Parallel Development and
The Incremental Commitment Spiral Model (ICSM)

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Outline

• **Current and future process challenges**
  – The Four D’s: Dynamism, Dependability, Doubtfulness, and Diversity

• Avoiding the Procrustean Bed
  – Of one-size-fits-all process models

• ICSM Overview

• The 4+ ICSM Principles
Current and Future Process Challenges-I
For Enterprises with Increasingly Diverse Projects

• Rapid pace of change
  – In competition, mission priorities, technology, widgets, apps, Commercial Off-the-Shelf (COTS), cloud services
  – Need incremental development to avoid obsolescence
  – Need concurrent vs. sequential processes
  – Need both prescience and rapid adaptability

• Brownfield vs. Greenfield development
  – Need to provide legacy continuity of service
  – Need to accommodate legacy, OTS constraints

• Always-on, never-fail systems
  – Need well-controlled, high-assurance processes
  – Need to synchronize and stabilize concurrency
  – Need to balance assurance and agility
Current and Future Process Challenges
For Enterprises with Increasingly Diverse Projects

• Multi-owner, multi-mission systems of systems (SoS)
  – Integrated supply chain: strategic planning, marketing, merchandising, outsourcing, just-in-time manufacturing, logistics, finance, customer relations management
  – Over 50 separately evolving external systems or services
  – Need to satisfice among multiple stakeholders
  – Wide diversity of needed capabilities
  – No one-size-fits-all solutions or processes

• Emergence and human-intensiveness
  – Requirements not pre-specifiable
  – Budgets and schedules not pre-specifiable
  – Need for evolutionary growth
  – Need to manage uncertainty and risk
Doubtfulness: The Cones of Uncertainty
– Need incremental vs. one-shot development

Uncertainties in competition, technology, organizations, mission priorities
Diversity: The Proliferation of Choices

Not just a million apps.  
A million great apps.

Shopping the App Store is a great experience because it’s easy to find the apps you want — and to discover new apps you didn’t even know you wanted. Browse freely by category. Or shop collections of apps and games handpicked by experts. Apple reviews everything on the App Store to guard against malware, so you’re buying and downloading from a trusted source.
Outline

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  – Of one-size-fits-all process models

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The Procrustean Bed

- Procrustes: Greek Mythology
  - Rogue smith and bandit
  - Hostel with one-size-fits-all bed
  - Guests too small: stretch them to fit
  - Guests too large: lop off the offending parts
Build Your Own Procrustean Bed

- Pure Waterfall, Vee: Fixed Price and Spec Contract
  - Lop off needed changes as requirements creep
- Pure Agile: Easiest First; Dedicated On-Site Customer
  - Later scalability and assurance problems; single-failure point
- Voice of the Customer: Accept All “Requirements”
  - Gold-plating; neglect voices of acquirer, developer, owner
- Piling on Incompatible Constraints: No Way Out
  - Project Example: Waterfall, COTS, Ada, GOTS Reuse
- Inflexible Standards: No Choice But Tailoring Down
  - MIL-STD-498: choice of 23, 6, or 1 DID denied
- Overconstrained Maturity Models: Excluding Expertise
  - Software CMM: Exclude software group from system rqs.
Current System Acquisition Methods
Too easy to misinterpret as one-size-fits-all

- V-Model\(^1\)

High level guidance assumes that acquirers have extensive acquisition experience...
Without experience, too easy to misinterpret and auger in with disastrous results...

1 http://en.wikipedia.org/wiki/V-Model

- Spiral Model\(^2\)

2 http://en.wikipedia.org/wiki/Spiral_model
Procrustean Example: DoD Acquisition Process
Progress: Draft DoDI 5000.02 2013-03-12

• **MODEL 1: HARDWARE INTENSIVE PROGRAM**
• **MODEL 2: DEFENSE UNIQUE SOFTWARE INTENSIVE PROGRAM**
• **MODEL 3: INCREMENTALLY FIELDED SOFTWARE INTENSIVE PROGRAM**
• **MODEL 4: ACCELERATED ACQUISITION PROGRAM**

• Hybrid Program A (Hardware Dominant).
• Hybrid Program B (Software Dominant).
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What is the ICSM?

- Risk-driven framework for determining and evolving best-fit system life-cycle process
- Integrates the strengths of phased and risk-driven spiral process models
- Synthesizes together principles critical to successful system development
  - Stakeholder value-based guidance
  - Incremental commitment and accountability
  - Concurrent multidiscipline engineering
  - Evidence and risk-driven decisions

Principles used by 60-80% of CrossTalk Top-5 projects, 2002-2005
The Incremental Commitment Spiral Model

Cumulative Level of Understanding, Product and Process Detail (Risk-Driven)

RISK-BASED STAKEHOLDER COMMITMENT REVIEW POINTS:

Opportunities to proceed, skip phases backtrack, or terminate

Evidence-Based Review Content
- A first-class deliverable
- Independent expert review
- Shortfalls are uncertainties and risks

Risk-Based Decisions

Negligible
Acceptable
Too High, Unaddressable
High, but Addressable

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ICSM Nature and Origins

• Integrates hardware, software, and human factors elements of systems life cycle
  – Concurrent exploration of needs and opportunities
  – Concurrent engineering of hardware, software, human aspects
  – Concurrency stabilized via anchor point milestones

• Developed in response to a variety of issues
  – Clarify “spiral development” usage
    • Initial phased version (2005)
  – Provide framework for human-systems integration
    • National Research Council report (2007)

• Integrates strengths of current process models
  – But not their weaknesses

• Facilitates transition from existing practices
Incremental Commitment in Gambling

- Total Commitment: Roulette
  - Put your chips on a number
  - E.g., a value of a key performance parameter
  - Wait and see if you win or lose

- Incremental Commitment: Poker, Blackjack
  - Put some chips in
  - See your cards, some of others’ cards
  - Decide whether, how much to commit to proceed
The Incremental Commitment Spiral Process: Phased View

**Stage I: Incremental Definition**
- **ICM Anchor Points / DoD Milestones**
  - ECR/MDP
  - VCR/MDD
  - FCR/A
- **ICM Lifecycle Phases / DoD Phases**
  - Exploration / Needs and Opportunities
  - Valuation / Material Solution Analysis & AOA
  - Foundations / Technology Development (TD) & CDD
- **Activities**
  - Concurrent risk-and-opportunity-driven growth of system understanding and definition
    - Initial scoping
    - Concept definition
    - Investment analysis
    - System life-cycle architecture and ops concept
    - Build-to increment plans and specifications
    - NDI, outsource partner selections
  - Evaluation of evidence of feasibility to proceed
    - Feasibility Evidence
  - Stakeholder review and commitment
    - High, but addressable
    - Acceptable
    - Too high, unaddressable
- **Risk Patterns**
  - Risk?
  - Negligible
  - Risk?
  - Risk?

Synchronize, stabilize concurrency via FEDs

**Stage II: Incremental Development and Operations**
- **Anchor Point Milestones**
  - DCR₁/B₁
  - Development¹ / Foundations¹ / Engineering and Development (EMD)¹ / TD & CDD¹
  - OCR₁ / Operations¹ / Operations & Production¹ / Foundations¹ / Engineering and Development (EMD)₂ / TD & CDD₂

Adjust scope, priorities, or discontinue

Risk patterns determine life cycle process

MDP = Materiel Decision Preparation
MDD = Materiel Development Decision
AoA = Analysis of Alternatives
ECR = Exploration Commitment Review
VCR = Valuation Commitment Review
FCR = Foundations Commitment Review
DCRₙ = Development Commitment Review
OCRₙ = Operations Commitment Review

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### ICSM Activity Levels for Complex Systems

#### Activity Definition

<table>
<thead>
<tr>
<th>Activity Category</th>
<th>Levels of Activity</th>
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<tbody>
<tr>
<td>Envisioning opportunities</td>
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<tr>
<td>System scoping</td>
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<tr>
<td>Understanding needs</td>
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<tr>
<td>Goals/objectives</td>
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<tr>
<td>Requirements</td>
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<tr>
<td>Architecting and designing solutions</td>
<td></td>
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<tr>
<td>a. system</td>
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<tr>
<td>b. human</td>
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<td>c. hardware</td>
<td></td>
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<tr>
<td>d. software</td>
<td></td>
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<tr>
<td>Life-cycle planning</td>
<td></td>
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<tr>
<td>Feasibility Evidence</td>
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<tr>
<td>Negotiating commitments</td>
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<tr>
<td>Development and evolution</td>
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<tr>
<td>Monitoring and control</td>
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<td>Operations and retirement</td>
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<tr>
<td>Organization capability improvement</td>
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</tbody>
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**Stage I: Incremental Definition**

- ECR/MDP
- VCR/MDD
- FCR/A

**Stage II: Incremental Development, Operations & Production**

- DCR/BI
- DCR/DF
- DCR/OB

**Terms and Abbreviations**

- MDP = Material Design Preparation
- MDD = Material Development Decision
- AOA = Analysis of Alternatives
- CCD = Capability Development Document
- OD = Operational Capability
- ECR = Exploration Commitment Review
- VCR = Valuation Commitment Review
- FCR = Foundations Commitment
- DCR = Development Commitment Review
- OCR = Operations Commitment Review
Anchor Point Feasibility Evidence Descriptions

- **Evidence** provided by developer and validated by independent experts that:
  
  If the system is built to the specified architecture, it will
  - Satisfy the requirements: capability, interfaces, level of service, and evolution
  - Support the operational concept
  - 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

- All major risks resolved or covered by risk management plans
- Serves as basis for stakeholders’ commitment to proceed
- Synchronizes and stabilizes concurrent activities

*Can be used to strengthen current schedule- or event-based reviews*
The Incremental Commitment Spiral Process: Phased View

Stage I: Incremental Definition
- Anchor Point
- Milestones
  - Concurrent engr.
  - OpCon, rqts, arch, plans, prototypes

Stage II: Incremental Development and Operations
- Anchor Point
- Milestones
  - Concurrent engr.
  - Incr.N (ops), N+1 (devel), N+2 (arch)

Activities
- Concurrent risk-and-opportunity-driven growth of system understanding and definition
- Initial scoping
- Concept definition
- System life-cycle architecture and ops concept
- Increment 1 Development
- Increment 2 Foundations rebaseline
- Increment 3 Foundations rebaseline

Evaluation of evidence of feasibility to proceed
- Feasibility Evidence
- ... ... ...

Stakeholder review and commitment
- High, but addressable
- Acceptable
- Too high, unaddressable
- Risk?
- Negligible
- Risk?
- Adjust scope, priorities, or discontinue

MDP = Materiel Decision Preparation
MDD = Materiel Development Decision
AoA = Analysis of Alternatives
CDD = Capability Development Document
Risk-Driven Scalable Spiral Model: Increment View

For each level of systems-of-interest

- **Rapid Change**
  - Unforeseeable Change (Adapt)
  - Short Development Increments
  - Future Increment Baselines

- **High Assurance**
  - Foreseeable Change (Plan)
  - Increment N Baseline
  - Stable Development Increments
  - Increment N Transition/Operations and Maintenance

- **Agile Rebaselining for Future Increments**
  - Deferrals
  - Short, Stabilized Development of Increment N
  - Future V&V Resources
  - Verification and Validation (V&V) of Increment N
  - Current V&V Resources
  - Continuous V&V
  - Artifacts
  - Concerns
Agile Change Processing and Rebaselining

Stabilized Increment-N Development Team

- Defer some Increment-N capabilities
  - Recommend handling in current increment
  - Negotiate change disposition
    - Accept changes
      - Handle Accepted Increment-N changes

Agile Future-Increment Rebaselining Team

- Assess Changes, Propose Handling
  - Handle in current rebaseline
  - Formulate, analyze options in context of other changes
  - Discuss, resolve deferrals to future increments

Future Increment Managers

- Proposed changes
  - Recommend no action, provide rationale
  - Recommend deferrals to future increments
  - Prepare for rebaselined future-increment development

Change Proposers

- Propose Changes
  - Discuss, revise, defer, or drop

3/1/2010
Role: Operational Concept Engineer

- Performs
- Responsible for

Operational Concept Engineer

Operational Concept Description (OCD)

- Analyze Current System
- Assess Operational Concept
- Establish New Operational Concept
- Identify Organizational and Operational
- Identify Shared Vision

Additionally Performs
- Analyze the Proposed System
- Client Interaction Report
- Initial Prototype Report
- Operational Concept Description (OCD)
- Prototype
- Supporting Information Document (SID)

Modifies
- Development Team
- Life Cycle Planner
- Project Manager
- IV&V
- Quality Focal Point
- Feasibility Analyst
- System Architect

Operational Concept Engineer

Project Roles
- WinWin Negotiation Roles
- Work Product List
- Client Interaction Report
- Progress Report
- Project Plan
- Initial Prototype Report
- Prototype
- Operational Concept Description (OCD)
Task: Analyze Current System

Contains the guide to analyzing the current system.

**Purpose**

To observe the current work process and analyze the current system being used at the organization.

**Relationships**

**Roles**
- Primary Performer:
  - Client
  - Development Team
  - Operational Concept Engineer
- Additional Performers:
  - Client Interaction Report
  - Operational Concept Description (OCD)

**Outputs**

- Client Interaction Report
- Operational Concept Description (OCD)

**Main Description**

Knowing how the current business works and ways that the current system is being used is critical in understanding the needs for the new system to be developed. Improvements that can be made to the current system may become obvious, thus, allowing the developers to better understand clients and the projects.
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Principles Trump Diagrams: Spiral
Several US Government Programs

Where are stakeholders, commitments, concurrency, risk?
Principles Trump Diagrams

1. Stakeholder value-based guidance

1. Incremental commitment and accountability

1. Concurrent system engineering

2. Evidence and risk-driven decisions

Counterexample: Bank of America Master Net

Good example: Symbiq Medical Infusion Pump
ICSM Principles Counterexample:
Bank of America Master Net

Users
- Many features
- Changeable requirements
- Applications compatibility
- High levels of service
- Voice in acquisition
- Flexible contract
- Early availability

Maintainers
- Ease of transition
- Ease of maintenance
- Applications compatibility
- Voice in acquisition

Acquirers
- Mission cost/effectiveness
- Limited development budget, schedule
- Government standards compliance
- Political correctness
- Development visibility and control
- Rigorous contact

Developers
- Flexible contract
- Ease of meeting budget and schedule
- Stable requirements
- Freedom of choice: process
- Freedom of choice: team
- Freedom of choice: COTS/reuse

PC: Process
PD: Product
PP: Property
S: Success
Principles Trump Diagrams: Master Net

1. Stakeholder value-based guidance
   - Overconcern with Voice of Customer: 3.5 MSLOC of rqts.
   - No concern with maintainers, interoperators: Prime vs. IBM

2. Incremental commitment and accountability
   - Total commitment to infeasible budget and schedule
   - No contract award fees or penalties for under/overruns

3. Concurrent multidiscipline engineering
   - No prioritization of features for incremental development
   - No prototyping of operational scenarios and usage

4. Evidence and risk-driven decisions
   - No evaluation of Premier Systems scalability, performance
   - No evidence of ability to satisfy budgets and schedules
Example ICSM Commercial Application:

Symbiq Medical Infusion Pump

Winner of 2006 HFES Best New Design Award

Described in NRC HSI Report, Chapter 5
Symbiq IV Pump ICSM Process - I

• Exploration Phase
  – Stakeholder needs interviews, field observations
  – Initial user interface prototypes
  – Competitive analysis, system scoping
  – Commitment to proceed

• Valuation Phase
  – Feature analysis and prioritization
  – Display vendor option prototyping and analysis
  – Top-level life cycle plan, business case analysis
  – Safety and business risk assessment
  – Commitment to proceed while addressing risks
Symbiq IV Pump ICSM Process - II

• Foundations Phase
  – Modularity of pumping channels
  – Safety feature and alarms prototyping and iteration
  – Programmable therapy types, touchscreen analysis
  – Failure modes and effects analyses (FMEAs)
  – Prototype usage in teaching hospital
  – Commitment to proceed into development

• Development Phase
  – Extensive usability criteria and testing
  – Iterated FMEAs and safety analyses
  – Patient-simulator testing; adaptation to concerns
  – Commitment to production and business plans
Principles Satisfaction: Symbiq IV Pump

1. Stakeholder value-based guidance
   – Extensive involvement of users, buyers, funders, regulators
   – Extensive use of prototyping, safety analysis methods

2. Incremental commitment and accountability
   – Expanding system definition and evidence elaboration
   – Decision to start with composable 1- and 2-channel pumps

3. Concurrent multidiscipline engineering
   – Concurrent evaluation of display, alarm, pump suppliers
   – Concurrent definition, evaluation of safety and business cases

4. Evidence and risk-driven decisions
   – Evidence-based reviews of technical and business feasibility
   – Outstanding risks covered by next-phase risk mitigation plans
ICSM and *Lean* Principles

- **Stakeholder value-based guidance**
  - *See the whole*
  - *Empower the team*

- **Incremental commitment and accountability**
  - *Amplify learning*
  - *Decide as late as possible*

- **Concurrent multidiscipline engineering**
  - *Deliver as fast as possible*
  - *Empower the team*

- **Evidence and risk-driven decisions**
  - *Build integrity in*
  - *Eliminate waste*
Meta-Principle 4+: Risk Balancing

• How much (system scoping, planning, prototyping, COTS evaluation, requirements detail, spare capacity, fault tolerance, safety, security, environmental protection, documenting, configuration management, quality assurance, peer reviewing, testing, use of formal methods, and feasibility evidence) are enough?

• Answer: Balancing the risk of doing too little and the risk of doing too much will generally find a middle-course sweet spot that is about the best you can do.