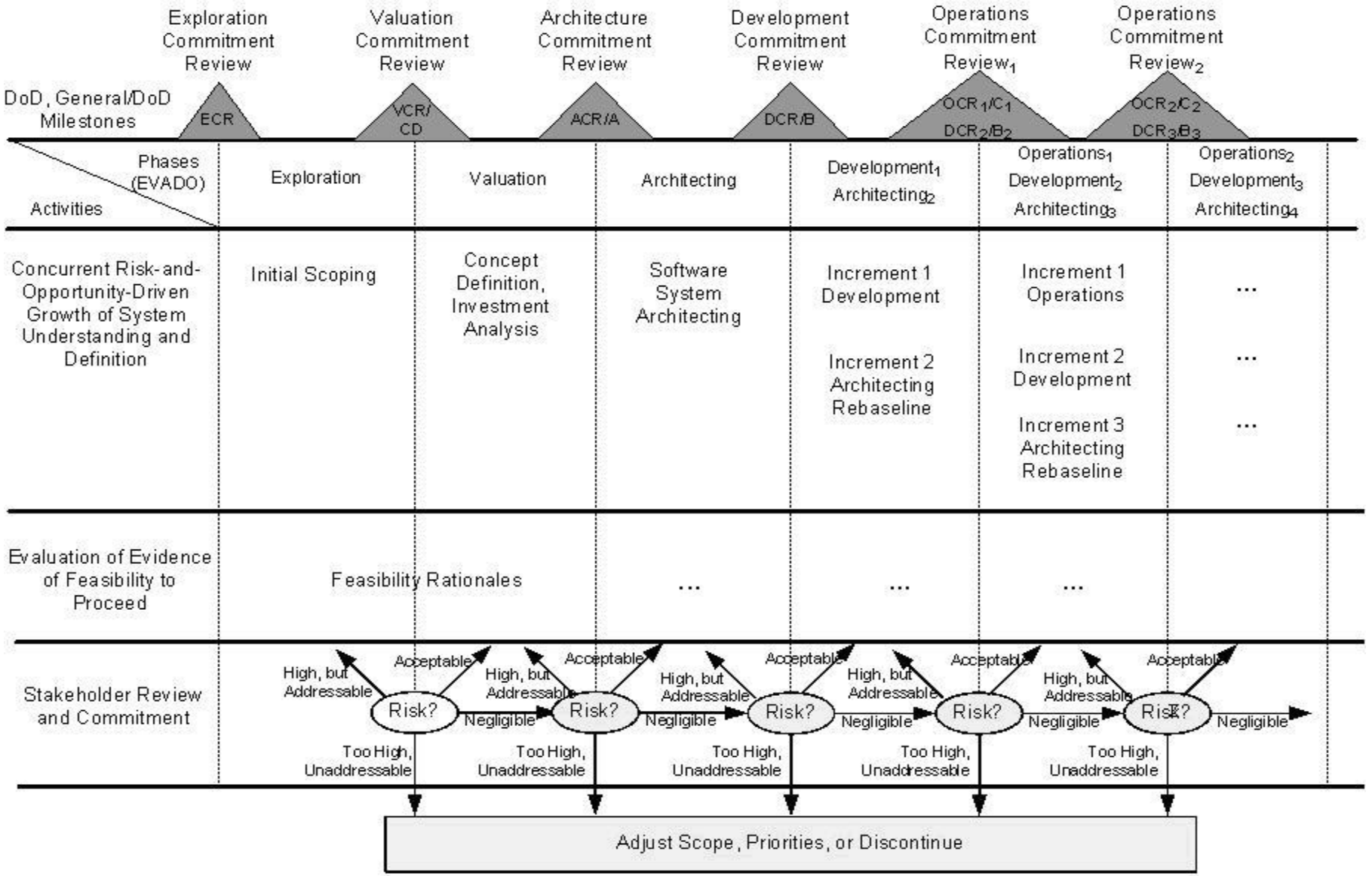
Productivity Decline in Directed System of Systems Software Development

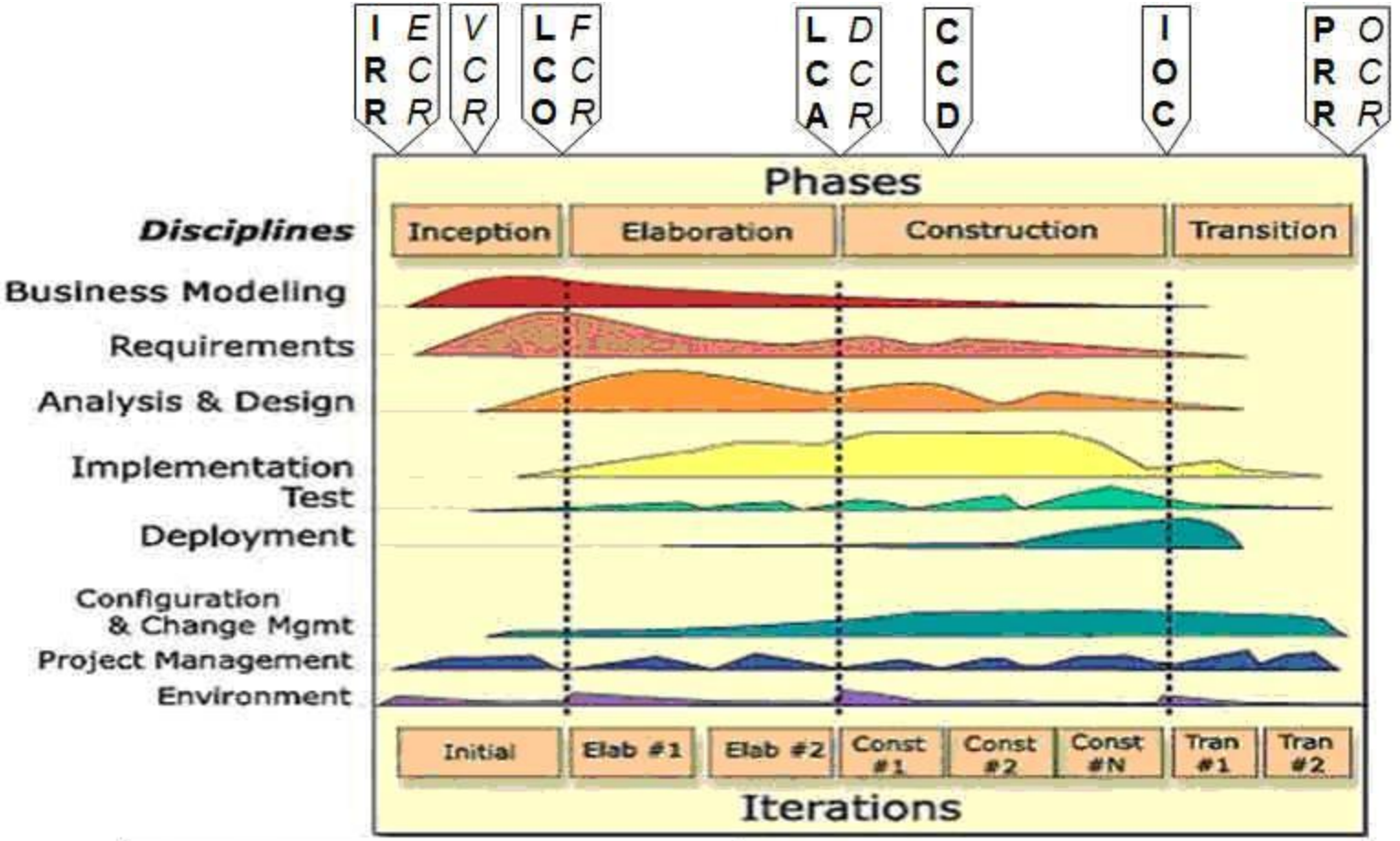
Ramin Moazeni
A. Winsor Brown
Barry Boehm

Table of Contents

ICM LC Processes for Systems



ICM-Sw/RUP Activity/Process Model



VCR: Valuation Commitment Review	DCR: Development Commitment Review
FCR: Foundations Commitment Review	OCR: Operations Commitment Review

Why Multiple Build Software Systems

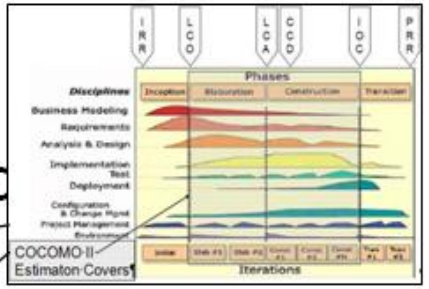
Simplest: Early Functionality in the hands of ALL users

- Architecture/Core plus some functionality
- Implies Full Qualification/Acceptance Sw Testing each software build so systems can go into Integration & Test earlier

Increasingly Complex Systems

- Multiple, diverse "platforms"
- Different "foci" of functionality (in each build)
- Network Centric Systems Operation
- Evolution/federation of legacy systems
- System of Systems by design

Overlaps Across Software Builds



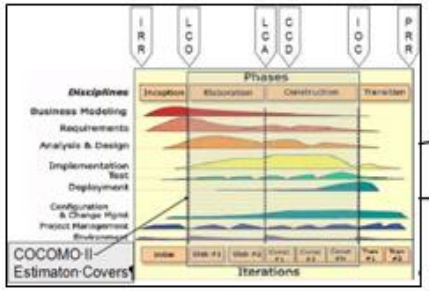
Evolve During Transition [After Sw IOC

Inception	Elaboration	Construction	Transition

Inception	Elaboration	Construction	Transition

Evolve After Architecture Complete

Inception	Elaboration with Evol. Req.	Construction	Transition

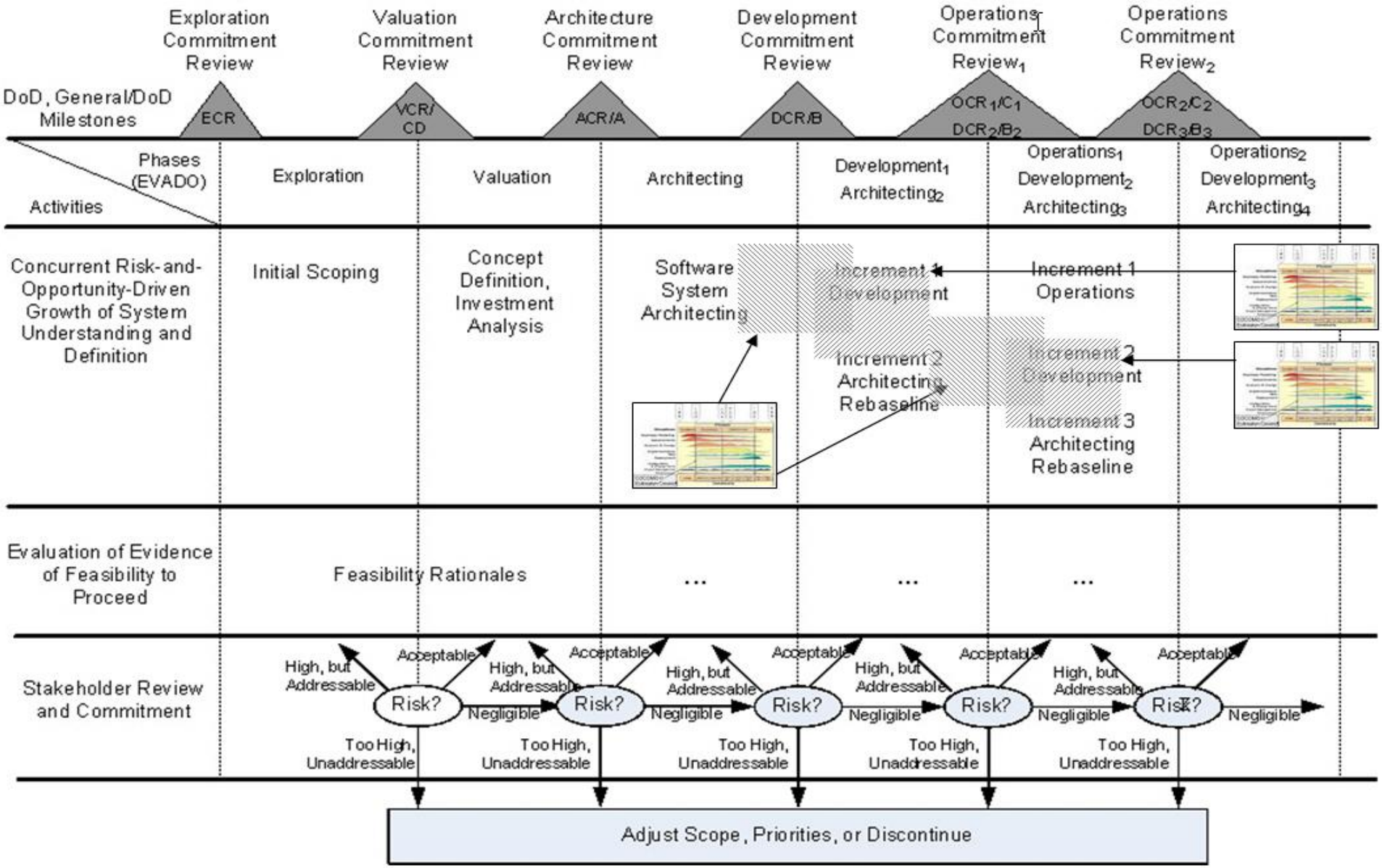


Incept.	Elaboration	Construction	Transition

I.	Elab.	Construction	Transition

. . .

ICM Showing Multi-Build Software in a System



What is a "System of Systems"

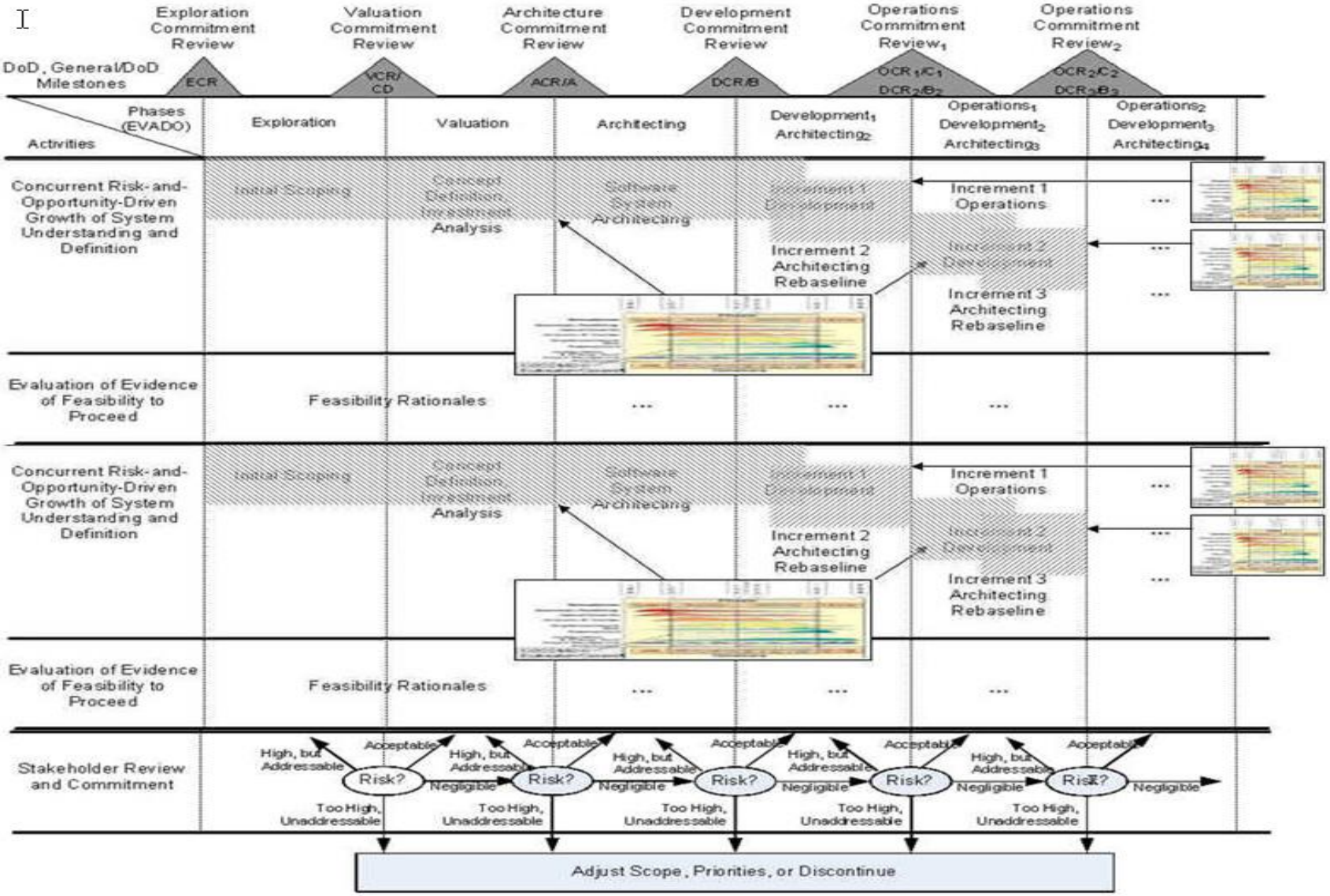
- Very large systems developed by creating a framework or architecture to integrate constituent systems.
- SoS constituent systems independently developed and managed
  - New or existing systems in various stages of development/evolution
  - May include a significant number of COTS products
  - Have their own purpose
  - Can dynamically come and go from SoS
- SoS exhibits emergent behavior not otherwise achievable by component systems
- Typical domains
  - *Business:* Enterprise-wide and cross-enterprise integration to support core business enterprise operations across functional and geographical areas
  - *Military:* Dynamic communications infrastructure to support operations in a constantly changing, sometimes adversarial, environment

Based on Mark Maier's SoS definition [Maier, 1998]

Types of "System of Systems"

- Virtual [Maier, 1998]
  - Lacks a central management authority and a clear SoS purpose
  - Often ad hoc and may use a service-oriented architecture where the constituent systems are not necessarily known
- Collaborative [Maier, 1998]
  - Constituent system engineering teams work together more or less voluntarily to fulfill agreed upon central purposes
  - No SoSE team to guide or manage activities of constituent systems
- Acknowledged [Dahmann, 2008]
  - Have recognized objectives, a designated manager, and resources at the SoS level (SoSE team)
  - Constituent systems maintain their independent ownership, objectives, funding, and development approaches
- Directed [Maier, 2008]
  - SoS centrally managed by a government, corporate, or Lead System Integrator (LSI) and built to fulfill specific purposes
  - Constituent systems maintain ability to operate independently, but evolution subordinated to centrally managed purpose

ICM Showing Multi-Build Software in DSOS



Multi-Build Software Cost Estimation Using COINCOMO

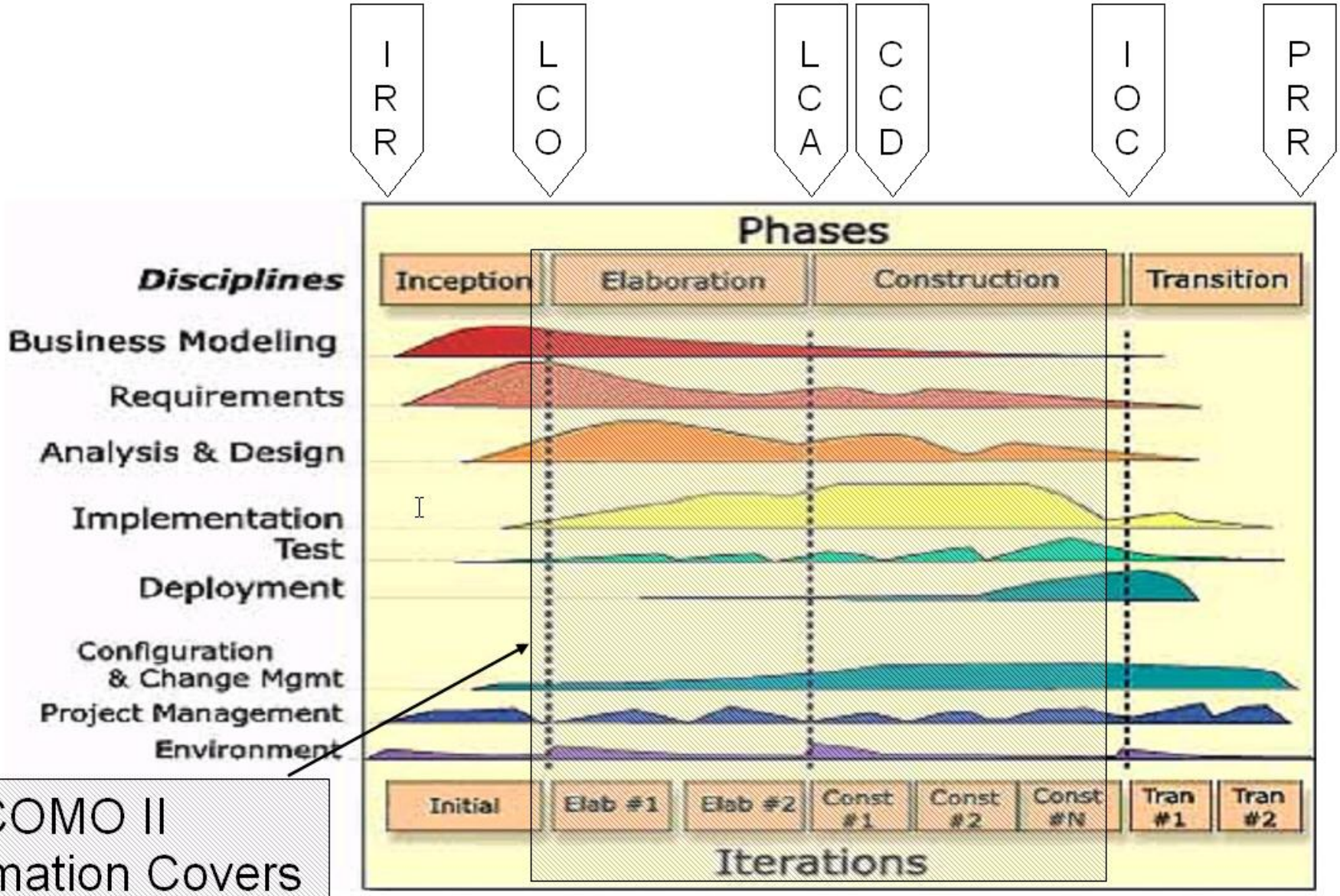
Using the COINCOMO 2.0 tool

- COCOMO model as a base: estimated the software Effort (PM) and Schedule (M) for each module
- COPSEMO model to separate the man power loading across Elaboration and Construction phases
- COPSEMO model to add additional effort and schedule for Inception and Transition phases

Used a spreadsheet to combine efforts AFTER aligning the beginning of Elaboration with the end of Construction

COCOMO calculates effort and schedule for the Elaboration and Construction phases of a build with new code and code carried forward from the previous build treated as re-used code with very favorable re-use parameters.

ICM-Sw/RUP Concurrent Activities



COCOMO II Estimation Covers

Incremental Development Productivity Decline (IDPD)

- **Overview**
  - The “Incremental Productivity Decline” (IDPD) factor represents the percentage of decline in software producibility from one increment to the next.
  - The decline is due to factors such as previous-increment breakage and usage feedback, increased integration and testing effort.
  - Another source of productivity decline is that maintenance of reused previous build software is not based on equivalent lines of software credited during the previous build, but on the full amount of reused software.
    - Build 1: 200 KSLOC new, 200K Reused@20% yields a 240 K ESLOC “count” for estimation models.
    - Build 2: there are 400 KSLOC of Build 1 to maintain and integrate
  - Such phenomena may cause the IDPD factor to be higher for some builds and lower for others.

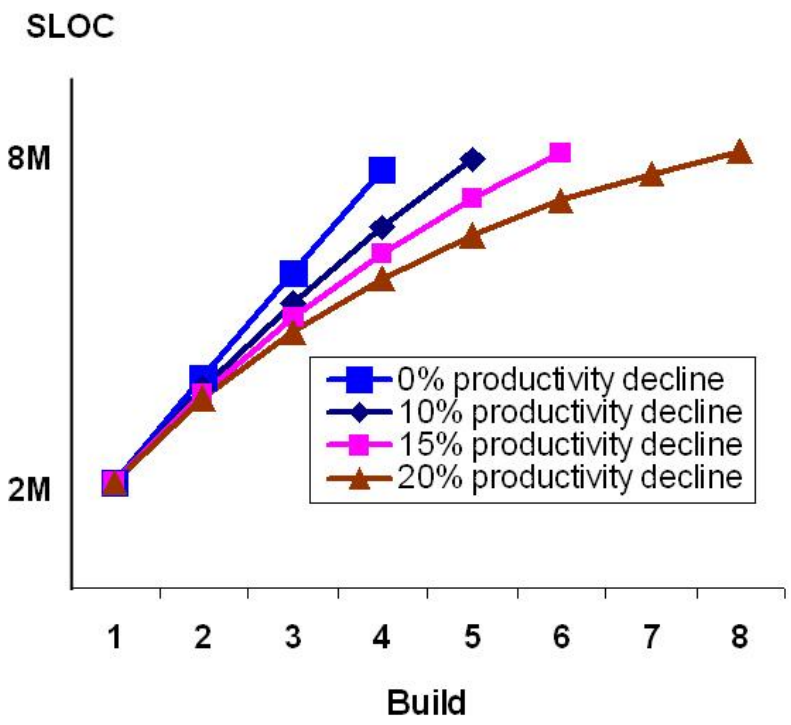
Incremental Development Productivity Decline (IDPD)

- **Example: Site Defense BMD Software**
  - 5 builds, 7 years, $100M
  - Build 1 productivity over 300 SLOC/person month
  - Build 5 productivity under 150 SLOC/PM
    - Including Build 1-4 breakage, integration, rework
    - 318% change in requirements across all builds
    - IDPD factor=20% productivity decrease per build
  - Similar trends in later unprecedented systems
  - Not unique to DoD: key source of Windows Vista delays

IDPD Ranges

- Some savings: more experienced personnel (5-20%)
  - Depending on personnel turnover rates
- Some increases: code base growth, diseconomies of scale, requirements volatility, user requests
  - Breakage, maintenance of full code base (20-40%)
  - Diseconomies of scale in development, integration (10-25%)
  - Requirements volatility; user requests (10-25%)
- Best case: 20% more effort (IDPD=6%)
- Worst case: 85% (IDPD=23%)

Effects of IDPD on Number of Increments



- Model relating productivity decline to number of builds needed to reach 8M SLOC Full Operational Capability
- Assumes Build 1 production of 2M SLOC @ 100 SLOC/PM
  - 20000 PM/ 24 mo. = 833 developers
  - Constant staff size for all builds
- Analysis varies the productivity decline per build
  - Extremely important to determine the incremental development productivity decline (IDPD) factor per build

Conclusion

- Staffing stability helps to improve team cohesion and developer experience, thus provide positive contribution to productivity outcome
- Design deficiency and code breakage causes productivity declines
  - If the original design is insufficient to accommodate additional modules, and a re-architecting effort was necessary to put this project back on track
  - Inserting new code into the previous build adds effort to read, analyze, and test both the new and old code in order to ensure nothing is broken, this extra effort may be mitigated by experienced staff

Q & A

- Questions?
- Comments?
- Thank you very much