Concept Engineering
Technologies to Advance
Model-Based Systems
Engineering

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October 22, 2012

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This material is based upon work supported, in part, by the U.S. Department of Defense through the Systems Engineering Research Center (SERC) under Contract H98230-08-D-0171. SERC is a federally funded University Affiliated Research Center managed by Stevens Institute of Technology
WHAT IS THE PROBLEM?
Where in the SE Process?
Three Guiding Definitions

**CONCEPT OF OPERATIONS:**
A Concept of Operations (CONOPS) document is produced early in the requirements definition process to describe what the system will do and why. It should also define any critical, top-level performance requirements or objectives (stated either qualitatively or quantitatively) and system rationale.


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**CONCEPT ENGINEERING:**
The phase of the System Engineering lifecycle prior to requirements elicitation, system architecting and design, during which developers “rapidly elucidate the need, explore solutions, develop CONOPs, and derive requirements for materiel solutions”

(Baldwin, Kristen. Acquisition Modeling & Simulation Update: NDIA M&S Committee. Feb 16 2010)
Model Based Systems Engineering:
The formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases. MBSE is part of a long-term trend toward model-centric approaches adopted by other engineering disciplines, including mechanical, electrical and software. In particular, MBSE is expected to replace the document-centric approach that has been practiced by systems engineers in the past and to influence the future practice of systems engineering by being fully integrated into the definition of systems engineering processes.

(INCOSE SE Vision 2020 [INCOSE-TP-2004-004-02 September, 2007])
How do you develop a system if you do not know what it is supposed to do?
The Problem with Today’s CONOPS

- It takes too long to create the textual document.
- Many times the customer is not involved.
- The CONOPS is static and not interactive.
- Cannot perform “what if” analysis on the CONOPS.
- The agreement of terminology during long meetings many times removes any real meaning behind the cartoons.

RESEARCH NEED: There is a need to quickly and graphically articulate a concept of operations (CONOPS) for new missions, business processes, and feature sets to realize a shared mental model and understanding of the mission, and potential solutions across a set of diverse stakeholders.
HOW IS IT SOLVED TODAY?
How Are CONOPS Created Today?

A need is identified, and sometimes documented.

Simple and/or custom simulations may be created (MatLab, etc).

Alternative solutions are considered (Pugh, AHP, etc).

The process is iterative...

Continued effort to narrow down possible concepts.

Finally, months later, a Concept of Operations may be published.

Depending on the domain, complex modeling may be used.

Evaluation of Conceptual Solutions

Analysis of Conceptual Solutions

Synthesis of Conceptual Solutions

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THE RESEARCH – USING SERIOUS GAMING APPROACHES TO CREATING A GRAPHICAL CONOPS
Game players come from all walks of life. The game taps into their 3-D spatial abilities to rotate chains of amino acids in cyberspace.

**ScienceDaily (Sep. 19, 2011) — Gamers have solved the structure of a retrovirus enzyme whose configuration had stumped scientists for more than a decade.** The gamers achieved their discovery by playing Foldit, an online game that allows players to collaborate and compete in predicting the structure of protein molecules.

After scientists repeatedly failed to piece together the structure of a protein-cutting enzyme from an AIDS-like virus, they called in the Foldit players. The scientists challenged the gamers to produce an accurate model of the enzyme. They did it in only three weeks.

The solution of the virus enzyme structure, the researchers said, "indicates the power of online computer games to channel human intuition and three-dimensional pattern matching skills to solve challenging scientific problems."


**Journal Reference:** Firas Khatib, Frank DiMaio, Seth Cooper, Maciej Kazmierczyk, Miroslaw Gilski, Szymon Krzywda, Helena Zabranska, Iva Pichova, James Thompson, Zoran Popović, Mariusz Jaskolski, David Baker. *Crystal structure of a monomeric retroviral protease solved by protein folding game players.* *Nature Structural & Molecular Biology*, 2011; DOI: [10.1038/nsmb.2119](10.1038/nsmb.2119)
What do we hope to accomplish with this research?

1. Improve the concept engineering process through the use of gaming and visualization technologies, enabling a team of end-users to more quickly agree on a common vision for a new product or service.

2. Provide an integration framework for visualizing new concepts using any number of analysis tools to generate an improved concept of operations (CONOPS) and operational architecture.
Concept Engineering
Application Approaches

**New Application**
- Create an entirely new class of product
- **Advantages**
  - Get exactly what is needed
  - Have resident knowledge to make changes
  - Able to deal with abstract/conceptual knowledge
- **Disadvantages**
  - Very Costly
  - Become a software shop rather than a research enterprise

**Hybrid**
- **PROVE the VALUE** of a new interface which allows easy interchange with existing applications
- **Advantages**
  - If cannot find what is needed, can create
  - Able to work with abstract/conceptual knowledge
- **Disadvantages**
  - Costly
  - Learning curve for each interface

**Existing Application**
- Use existing applications in a manner in which they were not designed
- **Advantages**
  - Take advantage of sunk costs
  - Quality product for minimal costs
- **Disadvantages**
  - Many are NoForn
  - Process to change the product difficult or cumbersome
  - Requires more detail than available at concept engineering
  - Complex to set up

We are focusing here...
Team is Using Unity 3D

- Unity is a popular IDE for creating 3D games.
- Extensive support community
- Cross platform deployment
- Rapid deployment and testing
- Interoperability of programming languages
- Database and networking support
- Currently being used by:
  - Building Construction Architects to model buildings
  - Defense contractors to develop training simulations
  - Process Engineers to model complex processes
  - Biologists to model complex biological behavior
The Scenario Builder

Add things to the scene here

Create relationships between things here

Graphically build scene here

Capture textual descriptions here

Chat with collaborators

A scenario is a collection of scenes

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Visually Developing a Shared Mental Model

Once the team agrees on the concepts, the scenario(s) can be put into motion for observation, analysis, and agreement.

The scenario(s) can be modified, or stored for later sharing with others for approval.
WHAT MIGHT THIS LOOK LIKE?
FUTURE VISION
Visual Concept Engineering Framework (ICEF) Vision

- Domain Libraries
  - Using information from
  - Integrated through
  - Produces
  - Using 3D Simulations
  - Produces

- Analysis Toolbox
- Enabling a shared vision among stakeholders

- New idea
- Virtual Environment
- Distributed Participation
- Touch Enabled

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PARTNERING FOR THE FUTURE
AGI Systems Tool Kit Framework

• Scenario generation
  – Mission & Analysis orchestration
• Physics and time consistency
  – Cross domain analytical engine
• Data normalization and configuration management
  – Common data structure and integration mechanism
• High fidelity visualization
  – Common 3D/2D interaction environment
STK Engineering Models

- Model vehicle position and attitude
- Model terrain, atmosphere & space
- Sensor Models
  Model sensor geometry & pointing
- Model RF propagation & interference
STK Systems Analysis

- Analyze system behavior in theater
- Calculate system performance
  Measure against mission objectives
- Evaluate system relationships
  Measure system impact
- Explore trade space
  Analyze system design
STK Integrated Visualization

Vehicles, routes, sensors & analysis

3D object representations
Position, orientation & articulation

Mission environment
Terrain & imagery

Convey results
Graphs, reports, images & videos
AGI Executable CONOPS

• MBSE Animator developed by SERCO
  – Execute and Visualize operational scenario CONOPS to play out mission threads
  – Evaluate effects of system characteristics

• Inputs
  – System architecture definition from COTS tool (i.e. IBM Rational)
  – System specific parameters (vehicle routes, sensor information, etc.)

• Results
  – Dynamic, system-driven, event-based, physics verified, 3D visualization
  – Verification of CONOPS and early system designs
Integrate
Open, documented API

Model System
Performance models
Environmental models
Operational models

Analyze Mission
Mission synthesis
Mission effectiveness

Convey Results
Data | Report | Graph | Chart
Video | Interactive animation

Collaborate
Manage STK and non-STK data
Use the SERC Graphical CONOPS as a Front End for the STK

SysML Model V(x)

Draft CONOPS

Iterate

SysML Model V(x+1)

Executed CONOPS

Reasoning Tools

Decision Makers

Requirements Engineer

System Requirements; SysML
USING AGILE PRINCIPLES AND TOOLS
Development Process and Tools

- Adopting a modified Scrum process
  - 30 Day Sprints
  - Weekly telcons with all parties invited

- Stevens is using an Internet tool – Trello to track Day-to-day work assignments

- Use Unity Asset Server to manage/share codebase

- Releases will be first Monday of each Month.

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Modeling the Integrated Concept Engineering System
Road Forward

• Research should provide initial answers to research questions in the next year

• Where do we take the research/concept from there?