Critical Success Factors for Milestone Review Risk Identification

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Summary

- Schedule-based and event-based reviews are risk-prone
- Evidence-based reviews enable early risk resolution
  - They require more up-front systems engineering effort
  - They have a high ROI for high-risk projects
  - They synchronize and stabilize concurrent engineering
  - The evidence becomes a first-class deliverable
    - It requires planning and earned value management
- They can be added to traditional review processes

Types of Milestone Reviews

- Schedule-based reviews (contract-driven)
  - We'll hold the PDR on April 1 whether we have a design or not
  - High probability of proceeding into a Death March
- Event-based reviews (artifact-driven)
  - The design will be done by June 1, so we'll have the review then
  - Large "Death by PowerPoint and UML" event
    - Hard to avoid proceeding with many unresolved risks and interfaces
- Evidence-based commitment reviews (risk-driven)
  - Evidence provided in Feasibility Evidence Description (FED)
    - A first-class deliverable
  - Shortfalls in evidence are uncertainties and risks
  - Should be covered by risk mitigation plans
  - Stakeholders decide to commit based on risks of going forward

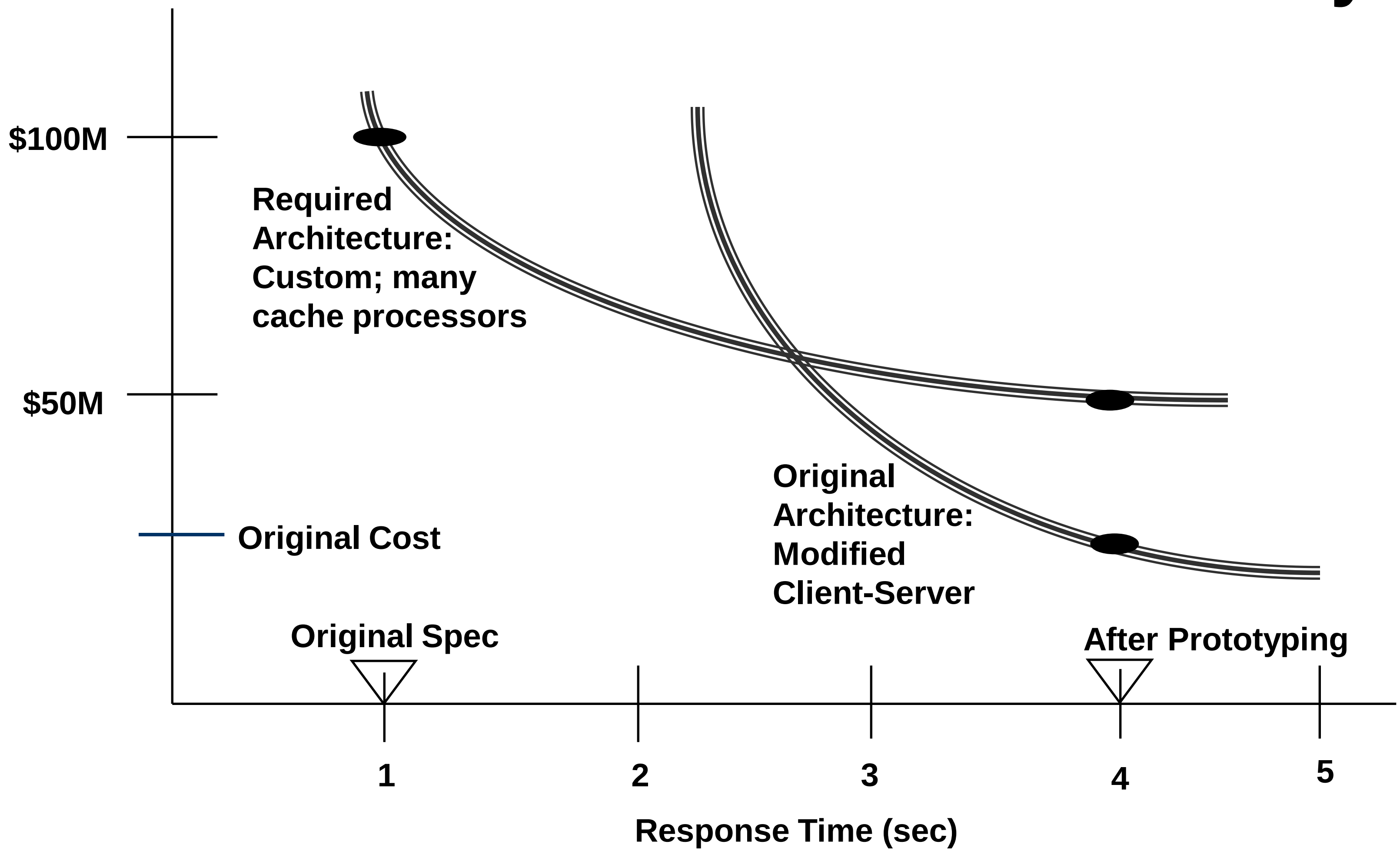
Nature of FEDs and Anchor Point Milestones

- ***Evidence*** **provided by developer and validated by independent experts that:**

  If the system is built to the specified architecture, it will
  - **Satisfy the specified operational concept and requirements**
    - **Capability, interfaces, level of service, and evolution**
  - **Be buildable within the budgets and schedules in the plan**
  - **Generate a viable return on investment**
  - **Generate satisfactory outcomes for all of the success-critical stakeholders**
- **Shortfalls in evidence are uncertainties and risks**
  - **Should be resolved or covered by risk management plans**
- **Assessed in increasing detail at major anchor point milestones**
  - **Serves as basis for stakeholders' commitment to proceed**
  - **Serves to synchronize and stabilize concurrently engineered elements**

Can be used to strengthen current schedule- or event-based reviews

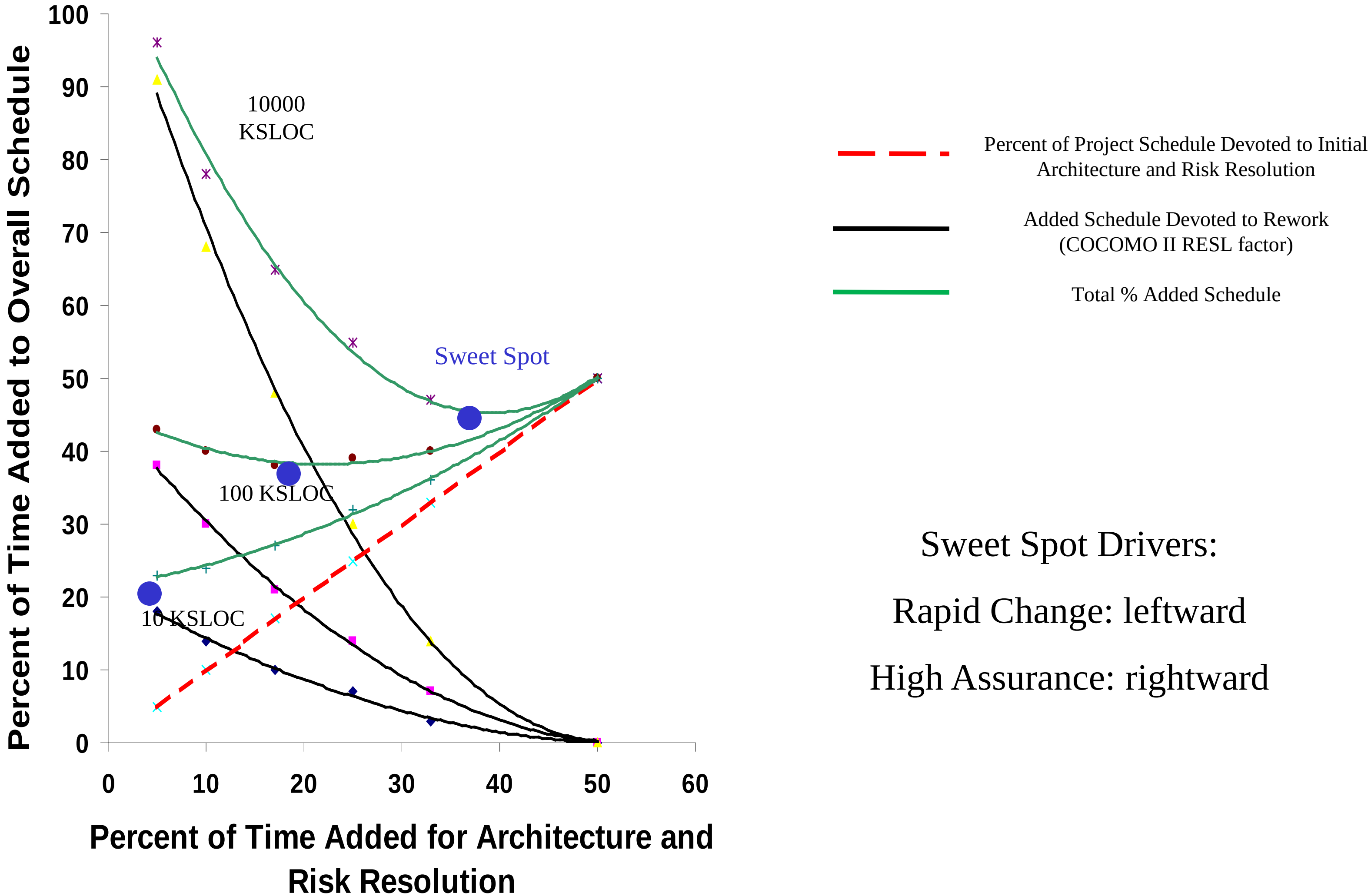
Problems Encountered without FED: 15-Month Architecture Rework Delay



Problems Avoidable with FED

- Attempt to validate 1-second response time
  - Commercial system benchmarking and architecture analysis: needs expensive custom solution
  - Prototype: 4-second response time OK 90% of the time
- Negotiate response time ranges
  - 2 seconds desirable
  - 4 seconds acceptable with some 2-second special cases
- Benchmark commercial system add-ons to validate their feasibility
- Present solution and feasibility evidence at anchor point milestone review
  - Result: Acceptable solution with minimal delay

Need for FED in Large Systems of Systems



Sweet Spot Drivers:

Rapid Change: leftward

High Assurance: rightward

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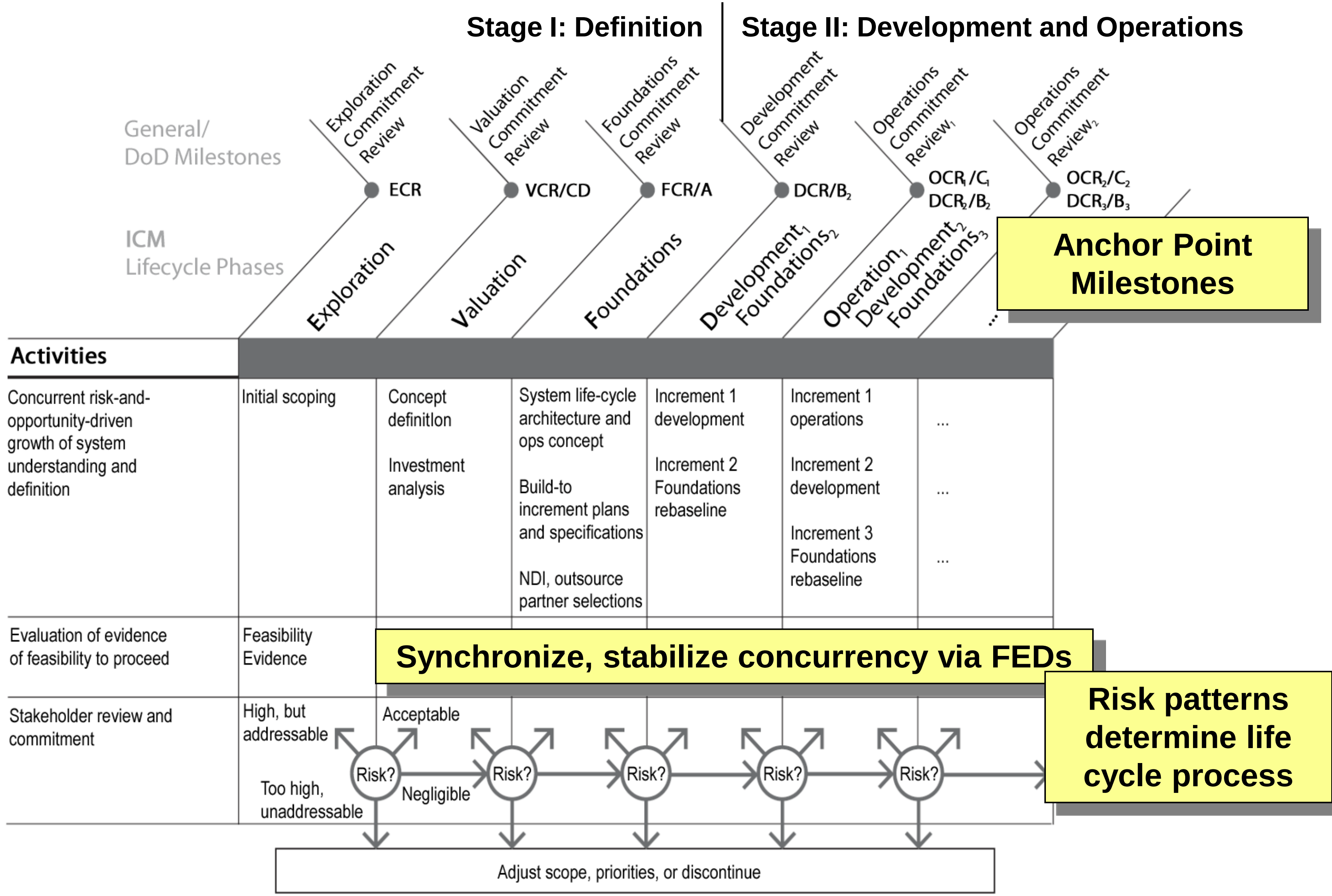
The Incremental Commitment Life Cycle Process: Overview



Nature of Feasibility Evidence

- Not just traceability matrices and PowerPoint charts
- Evidence can include results of
  - Prototypes: of networks, robots, user interfaces, COTS interoperability
  - Benchmarks: for performance, scalability, accuracy
  - Exercises: for mission performance, interoperability, security
  - Models: for cost, schedule, performance, reliability; tradeoffs
  - Simulations: for mission scalability, performance, reliability
  - Early working versions: of infrastructure, data fusion, legacy compatibility
  - Previous experience
  - Combinations of the above
- Validated by independent experts
  - Realism of assumptions
  - Representativeness of scenarios
  - Thoroughness of analysis
  - Coverage of key off-nominal conditions

Common Examples of Inadequate Evidence

1. Our engineers are tremendously creative. They will find a solution for this.
2. We have three algorithms that met the KPPs on small-scale nominal cases. At least one will scale up and handle the off-nominal cases.
3. We'll build it and then tune it to satisfy the KPPs
4. The COTS vendor assures us that they will have a security-certified version by the time we need to deliver.
5. We have demonstrated solutions for each piece from our NASA, Navy, and Air Force programs. It's a simple matter of integration to put them together.

Examples of Making the Evidence Adequate

1. Have the creative engineers prototype and evaluate a solution on some key nominal and off-nominal scenarios.
2. Prototype and evaluate the three examples on some key nominal and off-nominal scenarios
3. Develop prototypes and/or simulations and exercise them to show that the architecture will not break while scaling up or handling off-nominal cases.
4. Conduct a scaled-down security evaluation of the current COTS product. Determine this and other vendors' track records for getting certified in the available time. Investigate alternative solutions.
5. Have a tiger team prototype and evaluate the results of the simple matter of integration.

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FED Development Process Framework

- As with other ICM artifacts, FED process and content are risk-driven
- Generic set of steps provided, but need to be tailored to situation
  - Can apply at increasing levels of detail in Exploration, Validation, and Foundations phases
  - Can be satisfied by pointers to existing evidence
  - Also applies to Stage II Foundations rebaselining process
- Examples provided for large simulation and testbed evaluation process and evaluation criteria

Steps for Developing Feasibility Evidence

A. Develop phase work-products/artifacts
   - For examples, see ICM Anchor Point Milestone Content charts

B. Determine most critical feasibility assurance issues
   - Issues for which lack of feasibility evidence is program-critical

C. Evaluate feasibility assessment options
   - Cost-effectiveness, risk reduction leverage/ROI, rework avoidance
   - Tool, data, scenario availability

D. Select options, develop feasibility assessment plans

E. Prepare FED assessment plans and earned value milestones
   - Try to relate earned value to risk-exposure avoided rather than budgeted cost

"Steps" denoted by letters rather than numbers
to indicate that many are done concurrently

Steps for Developing Feasibility Evidence *(continued)*

F. Begin monitoring progress with respect to plans
   - Also monitor project/technology/objectives changes and adapt plans

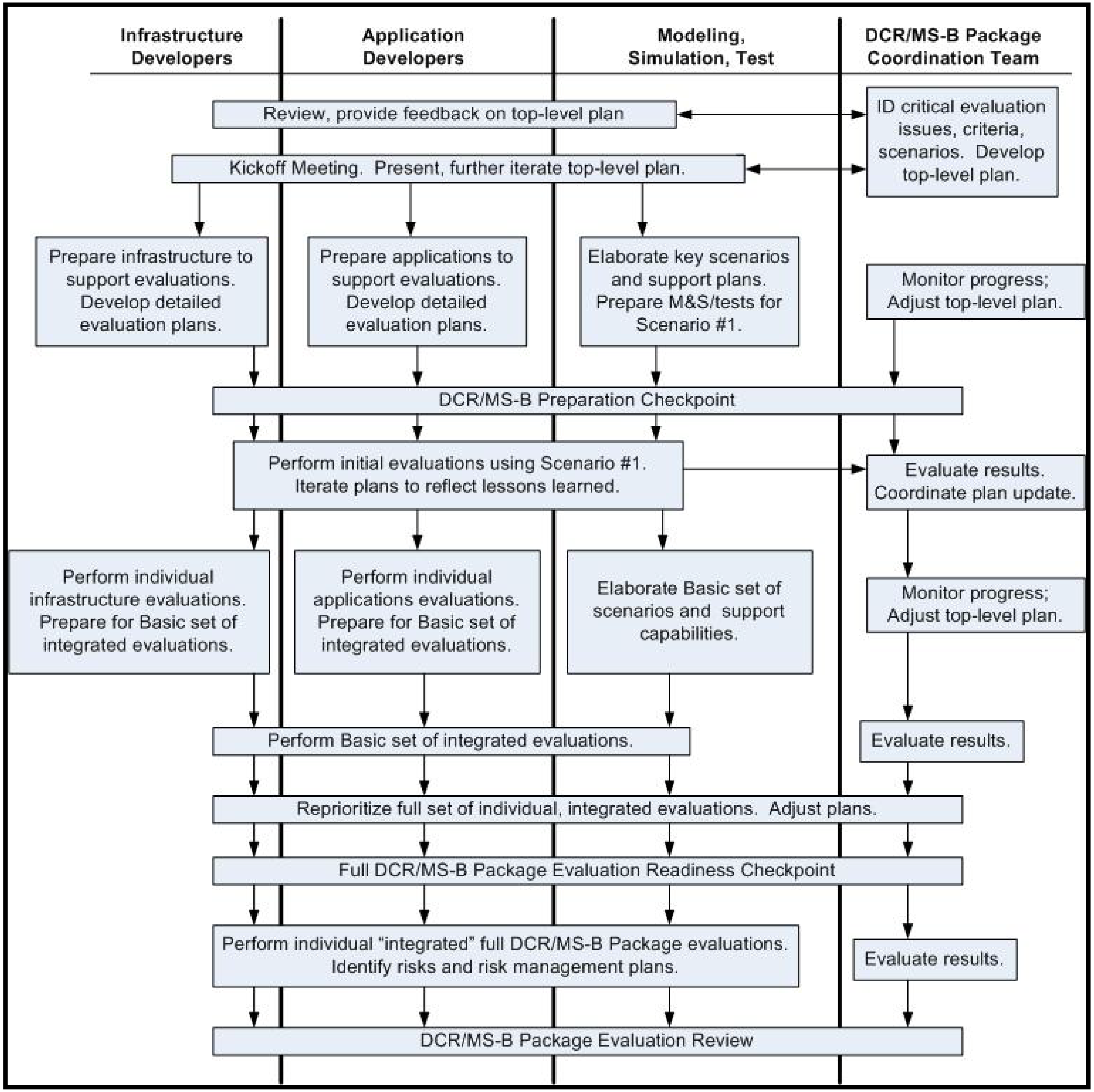
G. Prepare evidence-generation enablers
   - Assessment criteria
   - Parametric models, parameter values, bases of estimate
   - COTS assessment criteria and plans
   - Benchmarking candidates, test cases
   - Prototypes/simulations, evaluation plans, subjects, and scenarios
   - Instrumentation, data analysis capabilities

H. Perform pilot assessments; evaluate and iterate plans and enablers

I. Assess readiness for Commitment Review
   - Shortfalls identified as risks and covered by risk mitigation plans
   - Proceed to Commitment Review if ready

J. Hold Commitment Review when ready; adjust plans based on review outcomes

Large-Scale Simulation and Testbed FED Preparation Example



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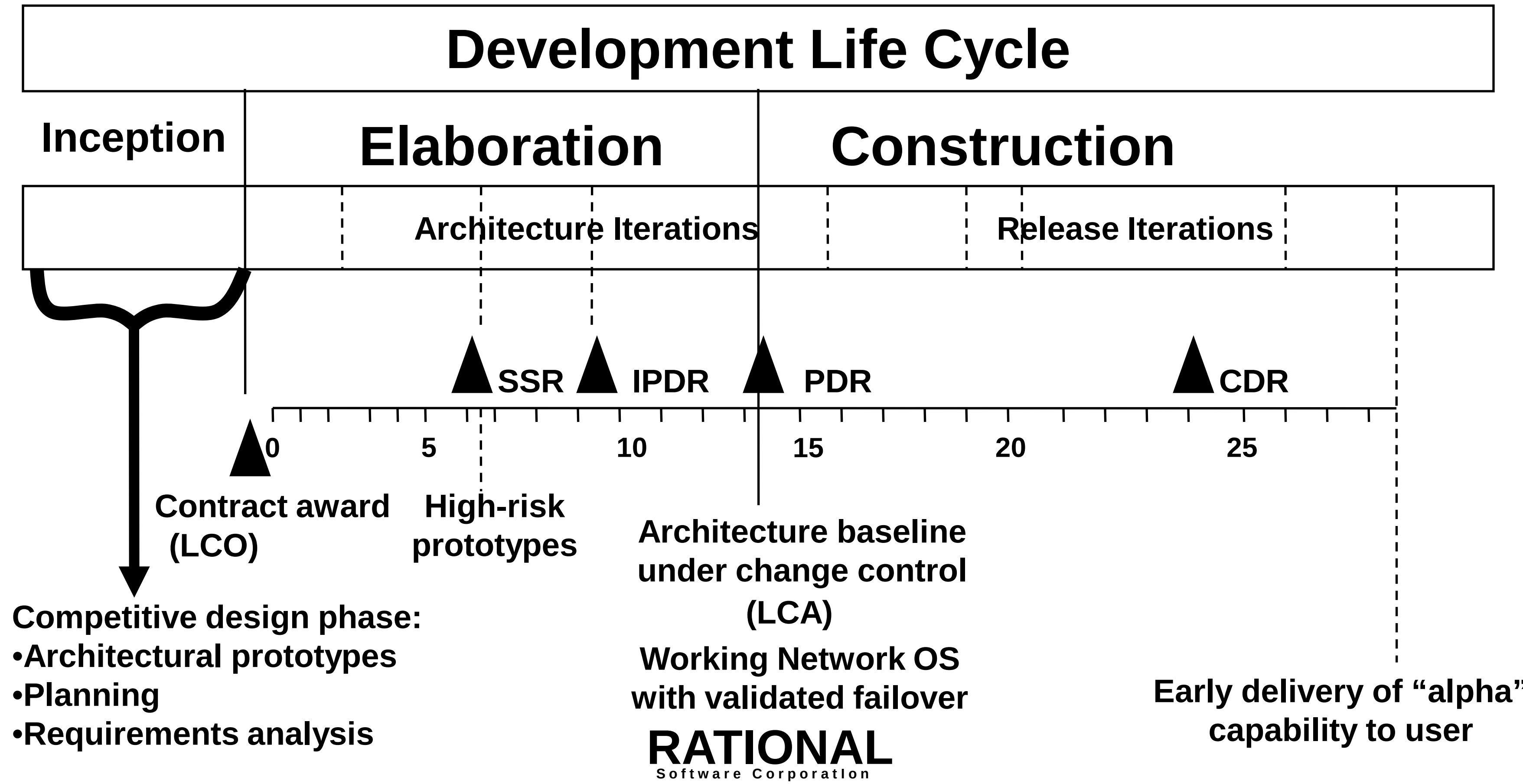
CCPDS-R Reinterpretation of SSR, PDR



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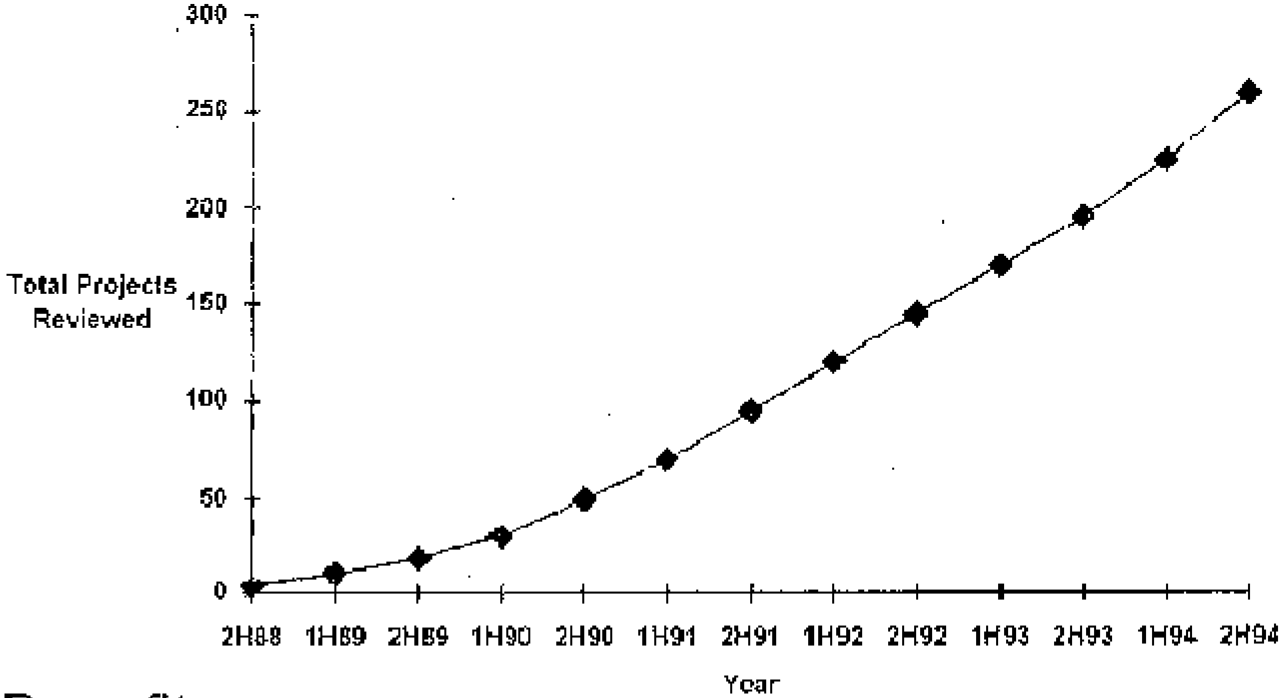
Backup Charts

AT&T Experience with AP Reviews



Benefits:

- Average 10% savings per reviewed project
- Substantially larger savings on a few reviewed projects

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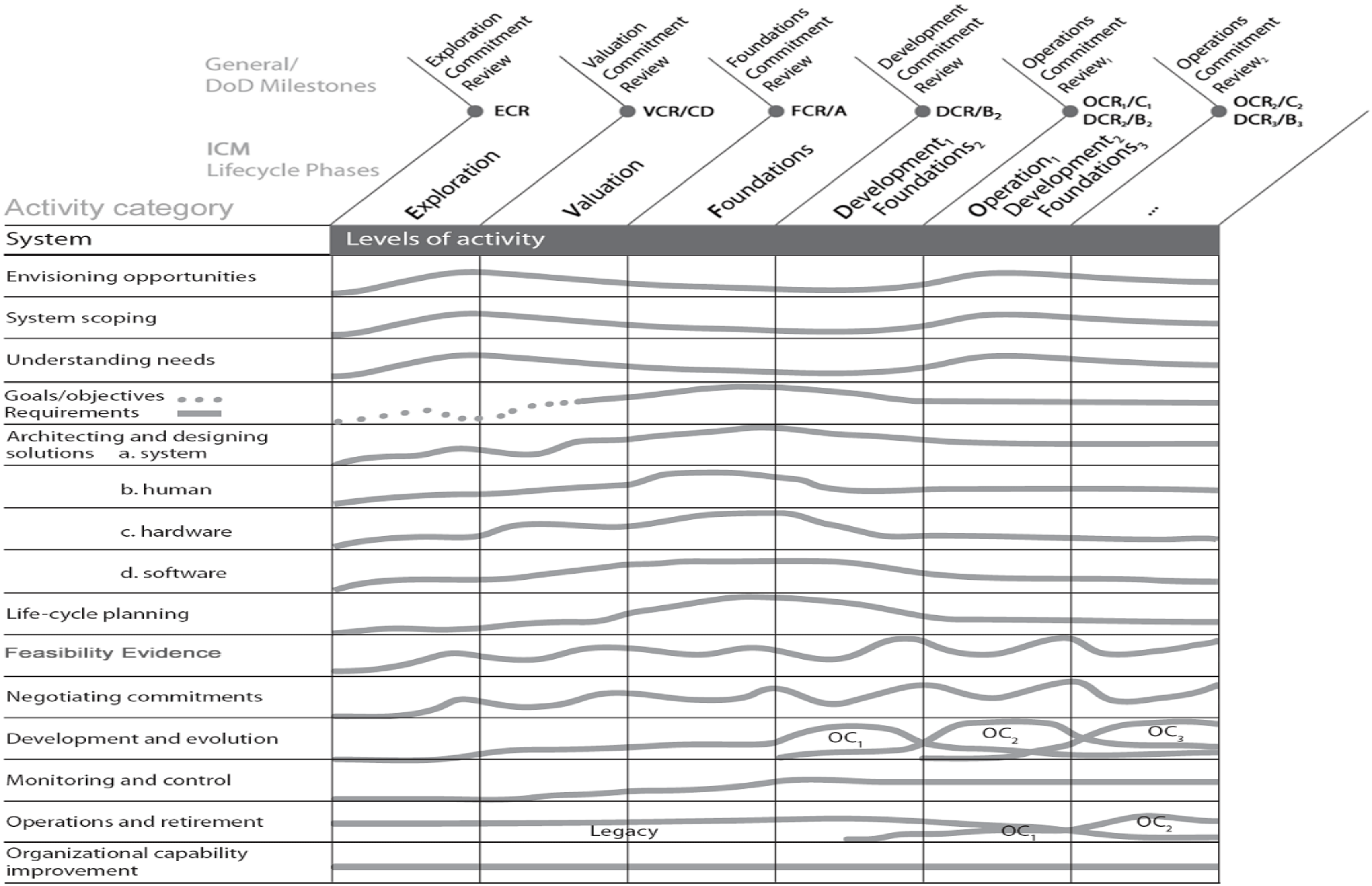
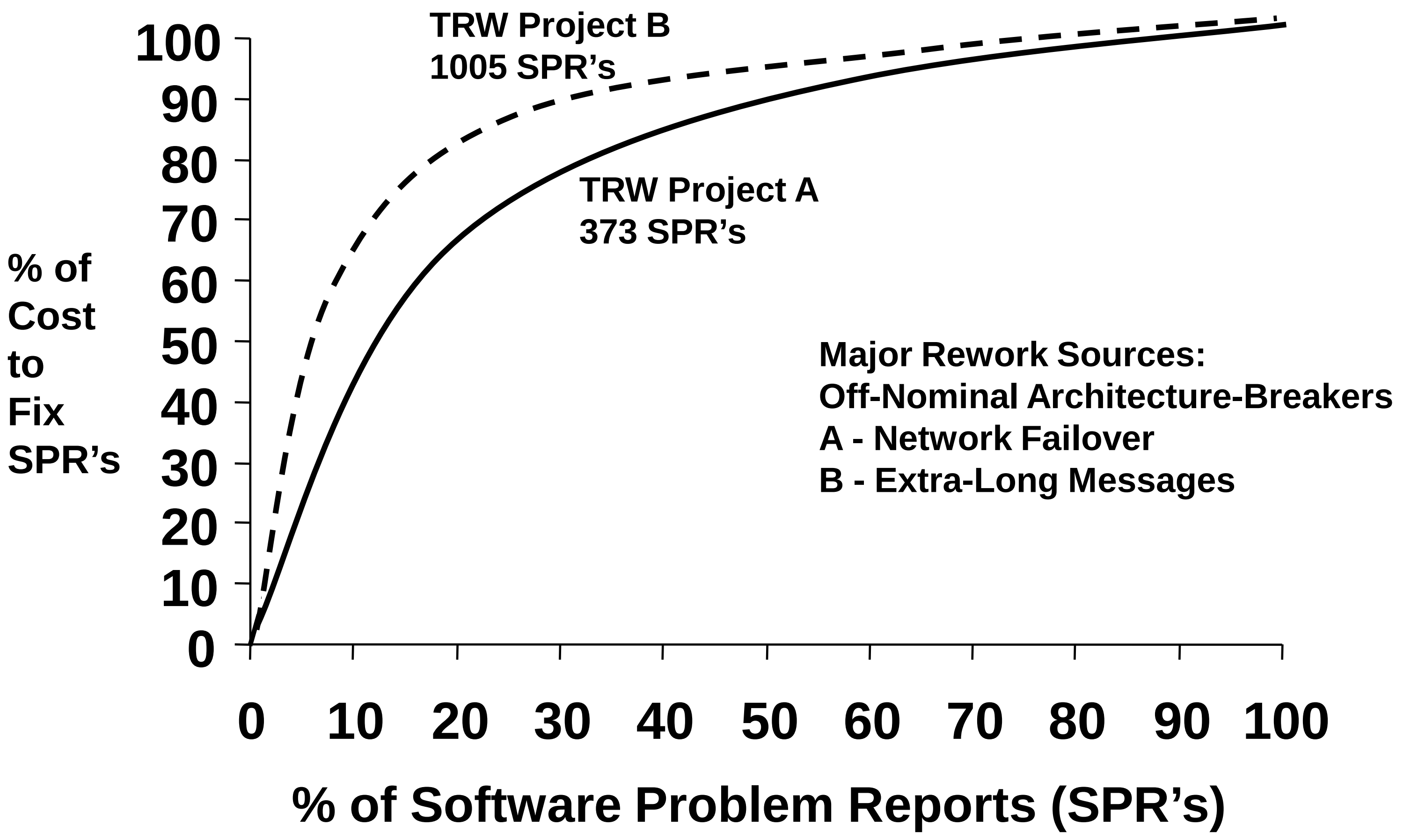
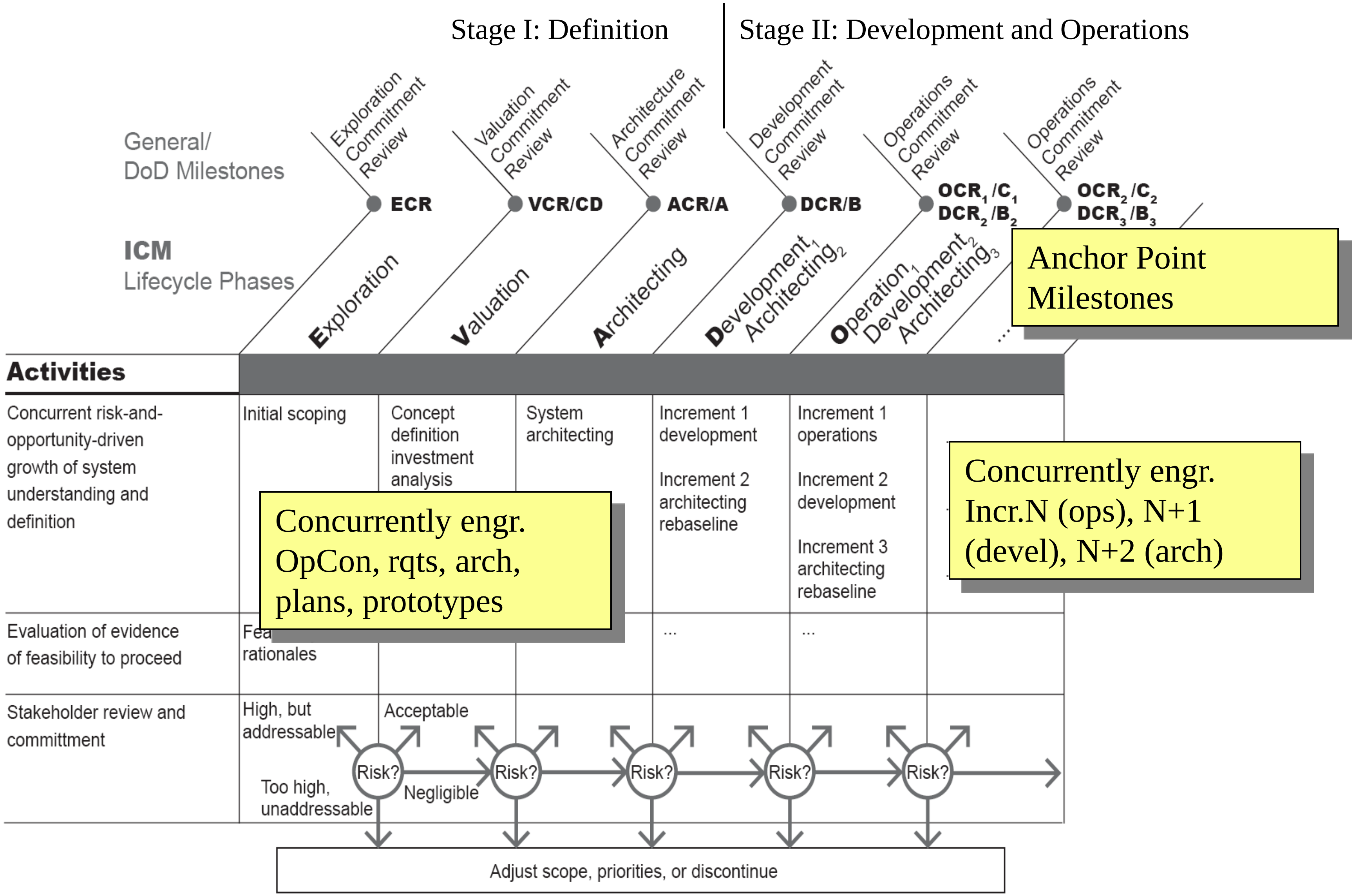
ICM Levels of Activity for Complex Systems

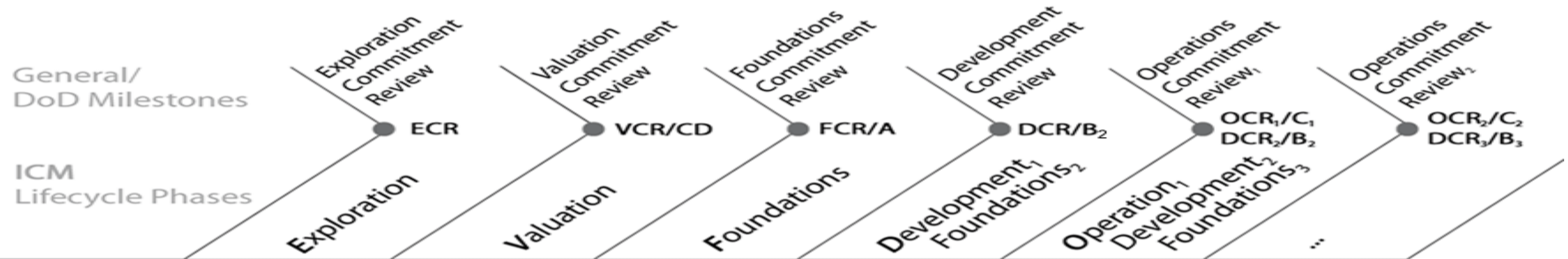


Off-Nominal Architecture-Breakers



The Incremental Commitment Life Cycle Process: Overview





Activities	Exploration	Valuation	Foundations	Development_1 Foundations_2	Operation_1 Development_2 Foundations_3	...
Concurrent risk-and-opportunity-driven growth of system understanding and definition	Exploration and initial scoping of technical, economic, sociopolitical, & managerial aspects of the new initiative - Environment - Competition - Mission needs - Stakeholder readiness	Definition & analysis of scope & solution alternatives - Human, hardware, software factors - Mission analyses, business cases Top level ops concept, requirements, architecture, life cycle plans	Detailed mission scenarios, business work flows, macro-ergonomics aspects NDI, outsource partner selections System/human/hardware/software build-to architecture Detailed ops concept, requirements, architecture, plans: System, increment Foundations (FDN) packages	Use FDN_1 package for stabilized development, V&V of increment 1 Concurrent, agile change processing, rebaselining of $FDN_2 \ldots FDN_N$ packages	Use FDN_2 package for stabilized development, V&V of increment 2 Concurrent, agile change processing, rebaselining of $FDN_3 \ldots FDN_N$ packages Operations and usage monitoring of increment 1	
Evaluation of evidence of feasibility to proceed	Ethnographic, operations analysis, models, simulations, prototypes	Top-level analysis of alternatives, business case	Detailed Feasibility Evidence Description, business case	Increment_1 readiness for operations; FDN_2 Feasibily Evidence Description	Increment_2 readiness for operations; FDN_3 Feasibily Evidence Description	
Stakeholder review and commitment						

Focus of Each Commitment Review

- Each commitment review evaluates the review package created during the current phase
  - Work products
  - Feasibility evidence
    - Prototypes
    - Studies
    - Estimates
    - Basis of estimates

Enter-Next-Phase Commitment Review	Source of Package Information
Valuation (VCR/CD)	Exploration phase
Foundations (FCR/MS-A)	Valuation phase
Development (DCR/MS-B)	Foundations phase
Operations (OCR)	Development phase

- Goal is to determine if
  - Efforts should proceed into the next phase
    - Commit to next phase – risk acceptable or negligible
  - More work should be done in current phase
    - Do more work before deciding to commit to next phase – risk high, but probably addressable
  - Efforts should be discontinued
    - Risk too high or unaddressable

Exploration Phase Activities

- Protagonist identifies need or opportunity worth exploring
  – Service, agency, joint entity
- Protagonist identifies additional success-critical stakeholders (SCSs)
  – Technical, Managerial, Financial, DOTMLPF
- SCS working groups explore needs, opportunities, scope, solution options
  – Materiel and Non-Materiel options
  – Compatibility with Strategic Guidance
  – SCS benefits realization
  – Analysis of alternatives
  – Define evaluation criteria
    - Filter out unacceptable alternatives
    - Identify most promising alternative(s)
    - Identify common-special-case process if possible
  – Develop top-level VCR/CD Package
- Approval bodies review VCR/CD Package

Major starting points in sequence, but activities concurrent

Top-Level VCR/CD Package

- Operations/ life cycle concept
  - Top-level system boundary and environment elements
  - Benefits chain or equivalent
    - Links initiatives to desired benefits and identifies associated SCSs
    - Including production and life cycle support SCSs
  - Representative operational and support scenarios
  - Prototypes (focused on top development and operational risks), objectives, constraints, and priorities
  - Initial Capabilities Document
- Leading solution alternatives
  - Top-level physical, logical, capability and behavioral views Life Cycle Plan
- Key elements
  - Top-level phases, capability increments, roles, responsibilities, required resources
- Feasibility Evidence Description
  - Evidence of ability to meet objectives within budget and schedule constraints
  - Evidence of ability to provide desired benefits to stakeholders
    - Mission effectiveness evidence

ICM Anchor Point Milestone Content (1)

(Risk-driven level of detail for each element)

Milestone Element	Foundations Commitment Review (FCR/MS-A) Package	Development Commitment Review (DCR/MS-B) Package
Definition of Operational Concept	• System shared vision update • Top-level system objectives and scope – System boundary; environment parameters and assumptions • Top-level operational concepts – Production, deployment, operations and sustainment scenarios and parameters – Organizational life-cycle responsibilities (stakeholders)	• Elaboration of system objectives and scope by increment • Elaboration of operational concept by increment – Including all mission-critical operational scenarios – Generally decreasing detail in later increments
System Prototype(s)	• Exercise key usage scenarios • Resolve critical risks – E.g., quality attribute levels, technology maturity levels	• Exercise range of usage scenarios • Resolve major outstanding risks
Definition of System Requirements	• Top-level functions, interfaces, quality attribute levels, including – Growth vectors and priorities • Project and product constraints • Stakeholders' concurrence on essentials	• Elaboration of functions, interfaces, quality attributes, and constraints by increment – Including all mission-critical off-nominal requirements – Generally decreasing detail in later increments • Stakeholders' concurrence on their priority concerns

ICM Anchor Point Milestone Content (2)

(Risk-driven level of detail for each element)

Milestone Element	Foundations Commitment Review (FCR/MS-A) Package	Development Commitment Review (DCR/MS-B) Package
Definition of System Architecture	• Top-level definition of at least one feasible architecture – Physical and logical elements and relationships – Choices of Non-Developmental Items (NDI) • Identification of infeasible architecture options	• Choice of architecture and elaboration by increment and component – Physical and logical components, connectors, configurations, constraints – NDI choices – Domain-architecture and architectural style choices • Architecture evolution parameters
Definition of Life-Cycle Plan	• Identification of life-cycle stakeholders – Users, customers, developers, testers, sustainers, interoperators, general public, others • Identification of life-cycle process model – Top-level phases, increments • Top-level WWWWWHH* by phase, function – Production, deployment, operations, sustainment	• Elaboration of WWWWWHH* for Initial Operational Capability (IOC) by phase, function – Partial elaboration, identification of key TBD's for later increments

*WWWWWHH: Why, What, When, Who, Where, How, How Much

ICM Anchor Point Milestone Content (3)

(Risk-driven level of detail for each element)

Milestone Element	Foundations Commitment Review (FCR/MS-A) Package	Development Commitment Review (DCR/MS-B) Package
Feasibility Evidence Description (FED)	• Evidence of consistency, feasibility among elements above – Via physical and logical modeling, testbeds, prototyping, simulation, instrumentation, analysis, etc. – Mission cost-effectiveness analysis for requirements, feasible architectures • Identification of evidence shortfalls; risks • Stakeholders' concurrence on essentials	• Evidence of consistency, feasibility among elements above – Identification of evidence shortfalls; risks • All major risks resolved or covered by risk management plan • Stakeholders' concurrence on their priority concerns, commitment to development

Overview of Example Review Process: DCR/MS-B

Review Planning Tasks
- Collect/distribute review products
- Determine readiness
- Identify stakeholders, expert reviewers
- Identify review leader and recorder
- Identify location/facilities
- Prepare/distribute agenda

Review Entrance Criteria
- Successful FCR/MS-A
- Required inputs available

Review Inputs
- DCR/MS-B Package: operational concept, prototypes, requirements, architecture, life cycle plans, feasibility evidence

Perform Pre-Review Technical Activities
- Experts, stakeholders review DRC/MS-B package, submit issues
- Developers prepare responses to issues

Conduct DCR/MS-B Review Meeting
- Discuss, resolve issues
- Identify action plans, risk mitigation plans

Review Exit Criteria
- Evidence of DCR/MS-B Package Feasibility validated
- Feasibility shortfalls identified as risks, covered by risk mitigation plans
- Stakeholder agreement on DCR/MS-B package content
- Stakeholder commitment to support Development phase
- All open issues have action plans
- Otherwise, review fails

Review Outputs
- Action plans
- Risk mitigation plans

Post Review Tasks
- Publish review minutes
- Publish and track open action items
- Document lessons learned

Lean Risk Management Plan:
Fault Tolerance Prototyping

1. **Objectives (The "Why")**
   - Determine, reduce level of risk of the fault tolerance features causing unacceptable performance (e.g., throughput, response time, power consumption)
   - Create a description of and a development plan for a set of low-risk fault tolerance features
2. **Deliverables and Milestones (The "What" and "When")**
   - By week 3
     1. Evaluation of fault tolerance option
     2. Assessment of reusable components
     3. Draft workload characterization
     4. Evaluation plan for prototype exercise
     5. Description of prototype
   - By week 7
     6. Operational prototype with key fault tolerance features
     7. Workload simulation
     8. Instrumentation and data reduction capabilities
     9. Draft Description, plan for fault tolerance features
   - By week 10
     10. Evaluation and iteration of prototype
     11. Revised description, plan for fault tolerance features

Lean Risk Management Plan: Fault Tolerance Prototyping *(continued)*

- **Responsibilities (The "Who" and "Where")**
  - **System Engineer: G. Smith**
    - **Tasks 1, 3, 4, 9, 11, support of tasks 5, 10**
  - **Lead Programmer: C. Lee**
    - **Tasks 5, 6, 7, 10 support of tasks 1, 3**
  - **Programmer: J. Wilson**
    - **Tasks 2, 8, support of tasks 5, 6, 7, 10**
- **Approach (The "How")**
  - **Design-to-Schedule prototyping effort**
  - **Driven by hypotheses about fault tolerance-performance effects**
  - **Use multicore processor, real-time OS, add prototype fault tolerance features**
  - **Evaluate performance with respect to representative workload**
  - **Refine Prototype based on results observed**
- **Resources (The "How Much")**

$60K - Full-time system engineer, lead programmer, programmer (10 weeks)*(3 staff)*($2K/staff-week)

$0K - 3 Dedicated workstations (from project pool)

$0K - 2 Target processors (from project pool)

$0K - 1 Test co-processor (from project pool)

<u>$10K</u> - Contingencies

$70K - Total

Example of FED Risk Evaluation Criteria

- Negligible
  - Anticipated 0-5% budget and/or schedule overrun
  - Identified only minor shortfalls and imperfections expected to affect the delivered system
- Low
  - Anticipated 5-10% budget and/or schedule overrun
  - Identified 1-3 moderate shortfalls and imperfections expected to affect the delivered system
- Moderate
  - Anticipated 10-25% budget and/or schedule overrun
  - Identified >3 moderate shortfalls and imperfections expected to affect the delivered system
- Major
  - Anticipated 25-50% budget and/or schedule overrun
  - Identified 1-3 mission-critical shortfalls and imperfections expected to affect the delivered system
- Severe
  - Anticipated >50% budget and/or schedule overrun
  - Identified >3 mission-critical shortfalls and imperfections expected to affect the delivered system

Case Study: CCPDS-R Project Overview

Characteristic	CCPDS-R
Domain	Ground based C3 development
Size/language	1.15M SLOC Ada
Average number of people	75
Schedule	75 months; 48-month IOC
Process/standards	DOD-STD-2167A Iterative development
Environment	Rational host DEC host DEC VMS targets
Contractor	TRW
Customer	USAF
Current status	Delivered On-budget, On-schedule

Reference: [Royce, 1998], Appendix D

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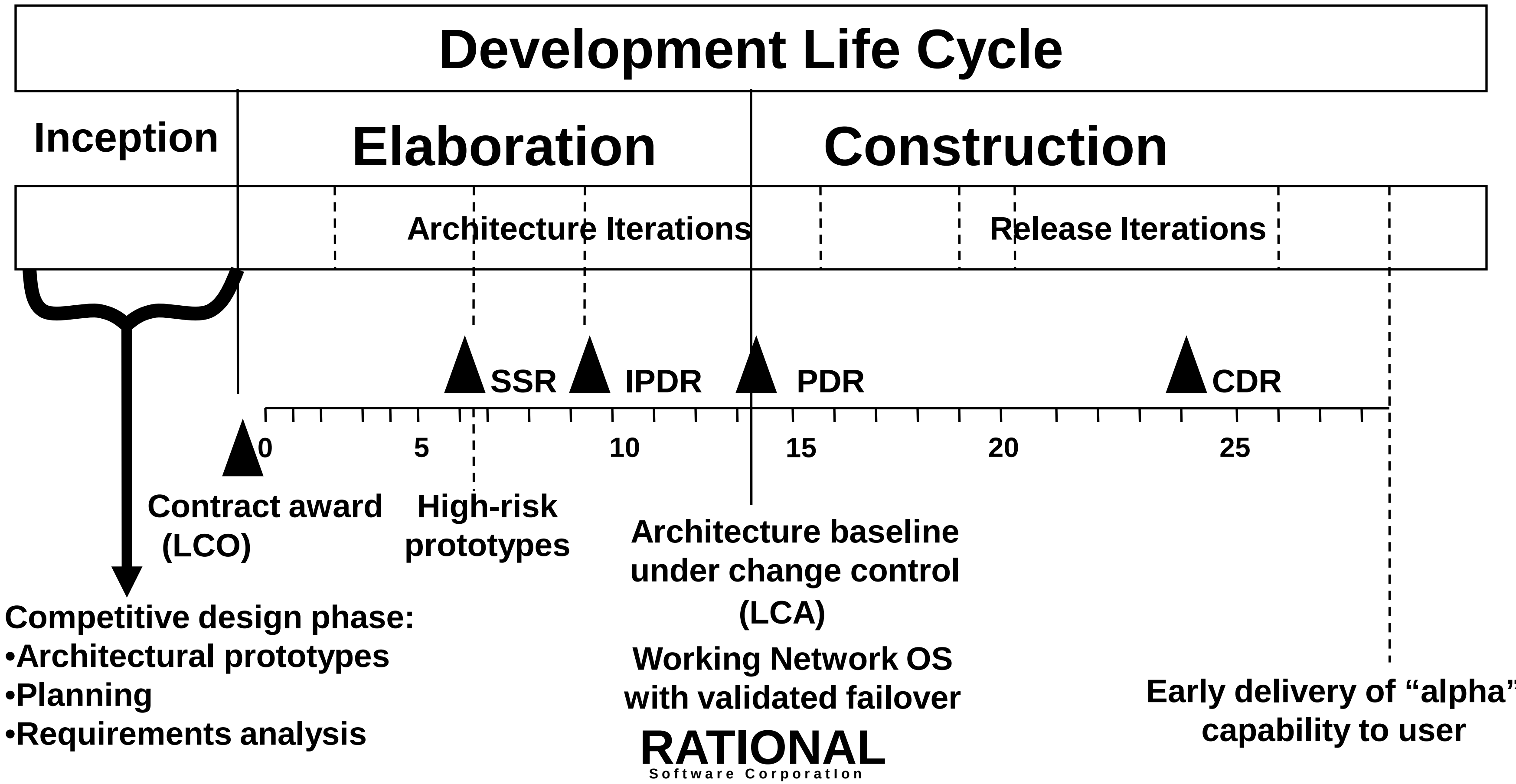
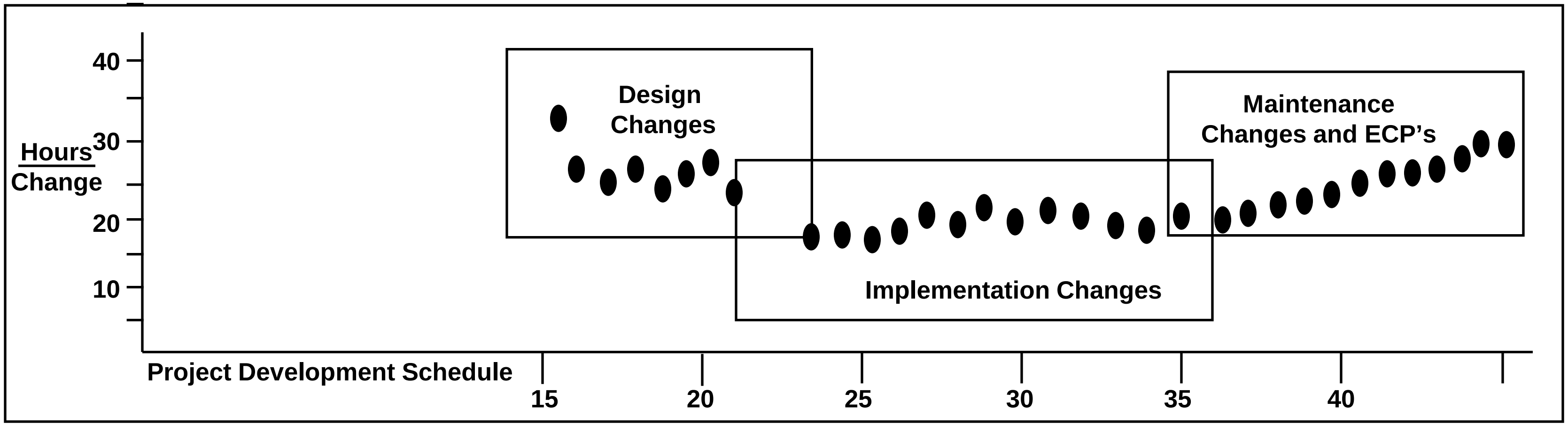


CCPDS-R Results: No Late 80-20 Rework

- Architecture first
  - -Integration during the design phase
  - -Demonstration-based evaluation
- Risk Management
- Configuration baseline change metrics:



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Conclusions

- Anchor Point milestones enable synchronization and stabilization of concurrent engineering
  - Have been successfully applied on small to large projects
  - CCPDS-R large project example provided in backup charts
- They also provide incremental stakeholder resource commitment points
- The FED enables evidence of program feasibility to be evaluated
  - Produced by developer
  - Evaluated by stakeholders, independent experts
- Shortfalls in evidence are sources of uncertainty and risk, and should be covered by risk management plans
- Can get most of benefit by adding FED to traditional milestone content and reviews

List of Acronyms

CD	Concept Development
CP	Competitive Prototyping
DCR	Development Commitment Review
DoD	Department of Defense
ECR	Exploration Commitment Review
EV	Expected Value
FCR	Foundations Commitment Review
FED	Feasibility Evidence Description
GAO	Government Accounting Office
ICM	Incremental Commitment Model
KPP	Key Performance Parameter
MBASE	Model-Based Architecting and Software Engineering
OCR	Operations Commitment Review
RE	Risk Exposure
RUP	Rational Unified Process
V&V	Verification and Validation
VB	Value of Bold approach
VCR	Valuation Commitment Review