When Does Requirements Volatility Stop All Forward Progress?

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Overview

• **Requirements: what are they and what are their characteristics?**
• Requirements volatility: all changes are not “equal”
• Quantitative observations about requirements volatility
• Conclusions

*Applies to systems, complex systems, and systems of systems (SoSs)*
What is a Requirement

  A statement that identifies a product or process operational, functional, or design characteristic or constraint, which is unambiguous, testable or measurable, and necessary for product or process acceptability (by consumers or internal quality assurance guidelines).

- **SEI [CMMI 2001]:**
  1. A condition or capability needed by a user to solve a problem or achieve an objective.
  2. A condition or capability that must be met or possessed by a product or product component to satisfy a contract, standard, specification, or other formally imposed documents.
  3. A documented representation of a condition or capability as in (1) or (2).

[IEEE 610.12-1990]
Cockburn Hierarchy as it Relates to Requirements
Hierarchy of Requirements

Capability

General Req$_1$

Component System$_1$
- CS1 req$_1$
- CS1 req$_2$
  ...
- CS1 req$_N$

Component System$_2$
- CS2 req$_1$
- CS2 req$_2$
  ...
- CS2 req$_N$

Component System$_3$
- CS3 req$_1$
- CS3 req$_2$
  ...
- CS3 req$_N$

... 

Component System$_n$
- CSN req$_1$
- CSN req$_2$
  ...
- CSN req$_N$
Types of Requirements

- Functional
- Interfaces
- Level of service (e.g., performance targets, interoperability*, security*, safety)
- Design constraints
- Quality attributes
- Acquisition (e.g., cost and schedule)
- Process

* Cited as the most important areas for SoSs [Kriegel, 1999].
Some Key Purposes for Requirements

• Specify needed system capabilities
• Coordinate work performed by multiple organizations/vendors (or to prevent incompatible design decisions within the system architecture)
• Ensure interoperability and compatibility between system components
• Control cost/schedule
• Establish acceptance criteria for development work performed
Why Do Requirements Change*?

- Changing business/user needs
  - Environment changes – Market trends
  - Legislative changes – New technology
- Incorporation of COTS upgrades
- Resolve requirements conflicts
- Specify missing requirements
- Manage cost/schedule
- Adjustment of requirements in response to design decisions
- Derivation of lower level requirements as solution evolves

* “Requirements change” as investigated here is the evolution of requirements over time, not the resolution of defective requirements
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Requirements Volatility Definitions

• Requirements change
  – Change to a baselined set of requirements
  – For projects where requirements are not baselined (e.g., agile projects), change to an operational capability

• Volatility
  – Rate of requirements change over time or per increment of development

• Impact of volatility
  – Effort and schedule changes other than those associated with actual effort/schedule required to implement the requirement
  – Includes
    • Rework
      – Work already completed for current increment
      – Increased defect densities associated with incomplete change analysis/attempted schedule compression
    • Delays due to related approval and contract modification activities
    • Productivity impacts due to project staff frustration
Influences on Effort to Change a Capability/Requirement

- Scope of change
- Level of change
- Number of components affected by requirement change
- Targeted increment for requirement implementation (current vs. future)
- Impact of change for each affected component
  - Number of component levels affected
  - Number of lower level suppliers affected
- How tightly coupled requirements are to supplier contracts at various levels
Influences on Schedule Required to Change a Capability/Requirement

- Time to assess impact of proposed requirement change
- Time to approve proposed requirement change (e.g., number of approvers)
- Time to flow down requirement change (e.g., number of required contract changes)
- Time to implement requirement change (e.g., scope of requirement change/required rework)
Influences on System Requirements Volatility

- Number of system missions/objectives
- Stability of system missions/objectives (e.g., business needs)
- System architecture stability/maturity
- Stability/maturity of system components
- Technology maturity/changes
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Scenarios for Analysis of Impacts

1. **Early**: Proposed requirement change received during requirements identification/analysis phase
   a. Limited scope
   b. Pervasive scope/no outside suppliers affected
   c. Pervasive scope/outside suppliers affected

2. **Middle**: Proposed requirement change received during implementation phase
   a. Limited scope
   b. Pervasive scope/no outside suppliers affected
   c. Pervasive scope/outside suppliers affected

3. **Late**: Proposed requirement change received during integration and test phase
   a. Limited scope
   b. Pervasive scope/no outside suppliers affected
   c. Pervasive scope/outside suppliers affected
Findings of System Dynamics Models Used to Evaluate Requirements Volatility

• **Ferreira Model***
  – Evaluates the effects of requirements volatility on a software project’s cost, schedule, and quality
  – Based on survey data from 232 projects
    • Over 78% of respondents experienced some level of requirements volatility
    • Average increase in software size due to volatility: 32%
  – Once the design process begins, the impact of requirements change is progressively greater
  – Captures low morale impacts (reduced productivity, higher error rates)

• **Madachy et al** Model
  – Reduction of impacts by deferring as much change as possible to future increments
  – Effort and schedule impacts when using various size teams in a hybrid agile/plan-driven approach

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Findings of System Dynamics Models Used to Evaluate Requirements Volatility

• **Brooks’ Law Model***
  - Adding more people late in the game can make the project later
  - Due to
    • Reduced productivity of initial staff to train new staff
    • Reduced productivity of new staff

• **Repenning’s Model**
  - Impact of fire fighting techniques to handle late changes
  - Leads to
    • Increased overtime
    • Staff burn-out and turnover
    • Continued fire fighting to work new issues introduced in previous fire fighting activities

Range of Requirements
Volatility Profiles

- Continual periodic change across increment
- Single mid-increment re-alignment
- Deferral to next increment
Average Change Processing Time: Based on Data From Two SoSs

- Plan for continual change and the development of future baselines
- Most SoS changes are typically across groups and may also require contract modifications to flow down changes to multiple suppliers and vendors
- Must also negotiate changes with strategic partners
- Need to minimize impacts to increment currently under development
- Need to continually monitor evolution (changes in) the component systems for potential SoS impacts
“Cost” to Change a Requirement with Relatively Local Scope

When comprehensive regression tests required to verify change (e.g., re-execution of acceptance tests), costs can exceed 100x the nominal effort to change the requirement.
Risk-Driven Scalable Spiral Model:
Increment View

Rapid Change

Foreseeable Change (Plan)

Short Development Increments

Increment N Baseline

High Assurance

Stable Development Increments

Short, Stabilized Development of Increment N

Increment N Transition
Hybrid Process for Managing Increments

Unforeseeable Change (Adapt)

Rapid Change

Foreseeable Change (Plan)

Short Development Increments

Increment N Baseline

Stable Development Increments

High Assurance

Deferrals

Short, Stabilized Development of Increment N

Artifacts

Concerns

Verification and Validation (V&V) of Increment N

FutureIncrementBaselines

Future V&V Resources

Increment N Transition/Operations and Maintenance

Current V&V Resources

Continuous V&V

Future V&V Resources

Agile Rebaselining for Future Increments

DI_{N+1} Baseline LCA

DI_{N+1} Re-Baselined LCA

DI_{N} LCA

DI_{N} IOC

DI_{N} Baseline LCA

DI_{N} IOC
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Conclusions

• Initial Question: When does requirements volatility stop all forward progress?
• Answer: It depends…
  – Continual, unending change: Probably for projects with higher change rates
  – A “few” controlled bursts: Maybe, but not for long
  – Deferral to next increment: Probably not
Conclusions (continued)

• “Change” is required to evolve systems in needed directions
• How change is handled can affect impact to cost, schedule, and developer productivity
  – Architecting for change
  – Having adequate staff very familiar with the system
  – Immediate change vs. deferral to future increments
• Business processes that can significantly add to change “overhead”
  – Starting development before key stakeholders have agreed on core requirements
  – Starting detailed development before determining architecture feasibility
  – Requiring contract modifications to implement changes
  – Adding changes late in a development cycle