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Name of Principal Author and all other author(s): Nicholas J. Pioch, James Melhuish, Corey Lofdahl, Michael Sao Pedro, and Basil Krikeles

Principal Author's Organization and address:
6 New England Executive Park
Burlington, MA 01803

Phone: 781-273-3388

Fax: 781-273-9345

Email: nicholas.pioch@baesystems.com

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An Integrated Development Environment for PMESII Model Authoring, Integration, Validation and Debugging

Presenter: James Melhuish

james.melhuish@baesystems.com

BAE Systems, Advanced Information Technologies
75th MORSS, EBO Special Session, June 12-14, 2007

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Agenda

- Background
- CMIST Overview
 - Architecture
 - Concept of Operations
- PMESII IDE
 - Model Representation
 - Model Integration
 - Model Execution
- Commander's IDE
 - Model Authoring
 - Model Debugging
 - Model Visualization
- Experimental Results
- Future Work
- Conclusions

Motivation: Understanding the Battlespace

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"...to *anticipate the evolution of the battlespace* in order to pre-empt, influence, and decisively defeat their adversaries *technological progress is still required* to actualize a *culture of prediction*..."

*USAF SAB, Predictive Battlespace Awareness to Improve Military Effectiveness
July 2002, Maj Gen George B. Harrison, USAF
(Retired), Study Chair*

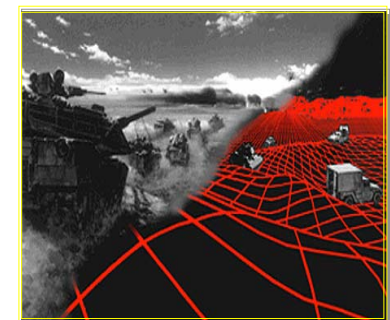
| Process | Objective |
|--|--|
| Joint Integrated Preparation of the Battlespace (JIPB) | Better understanding of the mission space: past, present, future |
| | Characterize and predict likely future events: intent, reactions, threats |
| System of Systems Analysis (SoSA) | Analyze the enemy as system of systems. |
| | Understand key relationships, dependencies, and vulnerabilities. |
| | Identify leverage points by which to influence capabilities, perceptions, decision making, and behavior. |

Visualization



A decision support environment that enables the JFC/JFACC to anticipate and shape the future battlespace

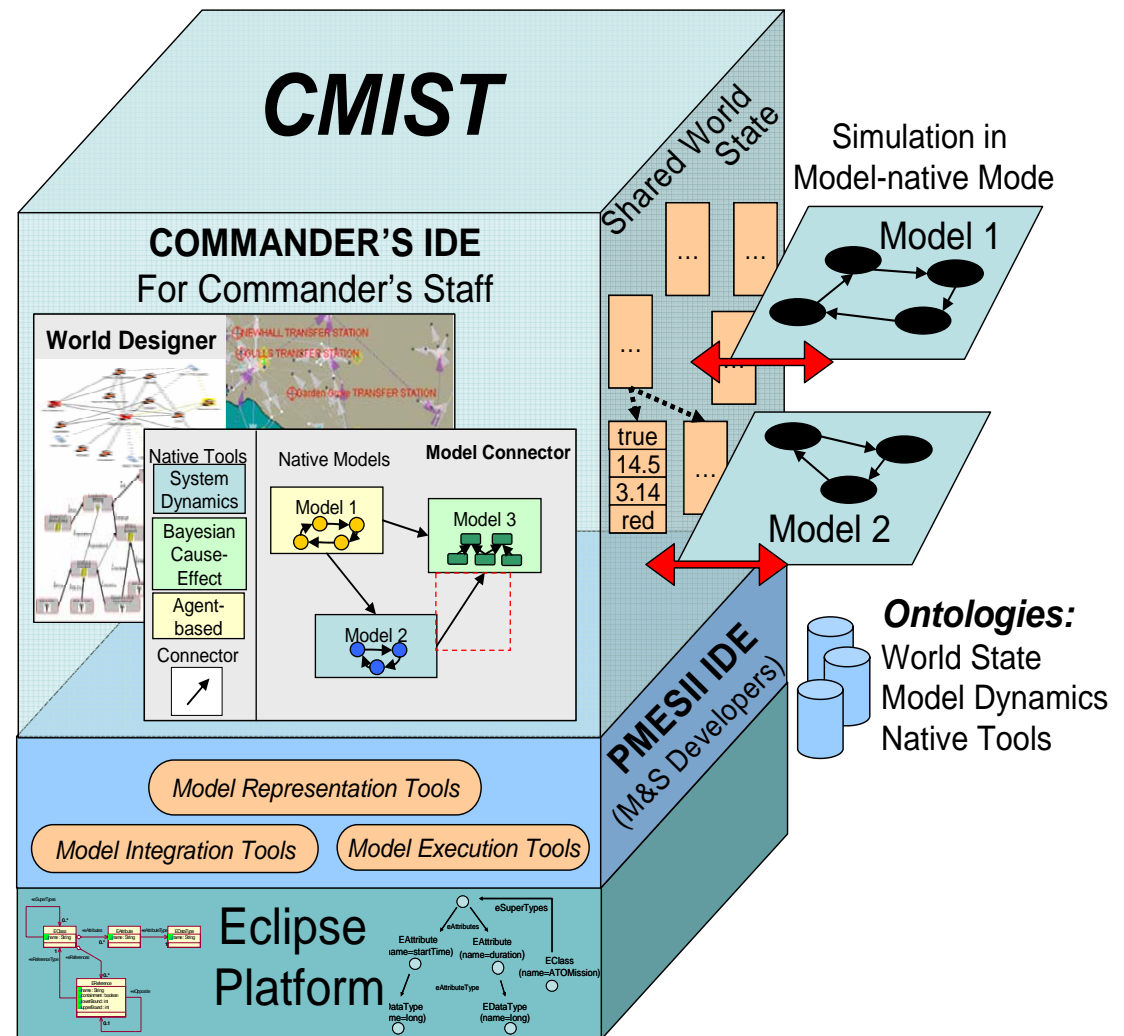
Predictive Battlespace Awareness



Cmdr's Model Integration & Simulation Toolkit (CMIST)

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- **Multi-perspective M&S IDE**
 - Commander-level tools for model authoring, debugging and visualization
 - PMESII M&S developer tools for sim. tool and model integration
- **Built on proven open standards and frameworks**
 - Plug-ins to Eclipse Java IDE
 - Ptolemy II (system dynamics), AFRL CAT (cause-effect), JADE/FIPA (agents)
- **Extensible libraries:**
 - Shared ontologies enable rapid native simulation tool integration
 - Transforms enable cross-model data exchange
 - Interaction patterns synchronize disparate time management within multiple native tools

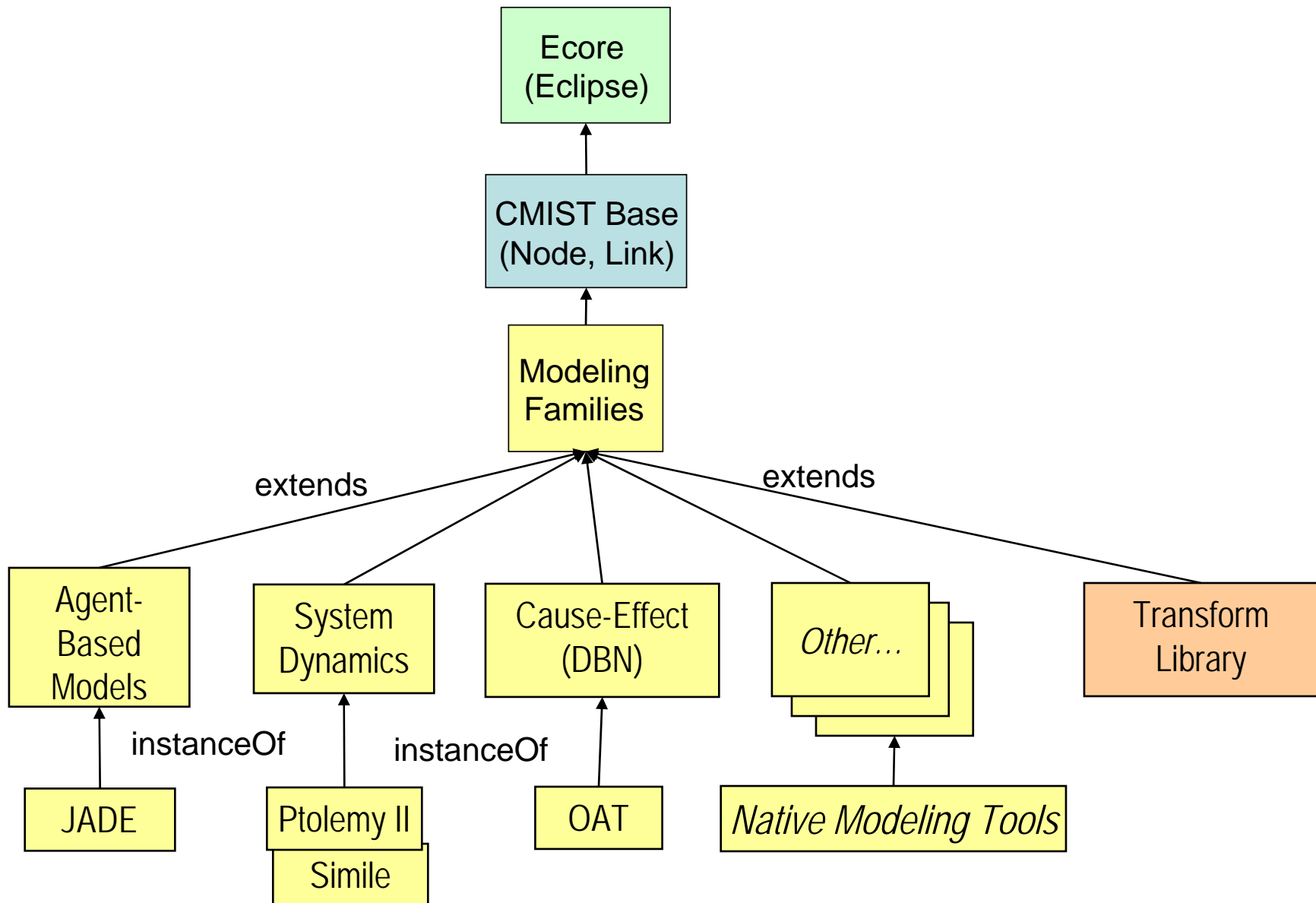


Sponsor:
AFRL/IFS, Commander's Predictive Environment

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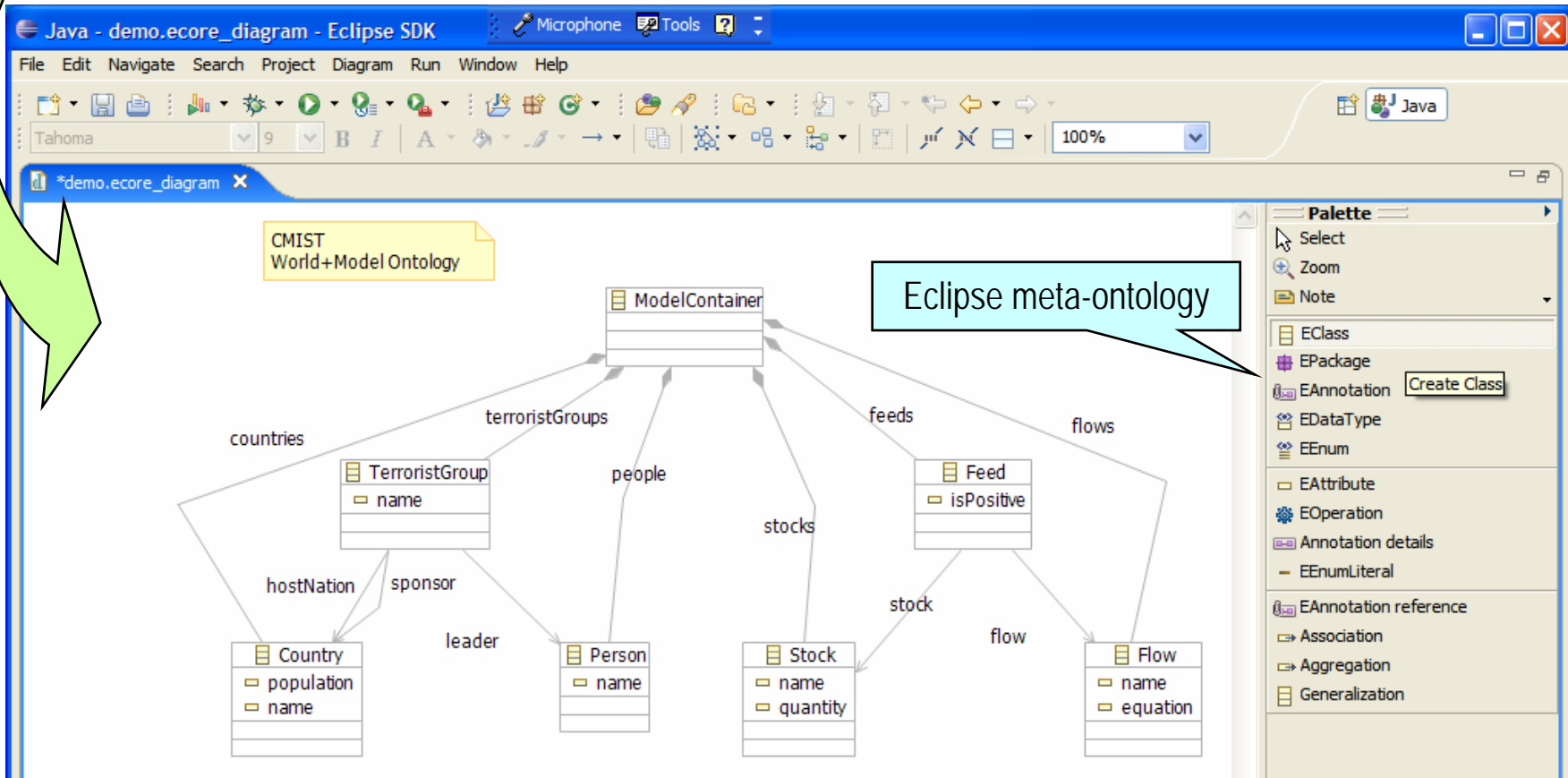
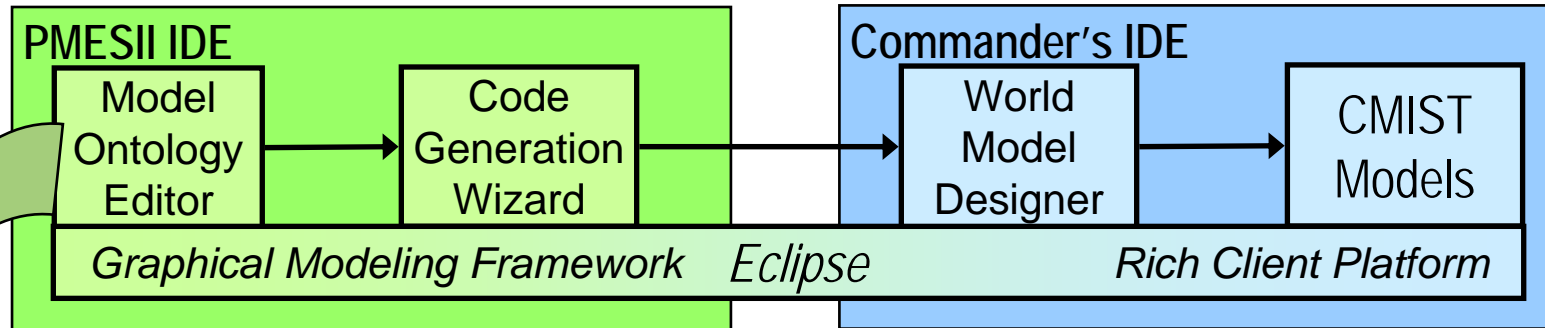
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PMESII IDE Model Representation



CMIST Tool-Making Tools (Editor of environment)

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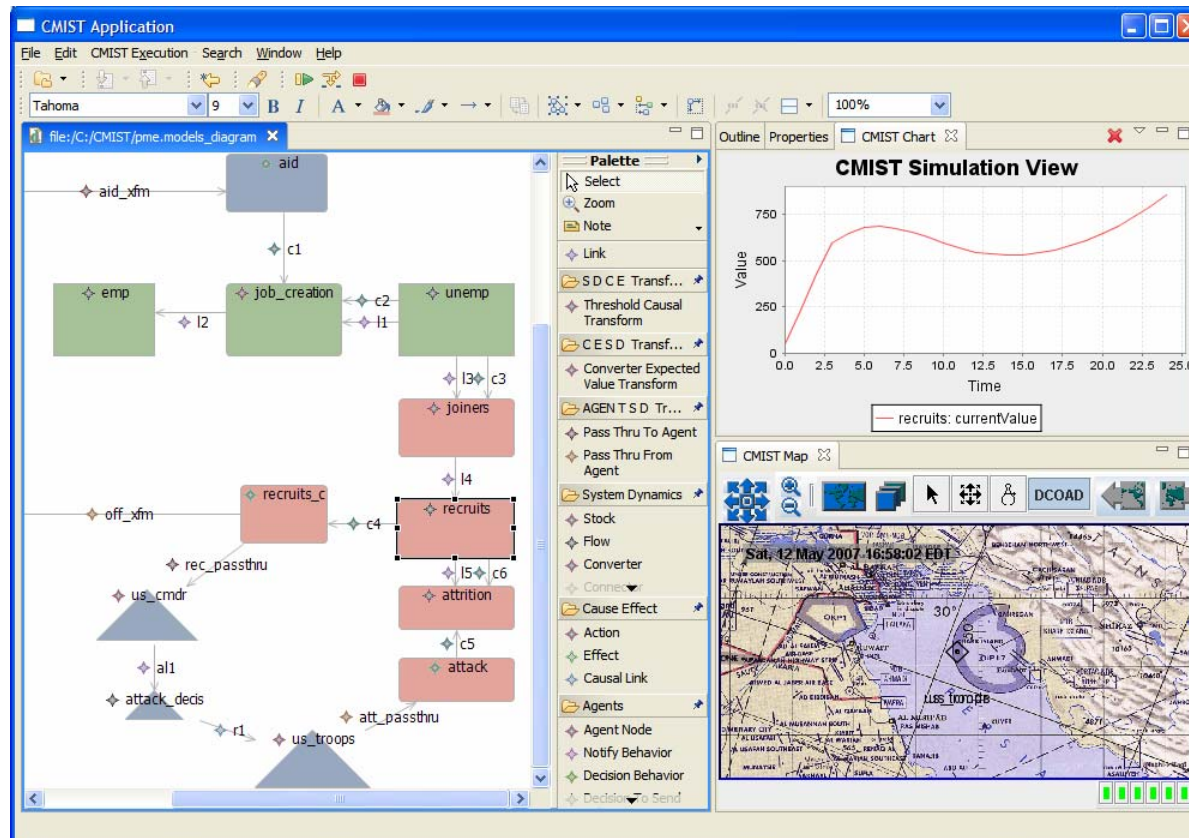
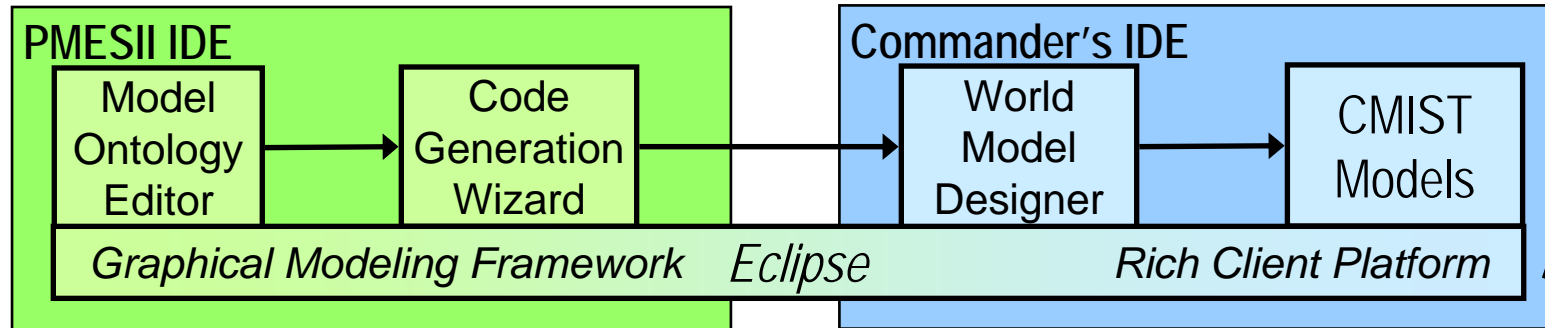


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Modeling tool (Editor of models)

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PMESII IDE Mediation Layer

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- **Alignment Mediators**

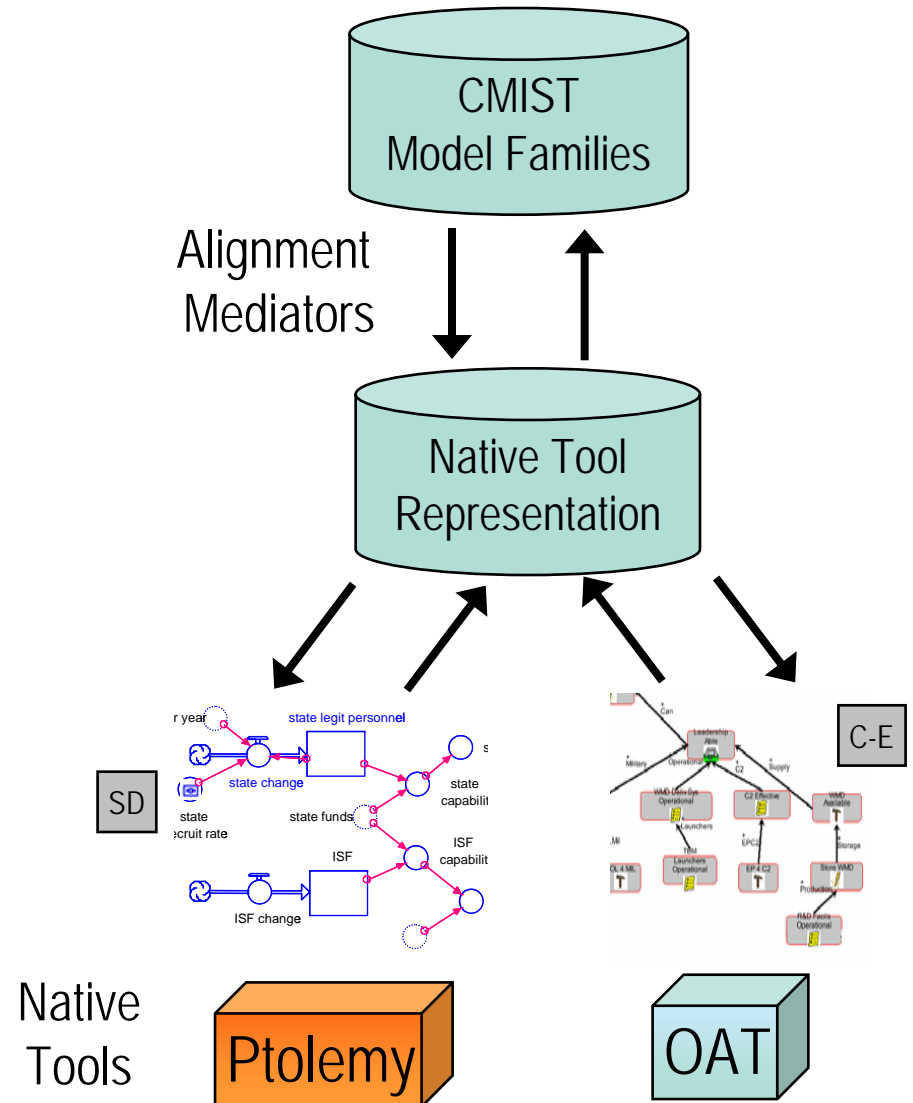
- Map from CMIST Model Ontology to native tool representation
- Automatically timestep the native tool
- Read inputs and write outputs each timestep
- Currently implemented for
 - OAT (Dynamic Bayes Net),
 - Ptolemy (System Dynamics)
 - JADE (Agent-based Modeling)

- **Input mediators**

- Imports a pre-existing native model into the Model Assembly Repository (encapsulation in CMIST)

- **Output mediators**

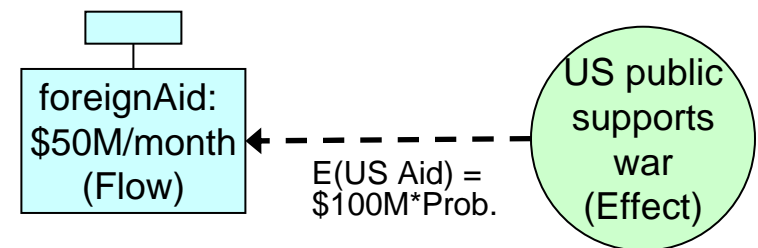
- Exports a CMIST model into a native tool's format



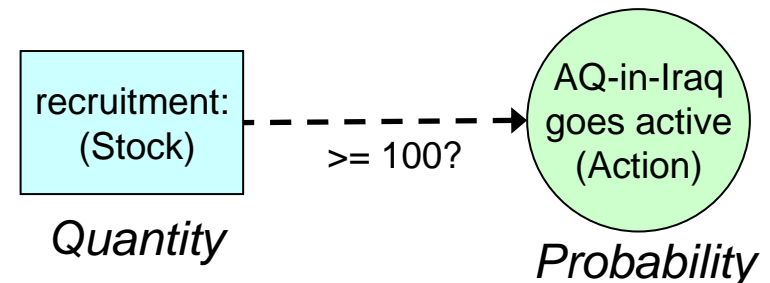
PMESII IDE Transform Library

- Many types of transforms:
 - Map model variables across disparate paradigms (e.g. system dynamics to causal)
 - Map model variables to world state variables
 - Map world state variables to derived variables (e.g. average, sum)
 - 1-to-1, 1-to-many, many-to-1, etc.
- Transform Library
 - Supports transformation reuse across multiple modeling paradigms
 - CMIST will develop canonical transforms for:
 - Probabilistic to deterministic variables
 - Deterministic to probabilistic
 - Agent-state to/from system dynamics
 - Others as needed
 - Library is extensible by end-users

Expected Value Transform

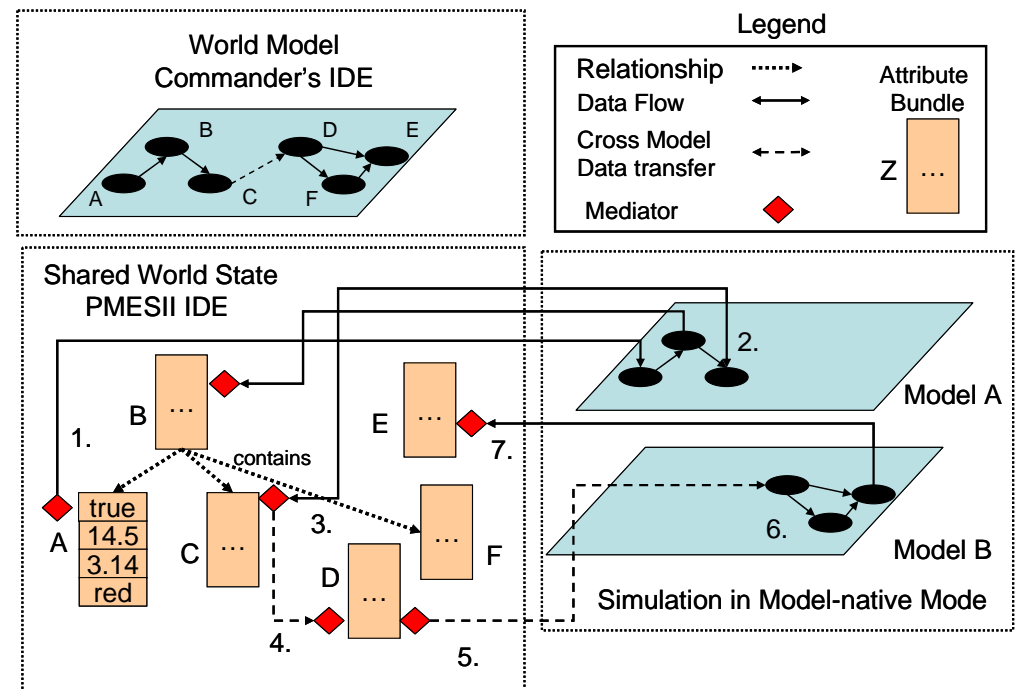


Threshold Transform

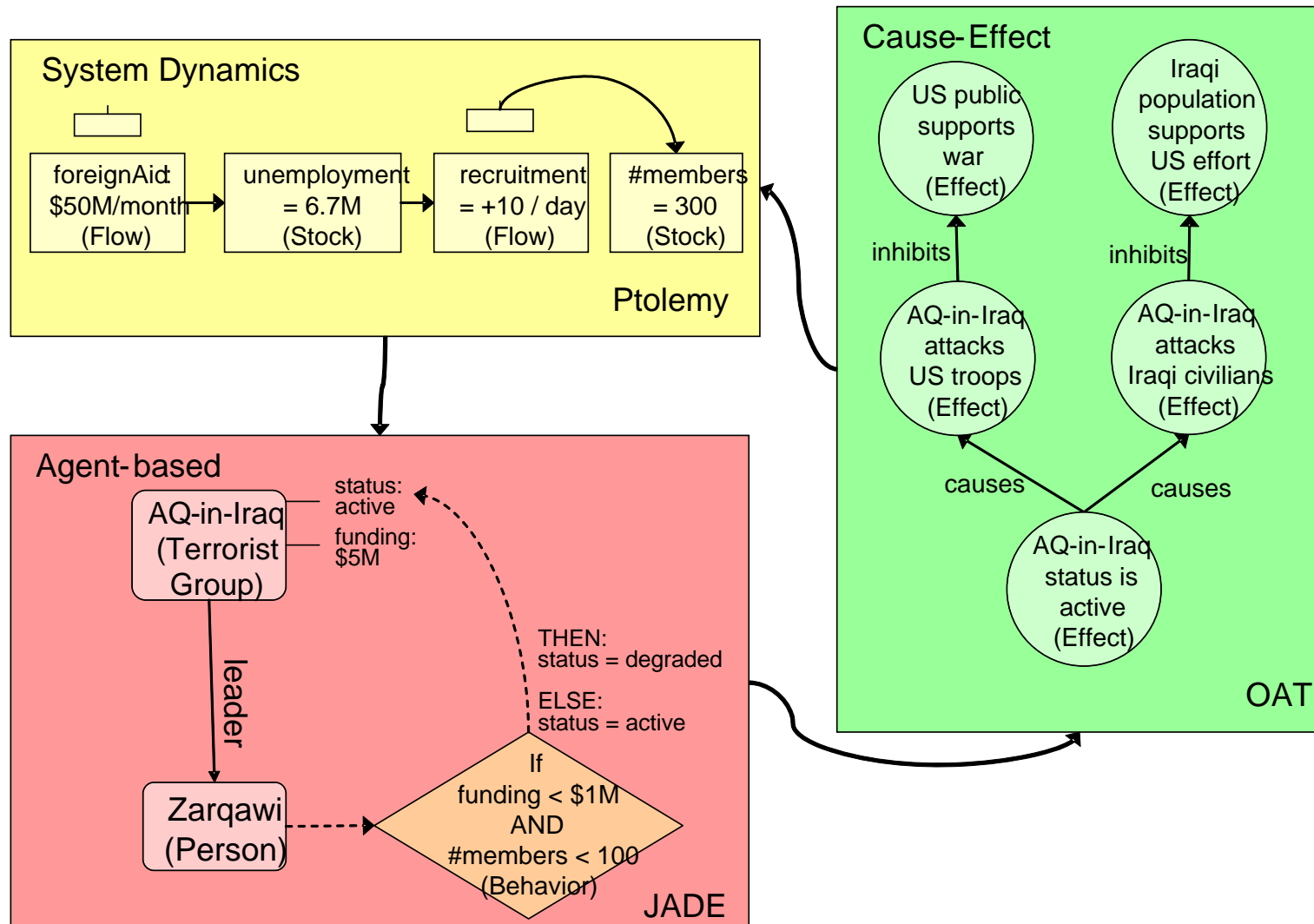


PMESII IDE Model Assembly

- Just prior to running the world model, CMIST compiles a *Model Assembly*
- Assemblies encapsulate:
 - Which world nodes are simulated by which native models & tools
 - How data flows within the *world model*
 - How these data flows are realized in native models via mediators and transforms
 - Structural mappings from CMIST relationships to equivalent native model relationships



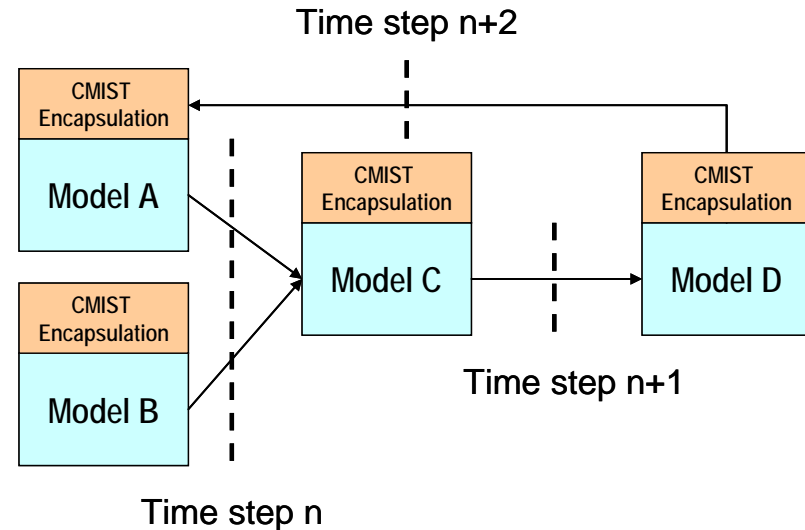
PMESII IDE Model Assembly Example



PMESII IDE Interaction Patterns

- **Parallel Partitions**

- Simple topology with feedback
- All models run synchronously in parallel at constant Δt
- Higher main-loop latency, appropriate for long time-horizons

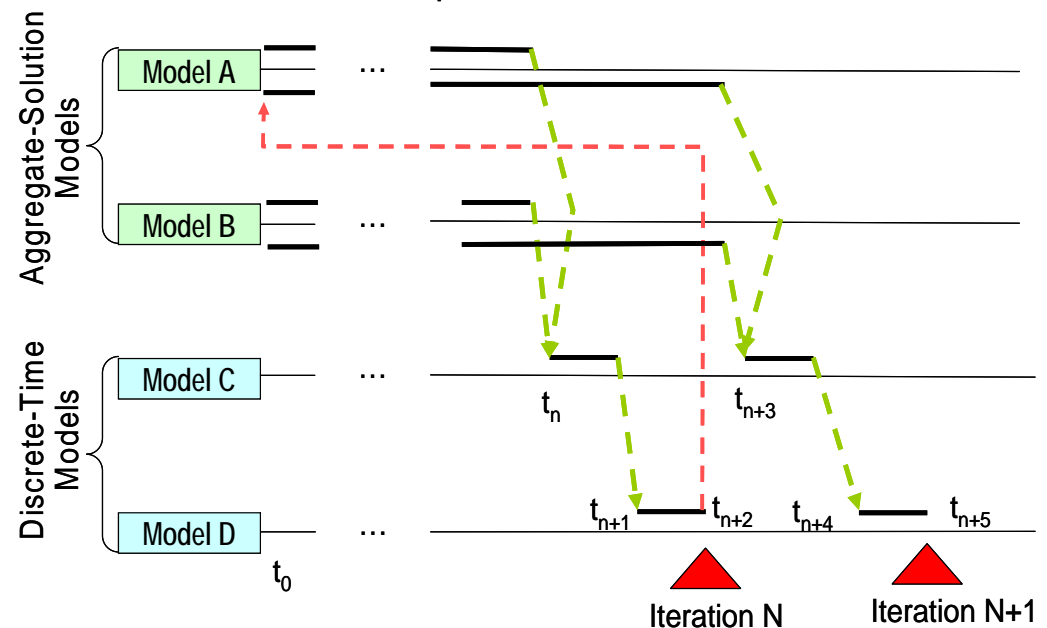


- **Aggregate Partitions**

- Same topology but with A & B as aggregate models
- Model A *reruns* from time 0 to current timestep
- Model B runs just once

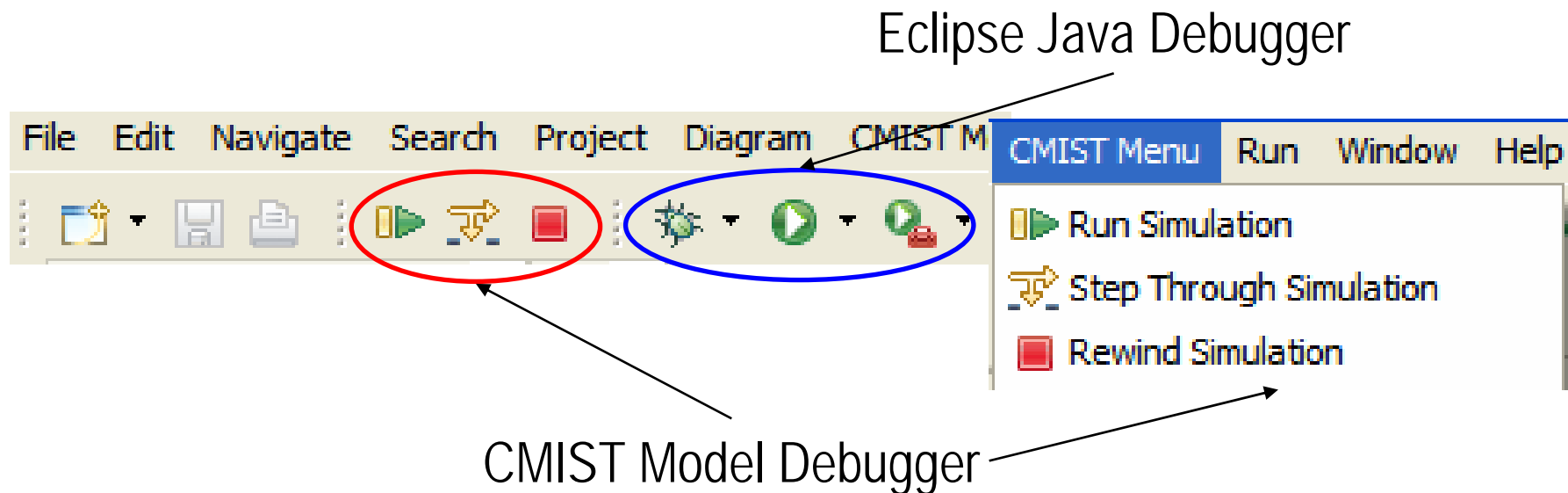
- **Sequential Partitions (TBD)**

- Run A+B, then C, then D
- Less efficient, but reduces data latency over main loop



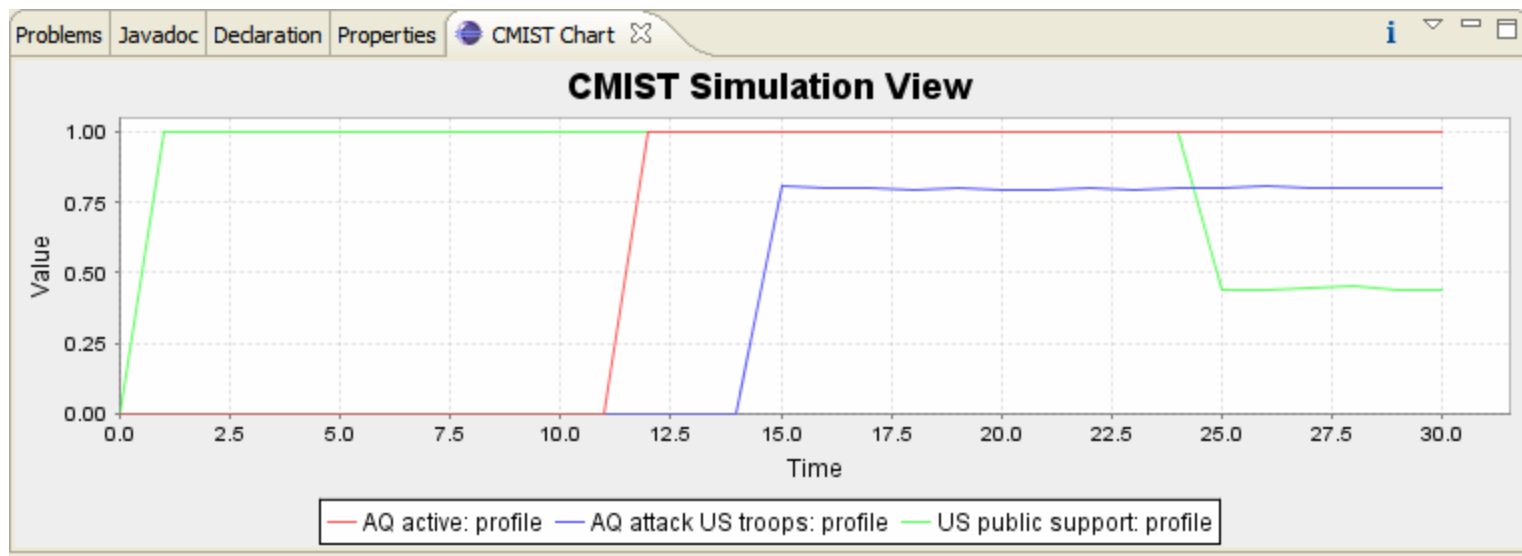
Commander's IDE Model Debugger

- Executes *world simulation* as a multi-resolution model (MRM)
- Analogous to software IDE debugger
- Supported operations:
 - *Run, Pause, Step, Set Breakpoint, Watch Variable*
- Edit configuration information:
 - *Start Time, End Time, Duration, Time Increment*



Commander's IDE World State Inspector

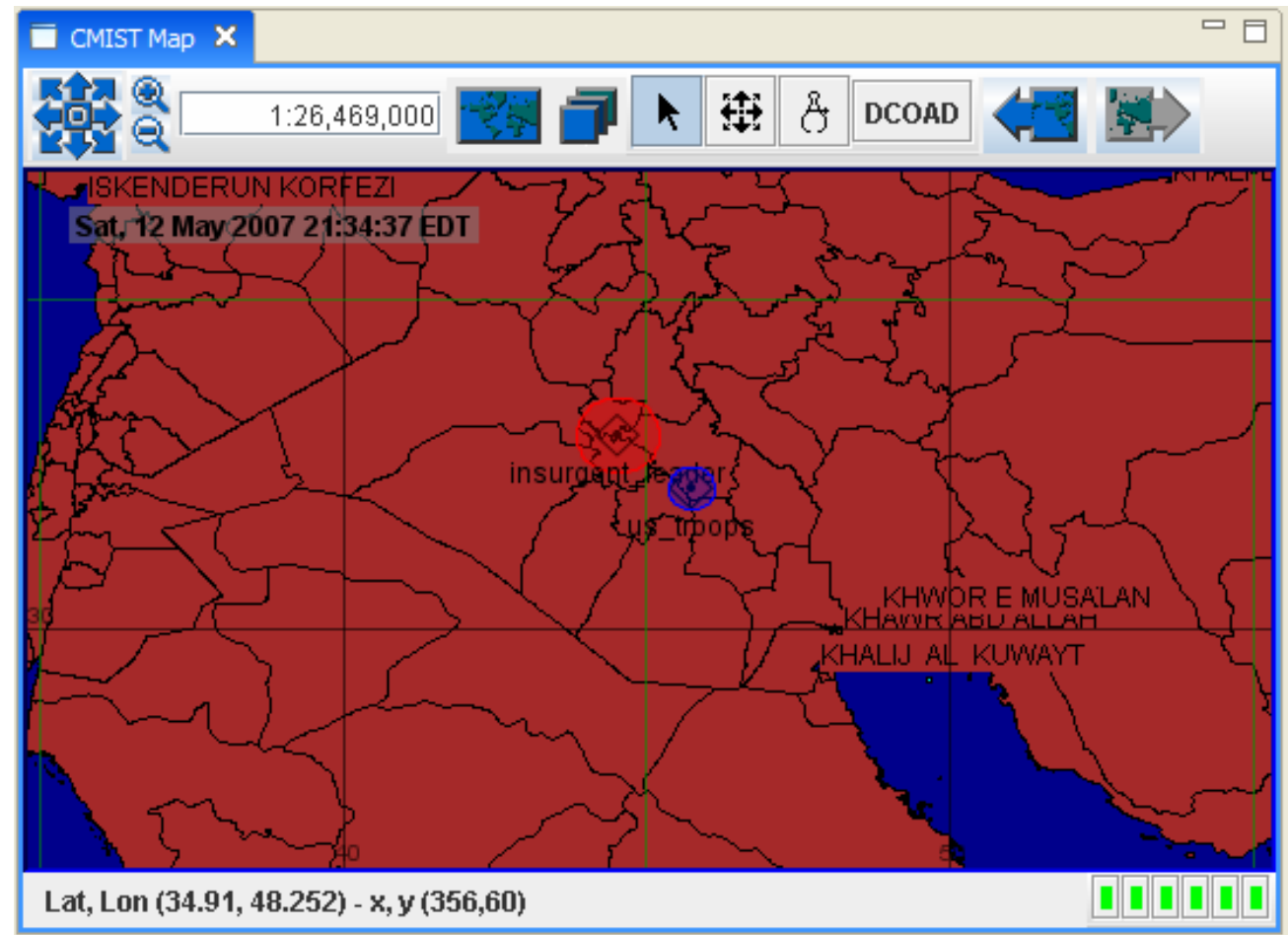
- Time series charts invoked from menu *world model* nodes in World Designer
- Based on JFreeChart



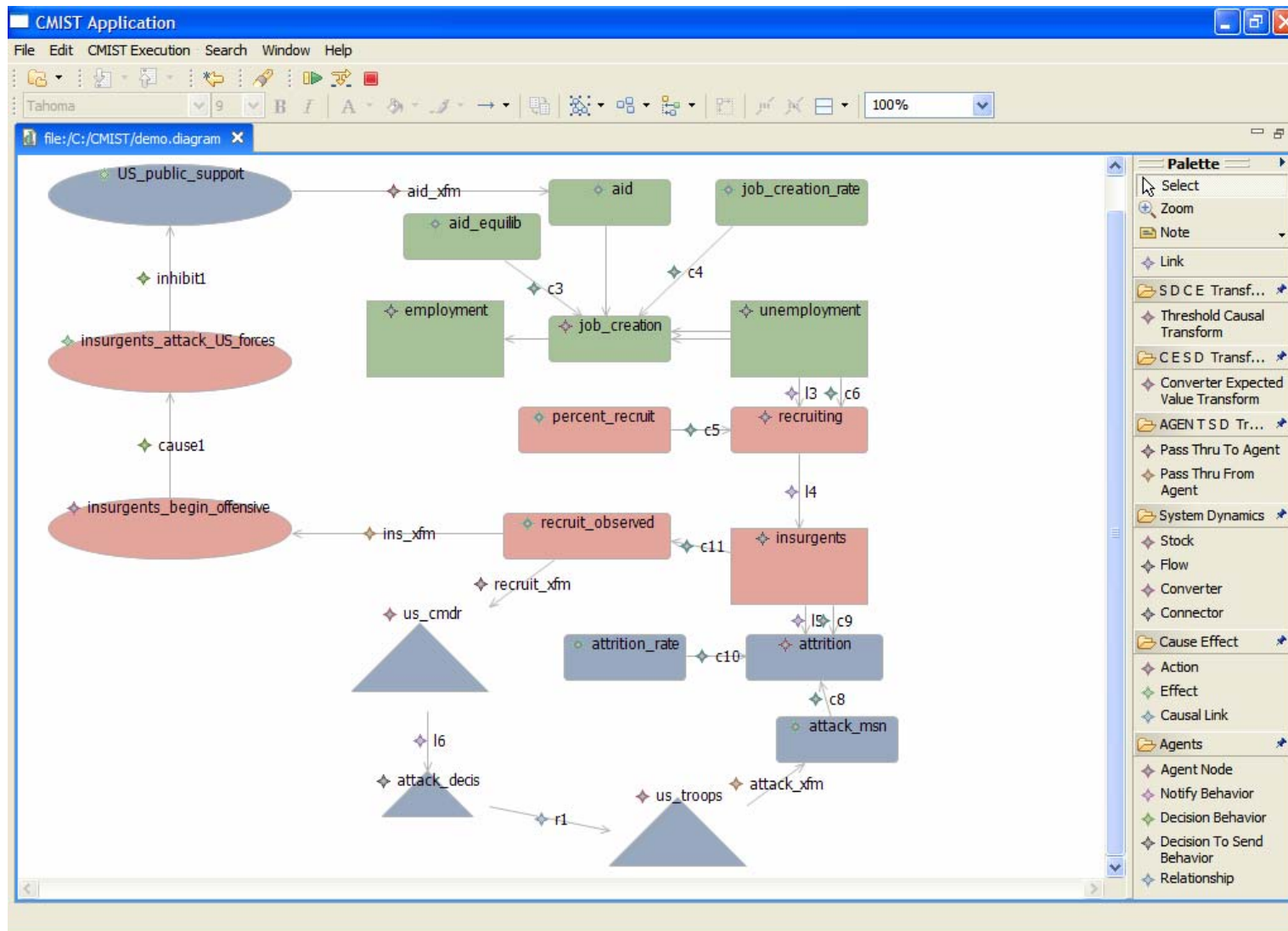
Commander's IDE CMIST Map

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- Leverages AFRL-funded Dynamic Course of Action Decision (DCOAD) tool
- Displays agents at user-specified lat/lon
- Transparent effect-rings grow/shrink in proportion to specified agent property



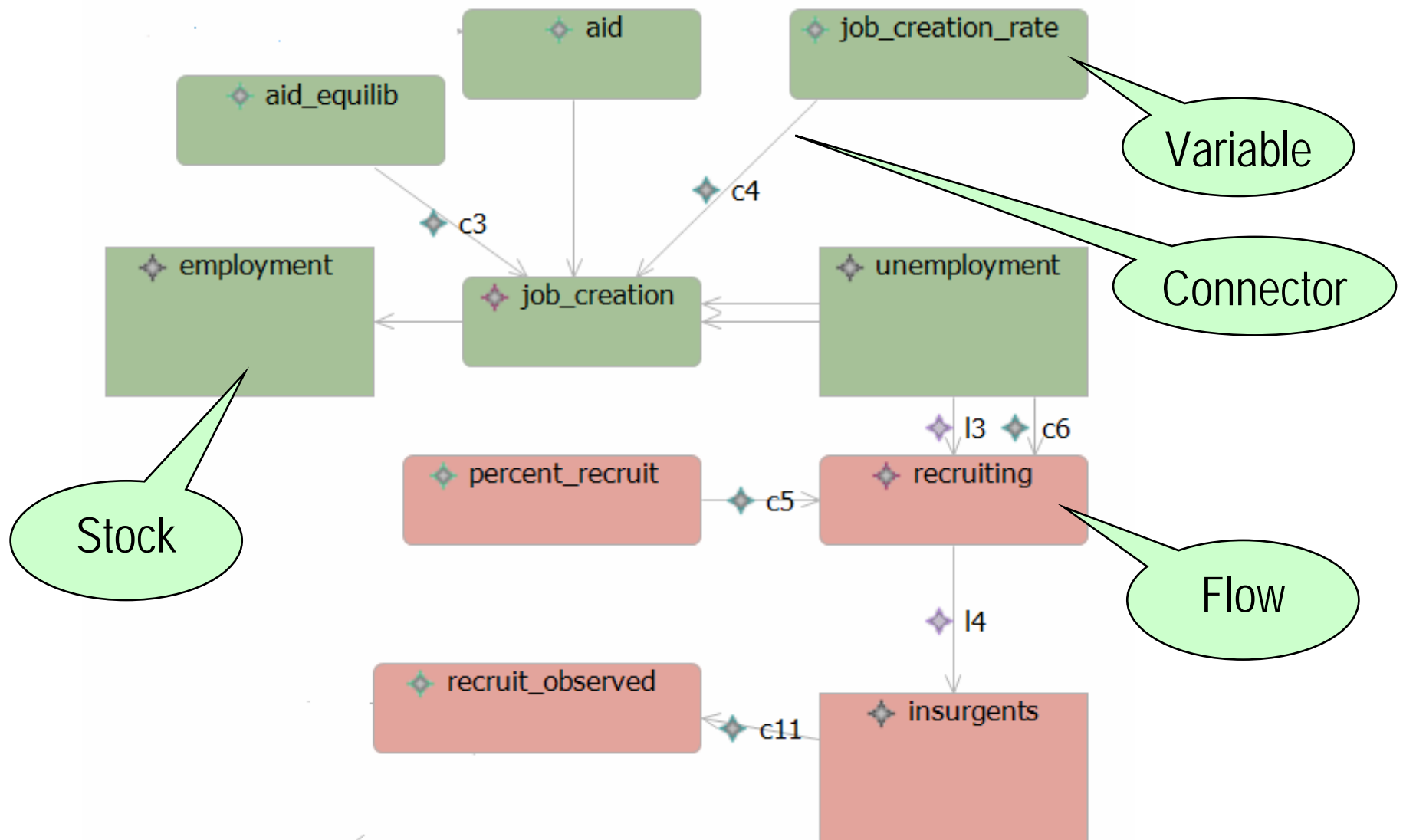
Pol-Mil-Eco Model Scenario



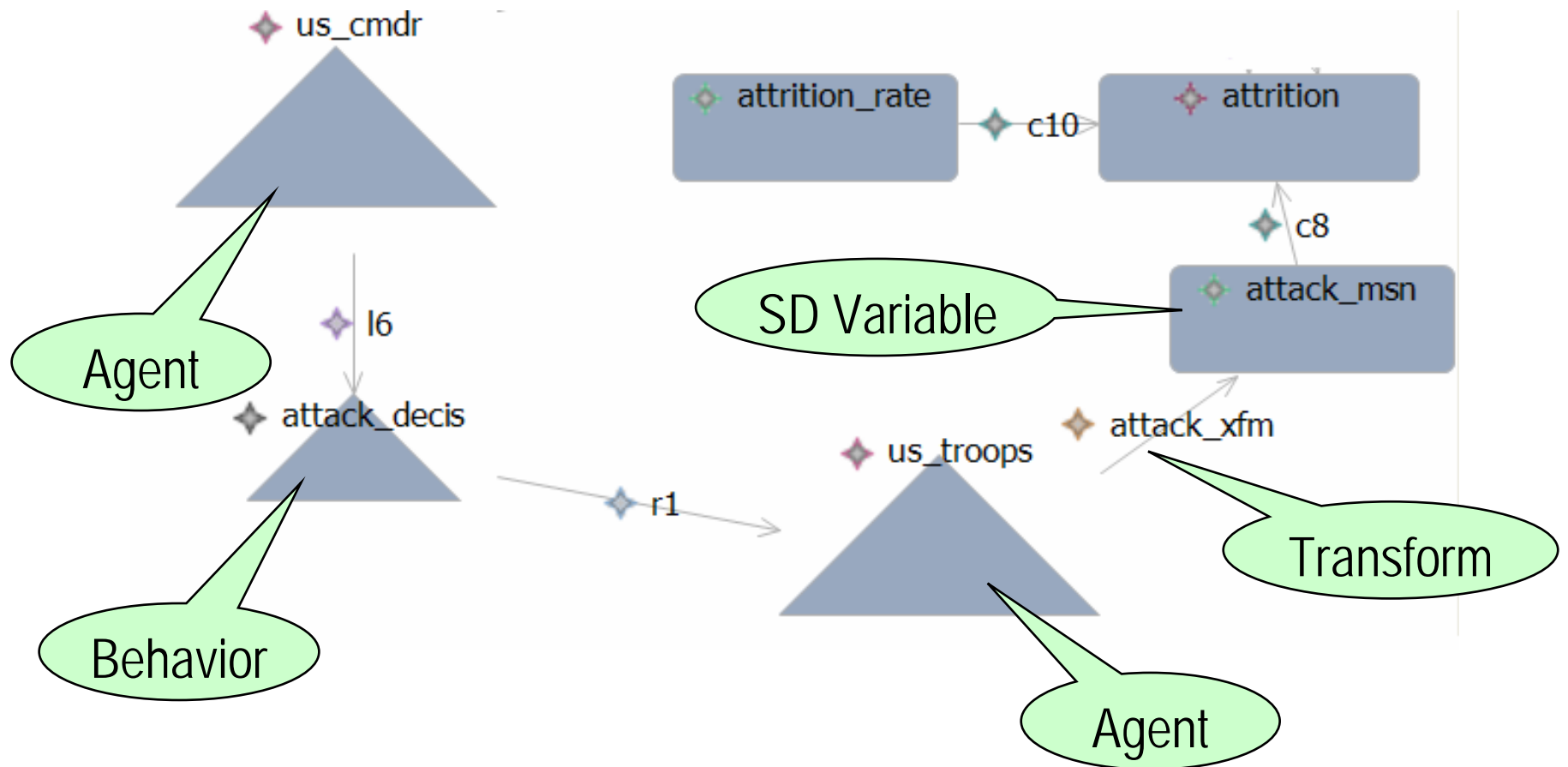
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System Dynamics Fragment

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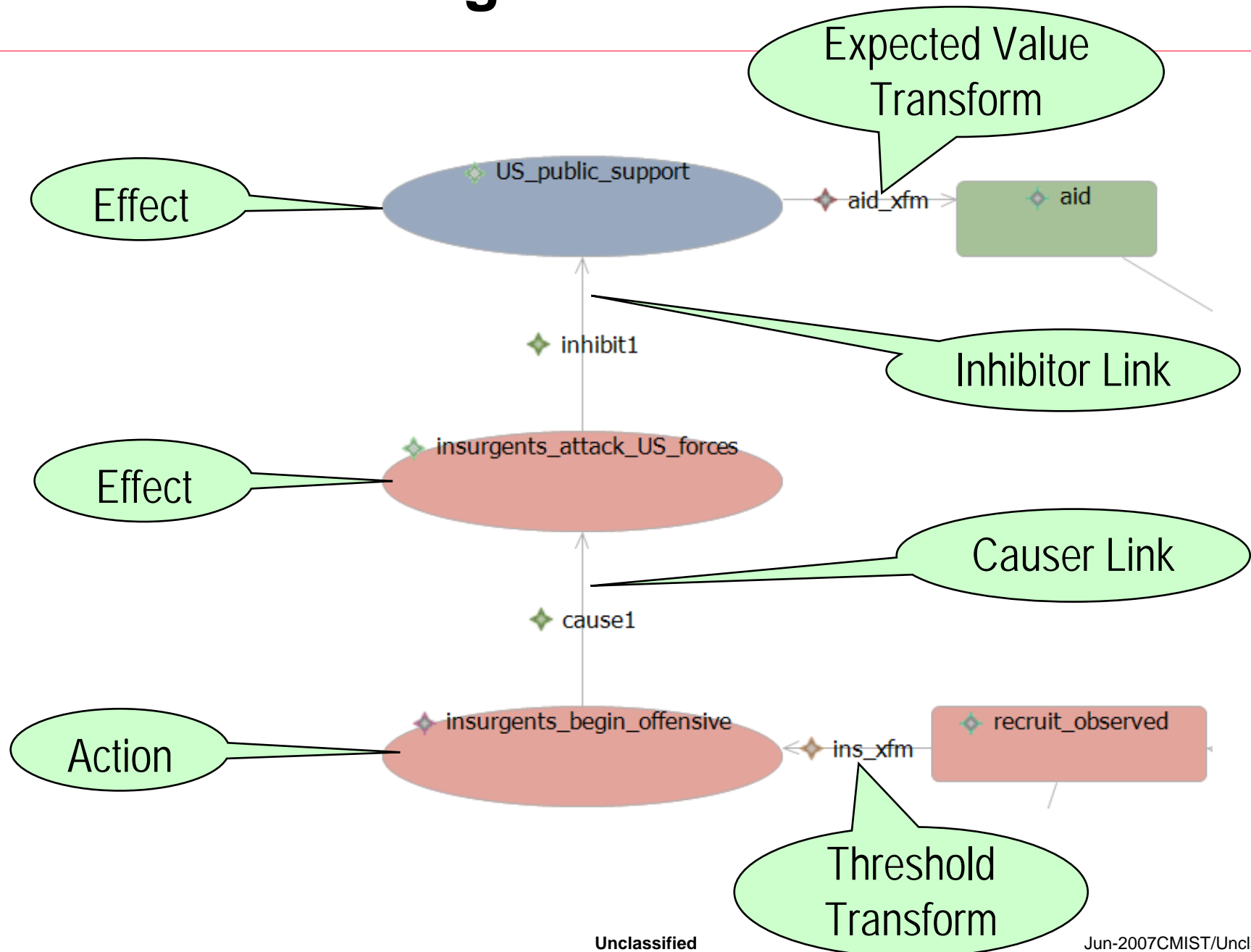


Agent-based Fragment



Cause-Effect Fragment

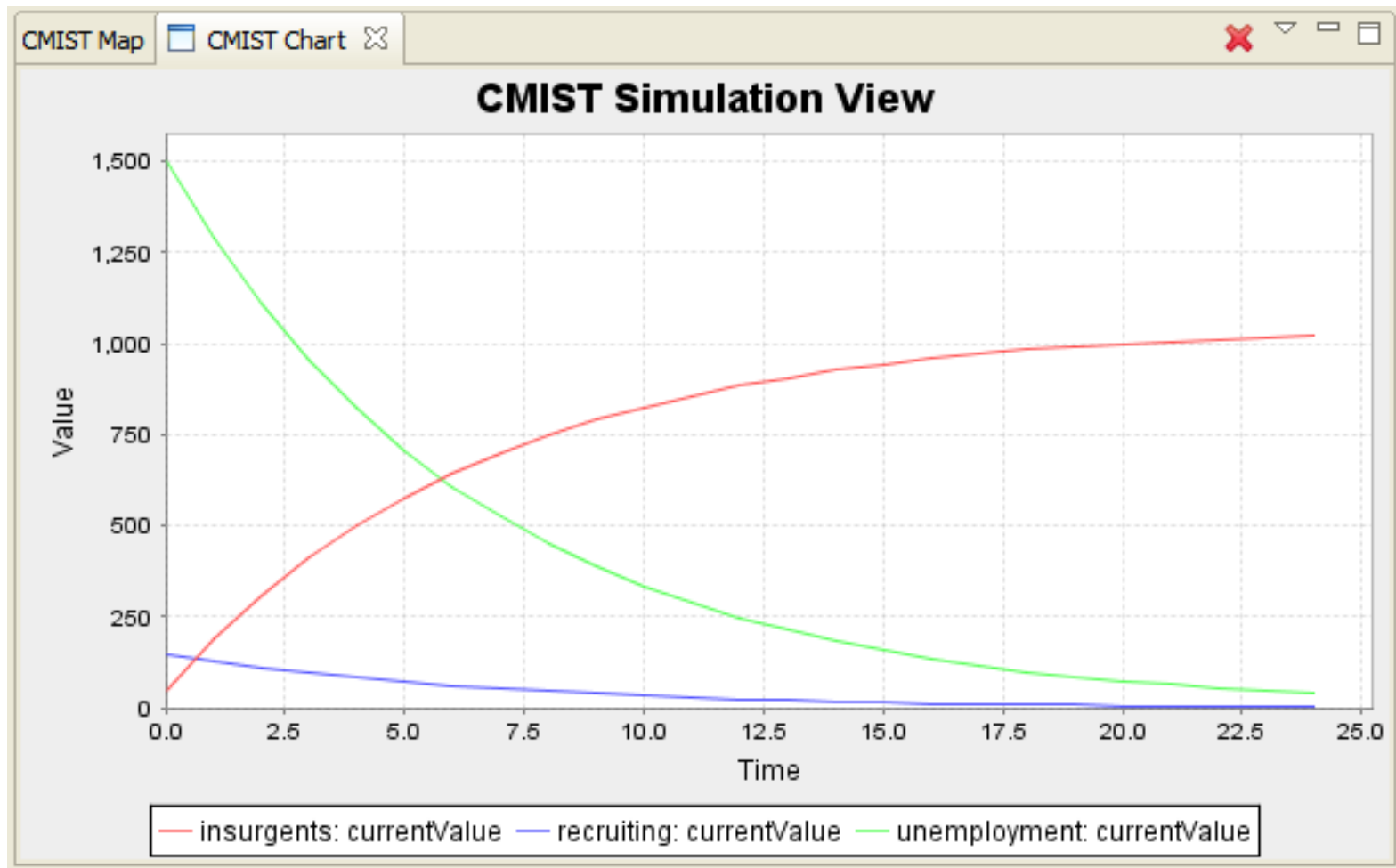
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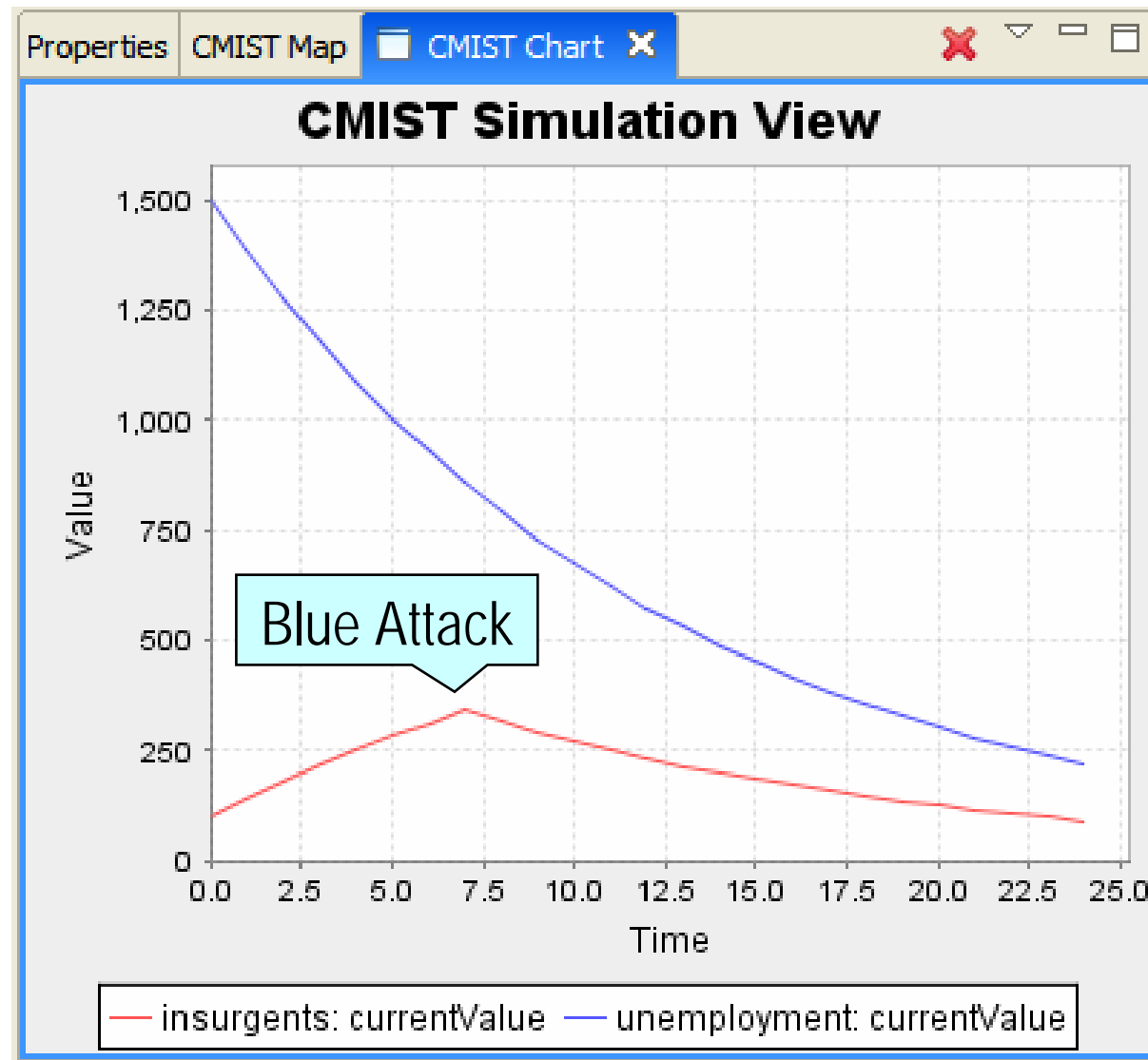
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Results – Baseline red model

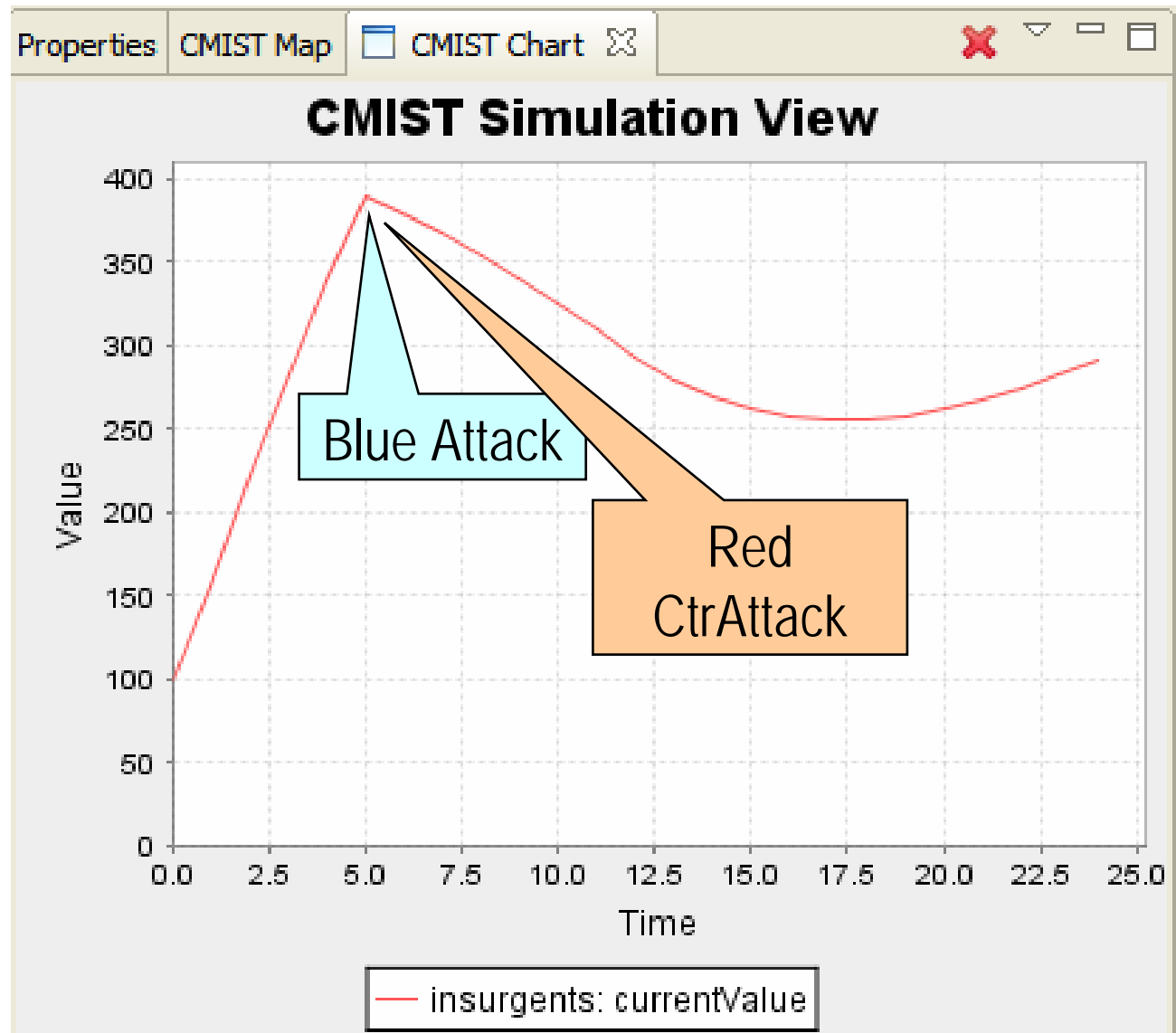


Results – Baseline + Blue Attack



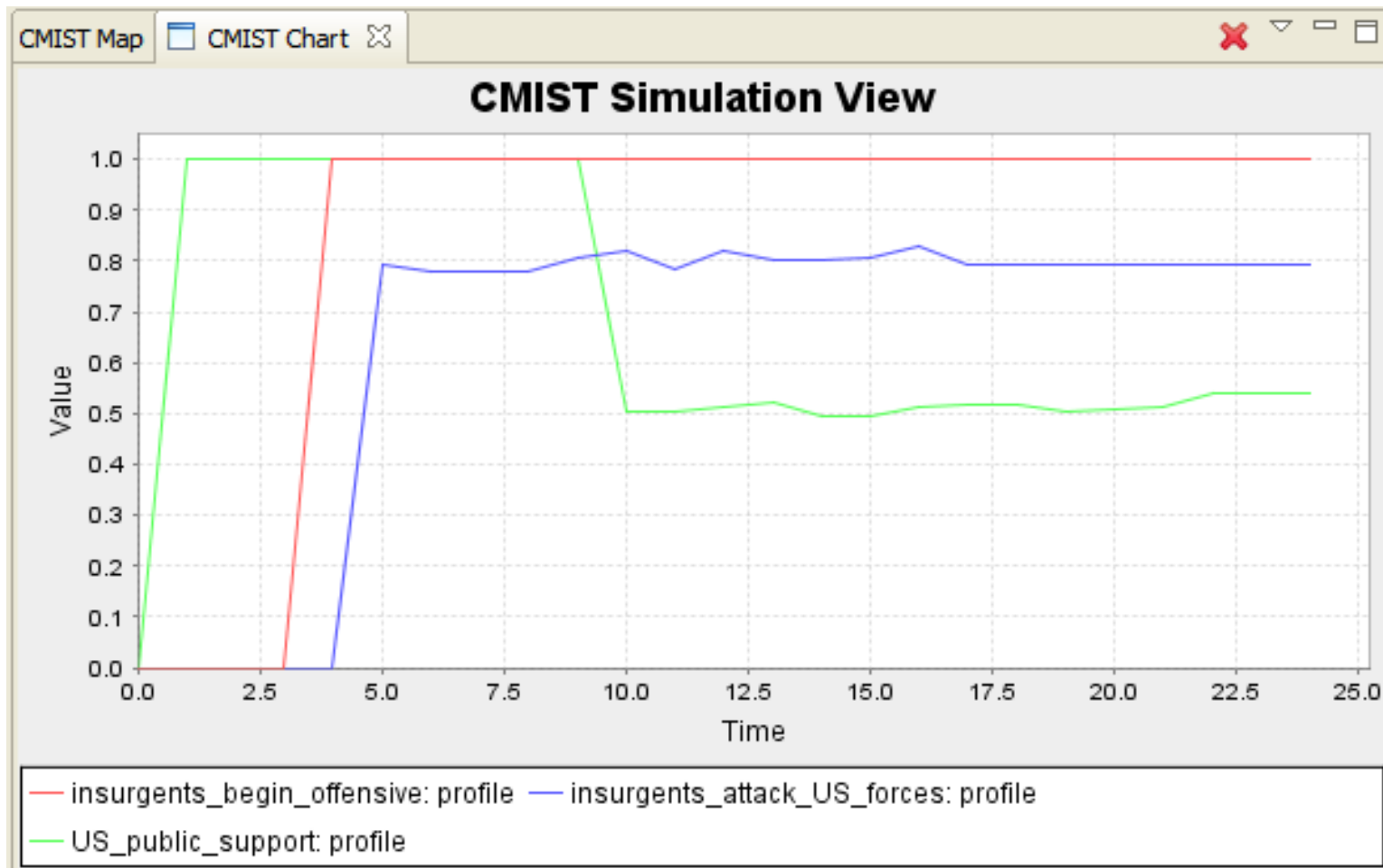
Results

Baseline + Blue Attack + Red CtrAttack



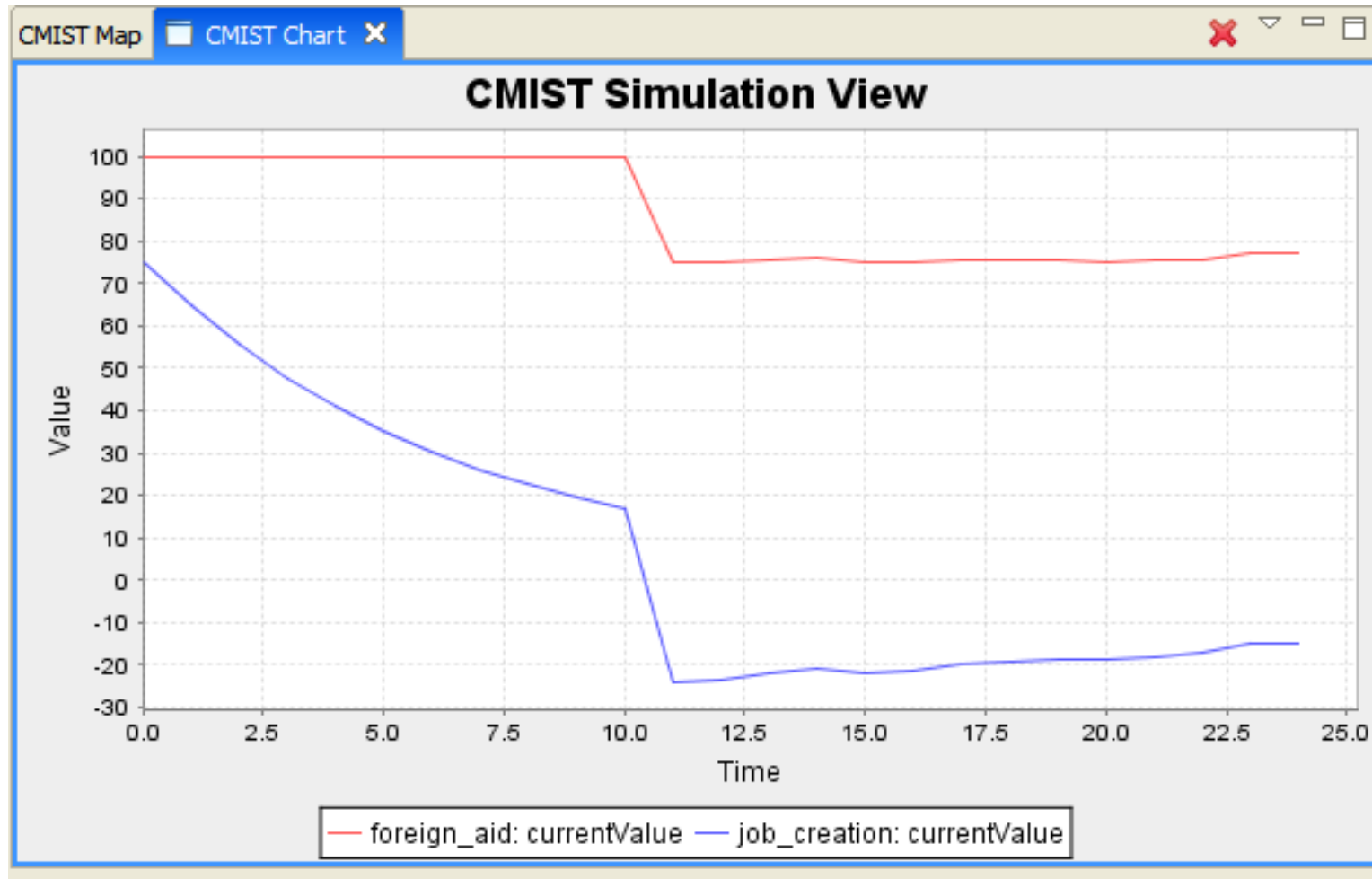
Results

Baseline + Blue Attack + Red CtrAttack



Results

Baseline + Blue Attack + Red CtrAttack



- **CMIST provides a rich platform for PMESII model integration**
 - PMESII IDE for M&S developers to rapidly integrate new native simulation tools
 - Commander's IDE for rapid model authoring, execution, and refinement
 - Powered by Eclipse Modeling Framework
- **Integrated modeling families & tools include:**
 - Cause-effect (AFRL CAT)
 - System Dynamics (Simulistics' SIMILE, U. Berkeley's Ptolemy II)
 - Agent-based modeling (TILab's JADE)
- **Promising initial results on small-scale Pol-Mil-Eco model**
 - Successfully demonstrates CE-SD interactions
 - Combines native tools with discrete vs. aggregate time management
- **Possible future research directions:**
 - Larger-scale modeling for DIME vs. PMESII counter-insurgency operations
 - Blue COA evaluation to support Joint Air Estimate Process

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 - Corey Lofdahl, James Melhuish (Modelers)

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