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Agenda

• Problem Statement
• The National Security Space Acquisition Policy (NSSAP 03-01) Acquisition Life Cycle Model
• Waterfall vs. Iterative/Incremental Development
• Anchor Points in The IBM/Rational Unified Process (RUP®)
• Risk-based Life Cycle Model (LCM) Selection
  - Opportunities and Risks of Various LCMs
  - Simplified Hierarchy of System and Software LCMs
  - Different WBS Levels – Different LCM Choices
• Reviews
  - System Technical Reviews
  - System Technical Reviews and Anchor Point Reviews
• Architecture-Centric Synergy of Elaboration, Evolution and Evaluation
• Conclusions

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Problem Statement

• Fundamental Lack of Understanding and Appreciation of LCMs
  ❖ **Current National Security Space Acquisition Policy (NSSAP 03-01)**
    – Acquisition phase-names imply a waterfall structure of development
    – Prescribes technical reviews that – in their names and their positioning – also imply waterfall development
    – Although, with respect to review details, no specifics are given
    – While does not explicitly exclude iterative development, it does not really supports it either
    – Index does not even has an “Iteration”-related entry
    – It is not properly harmonized with systems engineering standards
    – Although it is under revision, most likely the updated version will still
      – Maintain the obsolete, waterfall-oriented review-names
      – Lack of a solid, overarching, life cycle modeling foundation
NSSAP 03-01 Acquisition Life Cycle Model

Small Quantity System Model

NSS Space Acquisition Policy 03-01 (December 24, 2004)

Key Decision Points:
- **Pre KDP-A Approvals**
- **PHASE A Approval**
- **PHASE B Approval**
- **PHASE C Approval**
- **Build Approval**
- **1st Launch**
- **Upgrade Decision**
- **IOC**

Pre-Systems Acquisition:
- Pre KDP-A Concept Studies
- PHASE A Concept Development

Systems Acquisition:
- PHASE B Preliminary Design
- PHASE C Complete Design

Sustainment:
- PHASE D Build & Operations

Reviews:
- **SRR** – System Requirements Review
- **SDR** – System Design Review
- **PDR** – Preliminary Design Review
- **CDR** – Critical Design Review
Waterfall vs. Iterative/Incremental Development

**Waterfall**

- Requirements
- High-level Design (Architecture)
- Detailed Design
- Implementation (Coding)
- Unit Testing
- S/W Integration
- S/W Qualification Testing

**Disciplines**
- Business Modeling
- Analysis and Design
- Implementation
- Test
- Deployment

**RUP Phases**

- **INCEPTION**
- **ELABORATION**
- **CONSTRUCTION**
- **TRANSITION**

**Legend:**
- Approximate Effort (Notional)
- Flow of Execution (Mini-Waterfalls)
Anchor Points in RUP

- **Definition:**
  - Anchor points are a set of project planning milestones with specific objectives
    - **LCO** (Life Cycle Objectives)
    - **LCA** (Life Cycle Architecture)
    - **IOC** (Initial Operational Capability)
    - **PRR** (Product Release Review)

- **Anchor Points bring architecture focus into the life cycle**
  - Explicitly address architecture option-exploration and evolution
# Opportunities and Risks of Various Life Cycle Models

<table>
<thead>
<tr>
<th>Category</th>
<th>Item</th>
<th>Basic Life Cycle Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>High Requirements Volatility is expected due to user feedback</td>
<td>O R O R O R O R O R O R</td>
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<tr>
<td></td>
<td>System is not preceded</td>
<td>X X X X X</td>
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<tr>
<td></td>
<td>Requirements are not well understood</td>
<td>X X X X X</td>
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<td></td>
<td>User needs some capabilities delivered early</td>
<td>X X X X X</td>
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<tr>
<td>Technology</td>
<td>New technology is being incorporated</td>
<td>X X X X X</td>
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<td></td>
<td>Rapid changes of critical technologies are anticipated</td>
<td>X X X X X</td>
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<tr>
<td>Complexity</td>
<td>Size (SLOC, function points, etc.) is a concern</td>
<td>X X X X X</td>
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<td></td>
<td>High level of inter-dependencies amongst different disciplines</td>
<td>X X X X X</td>
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<td></td>
<td>The system naturally breaks into increments</td>
<td>X X X X X</td>
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<tr>
<td>Personnel</td>
<td>Concerns about responsiveness to funding/staffing needs</td>
<td>X X X X X</td>
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<tr>
<td>Politics</td>
<td>Concerns about securing funding for a large project</td>
<td>X X X X X</td>
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<tr>
<td></td>
<td>Difficult stakeholder conflicts are expected</td>
<td>X X X X X</td>
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**Risk Factor**

**Basic Life Cycle Models**

- **Once-Through**
- **Incremental**
- **Evolutionary**
- **Iterative**

**Rigid**

**Simple**

**Adaptive**

**Difficult**
Different WBS Levels – Different LCM Choices

WBS Hierarchy

- System
- Segments
- Elements
- Subsystems
- HW/SW Items
- HW/SW Units

LCM Hierarchy

Program management and systems engineering areas
- HW/SW discipline-independent considerations

Project management area
- HW/SW discipline and design/development methodology-dependent considerations
Simplified Hierarchy of System and Software LCMs
System Technical Reviews

Evolvative
Incremental

Acquisition

System Requirements
System Design
Incr 1 System Integration

Ground Software

SRR SDR PDR CDR

Spacecraft Software

Build 1 Build 1 Build 2 Build 2

Payload Software

SW Reqs Level Design Detail Design Impl Unit Test Integr & Test SW Qual Test

In-Process Review

GSAW/ACE3 2005 – Peter Hantos
System Technical Reviews and Anchor Point Reviews

- **Acquisition**
  - PHASE A
  - PHASE B
  - PHASE C
  - PHASE D

- **System**
  - System Requirements
  - System Design
  - Incr 1 System Integration
  - Incr 2 System Integration
  - System Qualification Test

- **Ground Software**
  - RUP

- **Spacecraft Software**
  - WATERFALL

- **Payload Software**
  - WATERFALL

- **Anchor Point Reviews**
## Architecture-Centric Synergy of Elaboration, Evolution and Evaluation

<table>
<thead>
<tr>
<th></th>
<th>Objective</th>
<th>Process Domain</th>
<th>Product Domain</th>
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</thead>
<tbody>
<tr>
<td><strong>Elaboration</strong></td>
<td>Understanding Internals (Refining Implementation)</td>
<td>LCM Hierarchy and Synchronization</td>
<td>Architectural Views (UML Diagrams)</td>
</tr>
<tr>
<td><strong>Evolution</strong></td>
<td>Understanding and Refining Changing Requirements</td>
<td>LCM Choices</td>
<td>Use Case Hierarchy</td>
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<tr>
<td><strong>Evaluation (Reviews)</strong></td>
<td>Progress Against Objectives Integrity of Artifacts</td>
<td>Validation of LCM Choices LCM-based Determination of Review Content</td>
<td>Verification of Artifacts Verification of Consistency with LCMs</td>
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</tbody>
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Conclusions

• **Life Cycle Models are key in ensuring the synergy across Evolution, Elaboration, and Evaluation**
  - Paraphrasing P. Kruchten, this is a high-level, “3+1 View Model” of Software-Intensive System development

• **Due to the dynamic nature of system development, state-of-the-art review standards would have to be structured around more meta-level definitions, e.g.,**
  - “Architectural views are consistent with the appropriate LCMs”
  - “… design has been defined to the level of completeness that is based on the selected LCM.”

• **Using such standards requires a higher level of sophistication from both the Contractor and the SPO**
  - Unfortunately, we don’t have a choice here
    - The sophistication of Evaluation must match the rapidly evolving sophistication of system Evolution and Elaboration
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>ACE3</td>
<td>Architecture-Centric Evolution, Evaluation, and Elaboration</td>
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<tr>
<td>CDR</td>
<td>Critical Design Review</td>
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<tr>
<td>HW</td>
<td>Hardware</td>
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<td>IOC</td>
<td>Initial Operational Capability</td>
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<td>Joint</td>
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<td>KDP</td>
<td>Key Decision Point</td>
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<td>LCA</td>
<td>Life Cycle Architecture</td>
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<td>Life Cycle Model</td>
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<td>Life Cycle Objectives</td>
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<td>O</td>
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<td>Product Release Review</td>
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<td>IBM/Rational Unified Process</td>
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<tr>
<td>SLOC</td>
<td>Source Lines Of Code</td>
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<td>Software</td>
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<td>USAF</td>
<td>United States Air Force</td>
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<tr>
<td>WBS</td>
<td>Work Breakdown Structure</td>
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