Moving from 4+1 to the 5+2 View
Modeling of Architecture:
ULCM\textsuperscript{sm} Views as Extensions of Architectural Views

Dr. Peter Hantos
The Aerospace Corporation
Acknowledgements

• This work would not have been possible without the following:
  ❖ Feedback
    – Dr. Sergio Alvarado, Software Architecture & Engineering Department
    – Suellen Eslinger, Software Engineering & Acquisition Subdivision
    – Dr. Leslie J. Holloway, Software Acquisition and Process Department
  ❖ Funding source
    – The Aerospace Corporation Independent Research & Development (IR&D) Program
Agenda

- Problem/Goal/Objectives
- The 4+1 View Model of Software Architecture
- Evolution of Architecture Artifacts in Iterative Development
  - Snapshots of views associated with architecture evolution
  - Concurrent development of artifacts in Iterative Development
- Unified Life Cycle Modeling (ULCM<sup>sm</sup>)
  - ULCM – The 10,000-foot view
  - The Spiral Model’s ULCM generator view using UML activity diagrams
  - ULCM enactment view of pre-planned increments
- Integrating the Views - A Little “View Algebra”
- Conclusions
- Acronyms
- References
- Backup Slides

© UML is registered in the U.S. Patent and Trademark Office by the OMG
<sup>sm</sup> ULCM is Service Mark of The Aerospace Corporation
Problem Statement

- **Process Architecting is not well aligned with System and Software Architecting**
  - Separately and together they are high-leverage activities of acquisition and development
  - Alignment would result in
    - Earlier identification and better management of problems
    - Ultimately, reduced life cycle cost
Presentation Goal and Objectives

• **Goal**
  - Show a key aspect of synergy between Architecture Views and Unified Life Cycle Modeling (ULCM) Views

• **Objectives**
  - Review how Architecture Views evolve during acquisition and development
  - Present ULCM Views*
  - Integrate ULCM Views with P. Kruchten’s 4+1 View Model of Architecture**

---

**Sources:**
* (Hantos 2005), (Hantos 2006)
** (Kruchten 1995)
The 4+1 View Model of Software Architecture

<table>
<thead>
<tr>
<th>VIEW*</th>
<th>DETAIL</th>
<th>STAKEHOLDERS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOGICAL</td>
<td>Subsystems, Classes</td>
<td>End User</td>
<td>Functionality</td>
</tr>
<tr>
<td>IMPLEMENTATION</td>
<td>Components, Packaging, Layering</td>
<td>Developer, Project Manager</td>
<td>Used to be called Development View</td>
</tr>
<tr>
<td>DEPLOYMENT</td>
<td>Topology, Mapping to Platforms</td>
<td>System Engineer</td>
<td>Used to be called Physical View</td>
</tr>
<tr>
<td>PROCESS</td>
<td>Performance, Throughput, Concurrency</td>
<td>System Integrator</td>
<td>It is a Computer Engineering term</td>
</tr>
<tr>
<td>USE CASE</td>
<td>Architecture Discovery, View Validation</td>
<td>Analyst, Tester</td>
<td>Sometimes called Scenarios</td>
</tr>
</tbody>
</table>

* Diagram and view names based on (Kruchten 1998). The author apparently instituted some name changes for selected views since the first publication (See Kruchten 1995).
Challenging Booch …

• “The 4+1 view model has proven to be both necessary and sufficient for most interesting systems”
  --- Grady Booch, IBM Fellow

This implicit temporal notion does not reflect the complete dynamics

* Emphasis by Hantos
Snapshots of Views Associated With Architecture Evolution

Development Milestones (Anchor Points)

Architecture evolution is reflected in view evolution
Concurrent Development of Artifacts in Iterative Development

Selected Artifacts

- Use Cases
- Class Diagrams
- Deployment Diagrams
- Activity & State Diagrams
- Package Diagrams
- Code

Legend:
- Light blue: 1st Cycle
- Orange: 2nd Cycle
- Pink: 3rd Cycle

Effort %
ULCM – The 10,000-Foot View

- ULCM is a highly intuitive, pattern-based approach for specifying, constructing, visualizing and documenting the life cycle processes of software-intensive system development
- ULCM aspires to be the “Occam’s Razor” of Life Cycle Modeling
  - The medieval rule of parsimony: “Plurality shouldn’t be assumed without necessity”
    - William of Ockham, 14th century philosopher
  - The LCM rule of parsimony: All Life Cycle Models are constructs or derivatives of 4 basic LCM patterns
- ULCM defines two views of life cycle models
  - Generator View
    - Algorithmic and sequencing aspects
  - Enactment View
    - Temporal or trace dimension
The Spiral Model’s ULCM Generator View Using UML Activity Diagrams

Boehm’s Spiral Diagram*

View shows activity sequencing and concurrency details of increments

Sources:
* Spiral Diagram: (Boehm 1988)
** Nested Spirals: (Hantos 2006)
ULCM Enactment View of Pre-planned Increments

View shows temporal dimension: timing, duration, and synchronization of increments
Integrating the Views - A Little “View Algebra”

• Why is Kruchten’s Model called the 4+1 View Model?
  ❖ The first 4 views are independent
  ❖ Use Cases of the 5\textsuperscript{th} view cross-cut across the other views
    – Initially used for discovery and design the architecture
    – Later they can be used to validate the integrity of the views

• How would ULCM Views fit into this structure?
  ❖ The Generator View would be a 5\textsuperscript{th}, independent view
  ❖ The Enactment View has an overarching function
    – As such, it should belong to the “+” category, similarly to the Use Case View

• And the result is:

  \textbf{5+2 View Model}
Conclusions

• Architectural View Models are not static during the acquisition and development life cycle
• Life Cycle Models are key in ensuring the synergy across Architecture Evolution, Elaboration, and Evaluation
• In view modeling ensuring integrity across views is critical
  ❖ The solution is to use overarching, cross-cutting views
• Using ULCM ensures the consistent level of modeling formality of architecture and life cycle models
  ❖ The use of these views could provide direct help to our SMC/NRO customers in implementing the guidelines of the current Software Development Standard for Space Systems (Adams 2005)
<table>
<thead>
<tr>
<th>Acronyms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBMS</td>
<td>Data Base Management System</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
</tr>
<tr>
<td>IR&amp;D</td>
<td>Independent Research &amp; Development</td>
</tr>
<tr>
<td>OMG</td>
<td>Object Management Group</td>
</tr>
<tr>
<td>TCP/IP</td>
<td>Transmission Control Protocol/Internet Protocol</td>
</tr>
<tr>
<td>ULCM</td>
<td>Unified Life Cycle Modeling</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
</tr>
</tbody>
</table>
References

Hantos, P., Interpreting the Spiral Model of Software-Intensive System Development – A ULCMSM Approach, CSER 2006, Los Angeles, California, April 2006 (To be published)
Backup Slides
Logical and Implementation View Examples

Components of Implementation 1

- **Design Model objects**
  - Screens
  - Computations
  - Reporting
  - DBMS

- **Implementation Model compilation**
  - Screens: `screens.c`
  - Computations: `computations.c`
  - Reporting: `reporting.c`
  - DBMS: `dbms.c`

  ![Compilation Objects](system.exe)

Components of Implementation 2

- **Design Model objects**
  - Screens
  - Computations
  - Reporting
  - DBMS

- **Implementation Model compilation**
  - Screens: `screens.c`
  - Computations: `computations.c`
  - Reporting: `reporting.c`
  - DBMS: `dbms.c`

  ![Compilation Objects](thin_client.exe)

Components of Implementation 3

- **Design Model objects**
  - Screens
  - Computations
  - Reporting
  - DBMS

- **Implementation Model compilation**
  - Screens: `screens.c`
  - Computations: `computations.c`
  - Reporting: `reporting.c`
  - DBMS: `dbms.c`

  ![Compilation Objects](client.exe)
Packages and Layers Example for Implementation 3
Deployment Views: Evaluating Deployment Options

Deployment of Implementation 2 Using Multiple PCs

- Multiple Windows PCs
- Computations
- Reporting
- DBMS
- Screens
- TCP/IP

Deployment of Implementation 3 Using One PC

- Single Windows PC
- Screens
- Computations
- Reporting
- DBMS
- TCP/IP

Deployment of Implementation 3 on Multiple PCs

- Windows PCs
- Screens
- Computations
- Reporting
- DBMS
- TCP/IP

Deployment of Implementation 3 Using Distributed Servers

- Single Windows PC
- Screens
- Computations
- Reporting
- DBMS
- Distributed Servers
- TCP/IP
Boehm’s Spiral Model

- Progress through steps
- Cumulative cost
- Evaluate alternatives, identify, resolve risks

**Steps:**
- Requirements plan
- Life-cycle plan
- Risk analysis
- Plan next phases
- Development plan
- Integration and test plan
- Requirement validation
- Design validation and verification
- Implementation
- Acceptance test
- Develop, verify next-level product
- Concept of operation
- Simulations, models, benchmarks
- Detailed design
- Code
- Unit test
- Integration and test
- Software product design
- Software requirements
- Prototype

**Review**
- Determine objectives, alternatives, constraints

**Commitment partition**
Increment Planning Example with Risk-based Considerations

Increment_1

Increment_2

Increment_3
Relevant references from the Standard:

5.6 Software design
“… if the system is developed in multiple builds, its design may not be fully defined until the final build. Software design in each build is interpreted to mean the design necessary to meet the software item requirements to be implemented in that build”

G.3 Scheduling deliverables
“...to the maximum extent possible ... leaving the door open for incremental delivery of software products, staggered development of software items…”

5.18.2 Joint management reviews
“The developer shall plan and take part in joint management reviews…”

Appendix E: Candidate joint management reviews
E.3.4b “The architectural design of the system/segment/…”
E.3.6b “The architectural design of a software item”
All trademarks, service marks, and trade names are the property of their respective owners