quality attributes

Source: D. Häggander, L. Lundberg, and J. Matton, "Quality Attribute Conflicts - Experiences from a Large Telecommunication Application," Proceedings of the Seventh International Conference on Engineering of Complex Computer Systems (ICECCS'01), New York: Institute of Electrical and Electronics Engineers, 2001.

Understanding Quality In The Context Of Architectural Structures

- Structures for describing architectures
  - *Functional structure* is the decomposition of the functionality that the system needs to support
  - *Code structure* is the code abstractions from which the system is built
  - *Concurrency structure* is the representation of logical concurrency among the components of the system
  - *Physical structure* is just that, the structure of the physical components of the system
  - *Developmental structure* is the structure of the files and the directories identifying the system configuration as the system evolves
- Using architectural structures to understand quality
  - *Concurrency and Physical* structures are useful in understanding system Performance
  - *Concurrency and Code* structures are useful in understanding system Security
  - *Functional, Code, and Developmental* structures are useful in understanding system Maintainability

Source: L. Bass and R. Kazman, Architecture-Based Development, CMU/SEI-99-TR-007. Software Engineering Institute, Carnegie Mellon University, April 1999.

Attribute-Driven Design

- Attribute-Driven Design (ADD) produces an initial software architecture description from a set of design decisions that show:
  - Partitioning of the system into major computational and developmental elements
  - What elements will be part of the different system structures, their type, and the properties and structural relations they possess
  - What interactions will occur among elements, the properties of those interactions, and the mechanisms by which they take place
- In the very first step in ADD, *quality attributes requirements* are expressed as the system's desired measurable quality attribute response to a specific stimulus
- Knowing these requirements for each *quality attribute* supports the selection of design patterns and tactics to achieve those requirements

Source: R. Wojcik, F. Bachmann, L. Bass, P. Clements, P. Merson, R. Nord, and B. Wood, Attribute-Driven Design (ADD), Version 2.0, CMU/SEI-2006-TR-023. Software Engineering Institute, Carnegie Mellon University, November 2006.

Understanding The Consequences Of Architectural Decisions With Respect To Quality Attributes

- The Architecture Tradeoff Analysis Method[SM] (ATAM[SM]) is dependent upon quality attribute characterizations, like those produced through ADD, that provide the following information about each attribute:
  - The stimuli to which the architecture must respond
  - How the *quality attribute* will be measured or observed to determine how well it has been achieved
  - The key architectural decisions that impact achieving the *attribute requirement*
- ATAM takes proposed architectural approaches and analyzes them based on quality attributes
  - generally specified in terms of scenarios addressing stimuli and responses
    - Use case scenarios, describing typical uses of the system
    - Growth scenarios, addressing planned changes to the system
    - Exploratory scenarios, addressing any possible extreme changes that would stress the system
- ATAM also identifies sensitivity points and tradeoff points

Source: R. Kazman, M. Klein, and P. Clements, ATAM: Method for Architecture Evaluation, CMU/SEI-2000-TR-004, Software Engineering Institute, Carnegie Mellon University, August 2000.

Making The Case For Architectural Quality

- The Quality Case
  - The set of claims, supporting arguments, and supporting evidence that provide confidence that the system will in fact demonstrate its expected *quality characteristics*
  - Common types of quality cases include:
    - *safety cases*
    - *security cases*
    - *assurance cases*
- The Architectural Quality Case
  - The *architectural* claims, supporting arguments, including architectural decisions and tradeoffs, architectural representations, and demonstrations that the architecture will exhibit its expected *quality characteristics*

Source: D. Firesmith, P. Capell, D. Falkenthal, C. Hammons, D. Latimer, and T. Merendino. The Method-Framework for Engineering System Architectures (MFESA): Generating Effective and Efficient Project-Specific System Architecture Engineering Methods, 2008.

Customer Implications Of Quality-Attribute-Based Architectural Approaches

- Customer *quality requirements* will have been distilled into *architectural drivers* which will have shaped the system architecture
- Tradeoffs will have been made to optimize the realization of important *quality characteristics*, in concert with customer expectations
- The level of confidence that the resultant architecture will meet those expectations will be known
- Customers will be knowledgeable of any *residual risk* they are accepting by accepting the delivered system

Source: R. Wojcik, F. Bachmann, L. Bass, P. Clements, P. Merson, R. Nord, and B. Wood, Attribute-Driven Design (ADD), Version 2.0, CMU/SEI-2006-TR-023. Software Engineering Institute, Carnegie Mellon University, November 2006.

Process Maturity Does Not Guarantee Product Quality

- The CMMI® embodies the process management premise that, *the quality of a system or product is highly influenced by the quality of the process used to develop and maintain it*

Source: CMMI® for Development, Version 1.2, CMU/SEI-2006-TR-008, Software Engineering Institute, Carnegie Mellon University, August 2006

- However:

  Several recent program failures from organizations claiming high maturity levels have caused some to doubt whether CMMI ® improves the chances of a successful project

Source: R. Hefner. CMMI Horror Stories: When Good Projects Go Bad. SEPG Conference, March 2006

. . . But Engineering Discipline Might

- Process maturity can in many cases improve project performance, but special attention to the engineering processes is required to ensure that customer quality expectations are realized in resultant products.

A Current Concern: Architecting For System Assurance

- The challenge:

  Integrating a heterogeneous set of globally engineered and supplied proprietary, open-source, and other software; hardware; and firmware; as well as legacy systems; to create well-engineered integrated, interoperable, and extendable systems whose security, safety, and other risks are acceptable – or at least tolerable.

  Source: P. Croll, "Engineering for System Assurance – A State of the Practice Report," Proceedings of the 1st Annual IEEE Systems Conference. New York: Institute of Electrical and Electronics Engineers, April 2007

- The vision:

  The requirements for assurance are allocated among the right systems and their critical components, and such systems are designed and sustained at a known level of assurance.

  Source: K. Baldwin. DOD Software Engineering and System Assurance New Organization – New Vision, DHS/DOD Software Assurance Forum, March 8, 2007

Architectural Principles For Assurance

- Isolate critical components from less-critical components
- Make critical components easier to assure by making them smaller and less complex
- Separate data and limit data and control flows
- Include defensive components whose job is to protect other components from each other and/or the surrounding environment
- Beware of maximizing performance to the detriment of assurance

Source: National Defense Industrial Association System Assurance Guidebook, Version 0.89. National Defense Industrial Association, System Assurance Committee, Arlington, Virginia February 2008.

Summary

- If we are to be successful in delivering systems that meet customer expectations, we must:
  - Start as early as possible in the design process to understand the extent to which those expectations might be achieved
  - Define a set of *quantifiable quality attributes* tied to customer expectations, against which we can measure success
  - Develop candidate system architectures and perform architecture trade-offs using those attributes

For More Information . . .

Paul R. Croll
CSC
10721 Combs Drive
King George, VA 22485-5824

Phone: +1 540.644.6224
Fax: +1 540.663.0276
e-mail: pcroll@csc.com