

Re-inventing the Approach to Concept Engineering

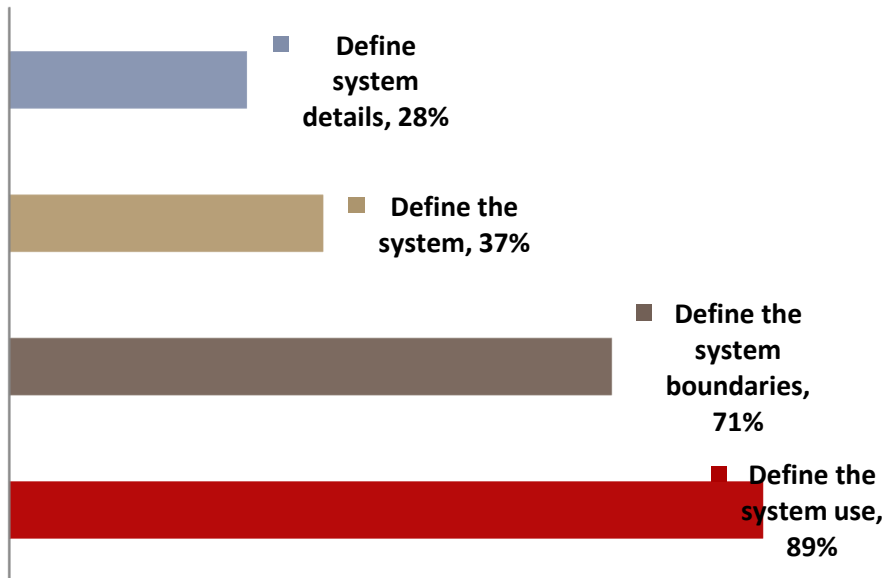
Integrated Concept Engineering System (ICES)

Dr. Robert Cloutier

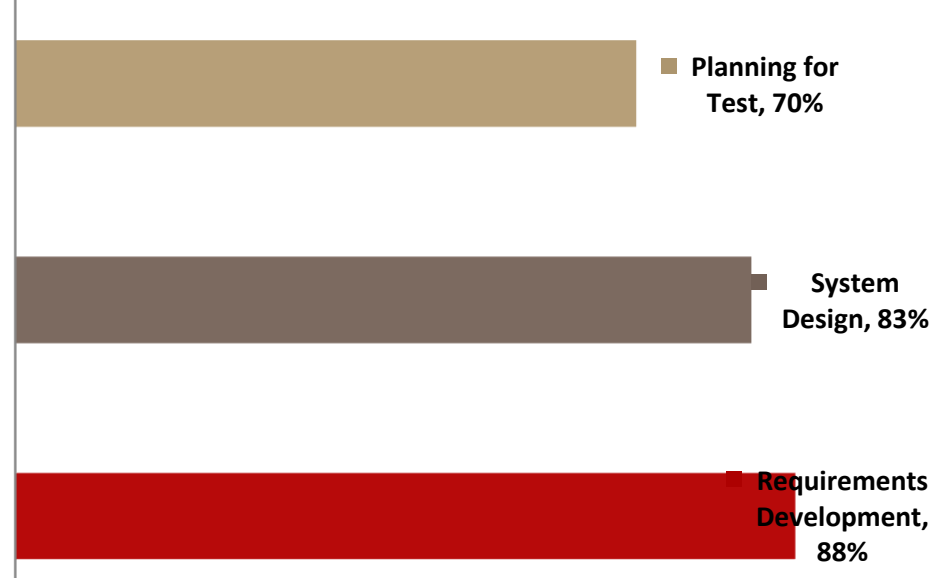
**How do you develop a system
if you do not know what it is
supposed to do?**

- Survey results from > 100 responses from 18 defense contractors, of which 36% had never worked on a program that had a CONOPS

Perceived Purpose of a CONOPS

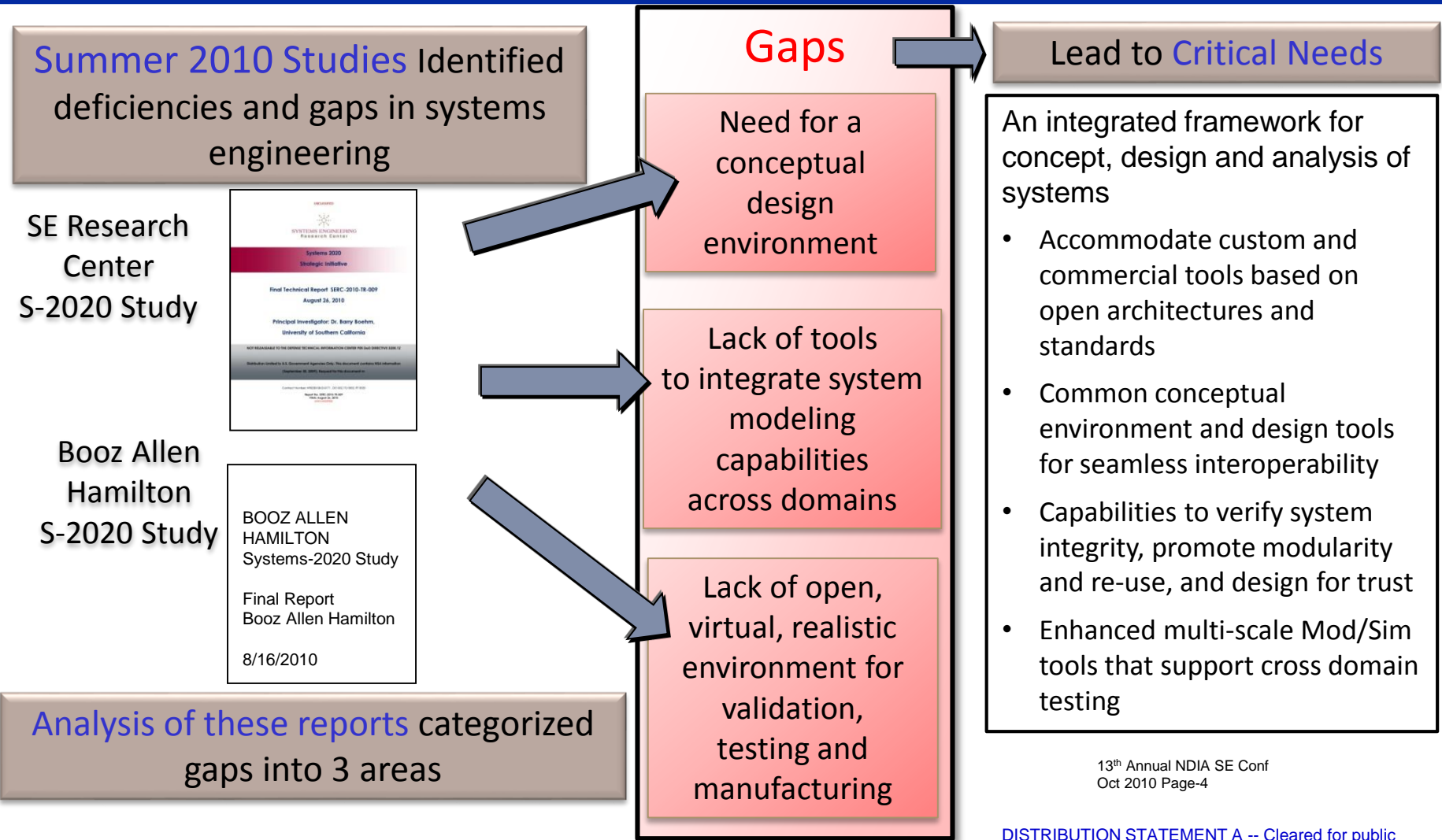


Perceived Program Phases that would Benefit Most



How are we building systems if our teams do not understand the purpose of the System?

Source: Roberts, N. and R. Edson. *System Concept of Operations: Standards, Practices and Reality*. in 11th Annual NDIA Systems Engineering Conference. 2008.



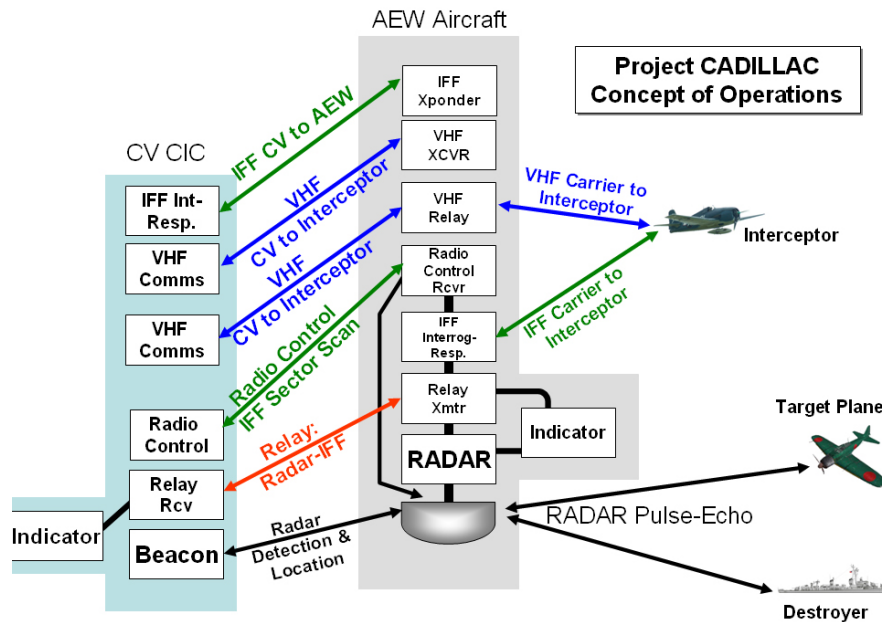
13th Annual NDIA SE Conf
Oct 2010 Page-4

DISTRIBUTION STATEMENT A -- Cleared for public release by OSR on XX October 2010 -- SR case number #10-S-#### applies.

CONOPS; Then and Now

We have not Progressed Far

First Airborne Early Warning System to defend against aircraft (1945)



Source: US Naval Institute Blog:
<http://blog.usni.org/?s=AEW&x=0&y=0>

PROBLEMS: There is no meaning behind the graphics;
There are no human roles represented

CONOPS from any current Naval program



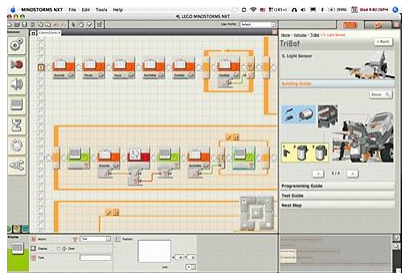


“Human-Centered Design”

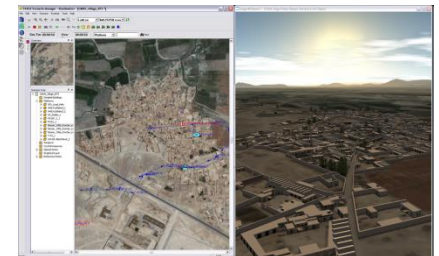
A significant amount of capability exists today – but it needs to be reconstituted to enable Concept Engineering



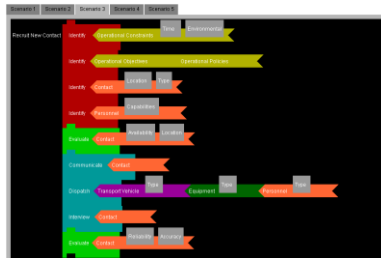
Immersive Virtual Environments



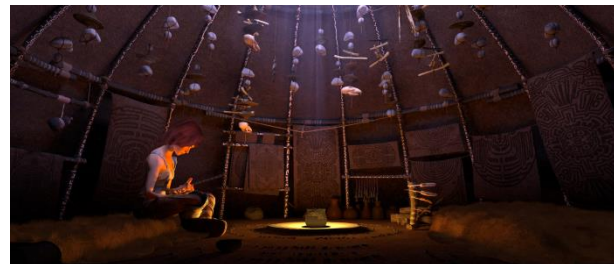
Graphical Programming



Rapid Virtual Environment generation



Lego-style interfaces



Gaming Platforms



Virtual Environment to CAD tool translation



CONOPS Navigator

Process	Data	Tool
Manager	Exchange	Execution
	Tool	Manager

Concept Engineers and Stakeholders will enter the tool through a virtual lobby. They will select their Avatar of choice.

As the team comes together in the ICES Lobby, each participant will select their individual role - developer or author.

The tool then provides guidance and navigation help through the process of integrating tools and developing the CONOPS.

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

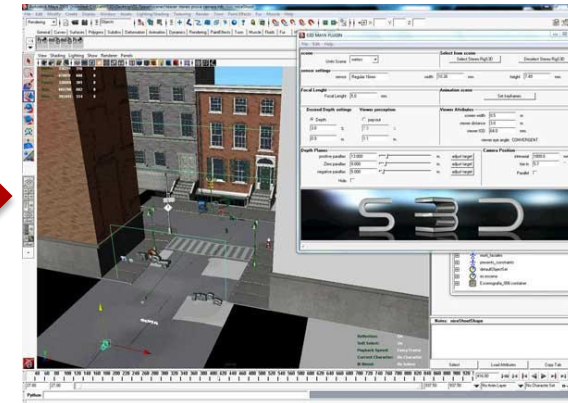
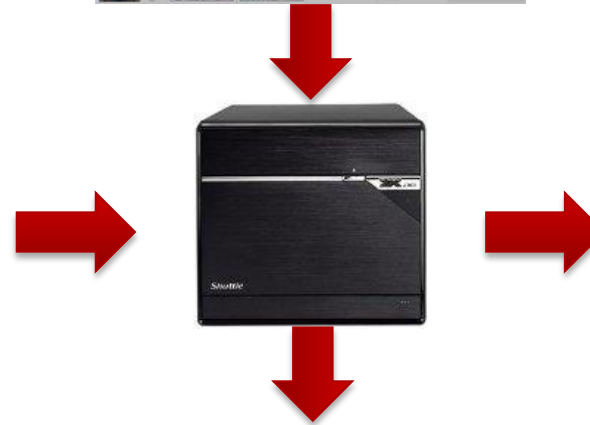
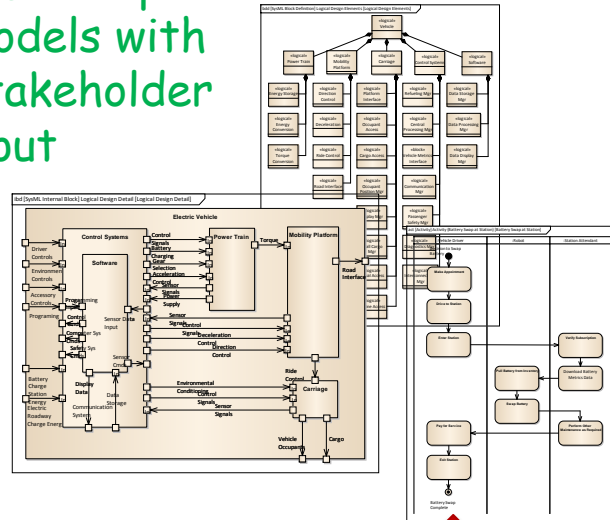
The scenario(s) can be modified, or stored for later sharing with others for approval



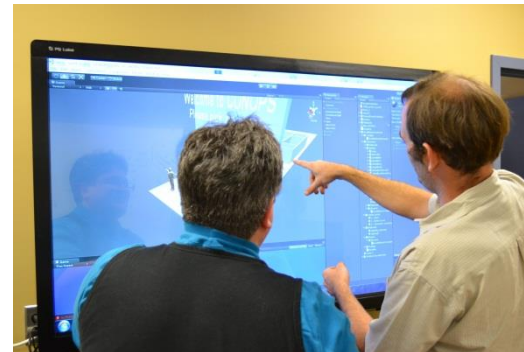
1. Develop initial Models with Stakeholder input



2. Reuse objects from libraries, or create new objects as necessary. Then, start with scenario fragments, or create new scenarios



4. Results are fed back to the model, updated, and run again



3. Collaborators are able to execute the scenario, and make adjustments

- The Challenge
- State of CONOPS Development
- ICES Approach
- ICES Progress to Date
- Integrating with Current CONOPS Tools
- Institution Investment
- Challenges
- Conclusions

Stevens

- Dr Rob Cloutier
- Dr Teresa Zigh
- Dr Mark Blackburn
- Peter Korfiatis, RA
- Alex Zhang, RA
- Behnam Esfahbod, RA

Purdue

- Dr Sarah McComb
- Dr Abhi Deshmukh
- Keith Hall, RA

Current State of CONOPS Development

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)

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.

(Systems Engineering Handbook INCOSE-TP-2003-016-02, Version 2a, 1 June 2004)

- ANSI/AIAA G-043-1992 – guide from American National Standards Institute
- IEEE 1362-1998 – IEEE guide for CONOPS document
- DI-IPSC-81430 – DoD data item description for CONOPS document

1. Scope. System identification, purpose, and overview. Contents, intention, and audience for the operational concept document

8. Operational Scenarios. Detailed sequences of user, system, and environmental events:
 - Normal conditions - "Stress" conditions
 - Failure Event - Maintenance mode
 - Handling anomalies

2. Referenced Documents

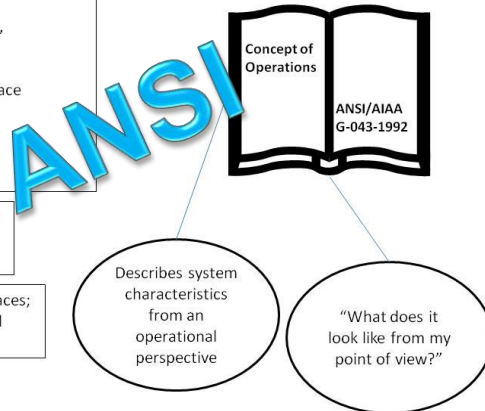
3. User-Oriented Operational Description.
 How mission accomplished: strategies, tactics, policies, constraints. Who users are and what the users do.
 - When and in what order operations take place
 - Personnel profile; organizational structure
 - Personnel interactions; activities
 - Operational process models: sequence, interrelationships

4. Operational Needs. Mission and personal needs that drive the requirements for the system

5. System Overview. Scope; users; interfaces; states and modes; capabilities; goals and objectives; system architecture

6. Operational Environment

7. Support Environment



Title page
 Revision chart
 Preface
 Table of contents
 List of figures
 List of tables
 1. Scope
 1.1 Identification
 1.2 Document overview
 1.3 System overview
 2. Referenced documents
 3. Current system or situation
 3.1 Background, objectives, and scope
 3.2 Operational policies and constraints
 3.3 Description of the current system or situation
 3.4 Modes of operation for the current system or situation
 3.5 User classes and other involved personnel
 3.6 Support environment
 4. Justification for and nature of changes
 4.1 Justification of changes
 4.2 Description of desired changes
 4.3 Priorities among changes
 4.4 Changes considered but not included
 5. Concepts for the proposed system
 5.1 Background objectives, and scope
 5.2 Operational policies and constraints
 5.3 Description of the proposed system
 5.4 Modes of operation
 5.5 User classes and other involved personnel
 5.6 Support environment
 6. Operational scenarios
 7. Summary of impacts
 7.1 Operational impacts
 7.2 Organizational impacts
 7.3 Impacts during development
 8. Analysis of the proposed system
 8.1 Summary of improvements
 8.2 Disadvantages and limitations
 8.3 Alternatives and tradeoffs considered
 9. Notes
 Appendices
 Glossary

IEEE

- 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



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- It takes too long to create the textual document



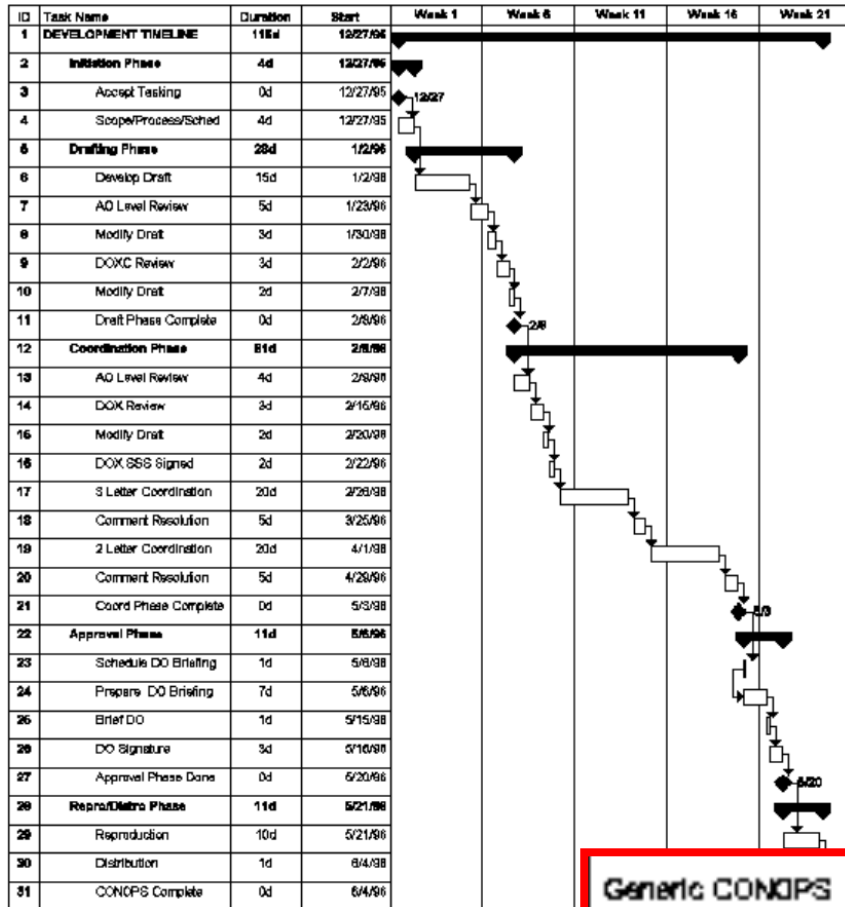
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- Many times custom involvement
- The CONOPS is not
- Cannot be analyzed
- CONOPS

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.

8.1 Summary of improvements
8.2 Disadvantages and limitations
8.3 Alternatives and trade-offs considered
9. Notes
Appendices
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CONOPS Development Timeline



Generic CONOPS timeline.
Use as a guide only.

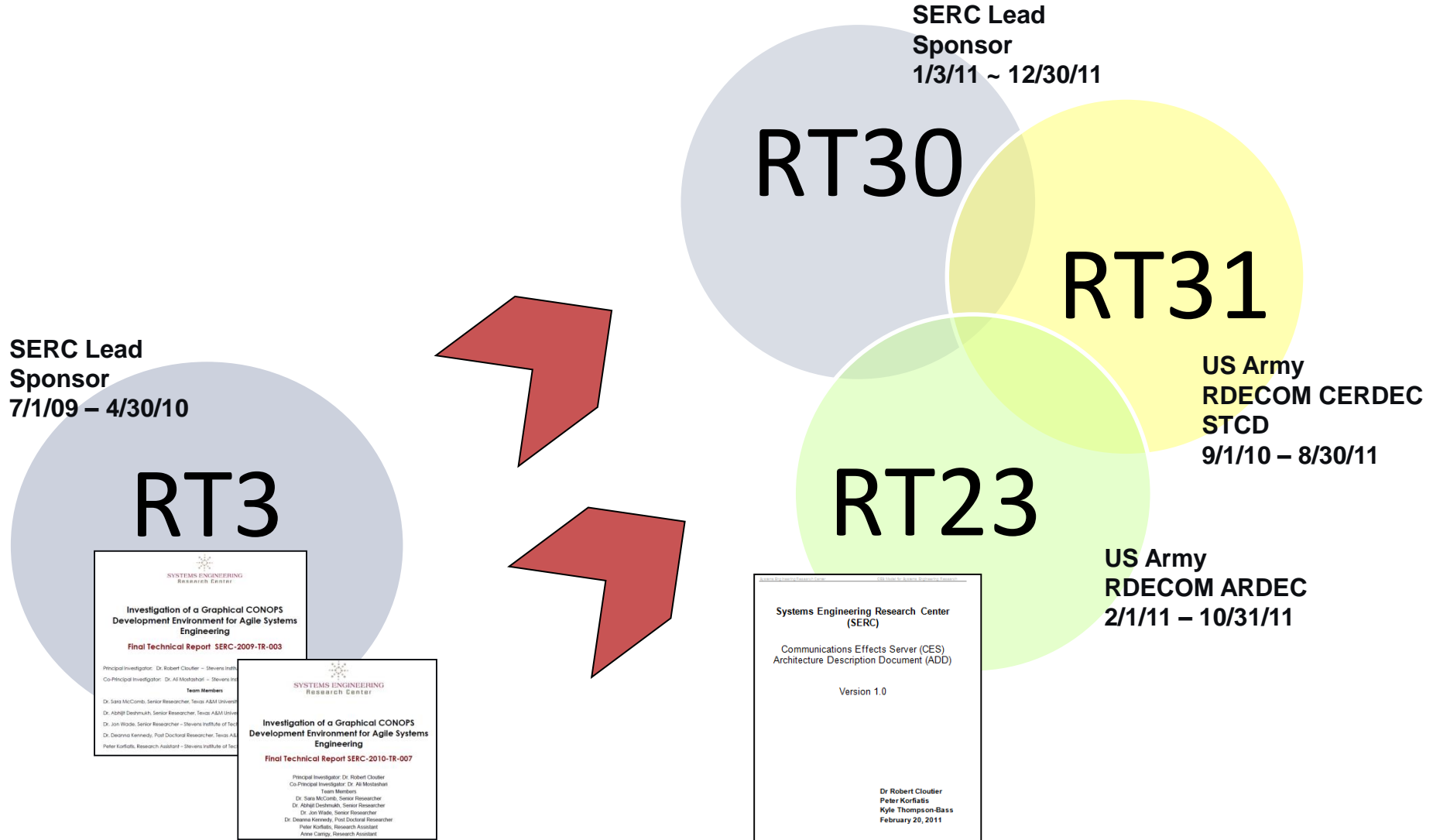
- Air Force Space Command
- AFSPCI 10-606, dated 2 May 1996, DEVELOPMENT AND USE OF CONCEPTUAL DOCUMENTS
- Clearly states to “Use as a guide only”
- However, notice example duration:



- Can the process of CONOPS development and understanding be improved through the use of a “drag and drop” graphical user interface?
- Can real-time collaboration between distributed stakeholders improve the CONOPS development? And, can a real-time collaboration environment enable quicker consensus on CONOPS generation?
- Does a mental model improve the communication among stakeholders? Do visual models allow domain-specific stakeholders to better communicate the needed operational needs?
- Will an immersive environment support non-real-time, but rather just-in-time asynchronous collaboration?
- Does 4D (3D + time) provide deeper insights into the operational concepts of a proposed system than traditional textual documents or static 2D story boarding?



The evolution of SERC Concept Engineering Research

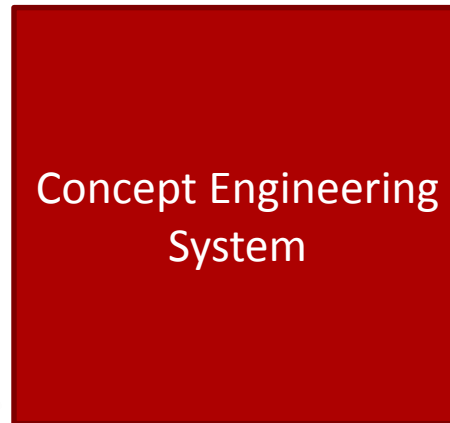


Graphical CONOPS Proof of Concept Prototype

CONOPS Author



**Primitive
Developer**



Outputs



Partial Textual
CONOPS



Graphical
Scenario
Descriptor

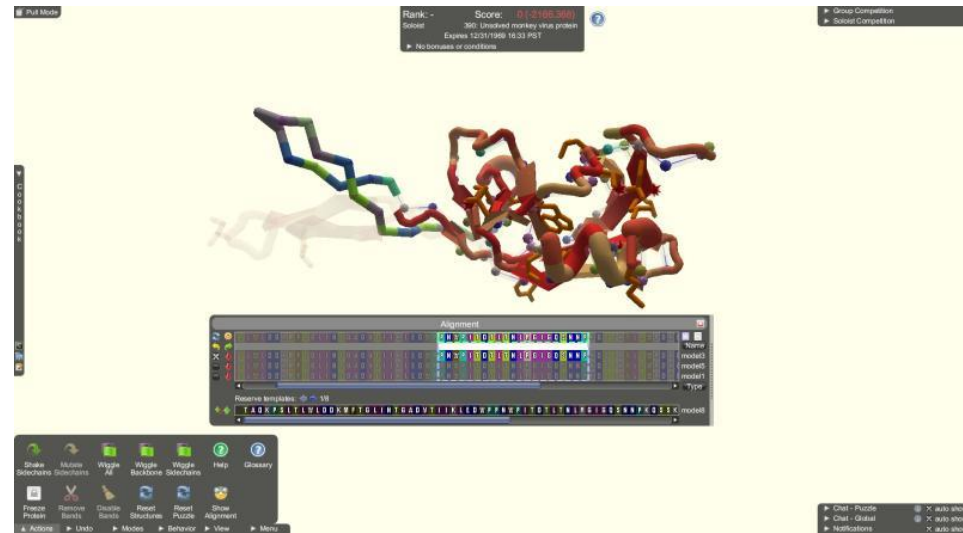
ICES Approach



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.

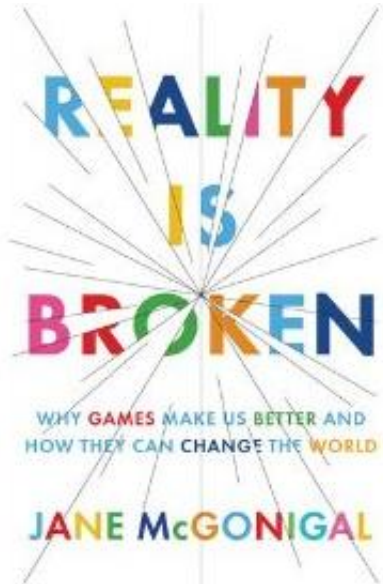
After scientists repeatedly failed to piece together the structure of a protein-cutting enzyme from an AIDS-like virus, they called in the **Foldit players**. The scientists challenged the gamers to produce an accurate model of the enzyme. They did it in only three weeks.



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."

Source: University of Washington. "Gamers succeed where scientists fail: Molecular structure of retrovirus enzyme solved, doors open to new AIDS drug design." *ScienceDaily*, 19 Sep. 2011. Web. 20 Sep. 2011.

Journal Reference: Firas Khatib, Frank DiMaio, Seth Cooper, Maciej Kazmierczyk, Mirosław 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](https://doi.org/10.1038/nsmb.2119)



Reality is Broken explains the science behind why games are good for us--why they make us happier, more creative, more resilient, and better able to lead others in world-changing efforts.

But some games are better for us than others, and there is too much of a good thing.

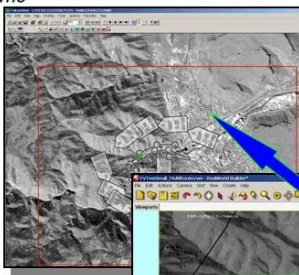
Play games you enjoy no more than 21 hours a week; face-to-face with friends and family as often as you can; and in co-operative or creator modes whenever possible.

DoD is Researching Virtual Mission Planning

SPAWAR SOMPE/RealWorld: Customer: SOCOM

Integrated Planning & Rehearsal

Systems Center ATLANTIC



Three routes laid out in SOMPE/FalconView. Draw terrain box marquee

Drag marquee to RealWorld. Terrain, routes, etc automatically transferred, routes automatically assigned to AI paths

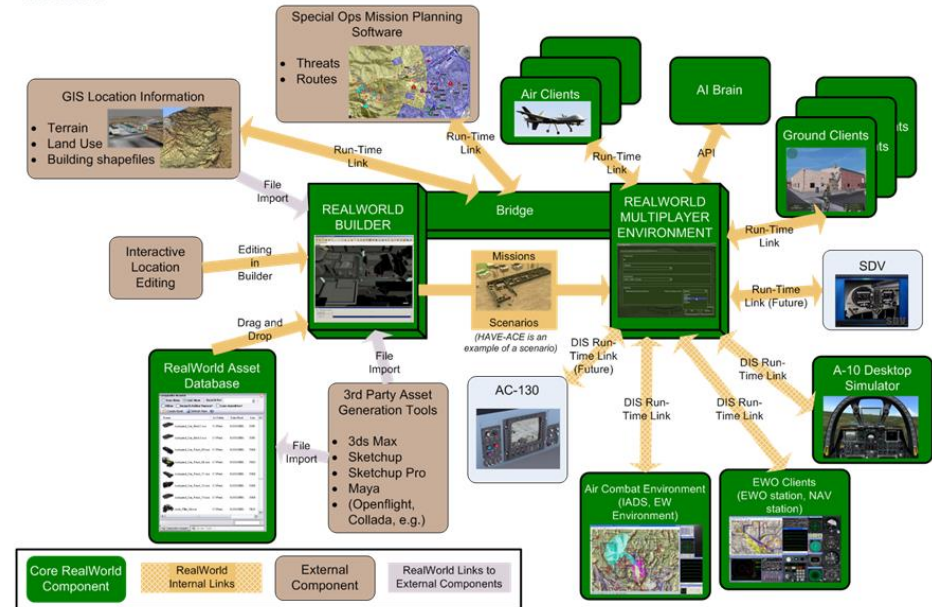
Press 'GO' and you are training!

PFPS 4.2 (2009)

- Visualize and simulate a mission plan within RealWorld that was generated in SOCOM's FalconView based Special Operations Mission Planning Environment (SOMPE)
 - Terrain data (valleys)
 - Routes
 - Thum
 - Threats
 - Local points, etc.
- Direct import of SOMPE terrain (CDB) into RealWorld
- Provides real-time 2-way interface. Create 2D plan in PFPS, visualize in 3D in RealWorld, adjust in either domain. When you like it, rehearse the mission!
- Improve the plan prior to real-life mission execution by replacing the "rock drill" thought exercise with a high-fidelity simulation of actual intel, terrain data, and mission plan

SPAWAR **RealWorld®** architecture combines ease of use with powerful capabilities

Systems Center ATLANTIC



The Department of Defense and DARPA have an initiative underway to investigate 3D for mission planning and training



Quickly generated scenario in Unity



Scene from Unity's Bootcamp Demo

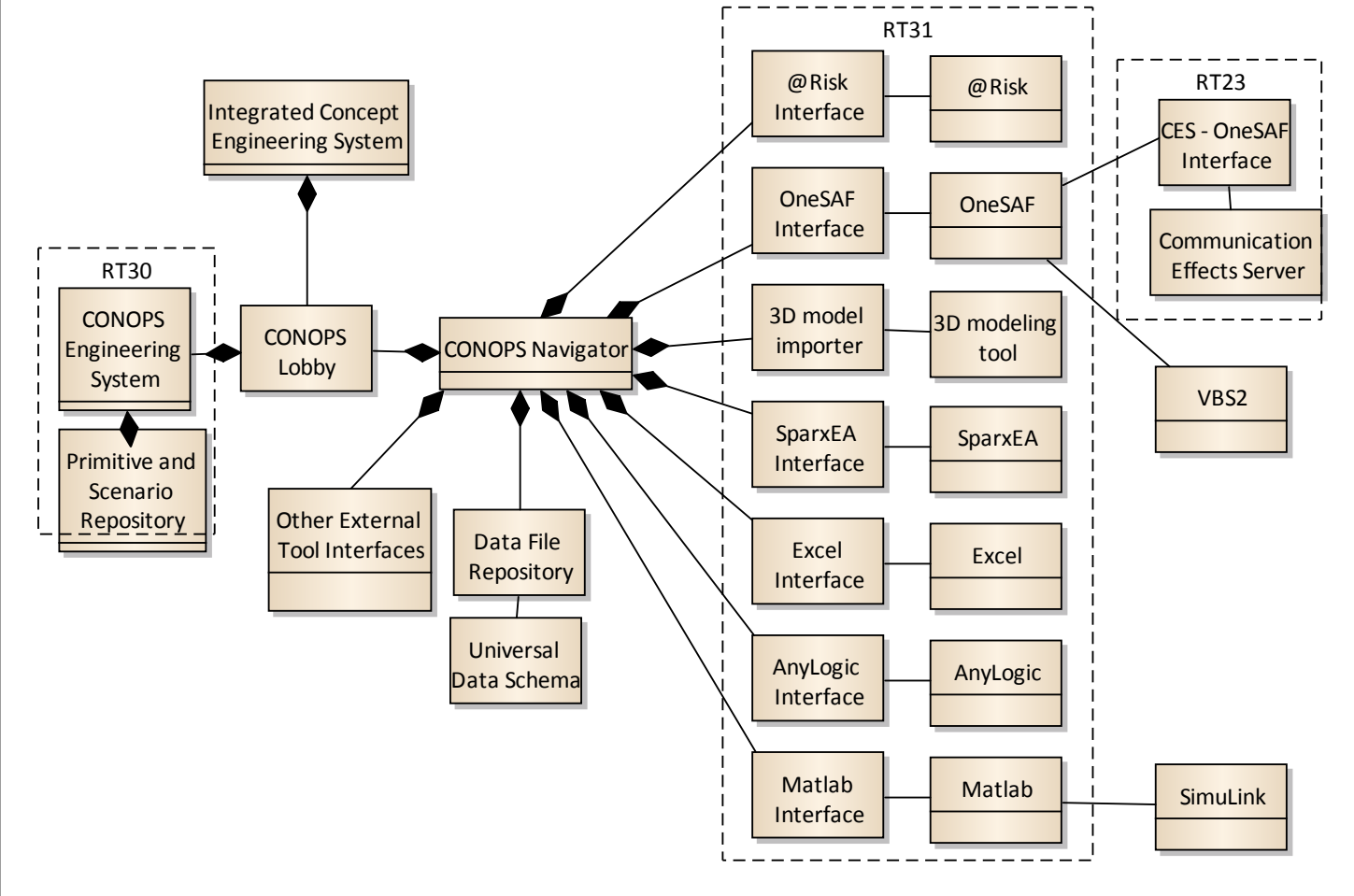
**We have chosen to use
the Unity³ game
development engine for
our research**

ICES Progress to Date

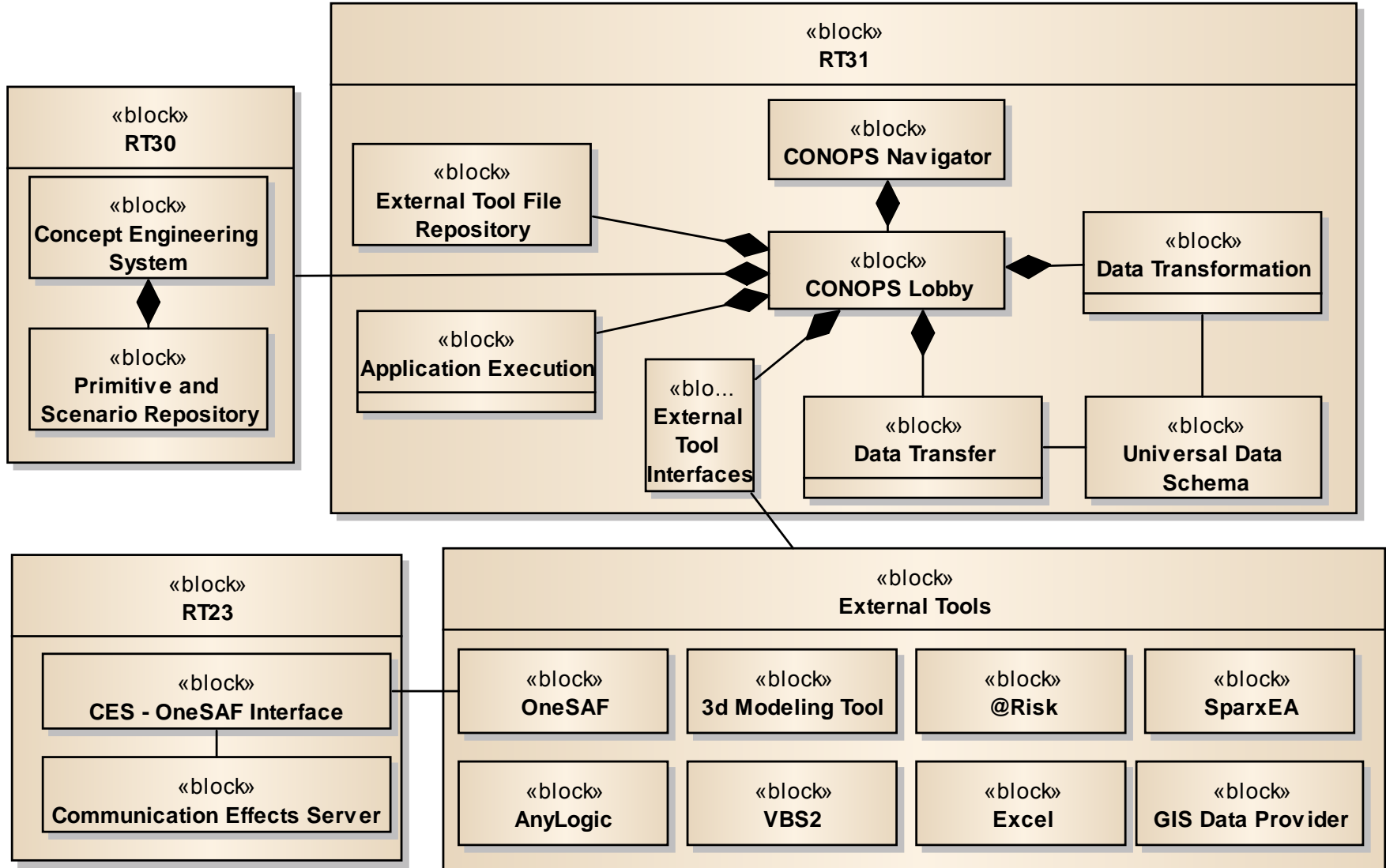
- Developing pilot scenarios with our research sponsor
- Will conduct a workshop in November to allow our sponsor to “exercise” the prototype

Conceptual Architecture

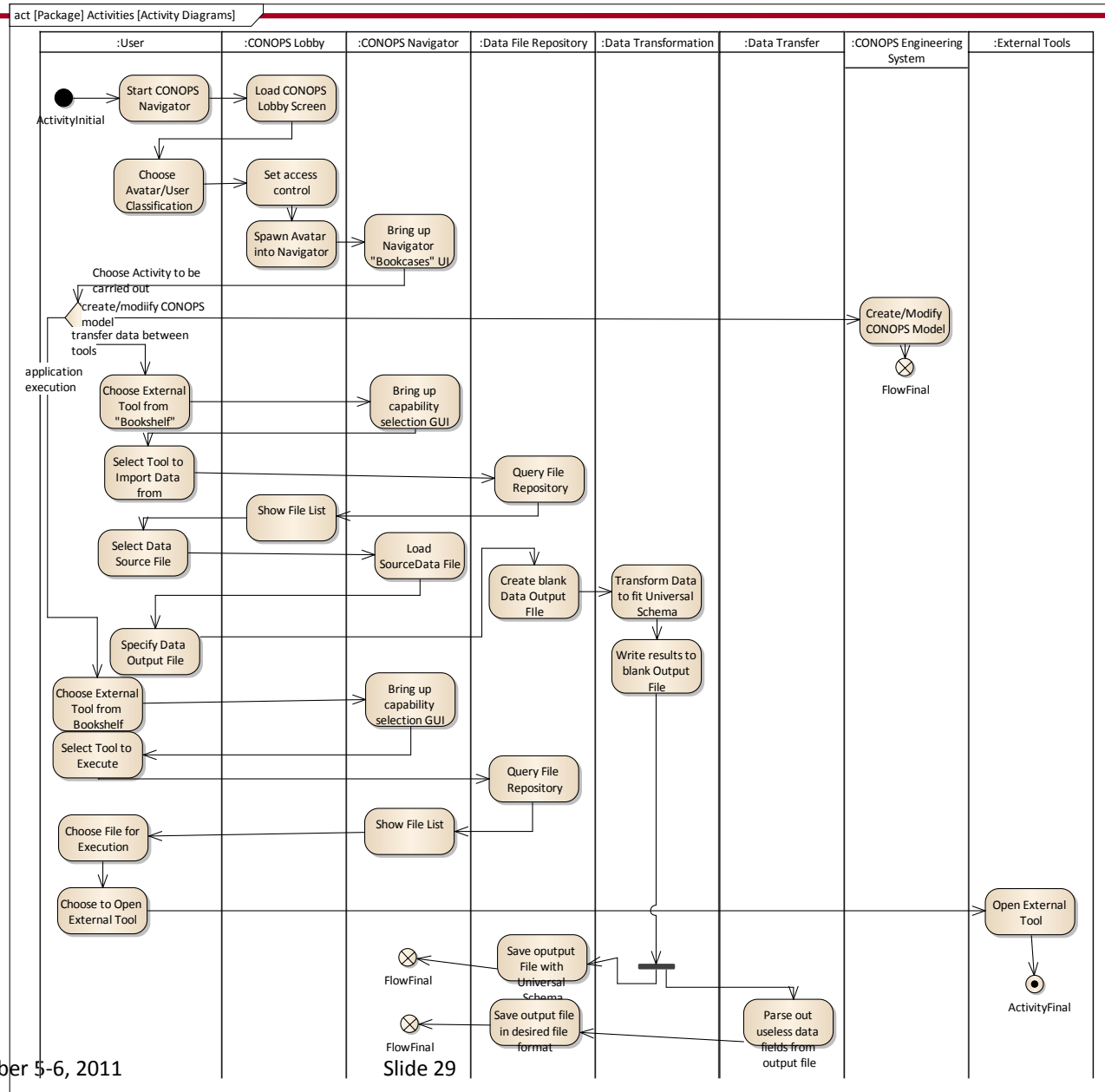
bdd [Package] ICES Architecture [ICES Conceptual Architecture]



bdd [Package] Interactions Between RTs [Interactions Between RTs]

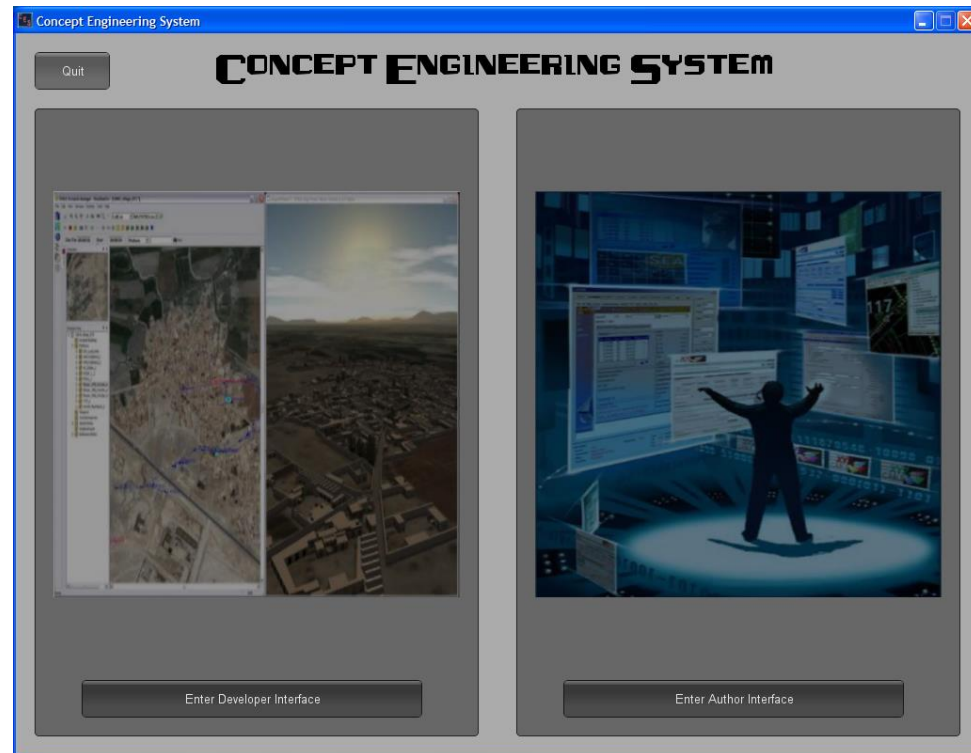


We are modeling the process of creating a CONOPS using a new ICES tool using SysML



ICES Users Choose one of Two Roles

- *Primitive Developer*
 - Seen as highly technical in terms of programming skills
 - Provides technical assistance to CONOPS author during primitive development
- *CONOPS Author*
 - Expected to have little or no programming knowledge
 - Will have deep domain knowledge, serving as subject-matter expert for primitive developers



- Primitives are created

- Primitives contain:

- A 3D model
- One or more domains
- One or more attributes

- Can have two states: immature or mature

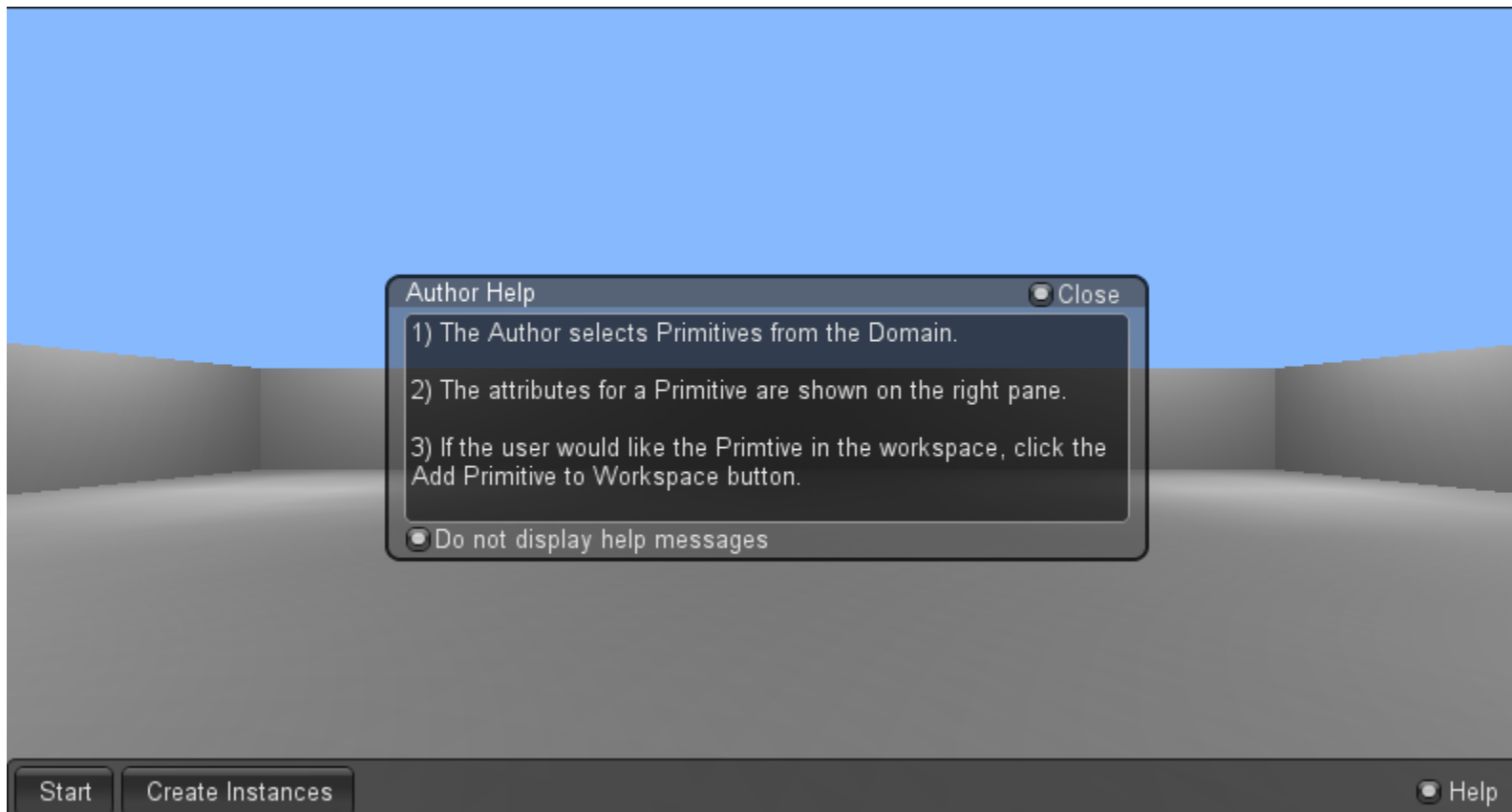
Immature - have a 3D model, or a domain or both, but have no specified attributes

Mature - have all required attributes specified and may have additional attributes as well

- Our demo/tool will have embedded help that serves three purposes:
 1. Help and workflow for users of the tools
 2. State of progress of demo development
 - For undeveloped features, the help screen will be presented describing plan for future development and demonstrations
 - This is useful for our developers and users
 3. We'll use the help scenarios and move to a hyperlinked web documentation for people to use if they have or do not have the tool

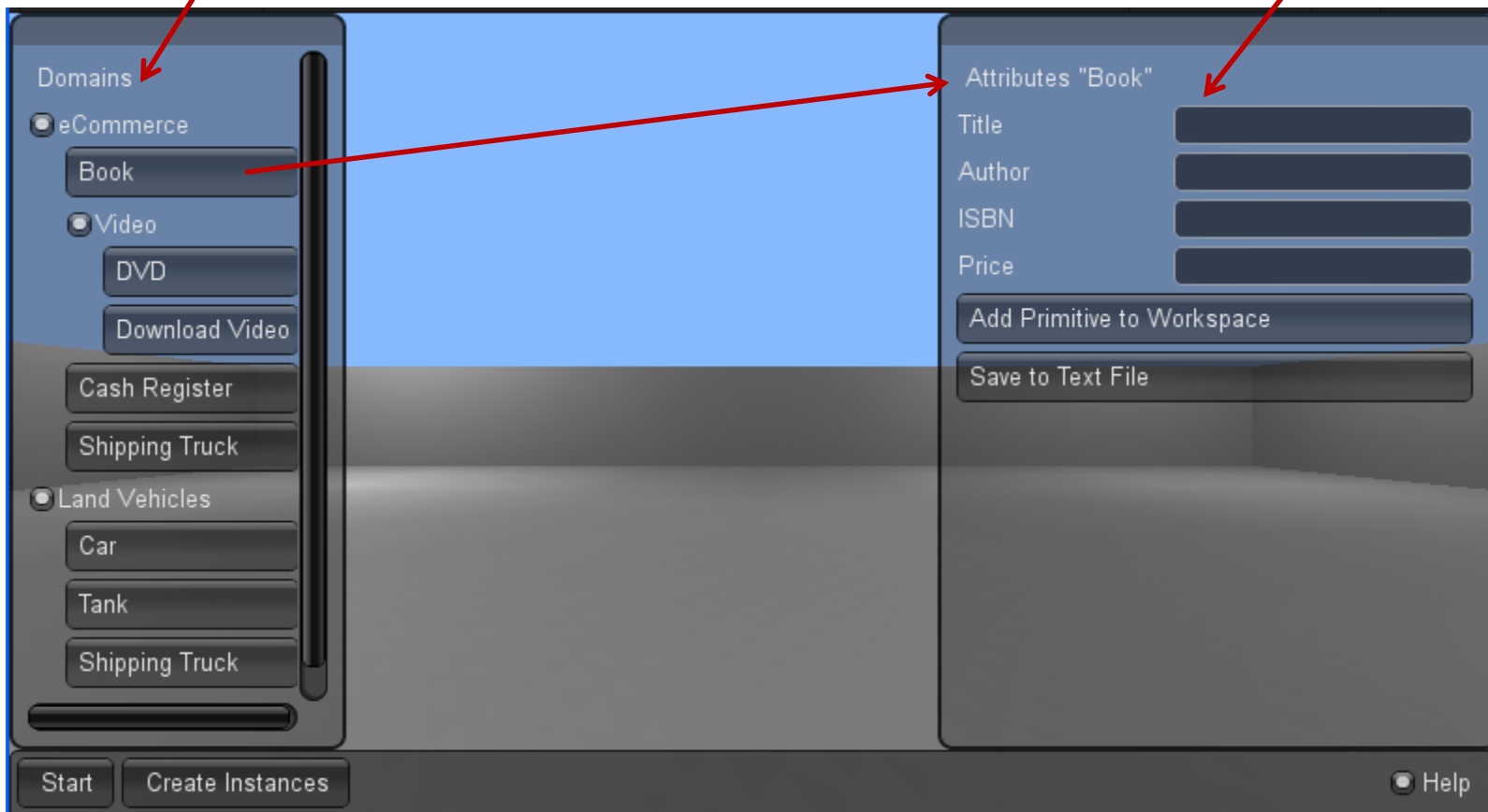
1. Start CES
2. Enter author interface
3. Select domain(s)
4. Add primitive to workspace (e.g., store)
5. Link primitives
6. Example:
 1. Add primitive for Book, Cash Register, Shipping Truck
 2. Link primitives
 3. Extend scenario – insert shopping cart, drag to link, auto connect, add primitive DVD, link to shopping cart

Author Interface Starts with Embedded Help/Workflow



Domains contain Primitives
and can be hierarchical (e.g., Video)

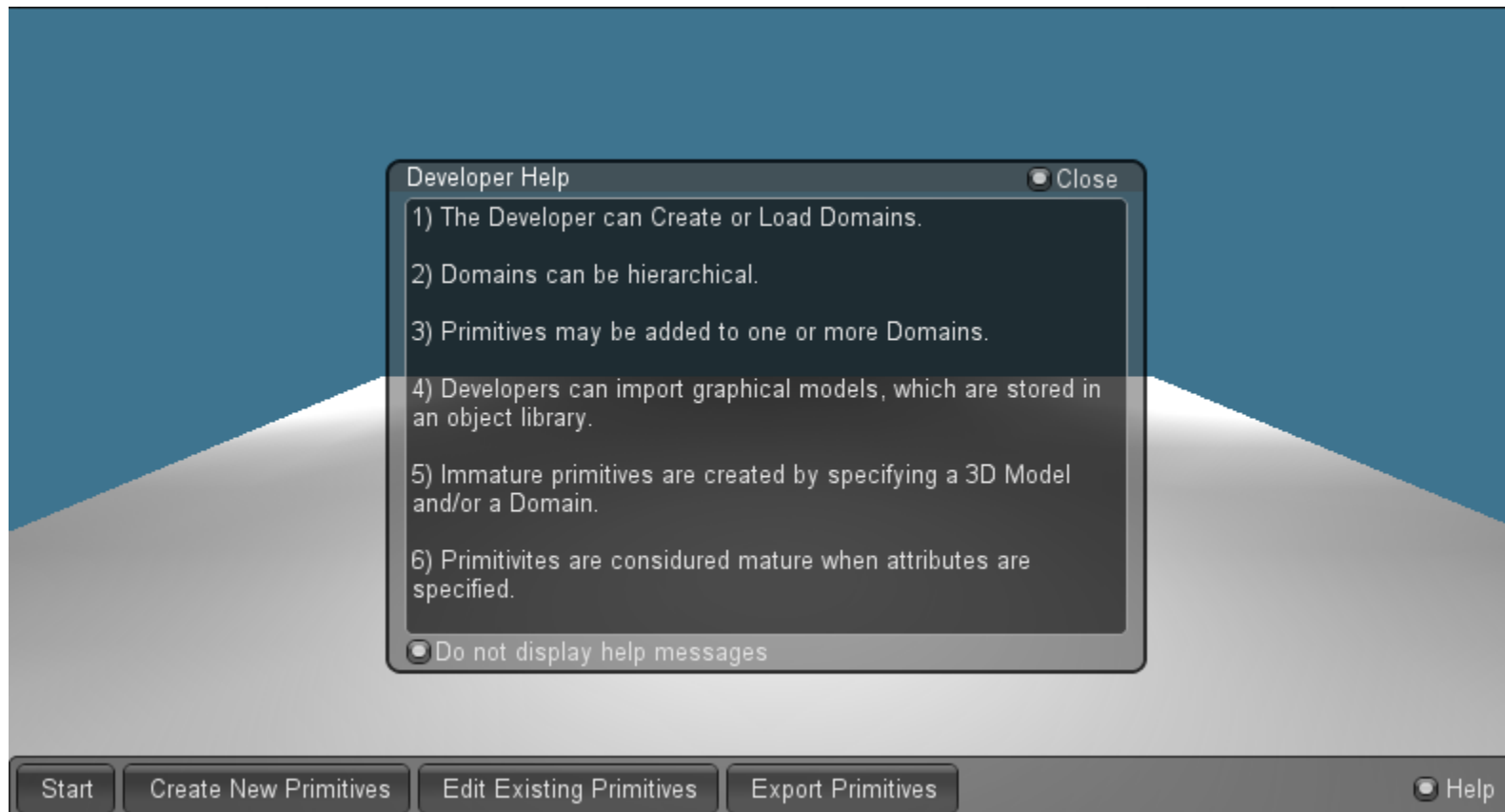
Attributes of Selected
Primitives



- Create / load domains
 - Will need hierarchical domain
- Import objects created from graphic modeling
 - All objects stored in object library
- Create primitive from object
 - Primitives are added to one or more domains
 - Defined primitive have attributes
 - Undefined primitive added to a domain will have “red” outline (if we decide to do this)
 - The thought is that developers can have different roles/skills
 - Graphic developers can add an undefined primitive to a domain, and someone that understands semantics can complete attributes

Developer Interface

Implement What's in Help





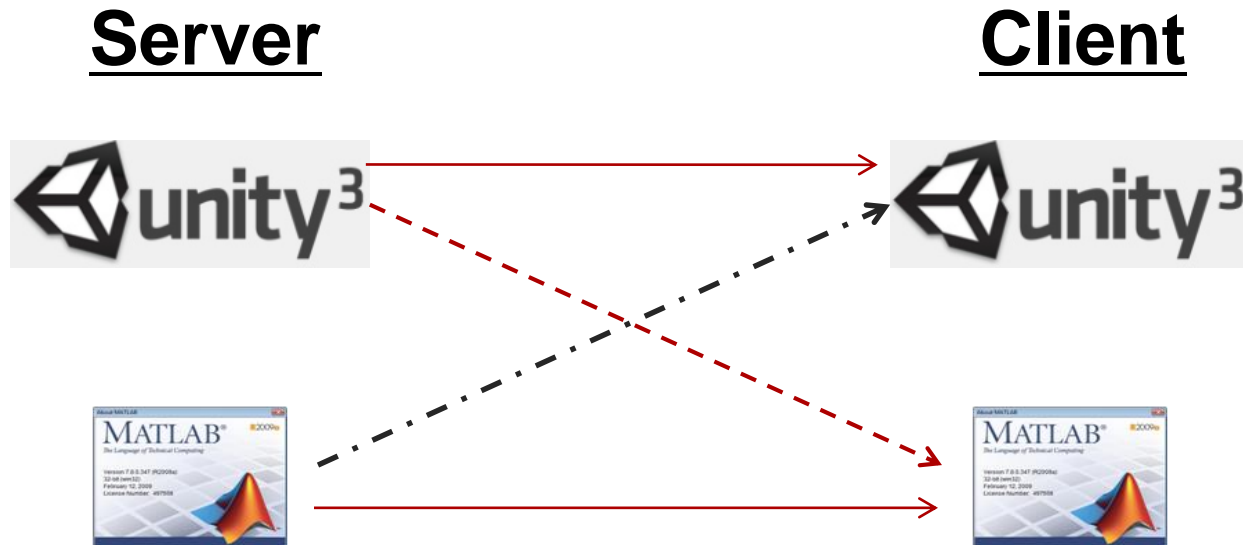
Prototype Workshop

New Agency scenarios for initial testing and feedback on CES Tool

1. Simple limited primitive scenario– *run as demo*
 - Author viewpoint
 2. Extended scenario– *run as demo*
 - Developer viewpoint – create new primitives, change attributes on existing primitives
 - Author viewpoint – import new primitives, modify existing scenario to include new primitives
 3. Multi-player (user and observer) – *run as exercise*
 4. User Scenario – Flexible to allow users to stretch CES – *run as exercise*
 - Author Viewpoint
 - Developer Viewpoint
- Gathering Metrics– *run as exercise*
- Split into teams and try to collect metrics related to CONOPS creation with and without CES

Integrating with Current CONOPS Tools

- Developed mechanisms to interface Matlab with Unity



- OneSAF imports MSDL (see next slide)

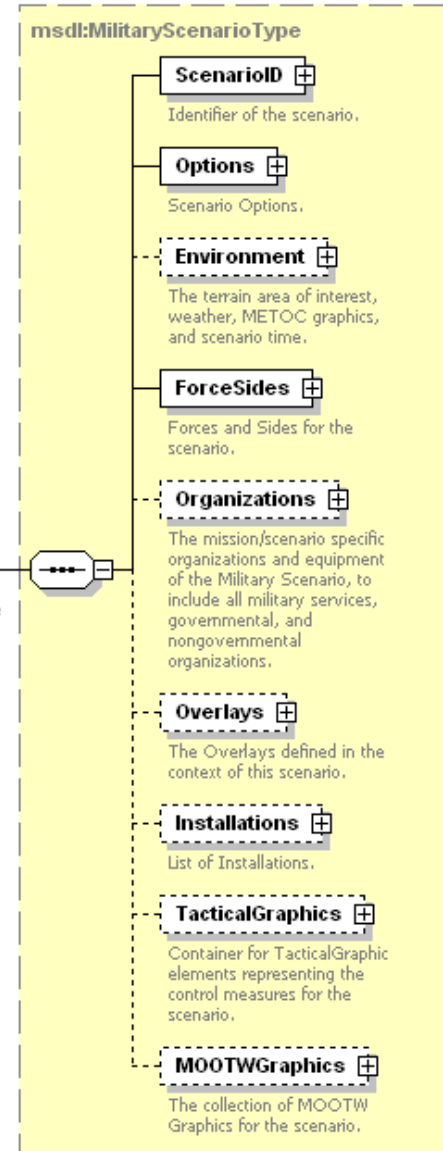


- MSDL is the Military Scenario Development Language
 - Formatted in XML, MSDL is used to exchange scenario data for interoperability across systems

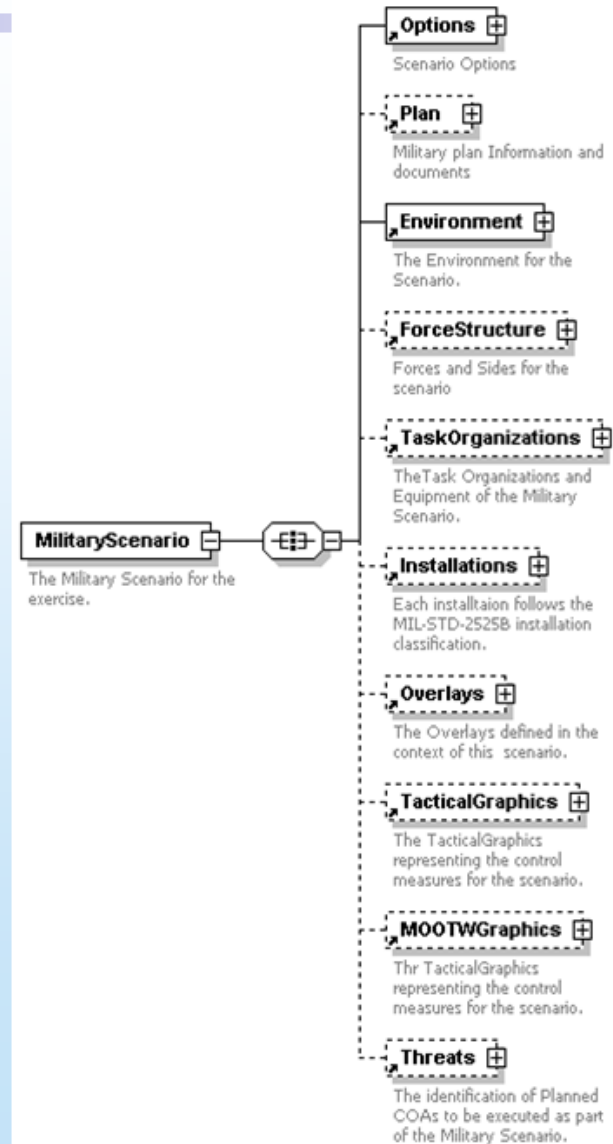
- Defines/Specifies
 - MSDL data structure
 - Cardinality of data elements
 - Mandatory and optional data elements
 - Valid data types (simple and complex)
 - Valid data boundaries
 - Valid domain values (enumerations)
 - Relationship among data elements
- Current XML schema definitions
 - MilitaryScenario.xsd
 - UnitEnumerations.xsd
 - EquipmentEnumerations.xsd
 - TaskEnumerations.xsd
 - msdlElements.xsd

XML Representation

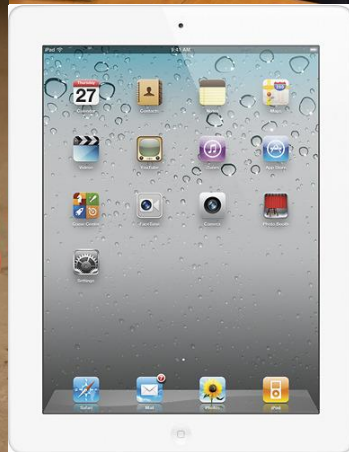
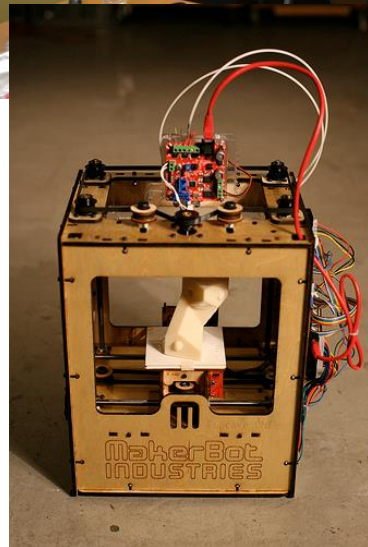
MilitaryScenario 
The Military Scenario for the exercise.



- **Options**
- **Plan & COA**
 - Who, What, When, Where, Why
- **Environment**
 - Where, When
- **Force Structure**
 - Who
- **Task Organizations**
 - Who
- **Installations**
 - Where
- **Overlays**
- **Tactical Graphics**
 - Where
- **MOOTW Graphics**
 - What, When, Where
- **Threats**



Investment



- **Multiple touch screen surfaces**
 - 60" multi-touch surface
 - 42" multi-touch surface and rolling base
 - Apple iPads
 - Android tablet
- **Multi-Core Mercury Server/CPU**
 - Dual AMD Opteron 6100 Series processors with Twelve/Eight-Core ready AMD Chipset
 - 128 GB DDR3 RAM
 - NVIDIA Tesla GPU M2050, 3GB
 - NVIDIA Quadro 2000D Video Graphics Cards
 - Dual-port GbE LAN Controller
- **RAID data storage – 12 TB**
- **MakerBot 3D Printer**

Challenges

- Developing re-usable templates for interfaces between gaming platform and various software packages
- Designing for flexibility of time progression when CONOPS users build scenarios
- Storage paradigms for functional objects and fully-developed scenarios
- The learning curve requires longer term funding to keep key researchers engaged for the life of the research task

Conclusions

- Concept Engineering is a critical step in successful systems engineering processes
- While systems, and SoS are growing in complexity, no significant advances have been made in concept engineering for 60 years
- 3D visualization has the potential to improve the way stakeholders reason about operational concepts
- We believe the technology exists or is emerging, to enable 3D/4D visualization of operational concepts in distributed, collaborative, cross-platform environments.
- RT30 has the potential to make the most significant contribution to concept engineering and CONOPS development in the past 60 years

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