Extending UML From Software to Systems

INCOSE Chapter
Crossroads of America
September 12, 2002

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Background

• *Increasing system complexity and software content*

• *Process standards evolving to enhance systems maturity and integration with software*

• *Need approach to model complex systems, which bridges with software and hardware modeling*

• *Initiatives underway to address this need*
  – *ISO AP-233 standards effort for SE data interchange and tool interoperability*
  – *INCOSE / OMG effort to extend UML to systems*
Current Practice for Describing Systems

- Specifications
- Interface requirements
- System design description
- Trade studies
- Test plans
Communications Challenge for SE

Translating Customer Requirements to HW, SW, Specialty, and Test requirements
Why Model Based Approach?

- Improved communications
- Reduced ambiguity
- Reduced errors
- More complete representation
- Enhanced knowledge capture
SE Modeling Techniques

• Many proven modeling techniques
  – Behavior diagrams
  – Data and control flow
  – Functional flow diagrams
  – IDEF
  – N2 charts
  – Schematic block diagrams
  – Signal flow diagrams (control loop)
  – State charts
  – Unstructured (e.g. power-point)

• Limitations
  – No broadly accepted standard
  – Scalability to address complexity
  – Do not integrate well with software
  – Extensibility mechanisms to adapt to specific applications
Why UML for Describing Systems?

- De-facto standard within the software community
- Robust and extensible language to meet SE needs
- OMG Infrastructure
  - Broad international and industry representation
  - Defined adoption process to evolve UML
- Tool vendor and training support
Modeling Language

- **UML**
  - *Is a modeling language*
  - *Is not a methodology*

- **Modeling Language = Syntax + Semantics**
  - *Semantics = meaning*
  - *Syntax = representation of meaning*

- **UML Approach**
  - *Layered meta-model with extension capability*
UML Models (V1.4)

- Class diagram
- Object diagram
- Use Cases
- Sequence diagram
- Collaboration diagram
- Activity diagram/Swim Lane
- State chart
- Component diagram
- Deployment diagram
System UML Modeling (Notional)

- Safety Model
- Behavior Models
- Structure Models
- Performance Model

Dynamics
\[ X(t) \rightarrow \text{Gain} \rightarrow \text{Compensation} \rightarrow \frac{1}{S} \rightarrow \frac{1}{S} \rightarrow Y(t) \]

Request to proceed
OMG Systems Engineering Domain
Special Interest Group (SE DSIG)

- Support development of UML for Systems Engineering, which supports the following goals:
  
  - Provide a standard SE modeling language to specify, design, and verify complex systems
  
  - Facilitate integration between systems, software, and other engineering disciplines
  
  - Promote rigor and correctness in the transfer of SE information between tools
Broad Participation & Interest
(First Three SE DSIG Meetings)

- Artisan
- Astrium GLSH
- BAE Systems
- Boeing
- Cubic Defense Systems
- Deere & Company
- Fujitsu
- General Dynamics
- Georgia Tech
- Hitachi Ltd
- Holagent
- Hyrdro Quebec
- I-logix

- Kennedy Carter
- Lockheed Martin
- Mitre
- NASA - JPL
- NIST
- NSWC
- Open Cascade
- OSD
- Popkin
- Rational
- Raytheon
- Telelogic
SE DSIG 2002 Goals

• *Establish requirements and candidate approaches for UML for SE*

• *Develop a roadmap for implementation through OMG technology adoption process*

• *Influence UML 2.0 responses to address SE concerns*
SE DSIG Progress


- INCOSE / OMG relationship established at OMG Technical Meeting in July 2001
  - Liaison exchange
  - SE DSIG charter (dtc/2001-07-02)

- SE DSIG kickoff in Toronto - Sept 13, 2001
  - Developed preliminary strategy and plans

- SE DSIG Anaheim meeting- Jan 29 - 31, 2002
  - Presented Initial SE Conceptual Model
  - Reviewed and Issued RFI
  - Established SE DSIG Teams
SE DSIG Progress

• SE DSIG Orlando meeting- Jan 24-27, 2002
  – Reviewed RFI responses
  – Reviewed updated SE Conceptual Model
  – Presented UML for SE Prototype Status
  – Reviewed draft req’ts analysis for UML for SE
  – Initiated dialogue with UML 2.0 submitters
  – Updated agenda for OMG SE Information Day

• INCOSE Symposium – July, 2002
  – UML for SE Panel
  – Issue Resolution on SE Conceptual Model

• SE DSIG-U2P Workshop – Sept 12-13, 2002
  – Assess the extent to which the U2P UML 2.0 proposals address the general requirements of Systems Engineering.
Req’ts Analysis for SE UML

- AP-233 Express Model
- SE Conceptual Model
- UML Meta-Model
- UML for SE Prototyping
- Industry Responses
- UML for SE RFI
- UML for SE Req’ts
- Issues & Approaches
- UML for SE Profile RFP
- UML V2.0 Input
  * Informal Channel
SE DSIG Teams

• **SE Conceptual Model** – D. Oliver

• **SE UML Prototyping & Evaluation** – R. Steiner

• **Requirements Analysis for SE UML** – S. Friedenthal

• **SE DSIG Technology Roadmap** – R. Burkhart
  – RFI Response
  – UML 2.0 Submission Team Coordination
Top Level Conceptual Model – Draft 7

Domain of Interest

System View

Stakeholder

Environment

SE_Thing

System

Requirement_S

Stakeholder Need

Property

Property Reference

Behavior

Structure

Physical Property

allocated to

budgeted to

collects

exhibits

interacts with

allocated to

satisfied by

represented by

derived from

statement of

reference for

derived from

(1)

(2)

(3)

(4)

(5)

(6)

(7)

(8)

(9)

(10)

(11)

(12)

(13)
RFI Questions (Top Level)

• How has UML or other modeling languages been used for systems engineering in your organization?

• If UML was used, what benefits were realized?

• If UML was used for systems engineering, or even if UML was considered but NOT used for systems engineering, discuss the limitations and issues perceived.

• What are the potential solutions for addressing the limitations/issues? Please provide references as appropriate?

• What is your level of interest in the development of UML for Systems Engineering?
RFI Responders

- Artisan
- BAE Systems (CNI Division)
- Georgia Tech
- Holistic Systems Engineering
- I-Logix
- INCOSE OOSEM Working Group
- Lockheed Martin Corporation
- Mitre
- Project Technology
- Rational Software
- Systems Engineering Consulting
- Tofs AB
- Volvo Car Corporation
RFI Response Summary

• *Positive indicators and results from the use of UML for SE*

• *Increased use of UML for SE, although it is still probably a small percentage of SE efforts*

• *UML needs to address a broader set of SE concerns to realize the potential benefits*
## SE Evaluation Matrix Example

<table>
<thead>
<tr>
<th>SE Concept</th>
<th>Cockburn Use Cases</th>
<th>OOSEM</th>
<th>Operational Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Requirements</strong></td>
<td>- User/stakeholder goals, needs.</td>
<td>- Text Requirements classes, linked to the model elements</td>
<td>- Actors</td>
</tr>
<tr>
<td></td>
<td>- Use Case Descriptions, Use Case associated information, separate requirement</td>
<td></td>
<td>- Level 0 Actor Diagram</td>
</tr>
<tr>
<td></td>
<td>tables</td>
<td></td>
<td>- Level 0 Operational Flows</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Domain Object Model of Types</td>
</tr>
<tr>
<td><strong>Functional</strong></td>
<td>- Steps in a Use Case Description, Scope of Use Case, linked data requirements</td>
<td>- Operations of a class, related to invocations on sequence</td>
<td>- Operational Flow Links</td>
</tr>
<tr>
<td><strong>requirements</strong></td>
<td></td>
<td>diagrams. Constraints on input/output values, conditions &amp; events</td>
<td>- System Operations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Domain and Types</td>
</tr>
</tbody>
</table>
Requirements Analysis for SE UML

• Initial draft developed based on multiple sources
  – SE Conceptual Model baseline from Anaheim
  – Previous SE RFI inputs
  – Related papers, etc.

• Draft reviewed at June ’02 meeting, and V0.3 made available as early input to UML V2.0 submitters

• Will continue to update and review through November meeting, based on evolving inputs

• Release V1.0 following Nov ’02 as input to technology roadmap, and continue to evolve
Summary of Perceived UML 1.x Limitations (Partial List)

- Continuous time behavior
- Decision tree (e.g. support for trade studies)
- Hierarchical modeling of scenarios and behavior
- Input/output flow (including data and mass/energy flow)
- Integration with other specialty engineering models
- Integration with geometric and spatial models
- Parametric relationships (e.g. performance models)
- Performance, physical and non-behavioral characteristics
- Physical interfaces and connections
- Problem definition and causal analysis
- Requirements constructs
- System, subsystem, element & component representations
- Terminology harmonization
- Verification and validation results
Summary

• Need system modeling language to address system complexity and bridge systems & software gap

• Extending UML offers a potential solution

• Established OMG SE DSIG with broad participation to extend UML from software to systems

• INCOSE is leveraging OMG activity to improve the practice of systems engineering
Upcoming Meetings

- **OMG Helsinki meeting** – Oct 1 ’02
- **SE Conceptual Model Review** – Nov 11-15 in DC
- **OMG Washington DC meeting** – Nov 18 - 22
  - **SE Information Day** Nov 18 – 19
OMG SE DSIG Website

http://syseng.omg.org