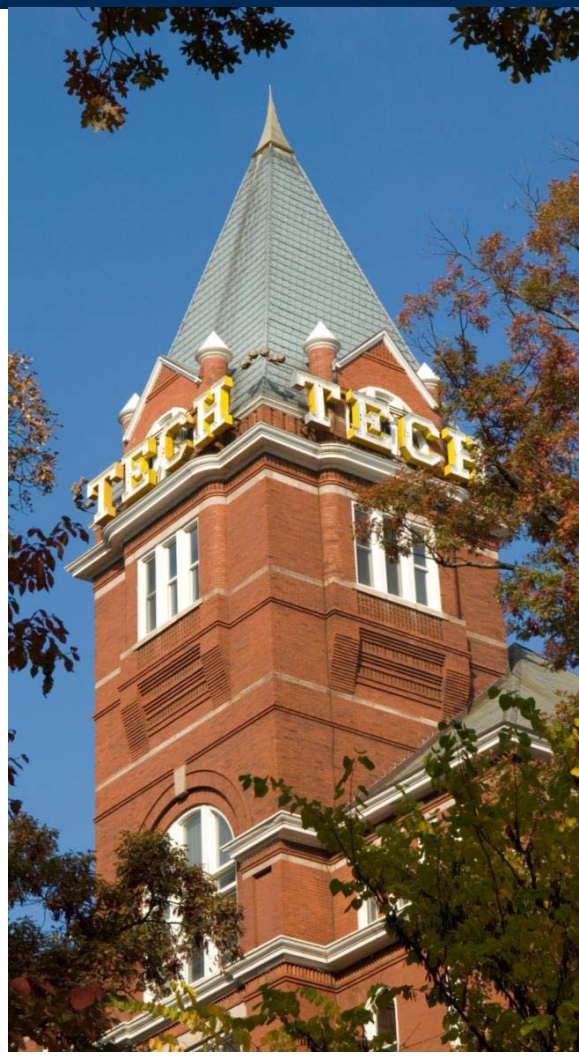
Georgia Tech Research Institute

Creating an Enhanced MBSE Learning Environment Using Lego® Mindstorms



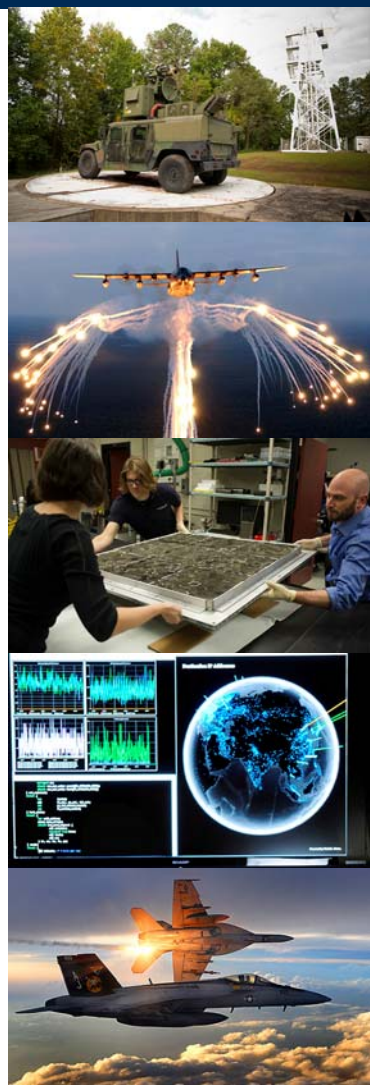
NDIA Systems and Mission Engineering Conference, Oct 21 – 24, 2019

Mike Shearin

Agenda

[9]

- Intro
- Current methodology
- Lego suitability to teaching MBSE Concepts
- Building the course, one brick at a time
- Demonstration



Intro – MBSE

- MBSE is HARD.
- Art as well as science
- Abstract in nature
  - But with massive and real consequences
- No established way to make MBSE tangible in a class

SE alone has masters and doctorate programs

One person's logical is another's conceptual.

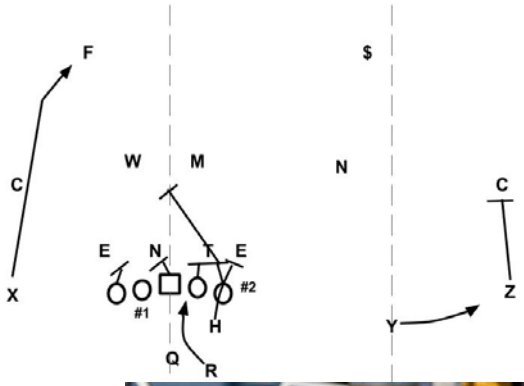
FMEA's – Learning only happens on failures

Sports teams use scrimmages to foster learning. *Why not for MBSE?*

We need to do better at teaching MBSE if it is to be a successful discipline

Intro – Fundamentals of learning

- Understanding the subject matter and the object matter
  - The subject matter are the concepts to be learned
  - The object matter is the context-rich 'why'
- Concept Encoding
  - Students construct their own version
  - They constantly refine the construct (see below)
- Feedback loop
  - Consequences
  - Coaching/positive feedback



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Students need to actively participate in the learning process

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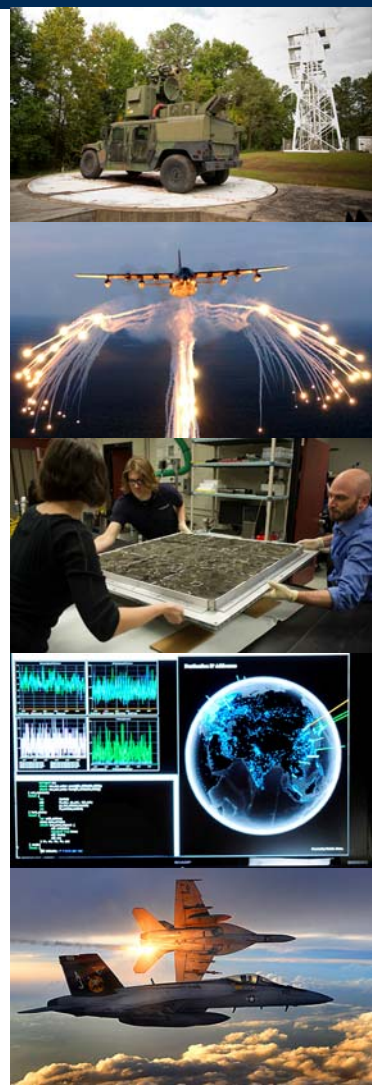

Current Teaching Methodology for MBSE courses

- Textbooks
- White papers/conference presentations
- Formal Classes / Hands-on
- Demonstrations
- Security Camera System (Friedenthal)
- This presentation
- Ski Resorts (Peek) / Multi-Function Printer (PMASE)
- Rovers (Peek)

Providing physical feedback on success and failure of MBSE concepts will speed up mastering and adoption

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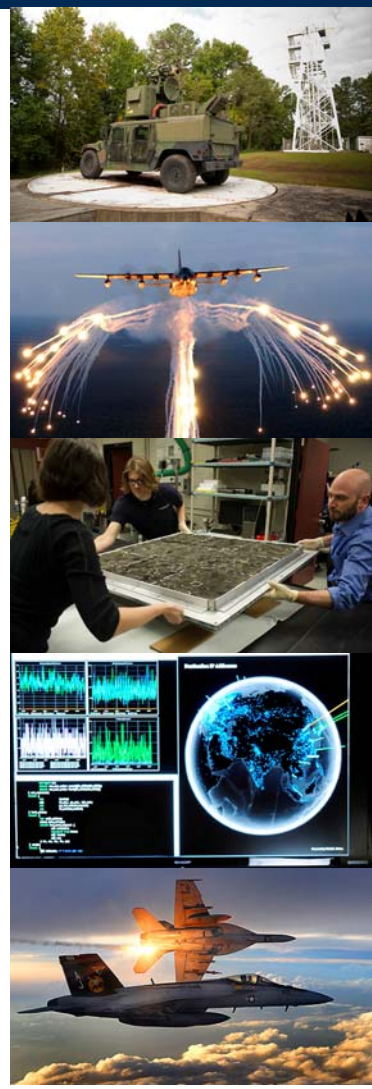

Lego suitability to … concept exploration

- Lego Architecture Set introduced in 2013
- Used by architects to study concepts
- Full disclosure: I own this one

[1]

Lego suitability to … prototyping design

- Lego Mindstorms (ev3) set introduced in 2013
- Education version used by STEM teachers
  - Lego has dedicated and curated curriculum
- FIRST Lego League

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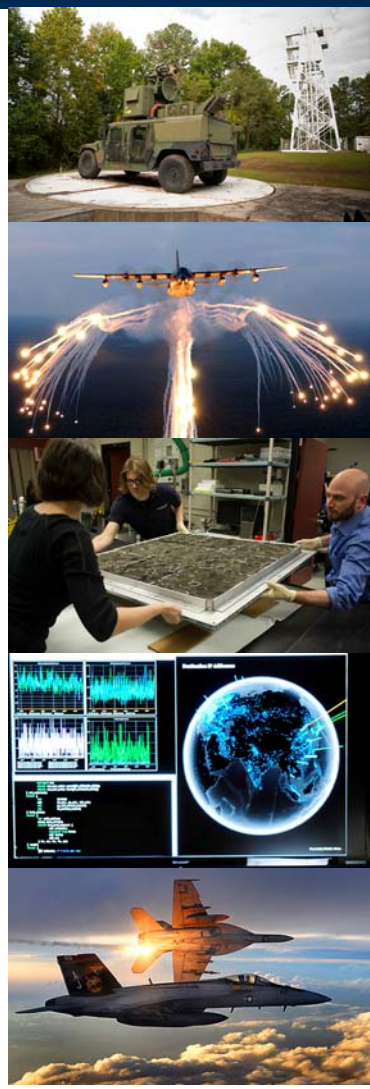

Building the Course: Core Modules

- Introduce problem, generate and model a concept (Concept Exploration)
- Model and analyze the tradespace (Concept/Design Exploration)
- Model the structure and behaviors (Design)
- Build and execute (V&V)
- Competition

} Legos provide a medium for these!

Each of these modules could be subdivided, then mixed and matched (like Legos) to keep the days short.

Building the Course: Provided Material

- Starter SysML Model
  - Analytical and pattern libraries
  - Model framework with best practices
  - Example models
  - Programming tutorials

[10]

Activity diagrams + custom Lego Mindstorms plugin

- Lego kits
  - Set of differing pre-built drive trains
  - Set of sensors
  - Set of chassis

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The challenge: rescue an injured person from a dangerous environment

- Carry an injured person (an egg)
- From point ‘a’ to ‘b’
- In a certain amount of time
- Egg must retain structural integrity
- Optional: retrieve a second egg
- Optional: drop off intel at a second location

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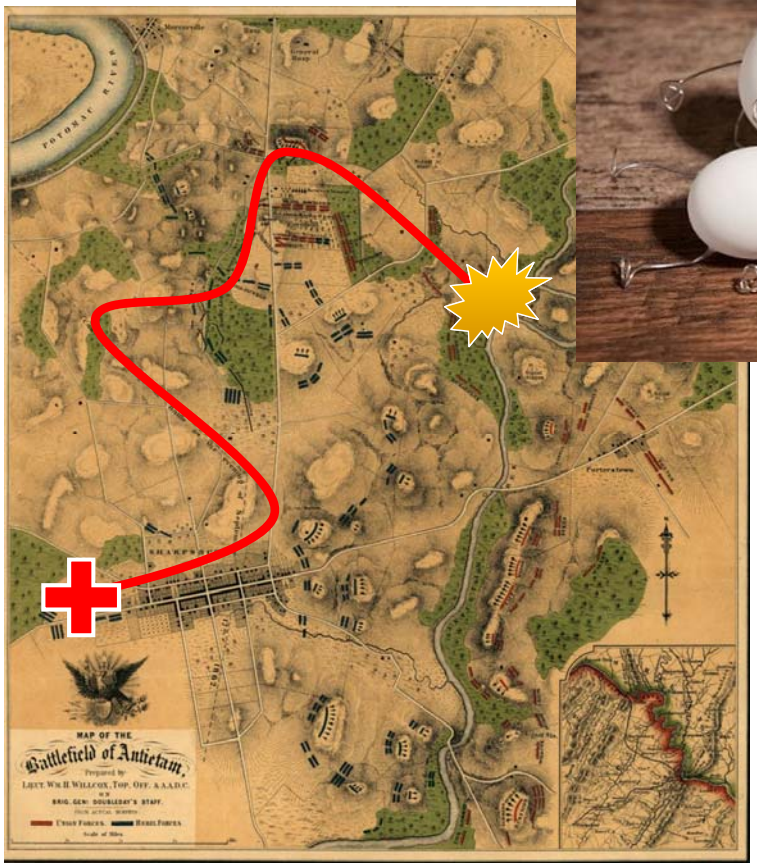

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How do we know it's effective?

- Use a study and a control group
  - Study group with Lego, control without
- Written test at end of course of core concepts and competencies
- 6 month later follow-up questionnaire of core concepts and competencies
- Compare results

[12]

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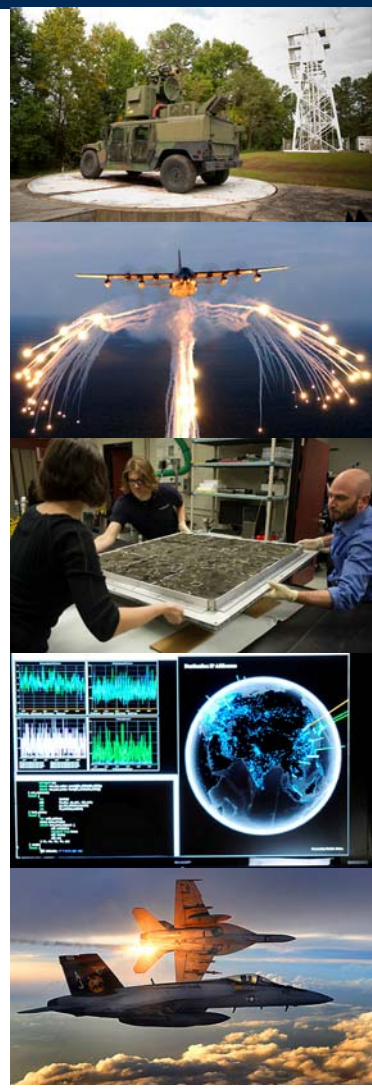

Demonstration – programming the robot with SysML

Questions

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Backup Slides

Backup: Programming References / Notes

- Currently using a directly-commanded approach with the default ev3 OS.
  - A great starter for programming in Python and Java (although Python is the author's preferred language)
  - http://ev3directcommands.blogspot.com/2016/01/no-title-specified-page-table-border_94.html

  - Another option for the firmware/OS is the Lejos embedded OS that is based on Java.
    - Earlier efforts chose this path with MD17/18.
    - https://blog.nomagic.com/collaboration-between-simulated-model-and-external-system-controlling-lego-mindstorms-with-cameo-simulation-toolkit/

- Create a library of Java APIs that can be called from CSM and other modeling tools.
- RESTful not currently researched. Given the embedded nature, likely a challenge.

Sources

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