Adaptive Computer-Based Tutoring in an ADL Context

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Outline

- **Technical Underpinnings of Tutors**
  - **Two types of tutors**
  - **Representations and processes in tutors**
- **Example Tutor**
  - **Task overview**
  - **How current AFRL research supports tutor development**
    - Technically realizing activity monitoring
    - Net-Centric execution
    - Performance monitoring
- **Long-Term Vision**

Technical Underpinnings of Tutors

Model/Knowledge Tracing Fidelity and the Cost of Tutors

Development, deployment, and maintenance costs

Example

- Allowed actions are demonstrated
- Anticipated errors are demonstrated and associated with bug messages and hints
- Remaining errors block progress
- Minimal programming
- Limited re-usability

Cognitive

- Models support activity monitoring
- Decomposition of task into representations of knowledge and skill supports performance monitoring and the tailoring of instructional material
- Impact of repetition and inactivity on learning can be predicted and explained
- Models explain differences between instructional approaches

Technical Underpinnings of Tutors

Representations Underlying a Cognitive Tutor

- **The task of interest**
  - **Task environment**
  - **Possible actions**

Interface Module

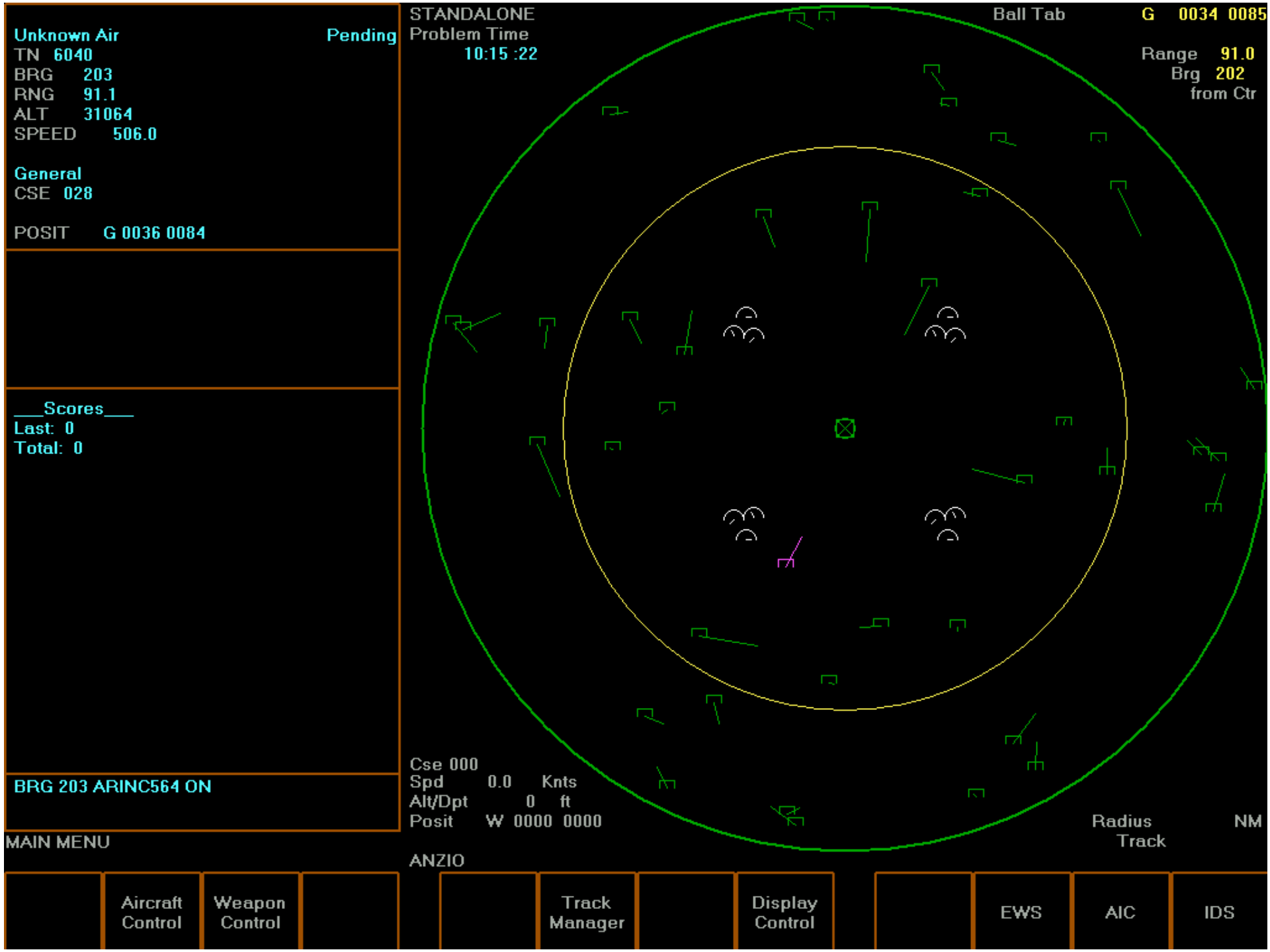
- **The trainee**
  - **Current knowledge**
  - **Current goals**
  - **Recent actions**
  - **Knowledge/skill strengths and weaknesses**

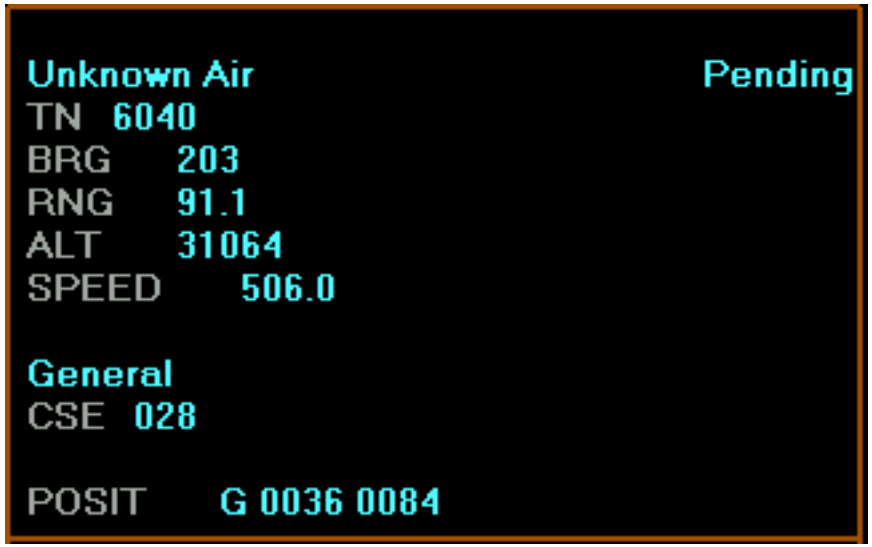
Student Module

- **Instruction**
  - **Optimal actions**
  - **Pedagogically effective actions**
  - **Intervention alternatives**

Expert Module

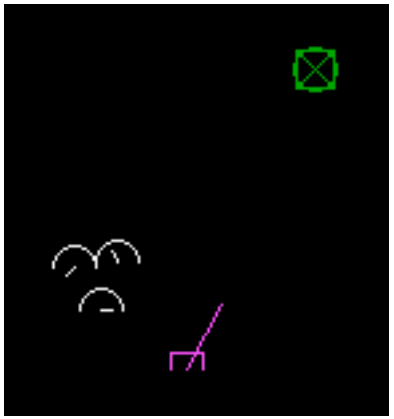
Tutor Module


Unknown Air
Pending
TN 6040
BRG 203
RNG 91.1
ALT 31064
SPEED 506.0
General
CSE 028
POSIT G 0036 0084
___Scores___
Last: 0
Total: 0
BRG 203 ARINC564 ON
MAIN MENU
STANDALONE
Problem Time
10:15 :22
Ball Tab
G 0034 0085
Range 91.0
Brg 202
from Ctr
Cse 000
Spd 0.0 Knts
Alt/Dpt 0 ft
Posit W 0000 0000
Radius NM
Track
ANZIO
Aircraft Control
Weapon Control
Track Manager
Display Control
EWS
AIC
IDS



2. Information in a “Character Readout”

4. Information in a “Track Report Area”

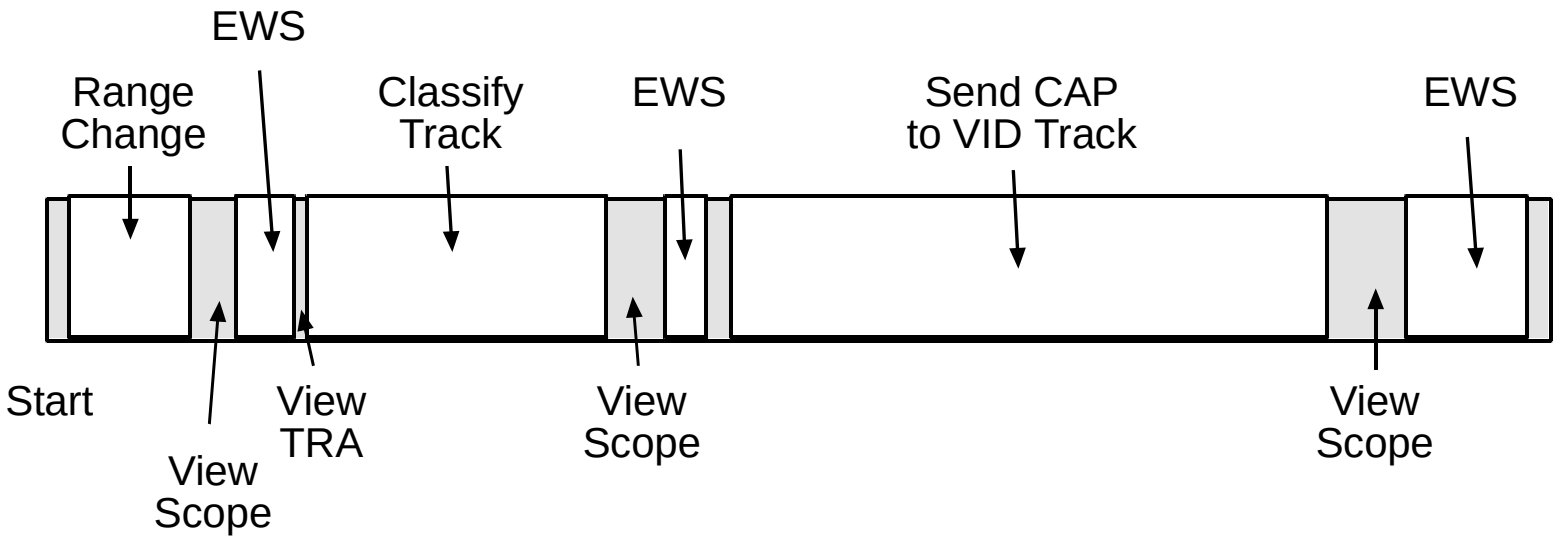


1. Track Selections
(visual assessments)

3. Interactions with interface and synthetic teammates through function-key panel
5. Entry of “Type” and “Threat” identifications

Tutoring in the AAWC Task

Monitoring Actions and Providing Instructional Support



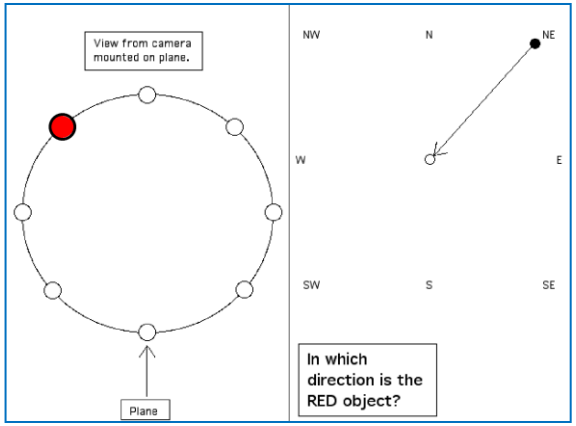
- **Task Selection**
  - Help trainee choose next unit task to execute
- **Task Execution**
  - Help trainee execute the current unit task

Where Cognitive Models and Agents are Going

The Challenges of Scale and Integration

Current Successes…

Student



Modeling the Cognitive Processes Underlying Spatial Rotation

- Models Execute in the Same Application as the Cognitive Architecture

Developing Challenges…

Reverse Engineer

Making sense of and defeating software protections

Modeling Sense-Making as Abduction-Based Inquiry in a Cyber Effects Testbed

- Agents Integrated into a Multi-Formalism M&S Environment

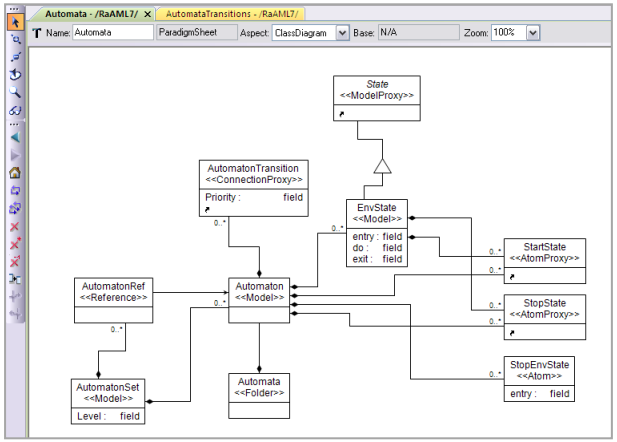
- Moving models to synthetic task environments
  - Modeling components of cyber/physical/human systems
    - Facing ***scaling*** and ***integration*** challenges

Large-Scale Cognitive Modeling (LSCM) Initiative

DSL Development using Model Integrated Computing

Sztipanovits and Gabor(2002) *"Model-Integrated Computing."*

1. Meta-Modeling -- *DSL Development*



Automated

2. Modeling -- *DSL Use*

?

Automated

3. Model Integration and Simulation -- *DSL Transformation, Integration and Execution*

$$SYS \equiv \langle T, X, \Omega, Q, \delta, Y, \lambda \rangle$$

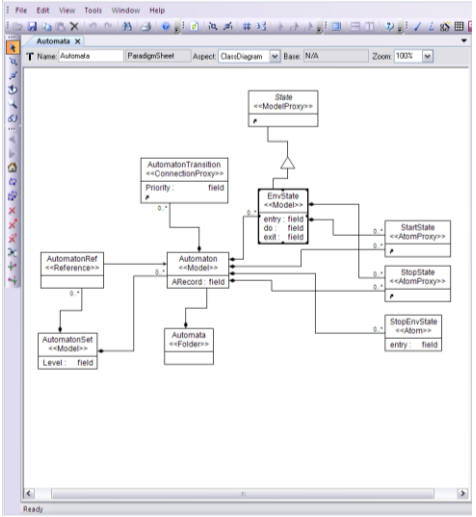
T	Time base
X	Input set
Ω	State
Q	State set
$\delta : \Omega \times Q \rightarrow Q$	Transition function
Y	Output set
$\lambda : Q \rightarrow Y$	Output function

- General Systems Theory
- DEVS: Discrete Event Systems
- HLA/DEVS Integration

Wymore, A. W. (1967)
"A Mathematical Theory of Systems Engineering the Elements."
Zeigler, Kim, & Praehofer (2000)
"Theory of Modeling and Simulation."

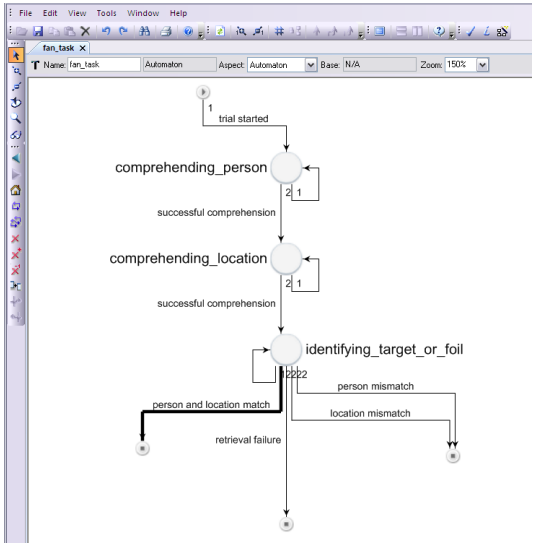
An Example Cognitive Modeling DSL

Abstract/Concrete Syntaxes based in ACT-R; Semantic Anchoring in DEVS



GME 11

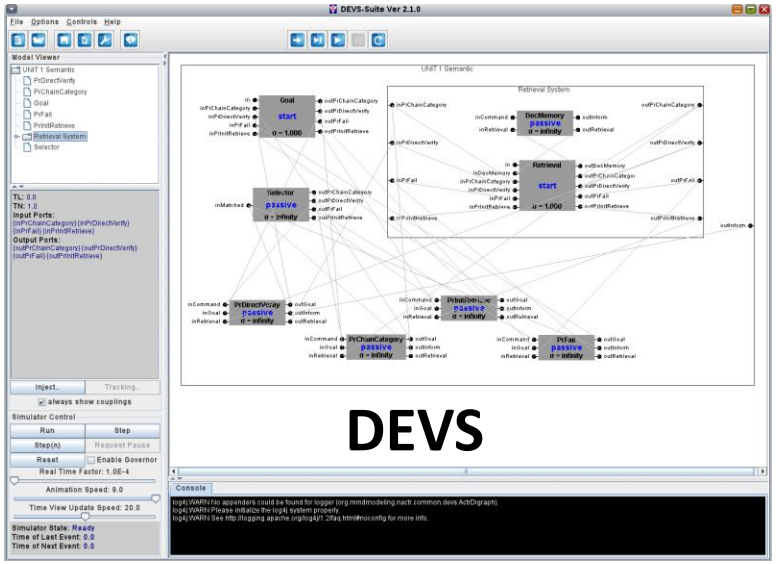
GENERIC MODELING ENVIRONMENT 11



Xtext

Language Development Framework

- Cognitive Fidelity
- Domain Concepts/Relations
- Human Modeling
  - Motor Behavior
  - Visual Behavior
  - Associative Memory

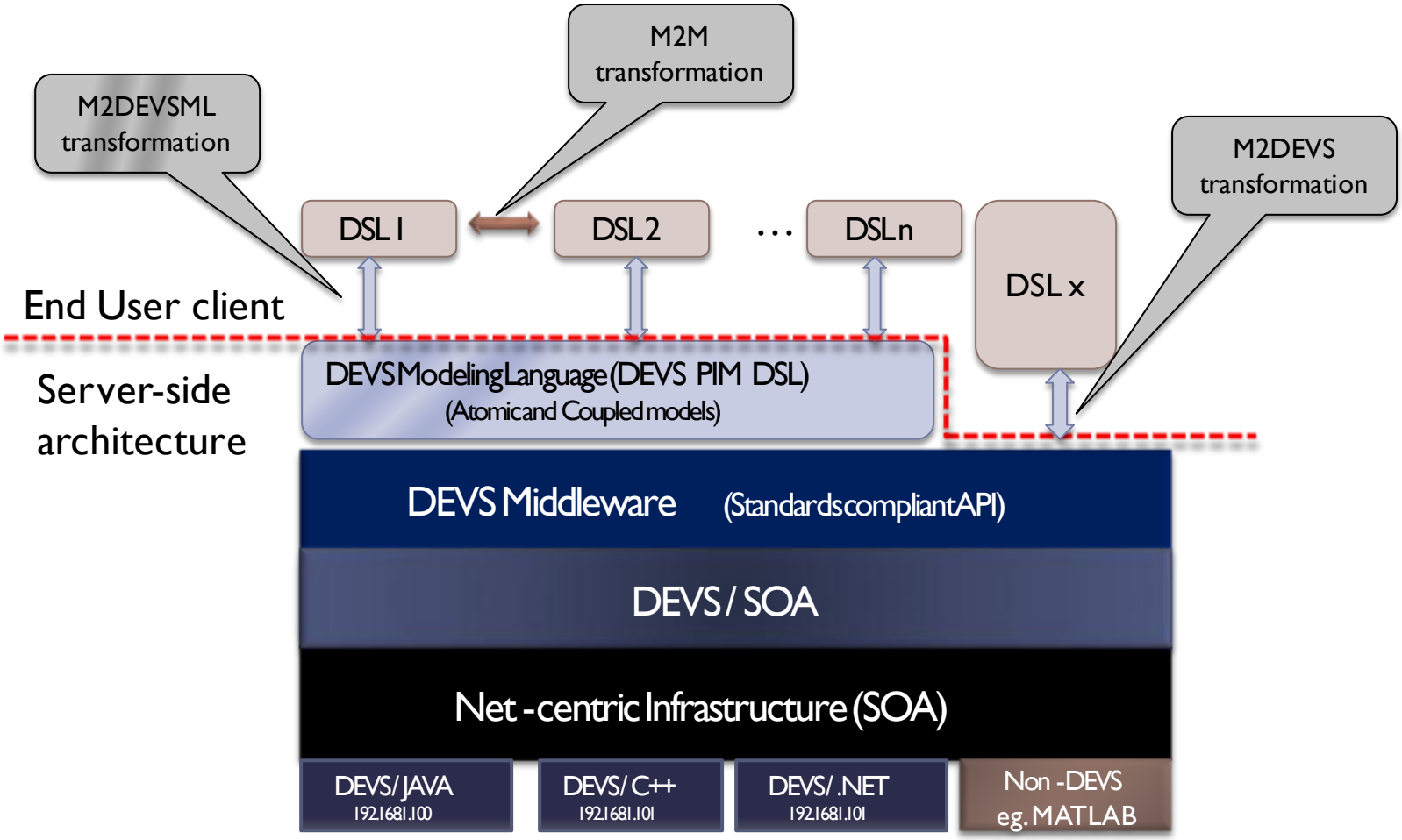


DEVS

- Formal Rigor
- Model Re-Usability
- Enhanced Interoperability
  - DoD Architectural Framework
  - DEVS-HLA
- Advanced M&S
  - Net-Centric Execution!

M&S Framework of the LSCM Initiative

Advanced M&S in a Service-Oriented Architecture (SOA)

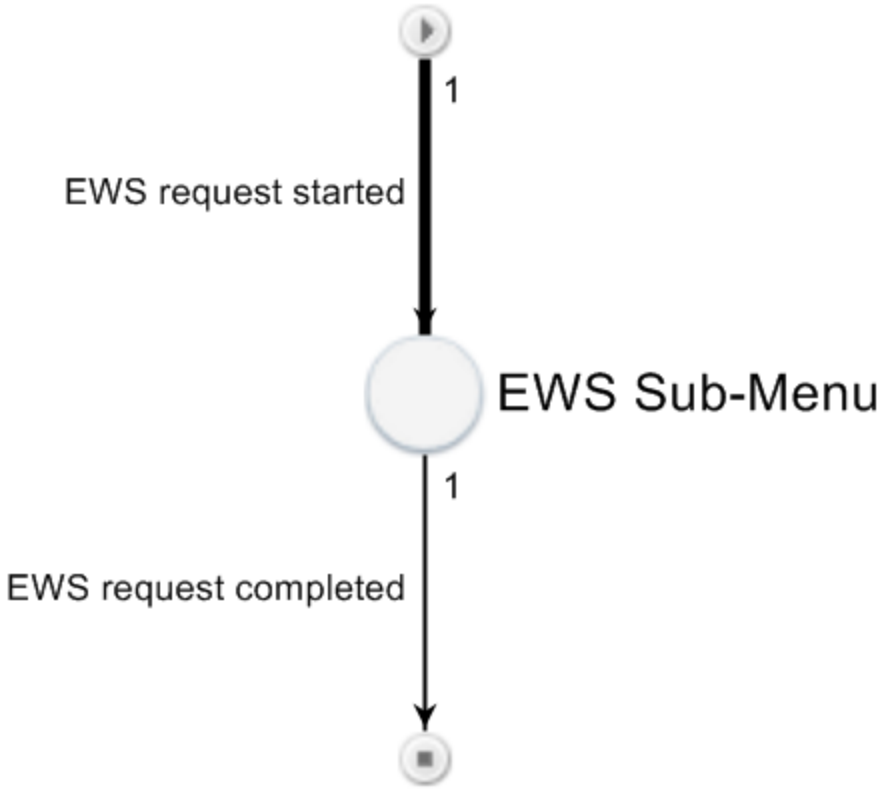


DEVS: discrete event system formalism
DEVSML: DEVS modeling language
DSL: domain-specific language
M2DEVS: model to DEVS

M2M: model to model
PIM: platform independent model
SOA: service oriented architecture

Behavior Models in Example DSL

Formal Representations that Recognize and Generate Behavior



Object Inspector

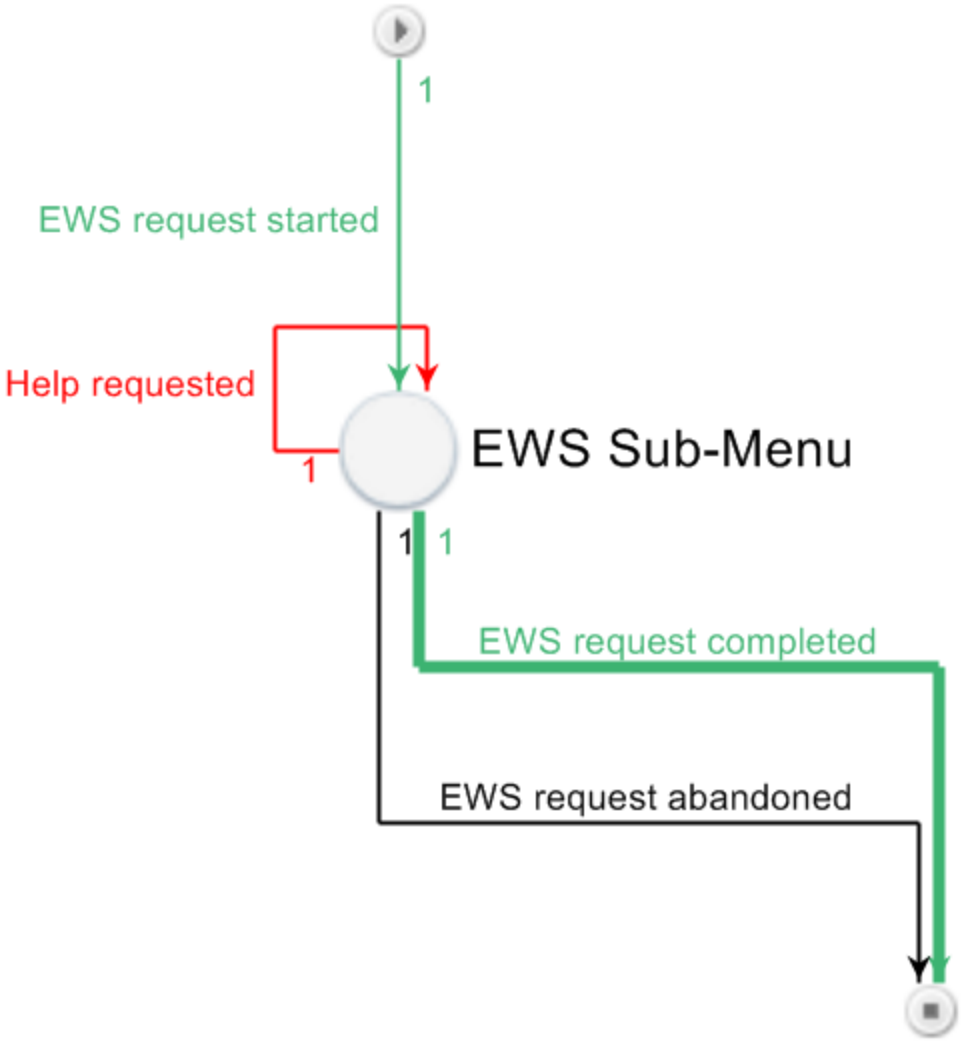
AutomatonTransition

Attributes | Preferences | Properties

Label	EWS request started
PreBindings	
PostBindings	hook_time=Time
Patterns	{menu_id, 0}, {hooked_track, Time}, {key_pressed, f10}
Functions	
Assertions	
Priority	1

Behavior Models in Example DSL

Formal Representations that Recognize and Generate Behavior



Object Inspector

AutomatonTransition

Attributes | Preferences | Properties

Label	EWS request completed
PreBindings	hook_time=Time
PostBindings	
Patterns	{key_pressed, f1}
Functions	
Assertions	{report_unit_task, ews_request, Time}
Priority	1

Behavior Models in Example DSL

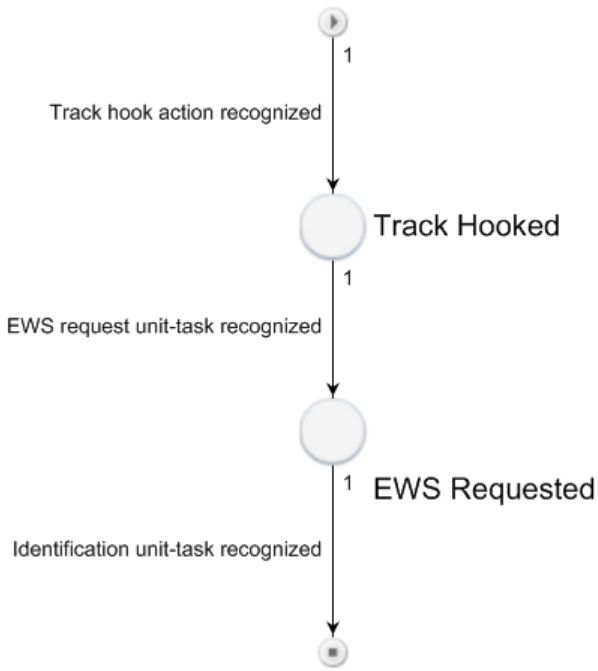
Formal Representations that Recognize and Generate Behavior

RML1.3 - ews_then_id_v1 - /agents/AAWC/

File Edit View Tools Window Help

track_hooked | ews_request_v1 | ews_then_id_v1 | ews_then_id_v2

Name: ews_then_id_v1 Automaton Aspect: Automaton Base: N/A Zoom: 150%



Object Inspector

ews_then_id_v2 for Kind

Attributes | Preferences | Properties

ARecord {hooked_track}

Part Browser

Automaton_

EnvState

StartState

StopEnvState

StopState

GME Browser

Aggregate | Inheritance | Meta

ews_then_id_v2

- agents
  - AAWC
    - comm_nonmil_id_v1
    - comm_nonmil_id_v2
    - ews_request_v1
    - ews_request_v2
    - ews_then_id_v1
    - ews_then_id_v2
    - track_hooked
    - vid_request
  - CDO_sandbox
  - book_CDOs
  - cs_base
  - debug_test
  - golf_CDOs
  - shared

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Behavior Models in Example DSL

Formal Representations that Recognize and Generate Behavior

RML1.3 - ews_then_id_v2 - /agents/AAWC/

File Edit View Tools Window Help

track_hooked | ews_request_v1 | ews_then_id_v1 | ews_then_id_v2

Name: ews_then_id_v2 | Automaton | Aspect: Automaton | Base: N/A | Zoom: 150%

Track hook action recognized

Another track hook recognized

Track Hooked

Some other unit-task recognized

EWS request unit-task recognized

Another track hook recognized

Help requested

EWS Requested

Some other unit-task recognized

Identification unit-task recognized

Object Inspector

AutomatonTransition | for Kind

Attributes | Preferences | Properties

Label	Identification unit-task recognized
PreBindings	hooked_track=Track
PostBindings	
Patterns	{report_unit_task, generic_id, Track}
Functions	
Assertions	{report_strategy, single_ews_id}
Priority	2

Part Browser

Automaton_

EnvState

StartState

StopEnvState

StopState

GME Browser

Aggregate | Inheritance | Meta

ews_then_id_v2

agents
- AAWC
  - comm_nonmil_id_v1
  - comm_nonmil_id_v2
  - ews_request_v1
  - ews_request_v2
  - ews_then_id_v1
  - ews_then_id_v2
  - track_hooked
  - vid_request
- CDO_sandbox
- book_CDOs
- cs_base
- debug_test
- golf_CDOs
- shared

Ready

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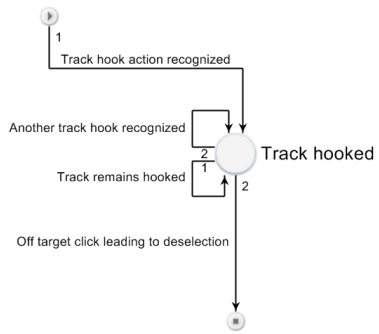
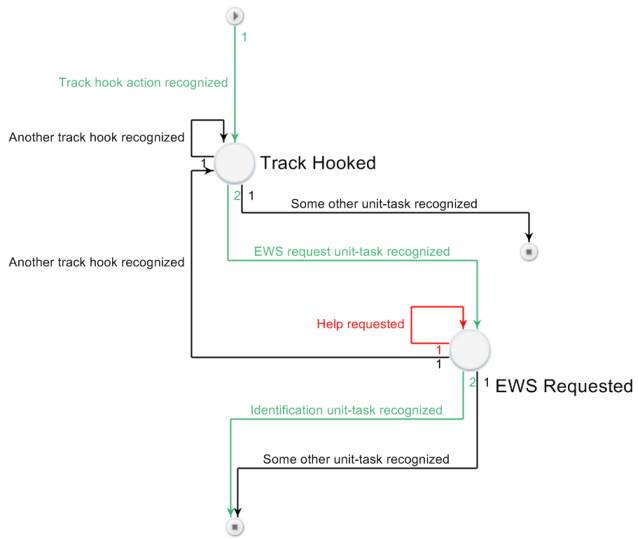
As Much Cognitive Fidelity as Necessary

"Cognitively Thin" Tutors can be Developed Quickly and then Scale

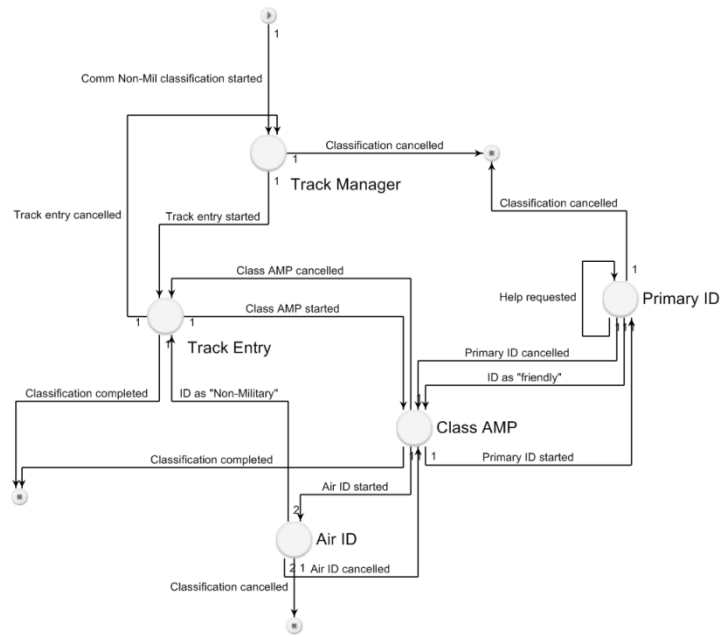
Increasingly more adherence to and use of cognitive architecture in behavior models

Example



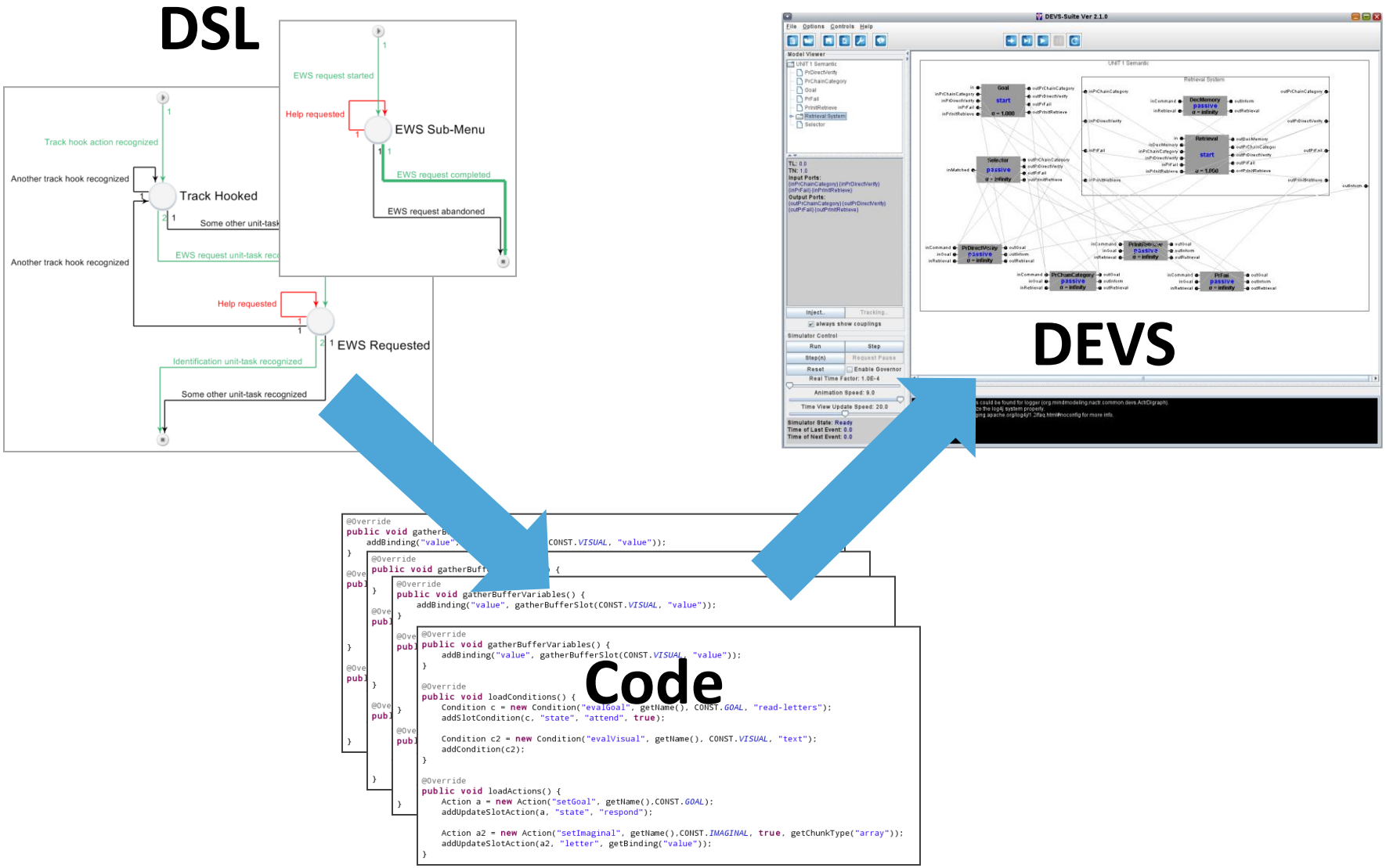


Cognitive



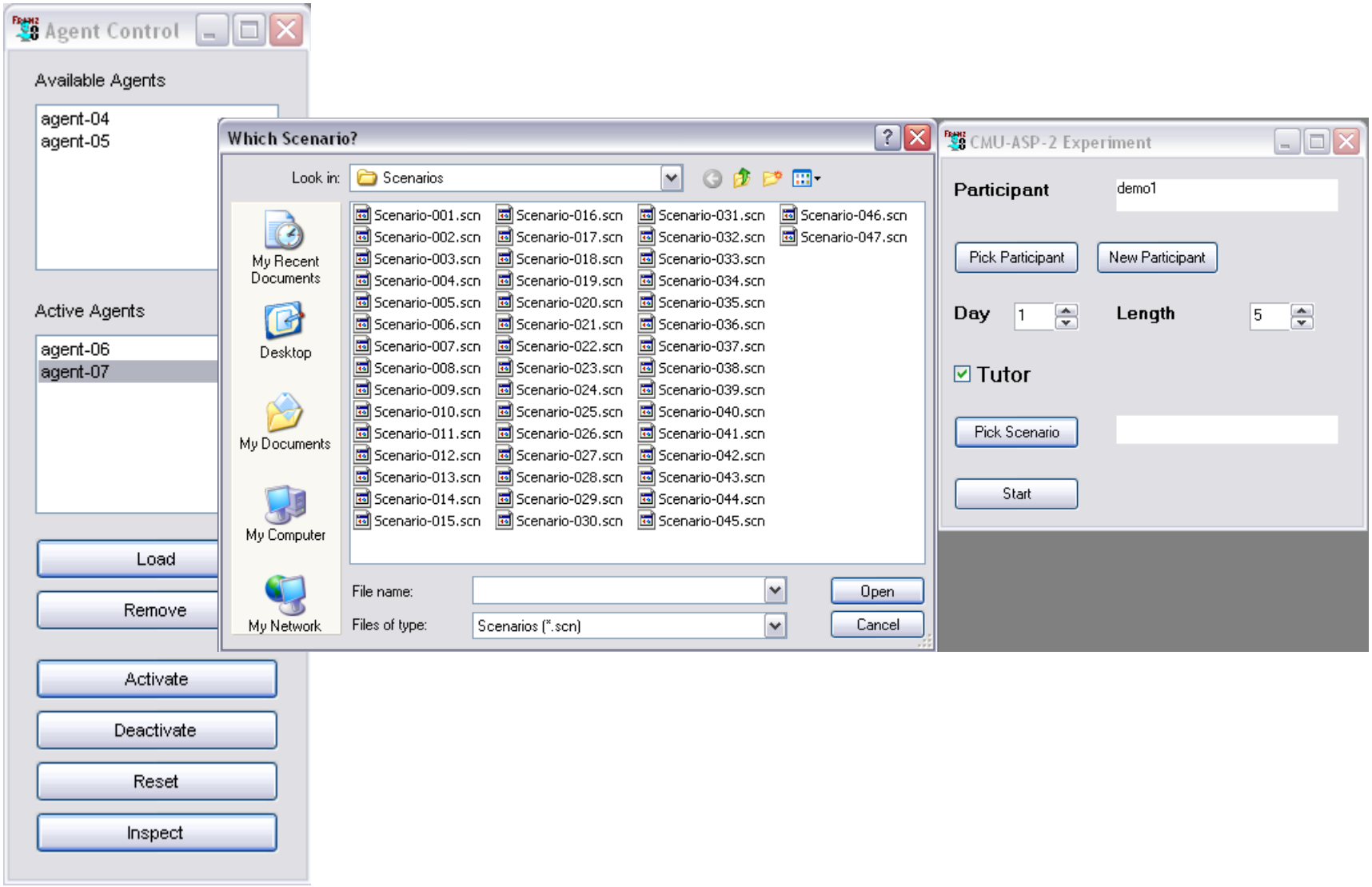
M2M Transformations and Execution

Minimizing Programming and Platform Dependence



M2M Transformations and Execution

Supporting the Execution and Control of Agents



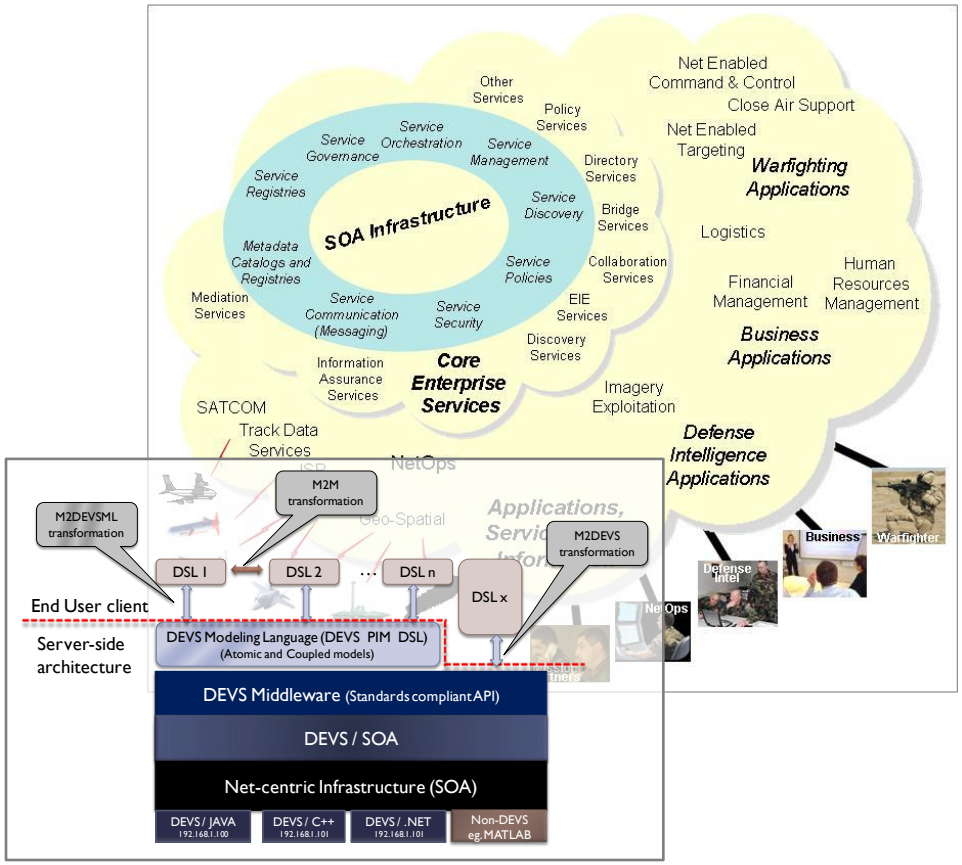
```
  6.719    {hook_noticed, 6040}
 13.766    {deliver_intervention, wav_attempt_ews}
 17.078    {keypress_noticed, f10}
 19.516    {show_tra_info, "BRG, 203, ARINC564, ON", 6040, requested_ews, positive}
 19.516    {keypress_noticed, f1}
 19.516    {report_unit_task, ews_request, 6040}
 26.562    {deliver_intervention, wav_use_ews_to_id}
 33.609    {deliver_intervention, wav_use_ews_to_id}
 40.656    {deliver_intervention, wav_use_ews_to_id}
 43.125    {keypress_noticed, f6}
...
 50.016    {keypress_noticed, f1}
 50.016    {report_unit_task, comm/non_mil_id, 6040}
 50.016    {report_strategy, single_ews_id}
```

SOA What!?

Why the LSCM Initiative is Exploring SOA-Based Cognitive M&S

Cognitive Agents and ADL in the GIG

- **Challenges of the future**
  - **Heterogeneity**
    - Increasing interoperability
  - **Change**
    - Responding to changing requirements
- **Potential of SOAs**
  - **Leverage existing systems**
  - **Facilitate integration**
  - **Manage complexity**
  - **Change pace/cost of development**

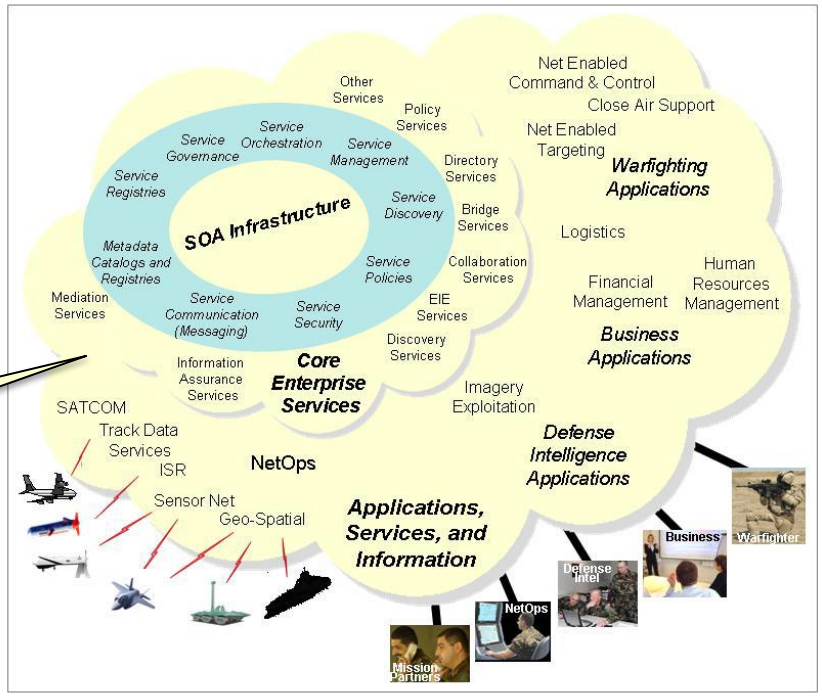


Future of ITS in ADL

ITS Built using DSLs and Executing in Net-Centric SOAs

- **ITS development in a net-centric cognitive modeling framework**
  - **Task, student, expert, and tutor modules specified in DSLs**
  - **Transformation of DSLs to executable artifacts**
  - **Net-centric execution**
- **Authoring environment that turns an ITS author into an end-user**
  - **DSLs tailored to the needs of domain experts**
  - **Re-use of behavior models**
- **ITS components integrated in a SOA**
  - **Pedagogical agent**
  - **Task environment**
  - **Performance repository**
  - **Instruction management system**
- **Standards**
  - **Development**
  - **Interoperability**
  - **Delivery/deployment**

Training/ADL Applications



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