# Developing an Introductory Course in:

# Model-Based Systems Engineering (MBSE) with the Systems Modeling Language (SysML)

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NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
NDIA
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

# Outline

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# Purpose of the Presentation

- **Discuss experiences developing and teaching a course in MBSE with SysML**
  - Discuss challenge of teaching a course in MBSE with SysML
  - Discuss course background information
  - Discuss techniques employed to enhance student learning

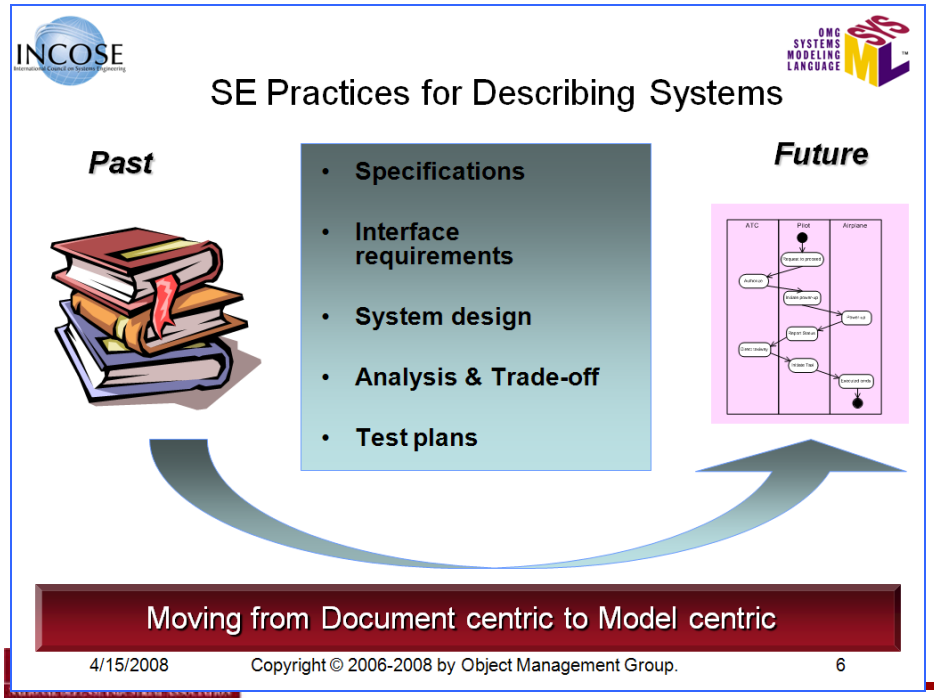
# MBSE/SysML Course Challenge

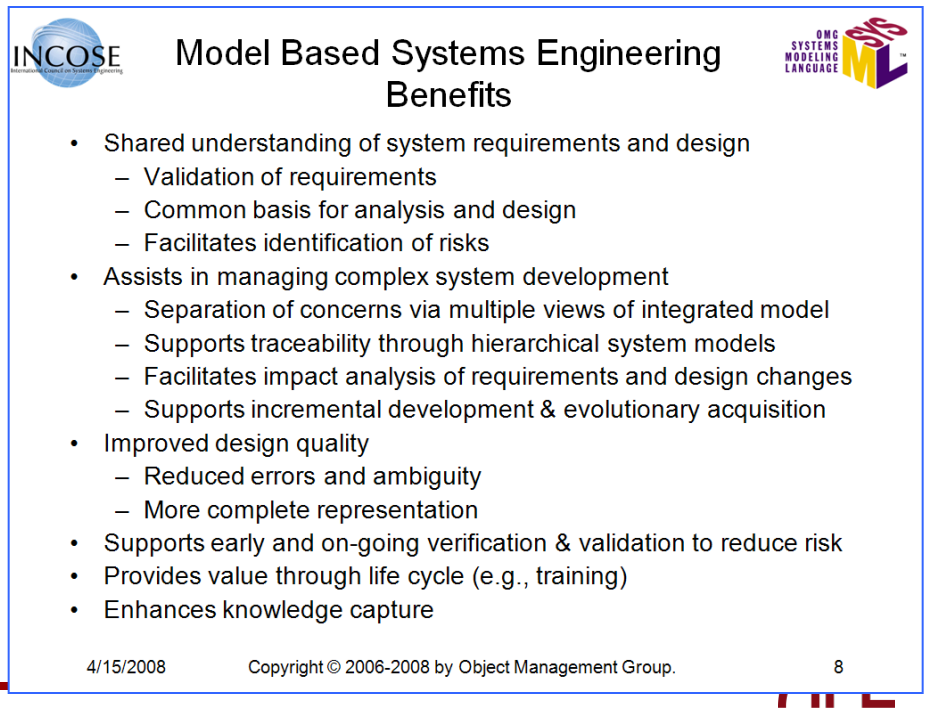
- **Develop an in-house course in MBSE with SysML**
  - Goal:  Teach concepts as well as practical application
  - Develop an effective alternative to the ‘all-day’ seminar
    - Fire-hose effect - too much info to absorb in a short period of time
    - Good for overviews but not enough hands-on learning
- **Bottom-line**
  - Provide students with training needed to apply SysML concepts and the use of a modeling tool to their current projects

# Course Background Information

# Course Background Information - Context

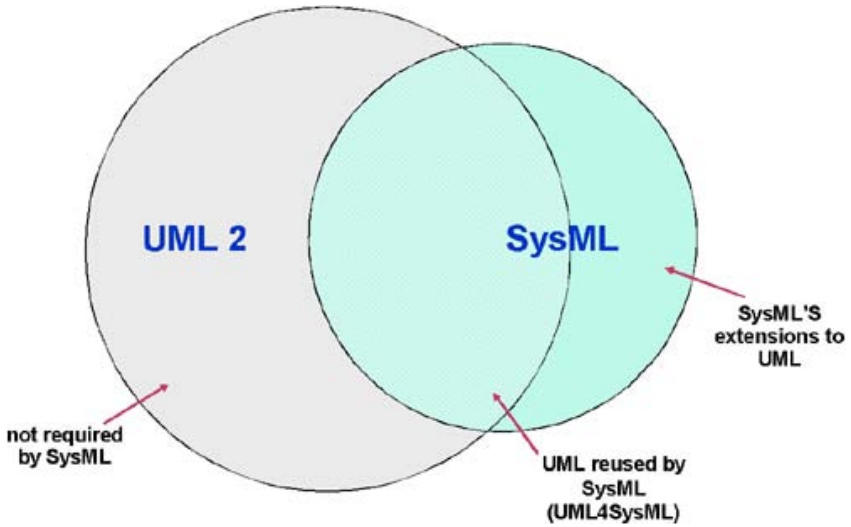
- **MBSE**
  - MBSE is the formalized application of modeling to support systems requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases. [INCOSE, Systems Engineering Vision 2020, Version 2.03, Sept 2007]

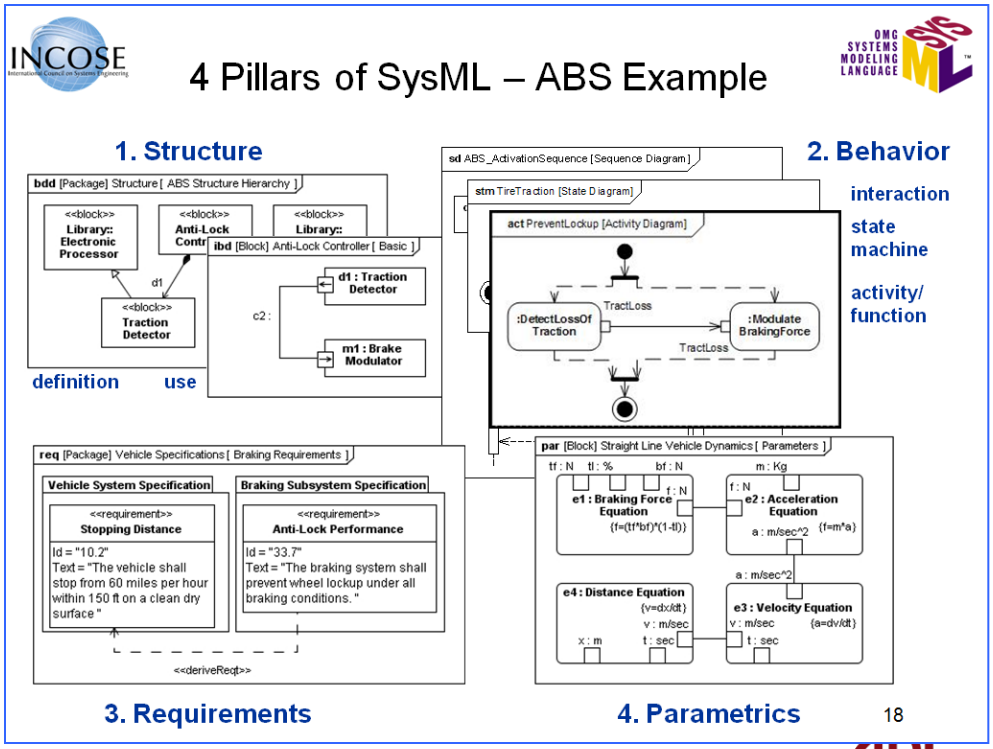


# Course Background Information - Context

- **SysML**
  - SysML is a general purpose graphical modeling language that supports the analysis, specification, design, verification, and validation of complex systems. [Friedenthal, Moore, and Steiner, A Practical Guide to SysML, p. 29]



# Course Background Information - Purpose

- **Teach MBSE, SysML concepts, and tool use to JHU/APL technical staff members**
  - Introduce Model Based Systems Engineering
  - Introduce and teach SysML concepts and techniques
  - Demonstrate and teach use of modeling tool to produce SysML artifacts
- **Motivation**
  - Increased awareness and use of MBSE and SysML
  - Application of concepts to projects
  - Increase staff awareness and comfort level with tool usage
- **Course Objectives**
  - Learn the basics of MBSE and SysML
  - Learn the basics of a SysML-based Tool
  - Practice application of basics to develop system models

# Course Background Information - Demographics

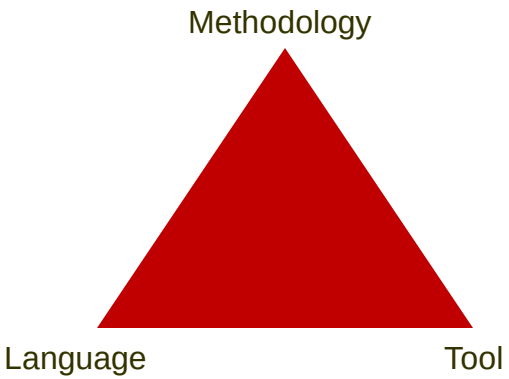
- **Student Information**
  - 18 Students (15 local, 3 remote)
  - Systems Engineering background
  - No prior MBSE knowledge required or assumed
  - No prior SysML or UML knowledge required or assumed
  - No prior SysML-based tool use required or assumed
- **Strategic Education Program (SEP) courses at JHU/APL**
  - Courses for JHU/APL technical staff – taught by JHU/APL staff
  - Non-credit
  - Pass/Fail

# Course Background Information - Text and Software Used

- **Course Text**
  - "A Practical Guide to SysML: The Systems Modeling Language"; Friedenthal, Moore and Steiner; 2008; Elsevier, Inc.
- **Course Software**
  - Sparx Systems "Enterprise Architect" (EA) Ultimate Edition version 7.5 (with SysML)
    - Academic Licenses for instructors and students
    - Instructor experience
  - Cisco MeetingPlace
    - Remote student participation
    - Recorded sessions (presentations and voice)
  - Microsoft SharePoint
    - Posting Course Material

# Course Background Information - Coverage

- **Three things required for modeling:**
  - Language
  - Tool
  - Methodology
- **Focus of this course is:**
  - Language (SysML)
  - Tool (EA)
- **Several MBSE Methods available**
  - Survey of Model-Based Systems Engineering Methodologies [INCOSE –TD-2007-003-01, 10 June 2008, Estafan]
- **SysML and EA are methodology-independent**
  - SysML concepts and the EA tool can be applied to various MBSE methodologies
  - Language and Tool study provide the foundation for Methodology study
  - Detailed look at methodologies – good candidate for follow-on course

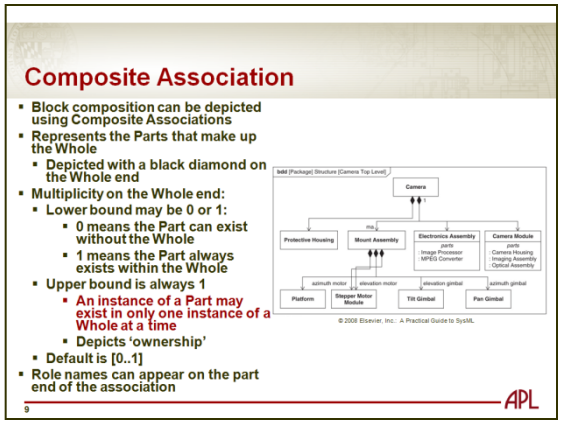


# Course Background Information - Course Schedule

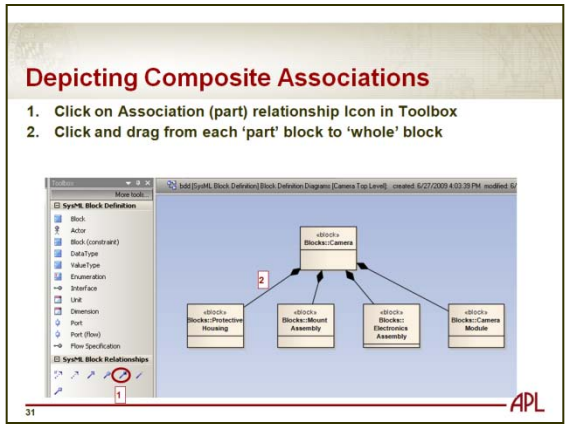
| Week | Date | Hour | Topic |
|---|---|---|---|
| 1 | 9/8 | 1&2 | Course Overview, Systems Engineering Overview, Model Based Systems Engineering Overview, and SysML Overview |
| 2 | 9/15 | 1&2 | Organizing the Model with Packages and EA Basics |
| 3 | 9/22 | 1&2 | Modeling Requirements and their Relationships |
| 4 | 9/29 | 1&2 | Motivation for MBSE and SysML |
| 5 | 10/6 | 1&2 | Modeling Functionality with Use Cases |
| 6 | 10/13 | 1&2 | Modeling Structure with Blocks (Block Definition Diagrams) |
| 7 | 10/20 | 1&2 | Modeling Flow-Based Behavior with Activities |
| 8 | 10/27 | 1&2 | Modeling Event-Based Behavior with State Machines |
| 9 | 11/3 | 1&2 | Modeling Message-Based Behavior with Interactions |
| 10 | 11/10 | 1&2 | Modeling Structure with Blocks (Internal Block Diagrams) |
| 11 | 11/17 | 1&2 | Modeling Constraints with Parametrics |
| 12 | 11/24 | 1&2 | Modeling Cross-Cutting Relationships with Allocations |

# Course Background Information - Typical Class Structure

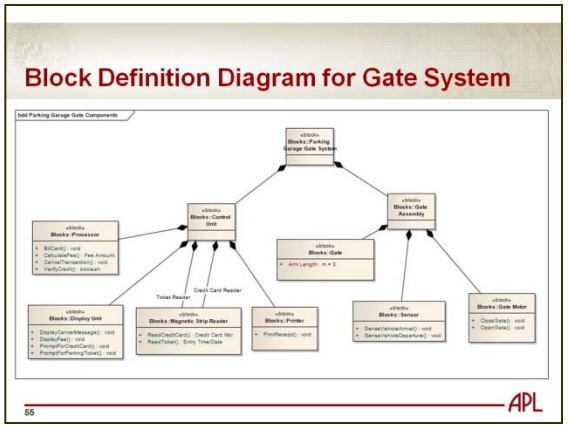
1. Homework Review
2. Motivation: Why Model <subject> Diagrams ?
3. Language: Concepts (from textbook)
4. Tool: Using EA to create <subject> Diagrams
5. Modeling Example: In-Class Project (automated parking garage gate)
6. Homework Assignment




Language




Tool



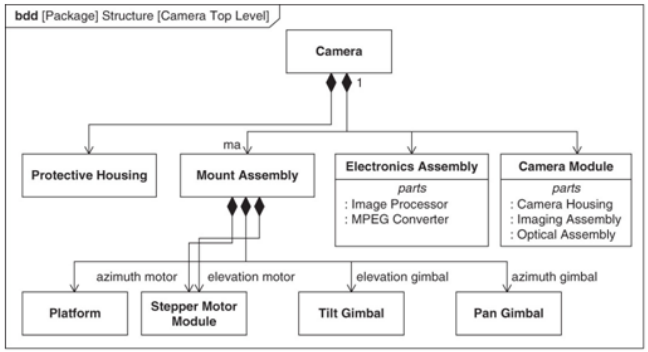

Model

# Sample Language Concepts Slide

- Introduction of SysML elements and relationships with a graphic example of each

## Composite Association

- Block composition can be depicted using Composite Associations
- Represents the Parts that make up the Whole
  - Depicted with a black diamond on the Whole end
- Multiplicity on the Whole end:
  - Lower bound may be 0 or 1:
    - 0 means the Part can exist without the Whole
    - 1 means the Part always exists within the Whole
  - Upper bound is always 1
    - An instance of a Part may exist in only one instance of a Whole at a time
    - Depicts 'ownership'
  - Default is [0..1]
- Role names can appear on the part end of the association





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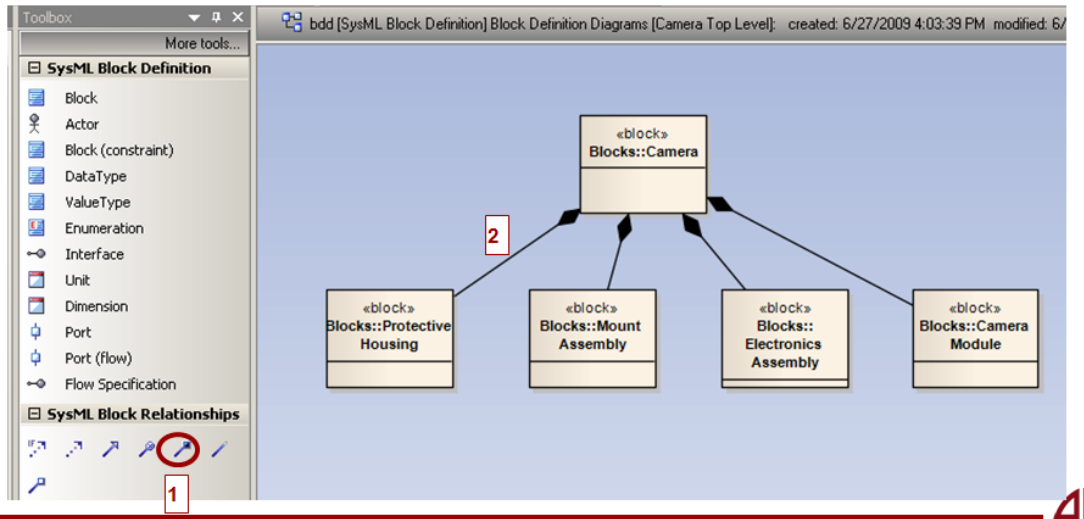
# Sample EA Tool Slide

- Step by step instructions using EA screen captures
- Simultaneous EA tool display demonstrating steps using EA
- Students practice using their own laptops

## Depicting Composite Associations

1. Click on Association (part) relationship Icon in Toolbox
2. Click and drag from each 'part' block to 'whole' block

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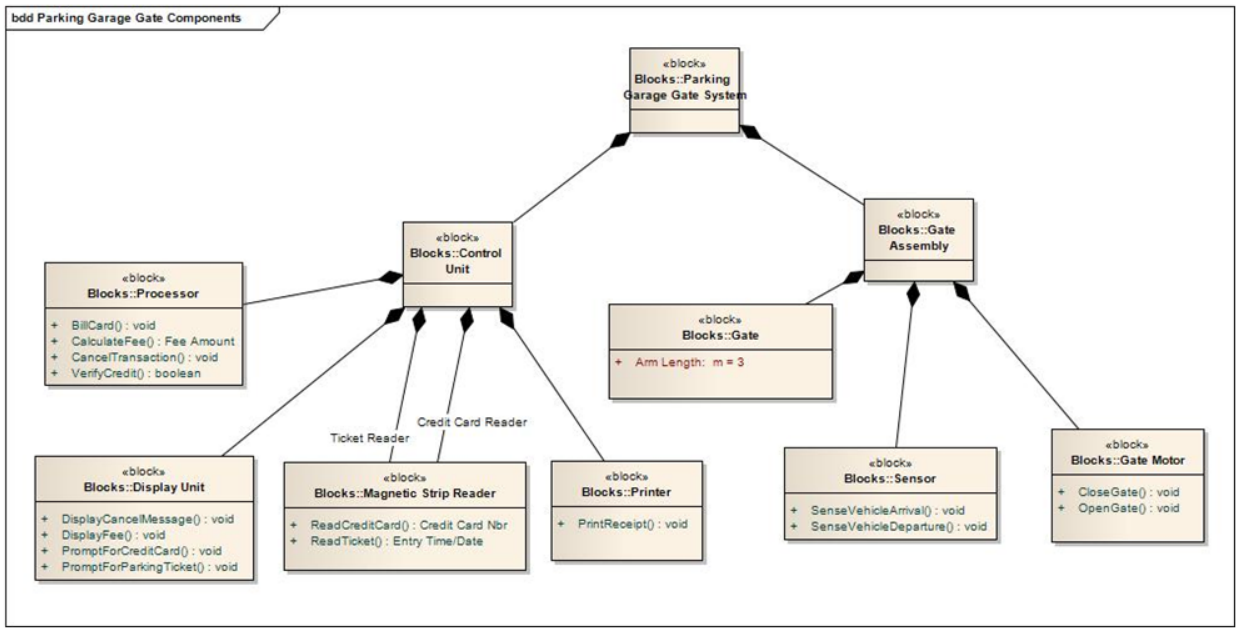
# Sample Modeling Example Slide

- Combining SysML concepts and tool usage to build a SysML artifact for an in-class 'real-world' project system

## Block Definition Diagram for Gate System

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# Course Background Information - Hands-on Projects

- **Homework Systems**
  - Alarm Clock Radio
  - Coke Machine
- **Why?**
  - Familiarity
  - Relatively simple systems (as compared to examples in text)
  - Compare and contrast student models
  - Practice
- **Group Homework Projects**
  - Students working in teams on homework

# Course Background Information - Development Details

- **Course Philosophy**
  - **Need to practice modeling to learn it – course needs to be hands-on**
  - **Minimalistic approach**
    - Focus of course is on the basics (not complete coverage)
    - Just enough to whet the appetite without being overwhelming
  - **Learn-a-little / Practice-a-little approach**
    - Two hour classes / once a week / twelve weeks
      - One chapter of textbook per week
    - Benefits
      - Immediate practice of learned concepts
      - Allows one week of practice for concepts to ‘sink-in’

# Course Background Information - Development Details

- **Section Development Process**
  - **Create 'Reader's Digest' version of a chapter from the text**
    - Extract information appropriate for an Introductory class
    - Create or extract graphics to illustrate each concept
    - Create SysML Concepts slides using information from book and corresponding graphics
  - **Create EA Tool slides**
    - Develop step-by-step process for utilizing the SysML concept within the EA Tool
    - Capture EA screens in order to 'visualize' the process
    - Create slides relating process steps to screen captures
  - **Create Modeling Example slides**
    - Apply concepts and process steps discussed to a real-world system
    - Create slide(s) capturing model depiction

# Course Background Information - Development Details

- **Course Material Peer Review**
  - All course material was presented at INCOSE OOSEM Working Group meetings for review and comment
  - INCOSE OOSEM Working Group consists of subject-matter experts with numerous years of experience in Systems and Software Engineering, MBSE, UML, and SysML
    - Includes textbook co-author (Sandy Friedenthal)
  - Course material was reviewed incrementally by the Working Group
    - Course Outline
    - Section Development
    - On-going input and feedback through Course Presentations
    - Planned:  Contributions to post-course improvements

# Summary and Take-aways

**MBSE/SysML courses should include adequate:**

- Visual learning techniques by using graphical examples of language concepts and graphical depictions of step-by-step tool usage (visual learning)
- In-class instructor-lead demonstrations of the modeling tool (learning through demonstrations)
- In-class hands-on training with a modeling tool (learning by doing)
- Time between sessions to give students time to learn and practice the concepts outside of class (incremental learning / “sink-in” time)
- Homework projects for the students to model to apply the concepts that they have learned to sample systems (learning through practice)
- Group homework (collaborative learning)
- Peer review of course matter with subject-matter experts (course validation and verification)
- Remotely accessible and recordable sessions for remote (or absent) students (remote learning)

# What's Next

- **Finish teaching current course (Nov 24th)**
  - Course Evaluation
  - Perform Course assessment
  - Implement improvements
- **Develop 'Methodology' Course as a follow-on to this Introductory course**
- **Investigate offering course publicly as an elective in the Johns Hopkins University Engineering for Professionals Master's Degree program in Systems Engineering**

# Questions