Model-Based Integration of Component-Based Embedded Systems:

A Case Study

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Outline

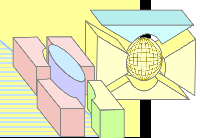
- DARPA Model-Based Integration of Embedded Systems (MoBIES) challenges and technology
  - Multi-view Modeling
  - Model-based Analysis
  - Model-based Composition
- MoBIES-enabled Development Process
- MoBIES toolchain
- Experimental Approach and Results
- Transitioning the Technology
- Conclusion

Model-Based Integration of Embedded Systems

Challenge Problems

Rapid, Predictable Integration And Deployment Of Component-Based Embedded Systems

- *Inter-Component Integration Addressing Cross-Cutting Concerns*
- *Static Component-Level Resource Management Analysis*



Experimentation and Demonstration

- *Design-Time Technology Experiments*
- *Run-Time and Design-Time Metrics*
  - *Performance*
  - *Cost,Schedule, Quality*

Technology Development Research

Model-based embedded system component integration tools and techniques

- *Multi-View Modeling of Cross-Cutting Constraints*
- *Meta-Code Generation*
- *Framework Coupling and Merging*

Working Group

Open Experimental Platform Research

Open products to integrate, verify, and transition embedded software integration technology

- *Primitive Real-Time CORBA Component Model Support*
- *Performance Instrumentation*
- *Representative Product Scenarios Highlighting Cross-Cutting Concerns*

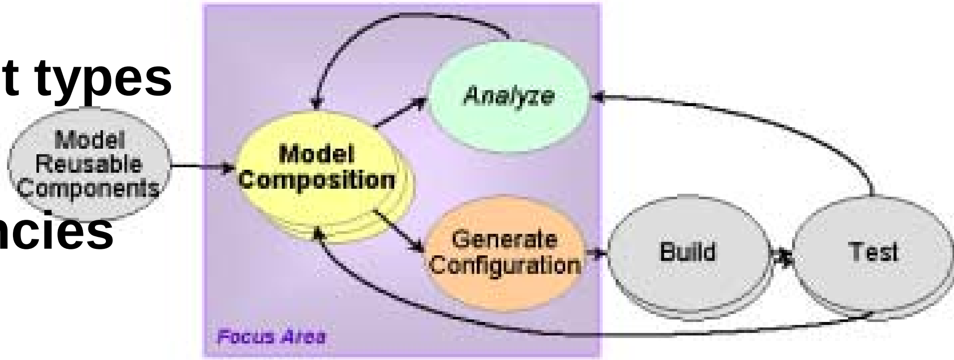
Rapid Embedded System Configuration For Evolving Warfighter Needs: Model Driven Architecture Applied To Embedded System Configuration

Challenges for Model-Based Component Integration

Multi-view modeling

– Primary and backup component types and modes

– Event and Invocation dependencies between components



– Threads, processes, processors, allocation of components

– QoS (rates, importance, resource requirements)

– Integrate multiple views

Model-based analysis

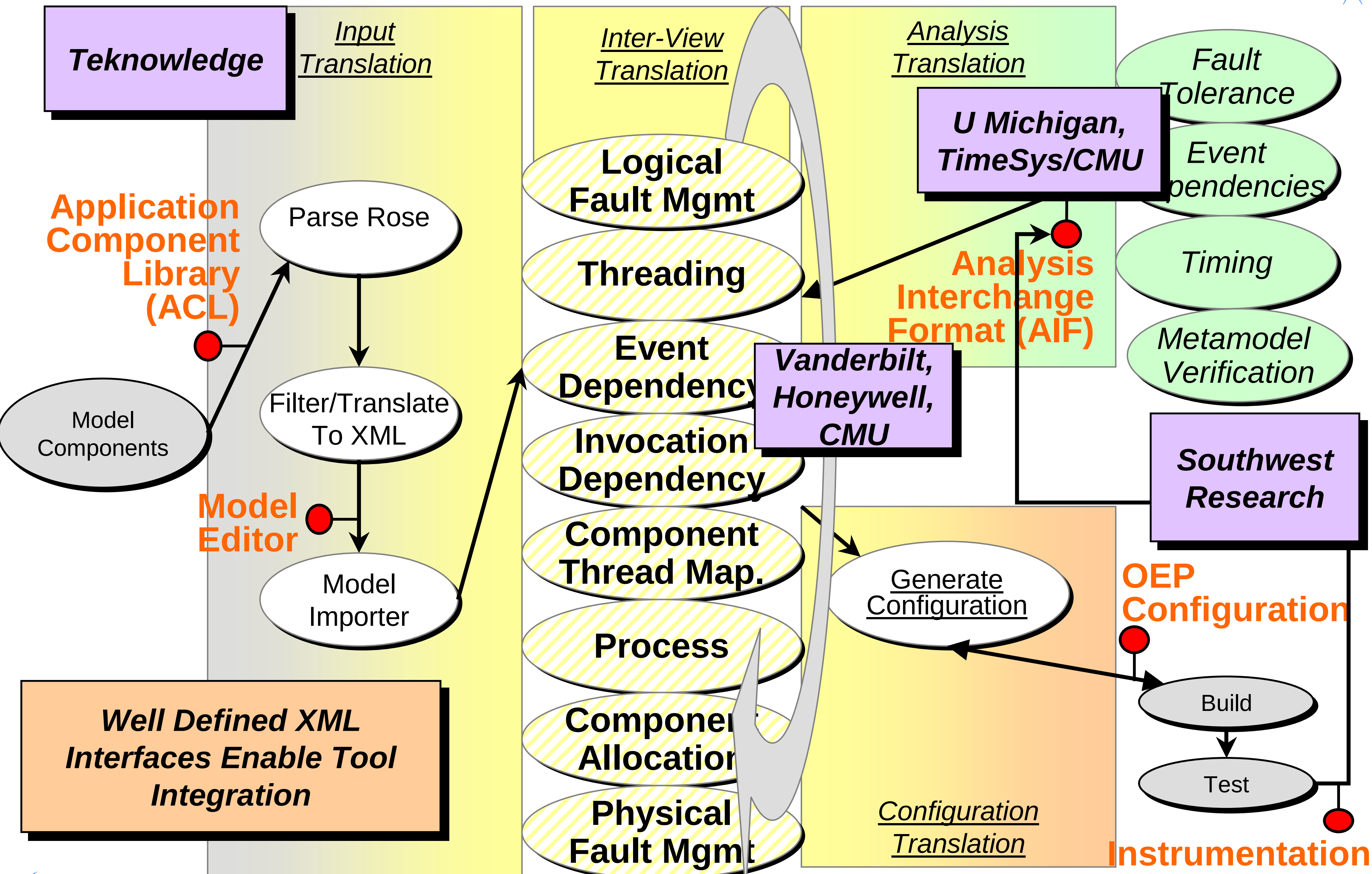
– Apply analytic methods to the design models to ensure satisfaction of cross cutting embedded constraints

- Event dependencies, timing and resource issues, schedulability

Model-based system configuration

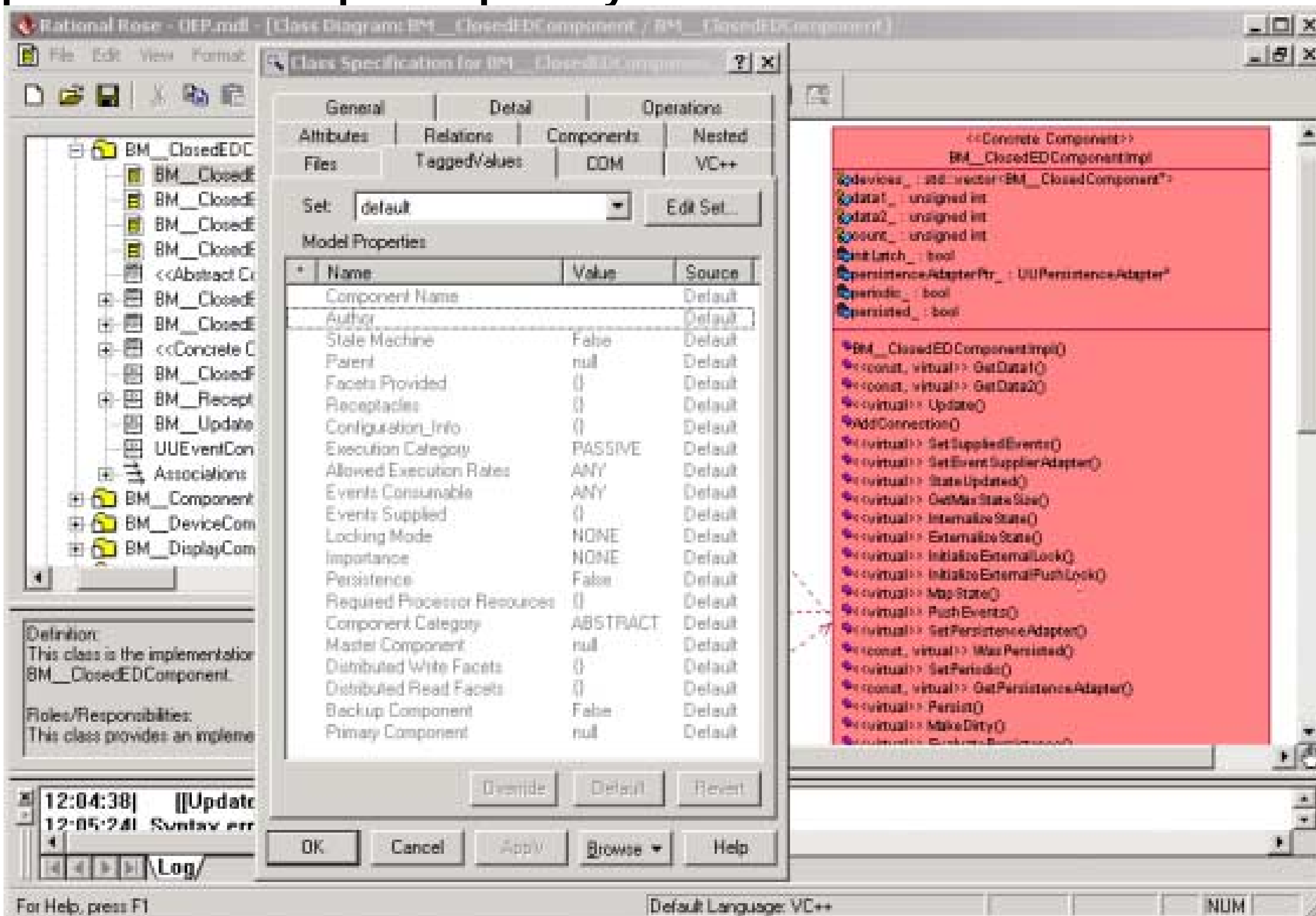
– Use system models to generate integration code needed to assemble a system from components

Resultant Process

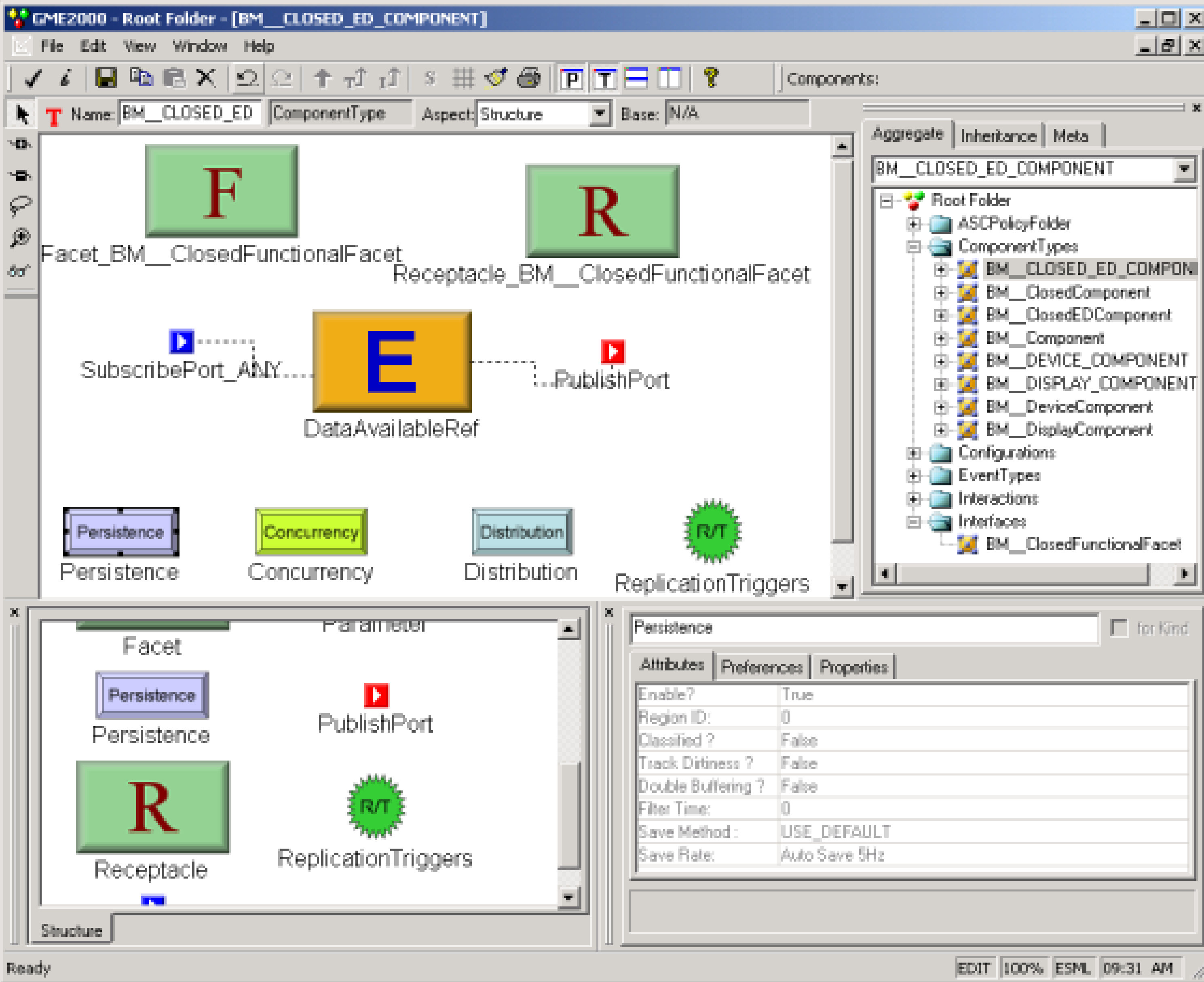


Input Translation

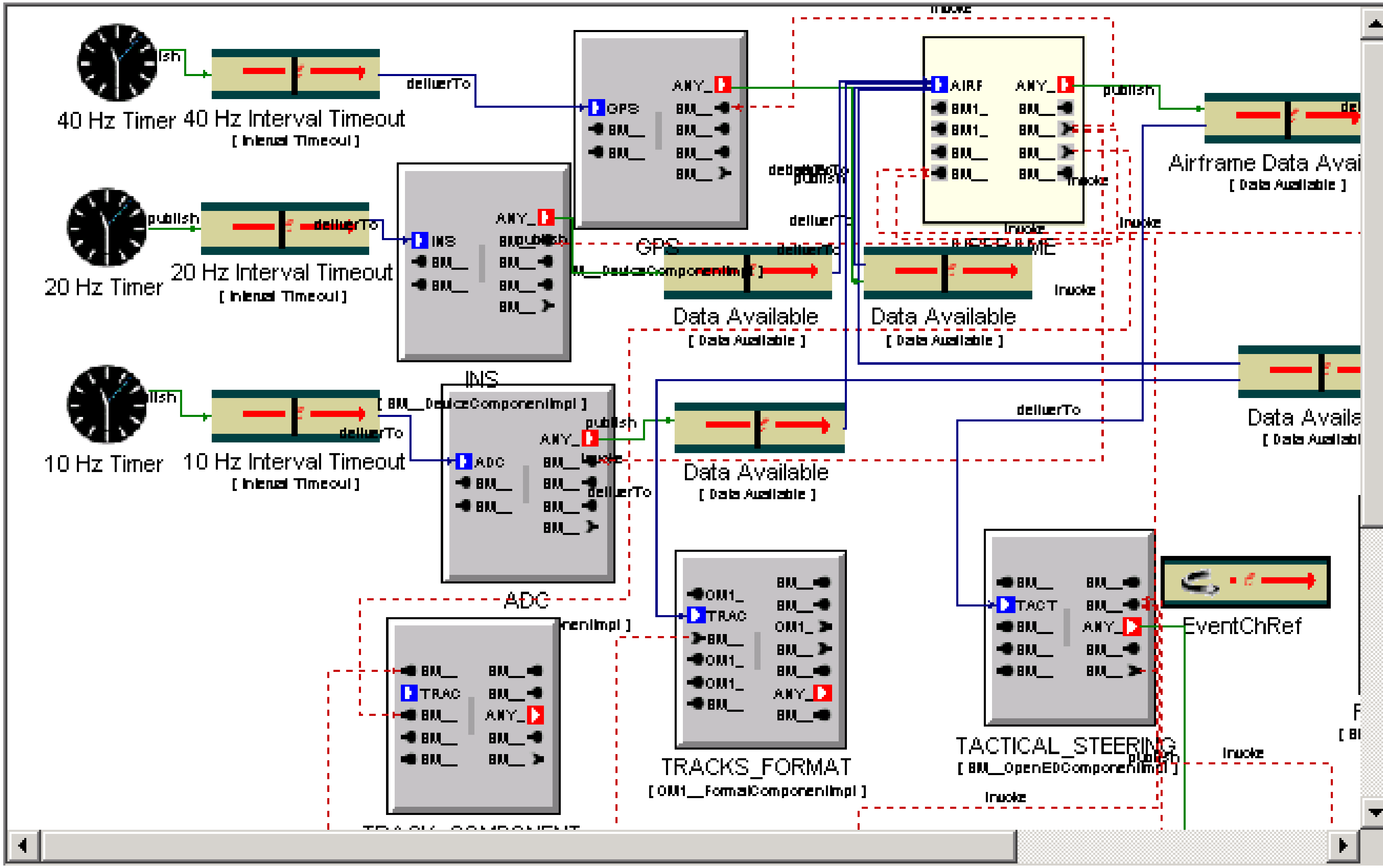
- The UML Interface provides access to attributes specific to the components represented by the stereotyped classes in Rose
  - Also provides XML export capability of this information from Rose



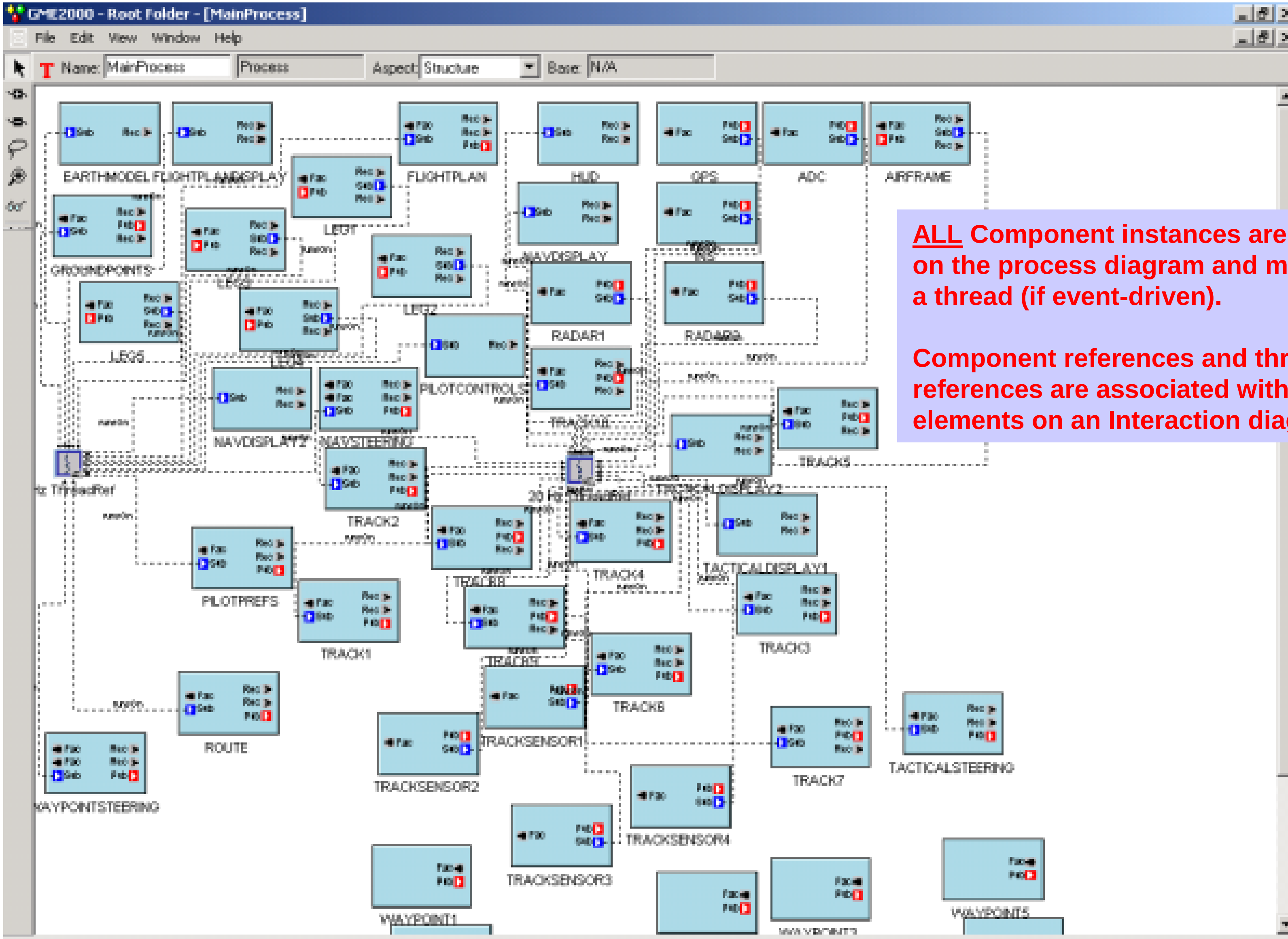
Embedded System Modeling Language (ESML) Component Type Information



ESML Interactions



ESML Deployment View
Component Allocation

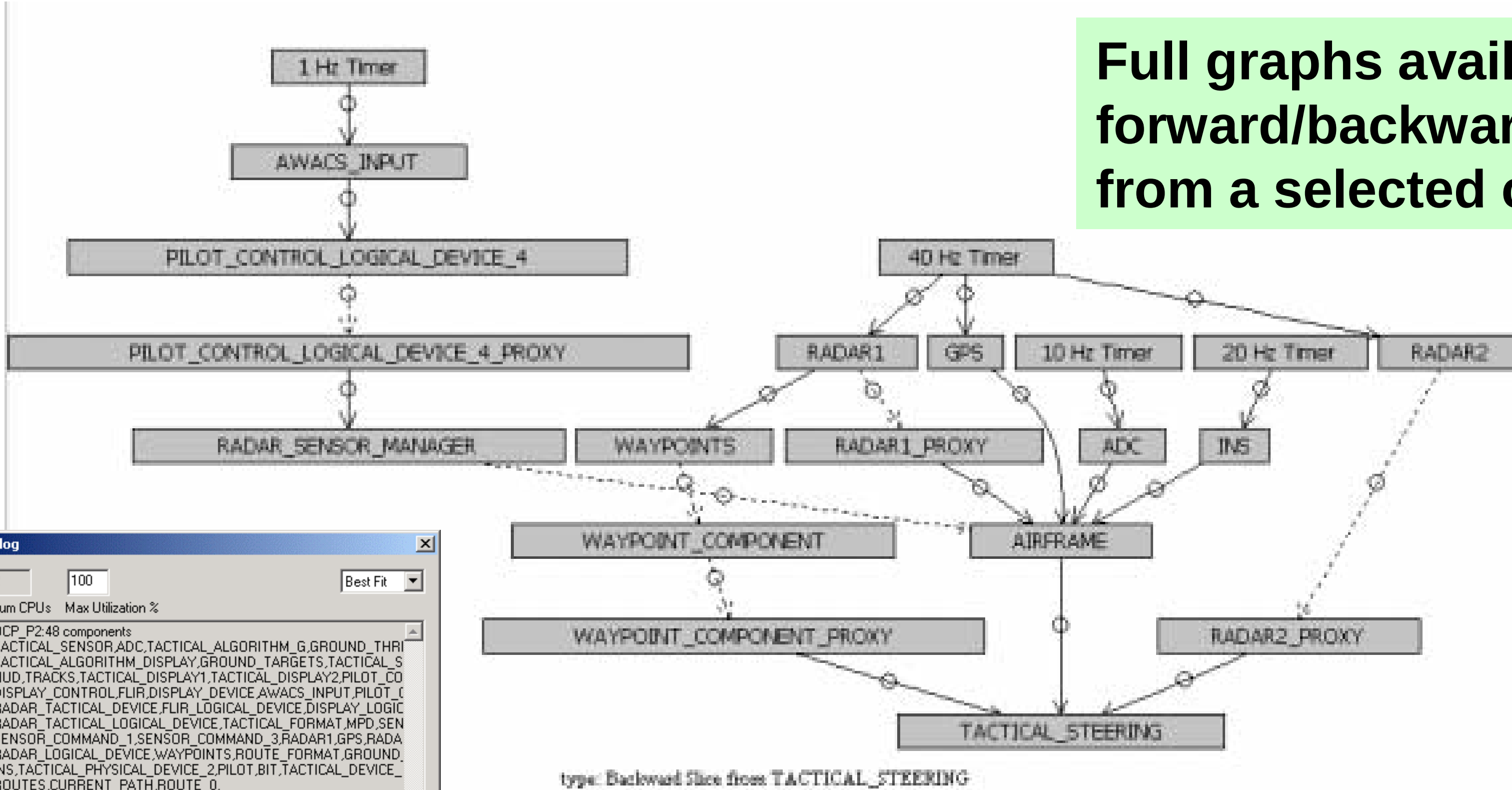


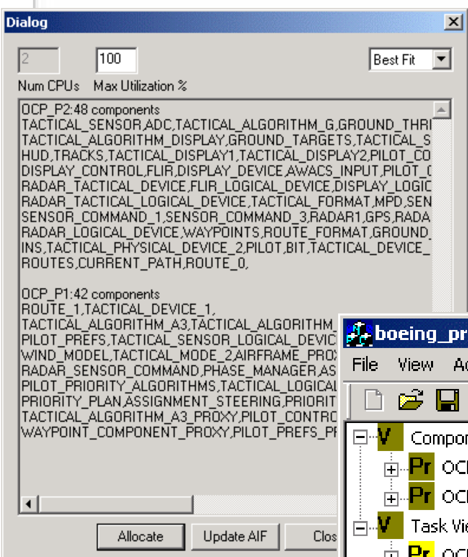
ALL Component instances are shown on the process diagram and mapped to a thread (if event-driven).

Component references and thread references are associated with actual elements on an Interaction diagram

Model Analysis

Full graphs available or forward/backward slices from a selected component





boeing_provided_aif.xml - Avionics

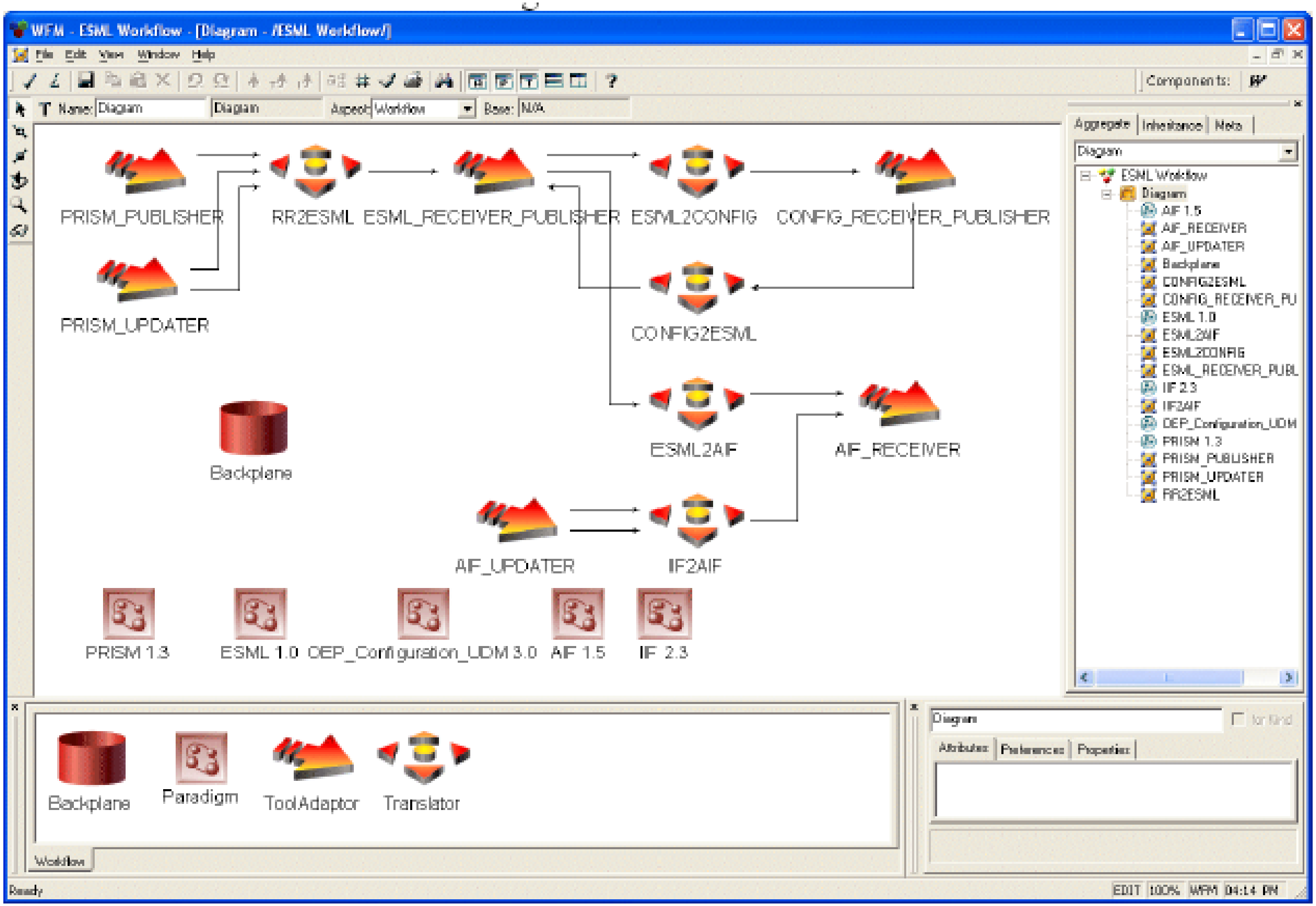
File View Actions Help

- Component View
  - OCP_P1
  - OCP_P2
- Task View
  - OCP_P1
  - OCP_P2

Task Name	Priority	Period	Deadline	WCET	Utilization	BCRT	WCRT	Schedulable	Blocking Time
T_10Hz	3	100000	100000	3148.00	0.03148	3148.00	4522.00	Y	0.00
T_1Hz	1	1000000	1000000	19660.00	0.01966	19660.00	24384.00	Y	0.00
T_20Hz	4	50000	50000	186.00	0.00372	186.00	1374.00	Y	0.00
T_40Hz	5	25000	25000	1188.00	0.04752	1188.00	1188.00	Y	0.00
T_5Hz	2	200000	200000	202.00	0.00101	202.00	4724.00	Y	0.00

Ready NUM

OTIF

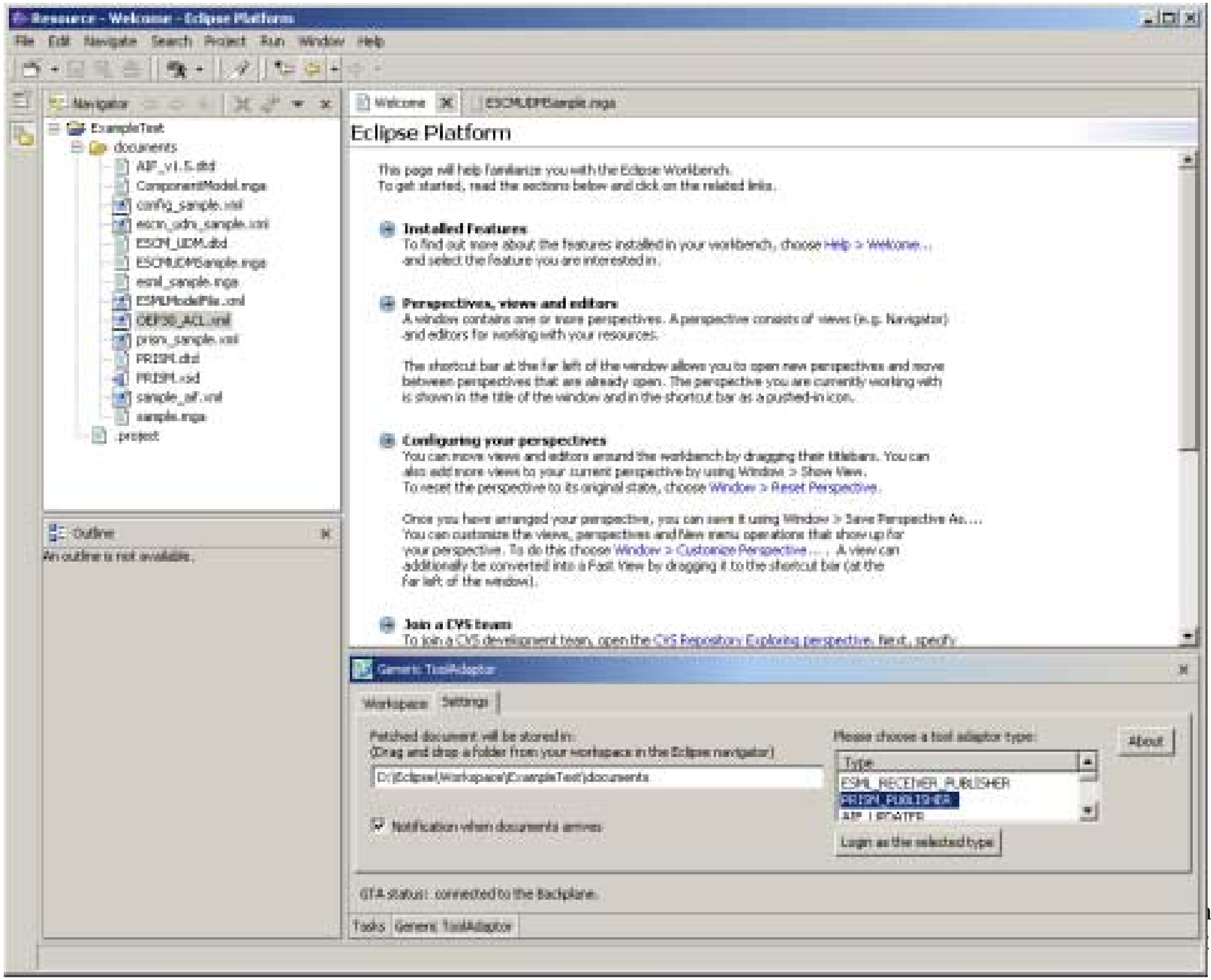


ESML workflow diagram in GME

Data Translations using OTIF

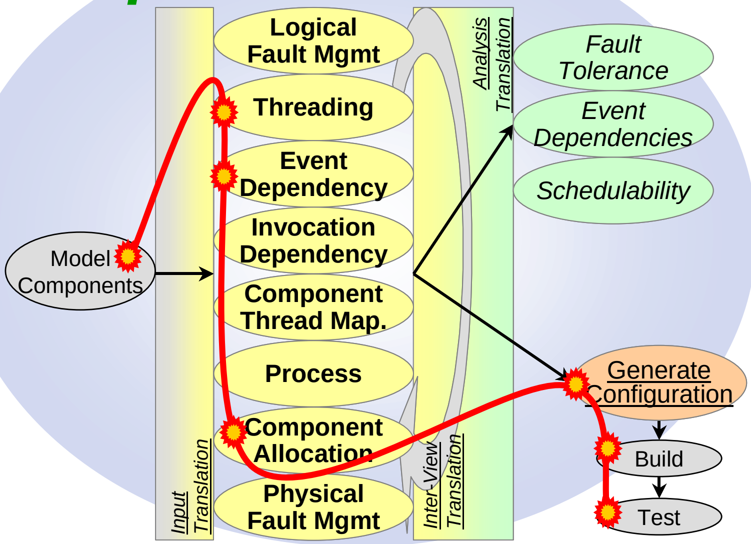
- Log in as the appropriate tool adaptor type (e.g. PRISM_PUBLISHER)
- Drag the document into the workspace area(e.g. OEP30_ACL.xml)

•Go back to the Settings tab and change the tool adaptor type (ESML_RECIEVER_PUBLISHER) and subscribe to the appropriate paradigm (ESML) on the Workspace tab and wait for the converted file to appear at the backplane as shown on the previous slide.

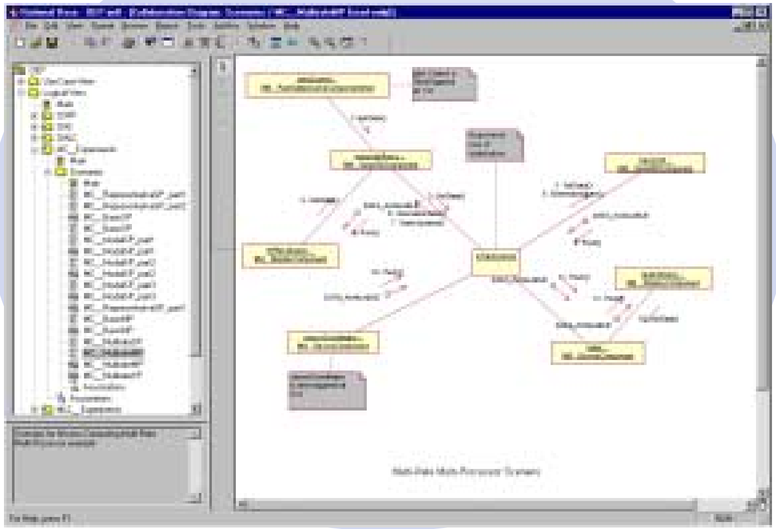


Experimentation Approach

Development Scenarios and …



Product Scenarios…



…Comprise Experiments

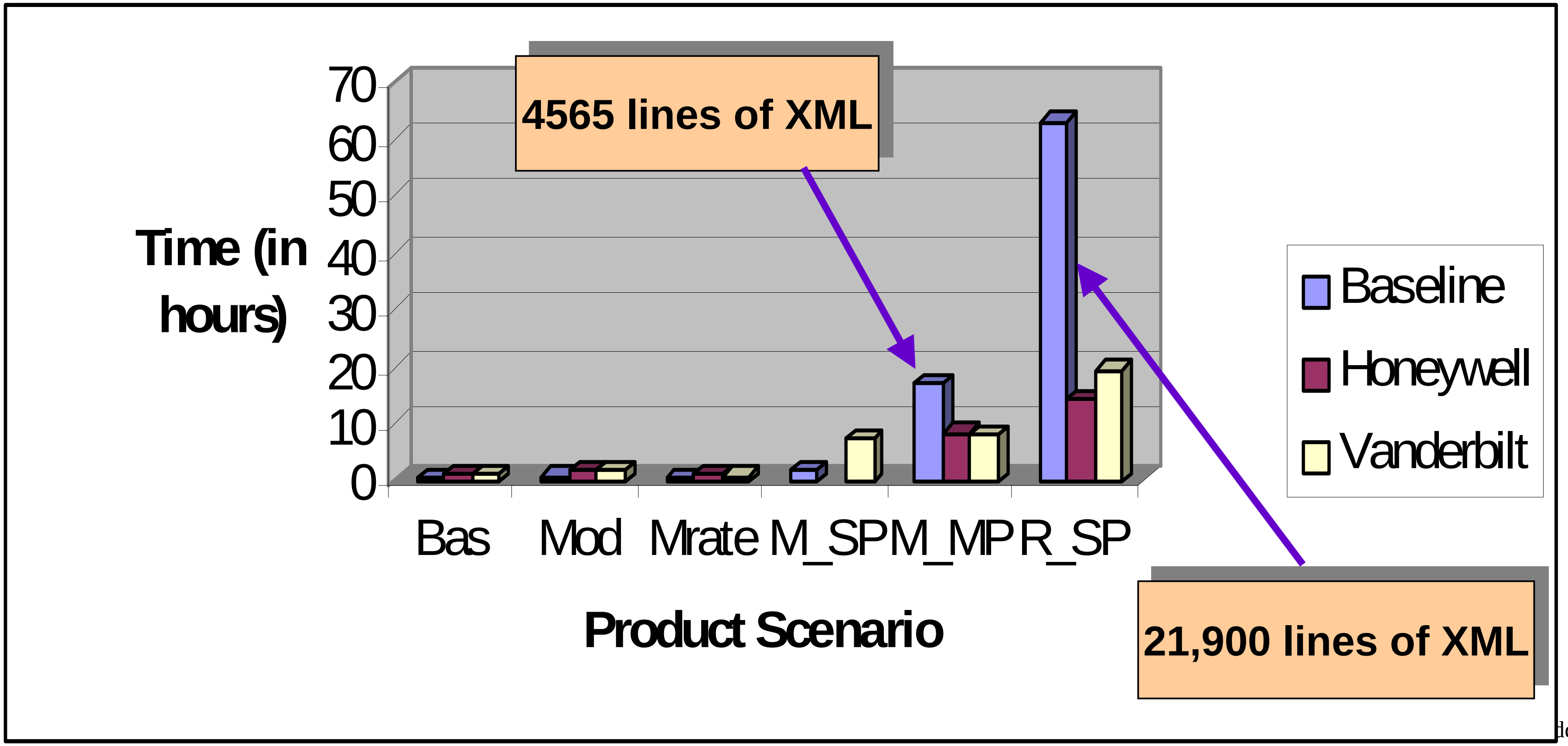
	PS 1 *Basic Single*	**PS 2** *Rep. Single*	**PS 3** *Basic Dist.*	**PS 4** *Rep. Dist.*
DS 1 *Basic*	**Exp 1-1**			
DS 2 *Evt Analysis*	**Exp 2-1**	**Exp 2-2**	**Exp 2-3**	**Exp 2-4**
DS 3 *Scheduling*	**Exp 3-1**	**Exp 3-2**	**Exp 3-3**	**Exp 3-4**
DS 4 *Fault Toler.*			**Exp 4-3**	**Exp 4-4**
DS 5 *Full*			**Exp 5-3**	**Exp 5-4**

Experimental Results

- **Validated feasibility of approach/process**
- **Integrated tool sets**
    - Bidirectional AIF and OEP Configuration Interface support
    - Incremental updates from design model changes
    - Open Tool Integrated Framework (OTIF) under investigation
    - Influence and refine interfaces via OMG MIC
- **Individual tools**
    - Selected tools targeted for transition
    - Scalability and usability issues remain
    - Continuing support through ESCHER
- **Aggregate productivity of Component Integrators increased**

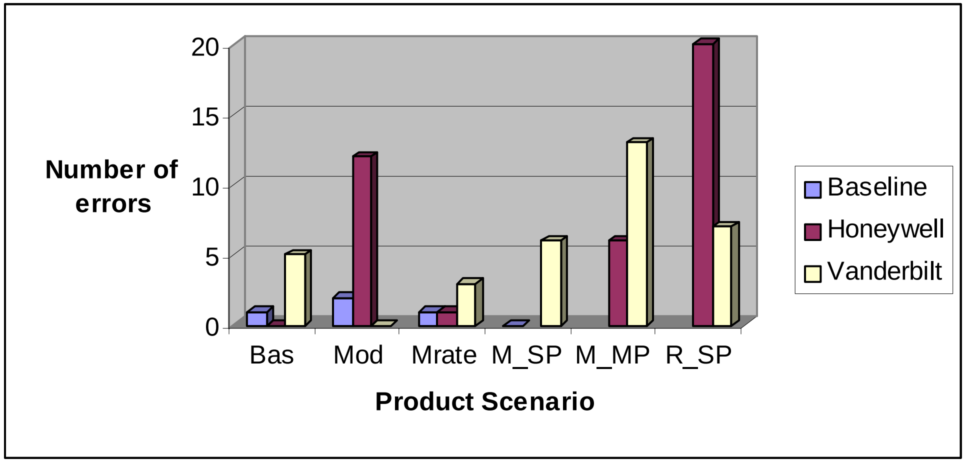
Savings in Configuration

- 2-4 times **longer** to configure the system in the modeling environments as opposed to working in the XML directly
- Significant advantages to modeling (2X to 4X **faster**) as the complexity of the scenarios and the skill of the modelers using the tools increased (as well as the maturity of the tools involved)



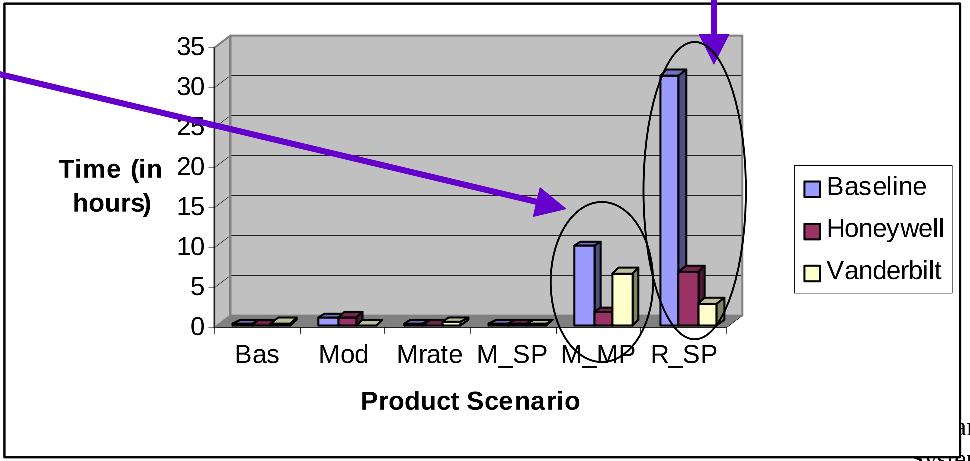
Savings to reconfigure, rebuild and execute the scenario when errors discovered

- **Errors discovered (build and run)**
- **Time spent to fix those errors and rebuild**



For the Representative SP scenario, VU toolset resulted in **11.5x savings** in time to find and fix errors

For the Medium MP scenario, Honeywell toolset resulted in almost a **6x savings** in time to find and fix errors



But even when we were still chasing a whole lot of errors in the model, it still resulted in a **2x to 6x** time savings!

Industry Technology Transition Efforts

- **ESCHER (Embedded Systems Consortium for Hybrid Embedded Research)**
  - Founding members: Boeing, Raytheon, GM
  - Creating repository for embedded system development tools, initially populated from DARPA programs
  - Joint government and industry funding of technology maturation
- **OMG Model Integrated Computing (MIC) SIG**
  - Goal is to influence standards and push interfaces, open tool frameworks and any other relevant technology (initially MoBIES-focused) into appropriate specifications
    - Will work closely with the RealTime, Embedded and Specification Systems PTF

Conclusion

- **~$50M In DARPA Research Has Created An End-To-End Development Approach For Model Driven Embedded Systems Development**
  - Multiple run-time component models and supporting middleware
    - CORBA Component Model style components
    - Task Network style components
  - Model-based deployment
  - Analysis
    - Strong tool support for Component dependency information and Component allocation
    - Timing scheduling analysis being integrated via commercial tools
  - Automated configuration code
  - Large scale configuration experiments indicate significant advances in
    - Productivity
    - Understandability
    - Defect avoidance, reduction, and correction