When Does Requirements Volatility Stop All Forward Progress?

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Jo Ann Lane and Barry Boehm
University of Southern California
Center for Systems and Software Engineering
http://csse.usc.edu

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

- **IEEE Std 1220-1998: Standard for Application and Management of the Systems Engineering Process**

  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).

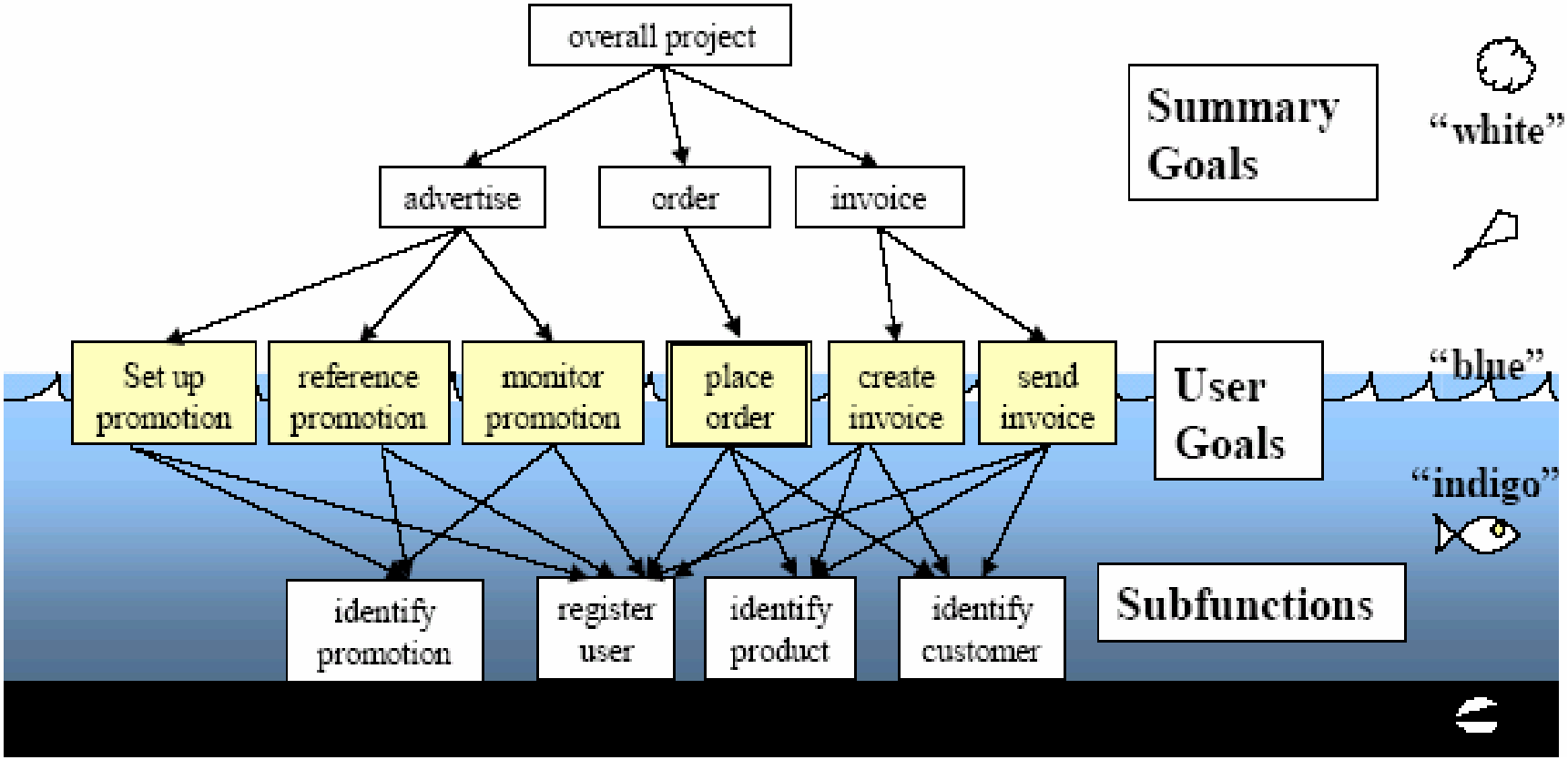
- **SEI [CMMI 2001]:**

  (1) A condition or capability needed by a user to solve a problem or achieve an objective.

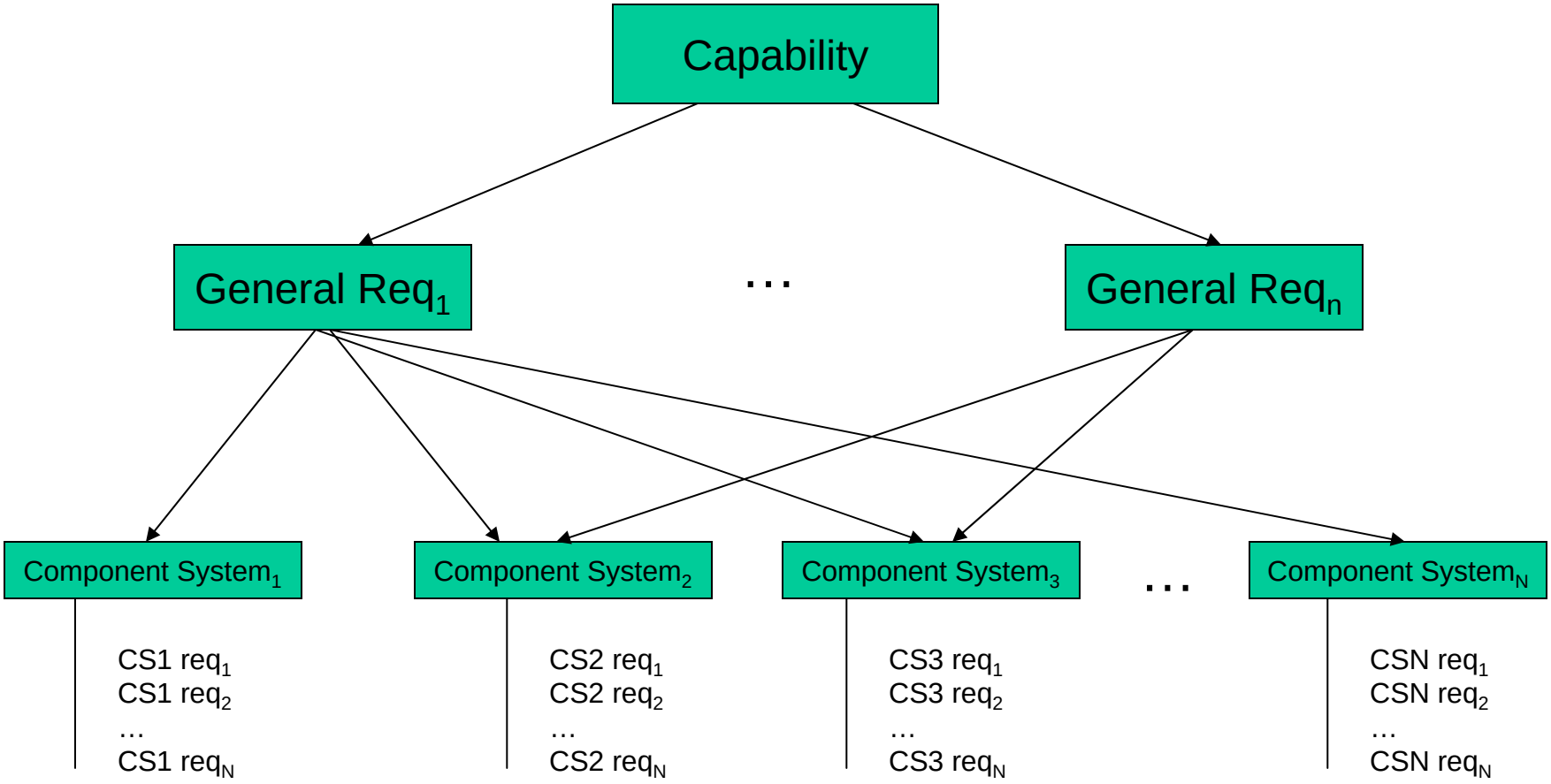
  (2) A condition or capability that must be met or possessed by a product or product component to satisfy a contract, standard, specification, or other formally imposed documents.

  (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



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

* Ferreira S, Collofello J, Shunk D, Mackulak G, Wolfe P. Utilization of Process Modeling and Simulation in Understanding the Effects of Requirements Volatility in Software Development. *Proceedings of the 4th International Workshop on Software Process Simulation and Modeling*, Portland OR, 2003., 2002.

** Madachy, R., Boehm, B., Lane, J. (2006); "Assessing Hybrid Incremental Processes for SISOS Development", USC CSSE Technical Report USC-CSSE-2006-623.

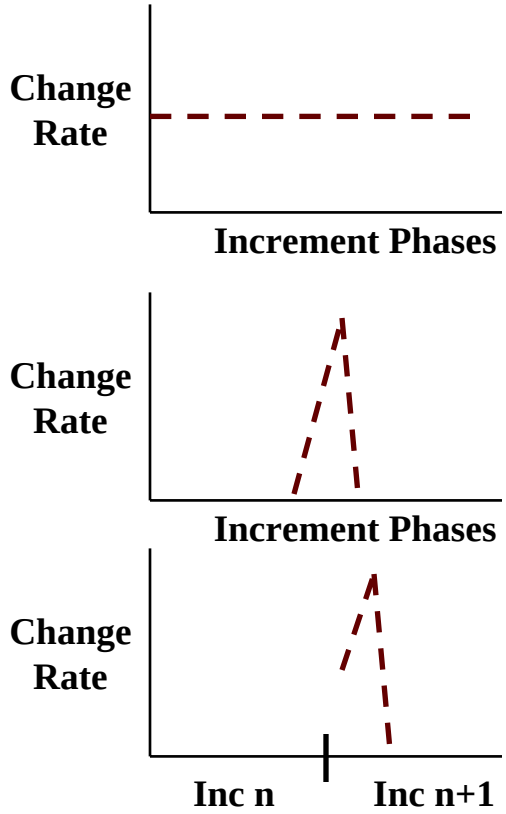
Findings of System Dynamics Models Used to Evaluate Requirements Volatility

- **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

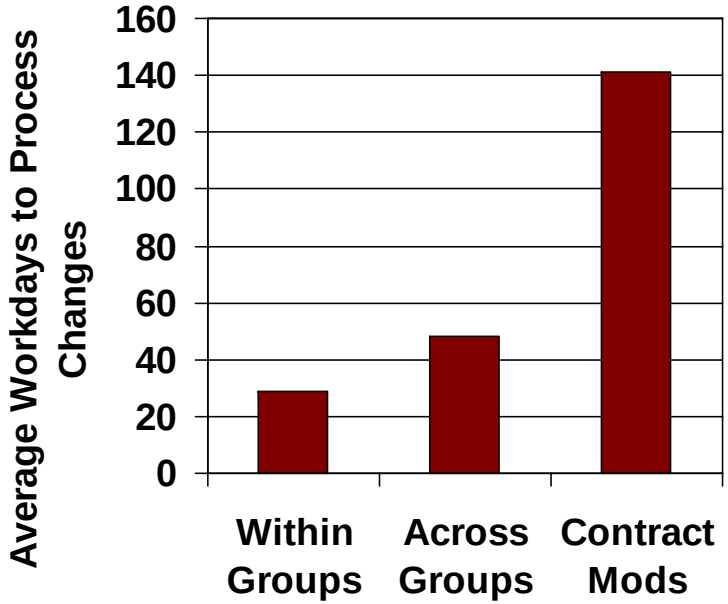
* Madachy, R., Software Process Dynamics, Wiley/IEEE Computer Society Press, 2007.
** Repenning, N., "Understanding Fire Fighting in New Product Development", Journal of Product Innovation Management, 18, pp. 285-200, 2001.

Range of Requirements Volatility Profiles

- Continual periodic change across increment
- Single mid-increment re-alignment
- Deferral to next increment

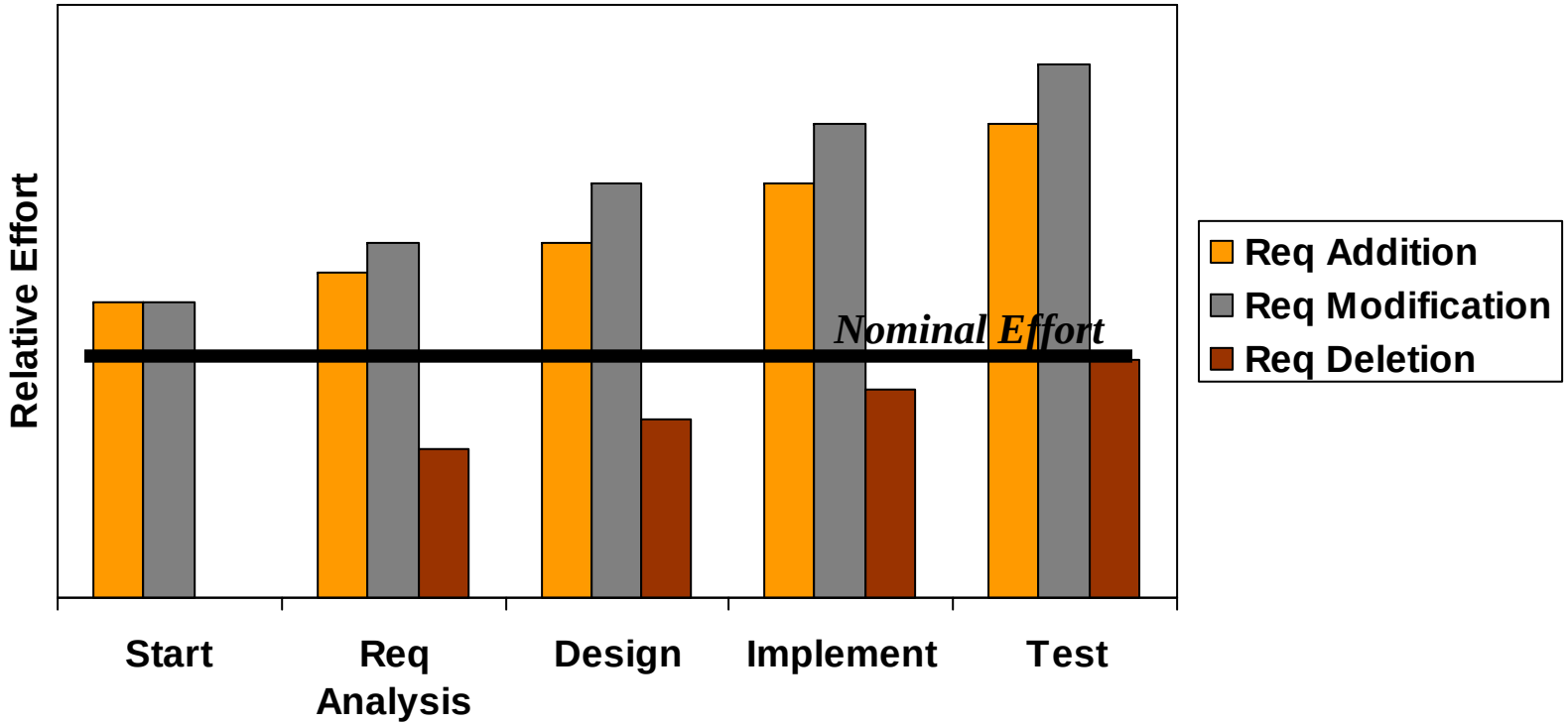


Average Change Processing Time: Based on Data From Two SoSs



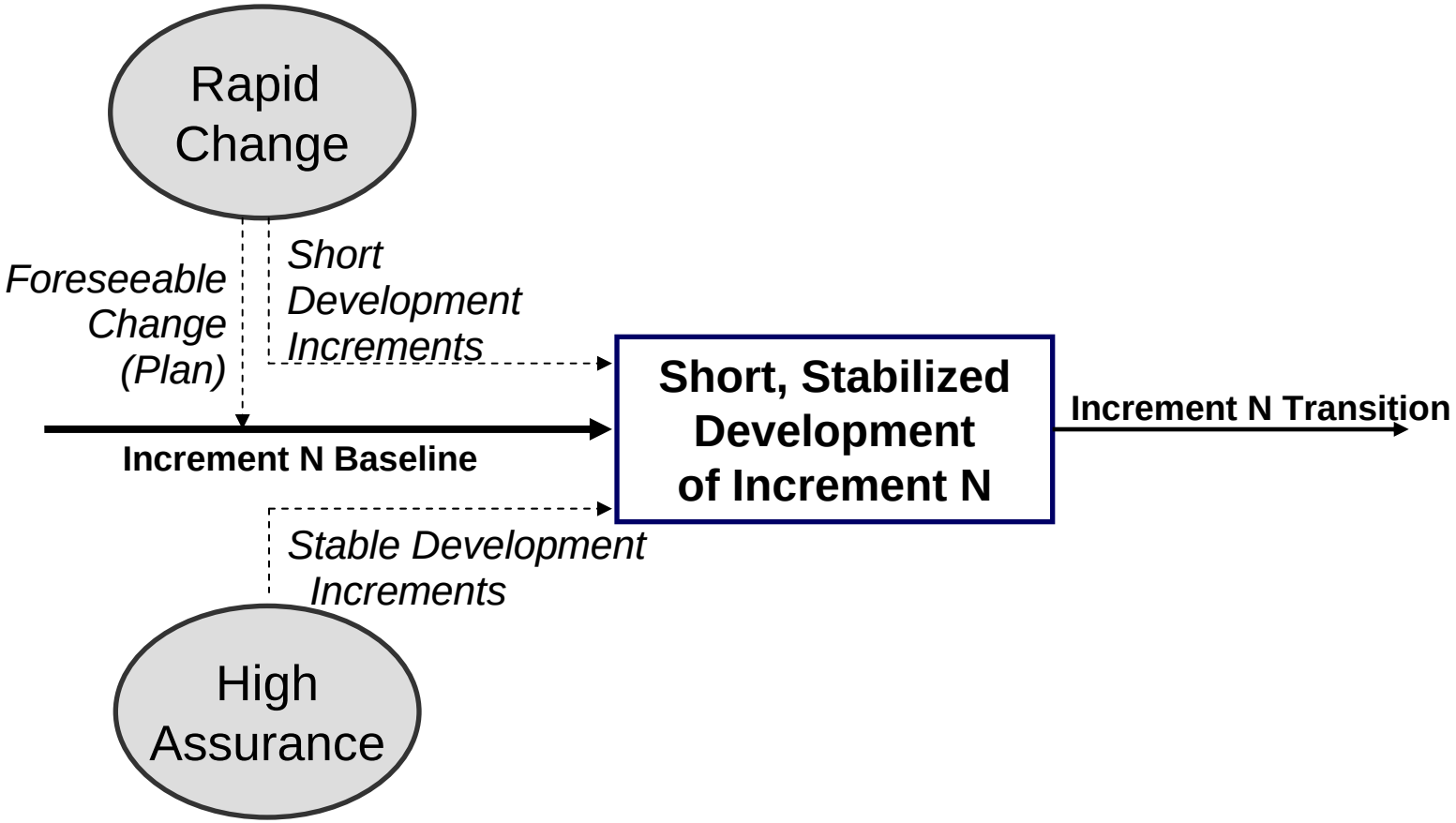
- Plan for continual change and the development of future baselines
- Most SoS changes are typically across groups and may also require contract modifications to flow down changes to multiple suppliers and vendors
- Must also negotiate changes with strategic partners
- Need to minimize impacts to increment 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

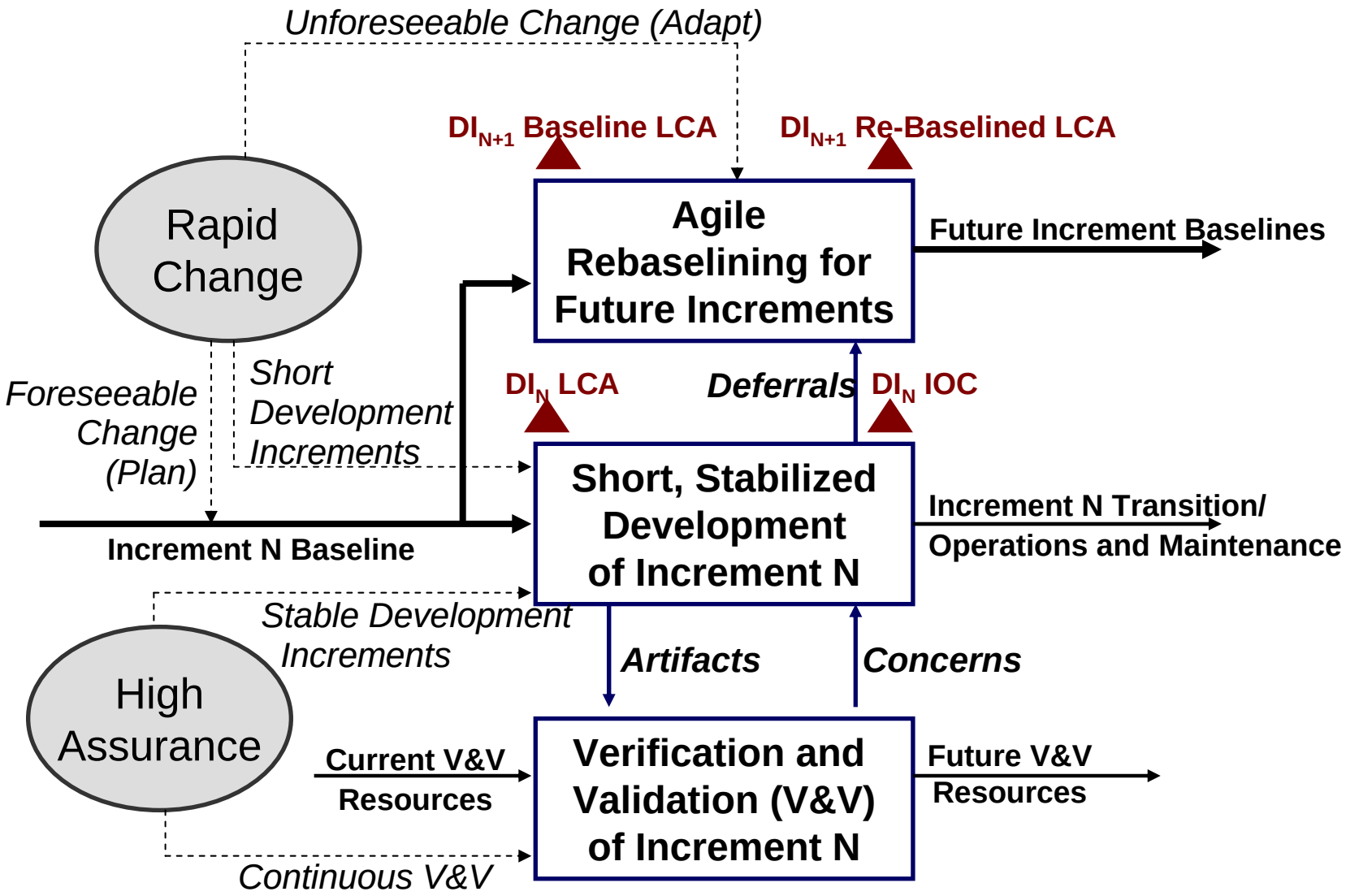


When comprehensive regression tests required to verify change (e.g., re-execution of acceptance tests), costs can exceed 100x the nominal effort to change the requirement

Risk-Driven Scalable Spiral Model: Increment View



Hybrid Process for Managing Increments



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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