

Model-Based Integration of Component-Based Embedded Systems:

A Case Study

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Real-Time and Embedded
Systems Workshop
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- **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**

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

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

Technology Development Research

Model-based embedded system component integration tools and techniques



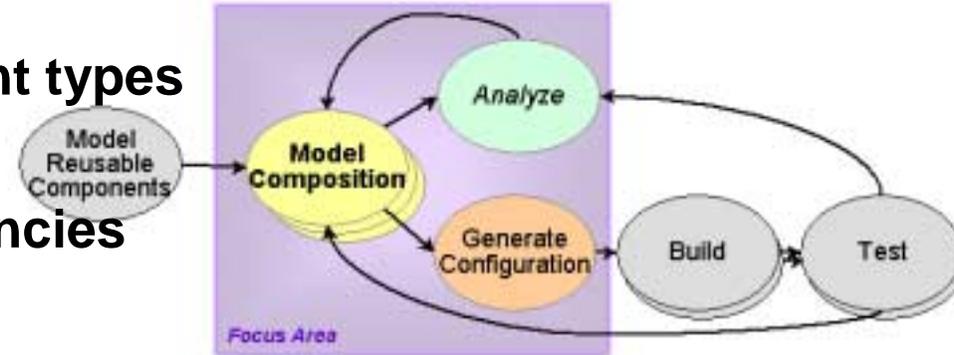
- Multi-View Modeling of Cross-Cutting Constraints
- Meta-Code Generation
- Framework Coupling and Merging



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

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



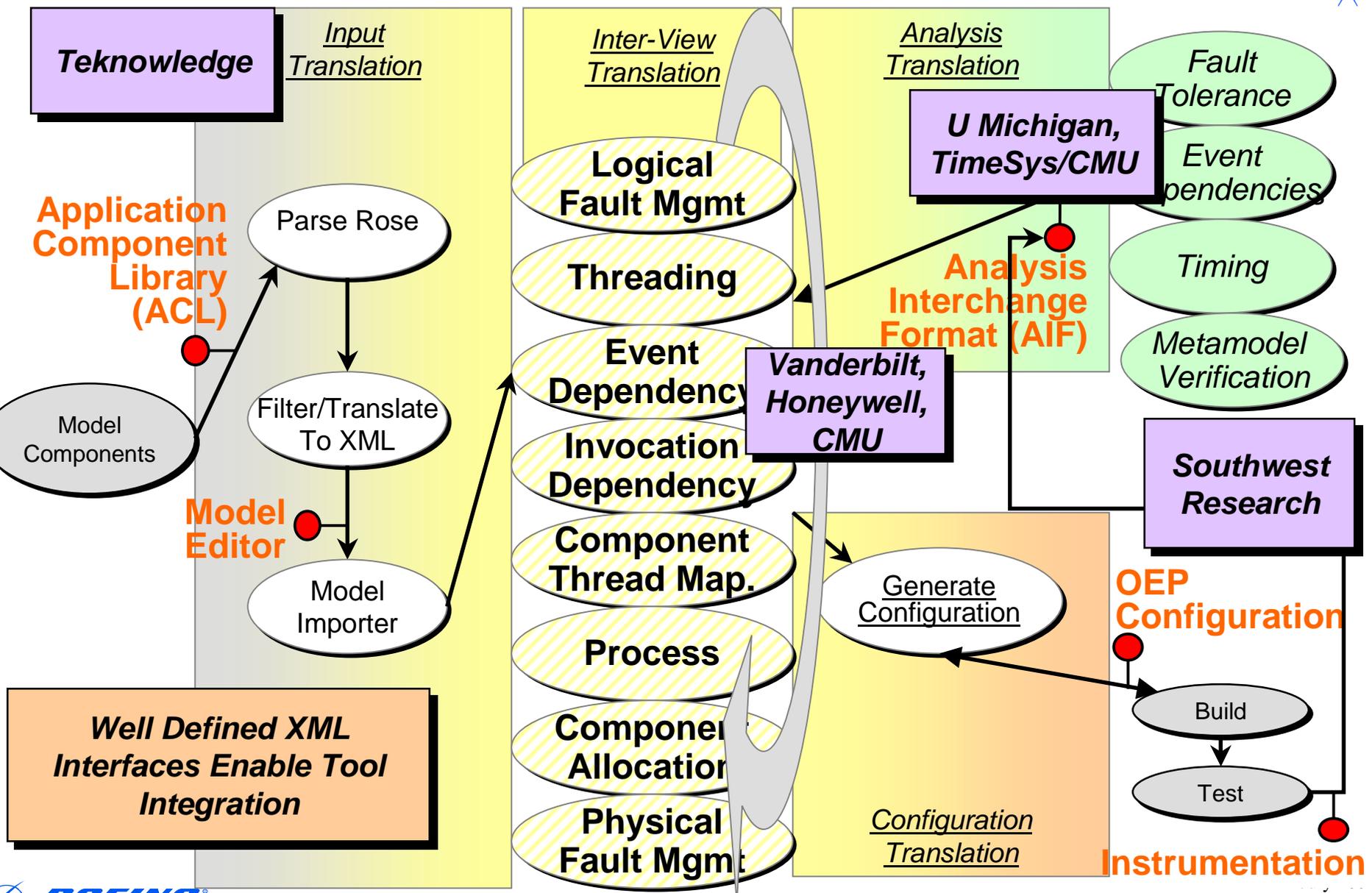
Model-based analysis

- 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



- 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

Class Specification for BM_ClosedEDComponent

General | Detail | Operations

Attributes | Relations | Components | Nested

Files | TaggedValues | COM | VC++

Set: default [Edit Set...]

Model Properties:

Name	Value	Source
Component Name	Default	Default
Author	Default	Default
State Machine	False	Default
Parent	null	Default
Facets Provided	()	Default
Receptacles	()	Default
Configuration_Info	()	Default
Execution Category	PASSIVE	Default
Allowed Execution Rates	ANY	Default
Events Consumable	ANY	Default
Events Supplied	()	Default
Locking Mode	NONE	Default
Importance	NONE	Default
Persistence	False	Default
Required Processor Resources	()	Default
Component Category	ABSTRACT	Default
Master Component	null	Default
Distributed Write Facets	()	Default
Distributed Read Facets	()	Default
Backup Component	False	Default
Primary Component	null	Default

Operations:

```

<<Concrete Component>>
BM_ClosedEDComponentImpl
+devices_ : std::vector<BM_ClosedComponent*>
+data1_ : unsigned int
+data2_ : unsigned int
+count_ : unsigned int
+initLatch_ : bool
+PersistenceAdapterPtr_ : UIPersistenceAdapter*
+periodic_ : bool
+persisted_ : bool

+BM_ClosedEDComponentImpl()
+<<const, virtual>> GetData()
+<<const, virtual>> GetData2()
+<<virtual>> Update()
+AddConnection()
+<<virtual>> GetSuppliedEvents()
+<<virtual>> GetEventSupplierAdapter()
+<<virtual>> StateUpdated()
+<<virtual>> GetMaxStateSize()
+<<virtual>> InternalizeState()
+<<virtual>> ExternalizeState()
+<<virtual>> InitializeExternalLock()
+<<virtual>> InitializeExternalPushLock()
+<<virtual>> MspState()
+<<virtual>> PushEvents()
+<<virtual>> GetPersistenceAdapter()
+<<const, virtual>> WasPersisted()
+<<virtual>> SetPeriodic()
+<<const, virtual>> GetPersistenceAdapter()
+<<virtual>> Persist()
+<<virtual>> MakeDirty()
+<<virtual>> RestorePersistence()
    
```

GME2000 - Root Folder - [BM_CLOSED_ED_COMPONENT]

File Edit View Window Help

Components:

Name: BM_CLOSED_ED ComponentType Aspect: Structure Base: N/A

Facet_BM__ClosedFunctionalFacet

Receptacle_BM__ClosedFunctionalFacet

SubscribePort_ANY

DataAvailableRef

PublishPort

Persistence

Concurrency

Distribution

ReplicationTriggers

Aggregate Inheritance Meta

BM_CLOSED_ED_COMPONENT

- Root Folder
 - ASCPolicyFolder
 - ComponentTypes
 - BM_CLOSED_ED_COMPONI
 - BM__ClosedComponent
 - BM__ClosedEDComponent
 - BM__Component
 - BM__DEVICE_COMPONENT
 - BM__DISPLAY_COMPONENT
 - BM__DeviceComponent
 - BM__DisplayComponent
 - Configurations
 - EventTypes
 - Interactions
 - Interfaces
 - BM__ClosedFunctionalFacet

Facet

Parameter

Persistence

Persistence

Receptacle

ReplicationTriggers

PublishPort

ReplicationTriggers

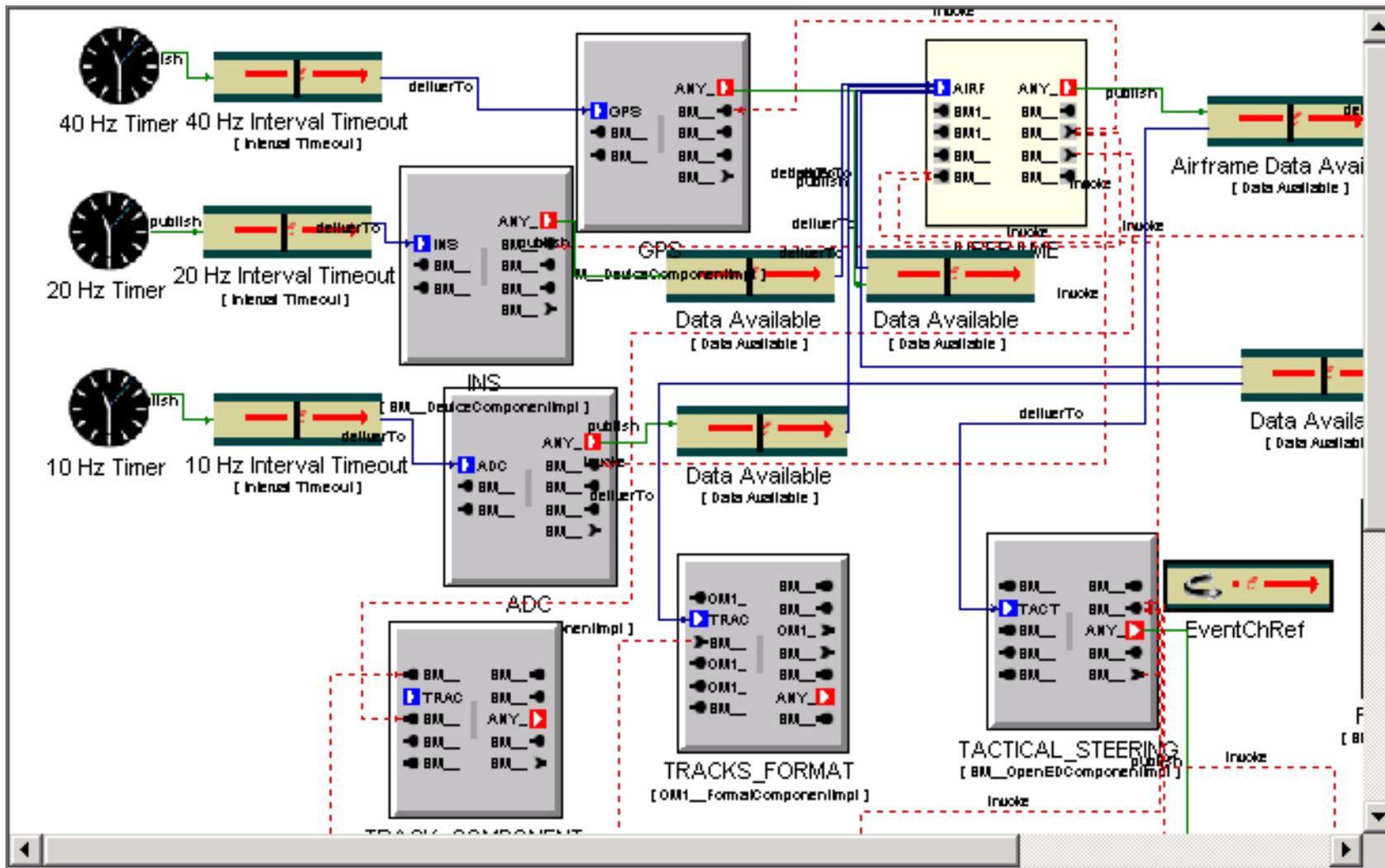
Persistence

Attributes Preferences Properties

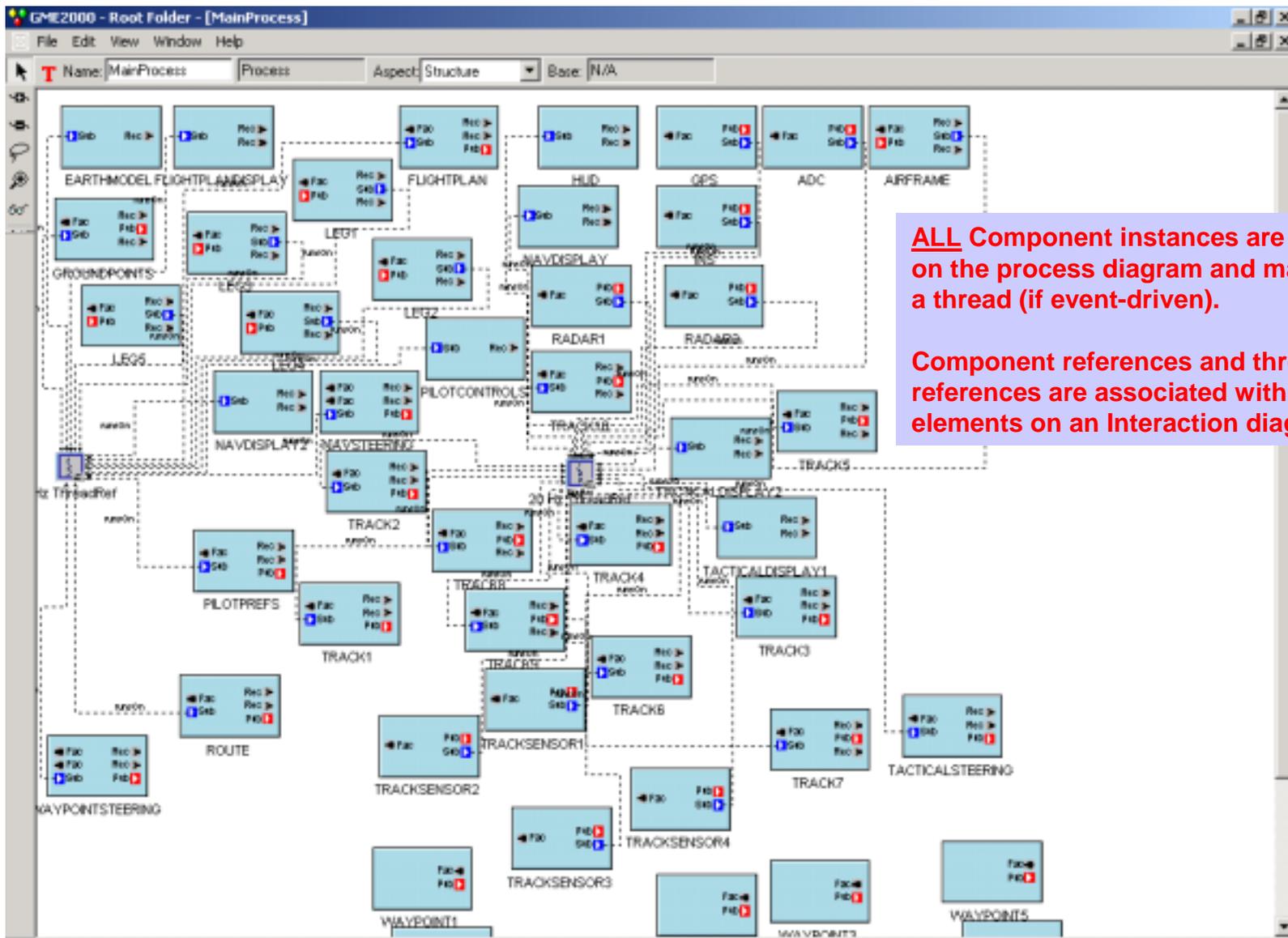
Enable?	True
Region ID:	0
Classified?	False
Track Dirtyness?	False
Double Buffering?	False
Filter Time:	0
Save Method:	USE_DEFAULT
Save Rate:	Auto Save 5Hz

Ready

EDIT 100% ESML 09:31 AM



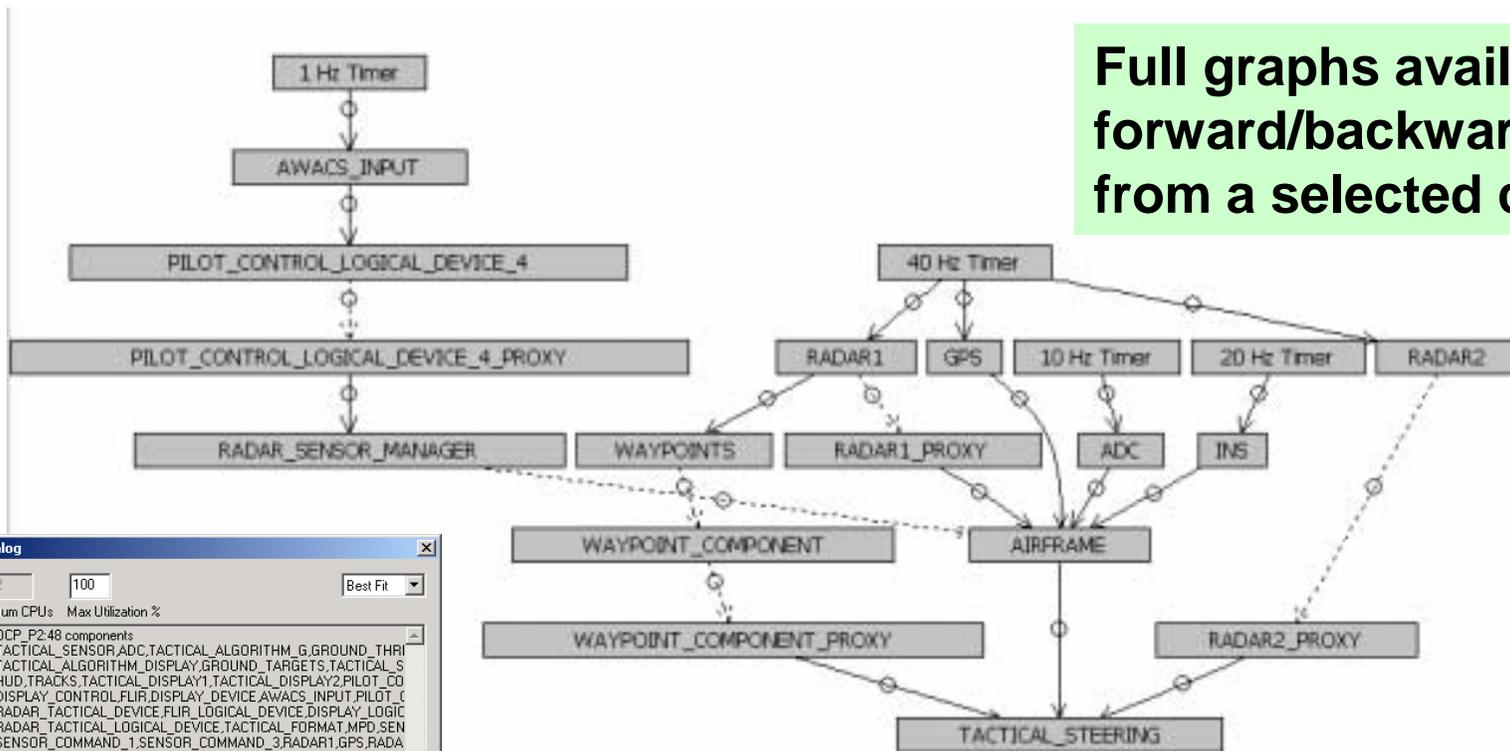
ESML Deployment View Component Allocation



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

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



type: Backward Slice from TACTICAL_STEERING

Dialog

2 | 100 | Best Fit

Num CPUs: Max Utilization %

OCP_P2:48 components
 TACTICAL_SENSOR.ADC.TACTICAL_ALGORITHM_G.GROUND_THRI
 TACTICAL_ALGORITHM_DISPLAY.GROUND_TARGETS.TACTICAL_S
 HUD.TRACKS.TACTICAL_DISPLAY1.TACTICAL_DISPLAY2.PILOT_CO
 DISPLAY_CONTROL.FLIR.DISPLAY_DEVICE.AWACS_INPUT.PILOT_C
 RADAR.TACTICAL_DEVICE.FLIR.LOGICAL_DEVICE.DISPLAY_LOGIC
 RADAR.TACTICAL_LOGICAL_DEVICE.TACTICAL_FORMAT.MPD.SEN
 SENSOR_COMMAND_1.SENSOR_COMMAND_3.RADAR1.GPS.RADA
 RADAR.LOGICAL_DEVICE.WAYPOINTS.ROUTE_FORMAT.GROUND.
 INS.TACTICAL_PHYSICAL_DEVICE_2.PILOT.BIT.TACTICAL_DEVICE_
 ROUTES.CURRENT_PATH.ROUTE_0.

OCP_P1:42 components
 ROUTE_1.TACTICAL_DEVICE_1.
 TACTICAL_ALGORITHM_A3.TACTICAL_ALGORITHM
 PILOT_PREFS.TACTICAL_SENSOR_LOGICAL_DEVIC
 WIND_MODEL.TACTICAL_MODE_2.AIRFRAME_PRO
 RADAR_SENSOR_COMMAND_PHASE_MANAGER.AS
 PILOT_PRIORITY_ALGORITHMS.TACTICAL_LOGICAL
 PRIORITY_PLAN.ASSIGNMENT_STEERING_PRIORIT
 TACTICAL_ALGORITHM_A3_PROXY.PILOT_CONTRC
 WAYPOINT_COMPONENT_PROXY.PILOT_PREFS.PI

Allocate Update AIF Close

boeing_provided_aif.xml - Avionics

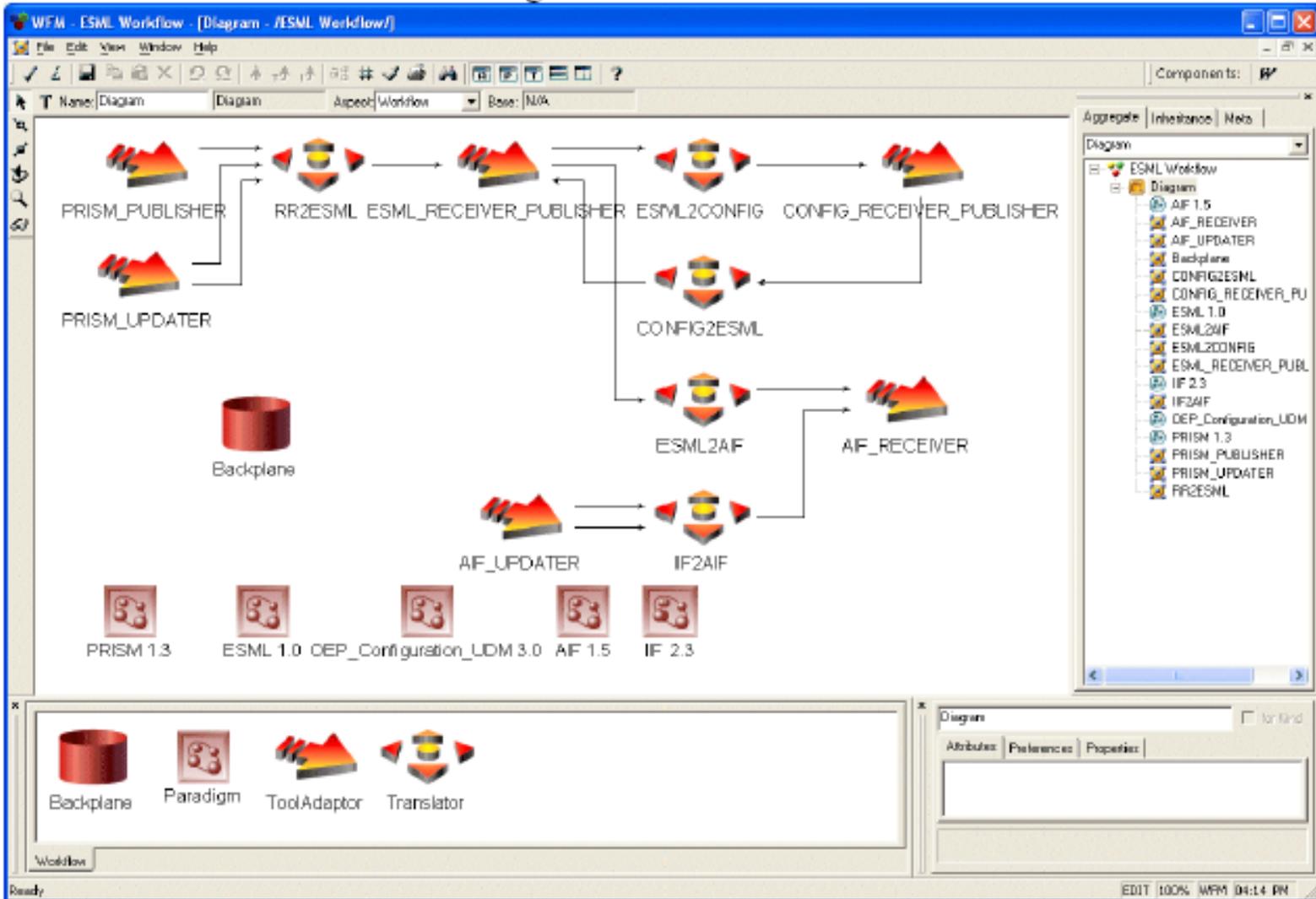
File View Actions Help

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

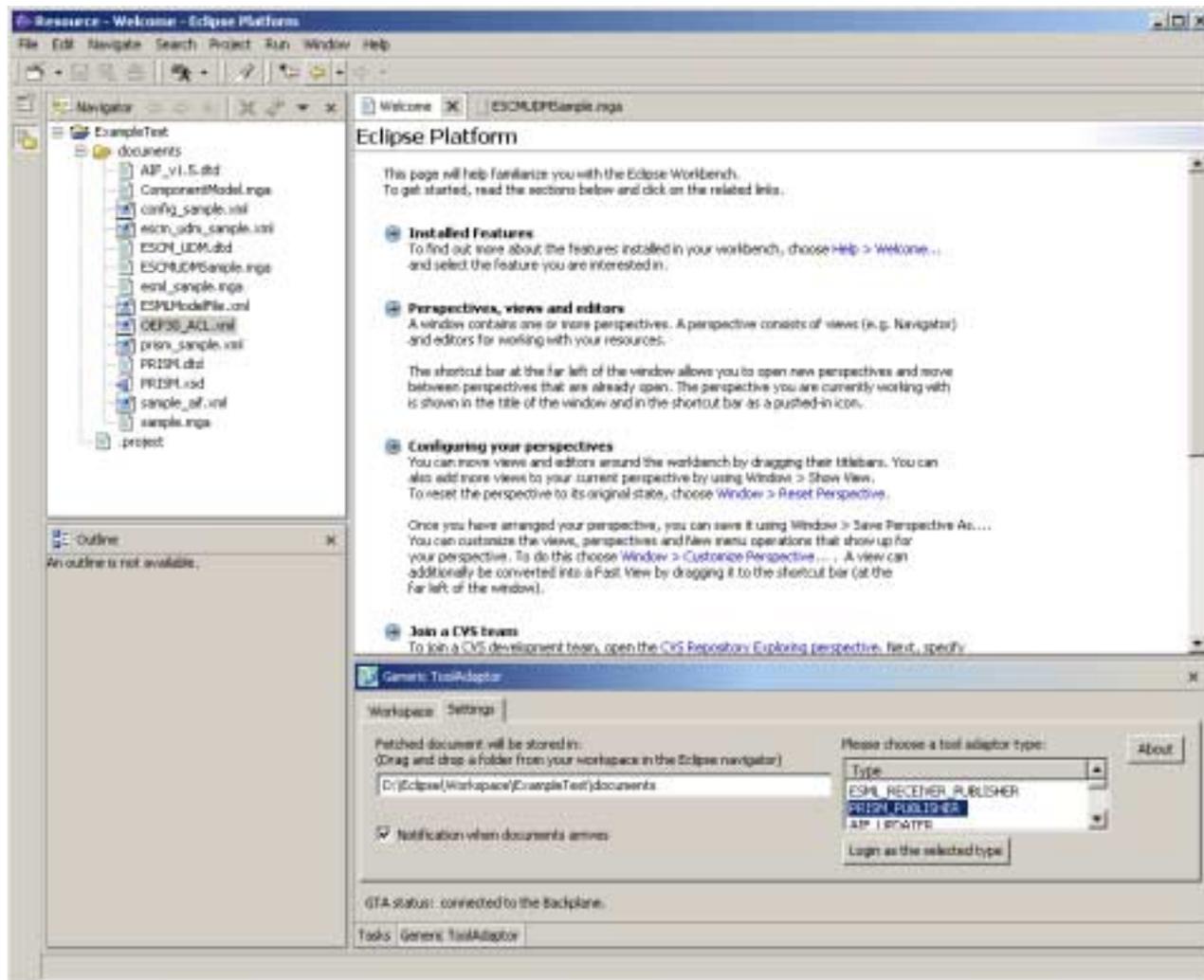
Ready



ESML workflow diagram in GME

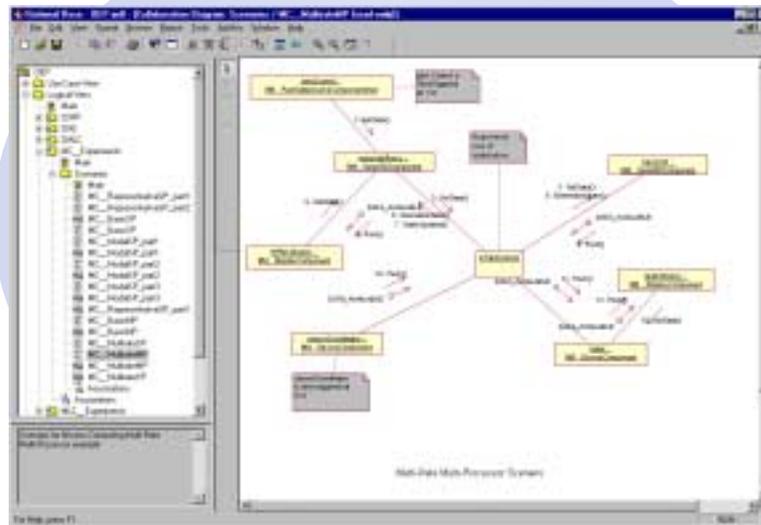
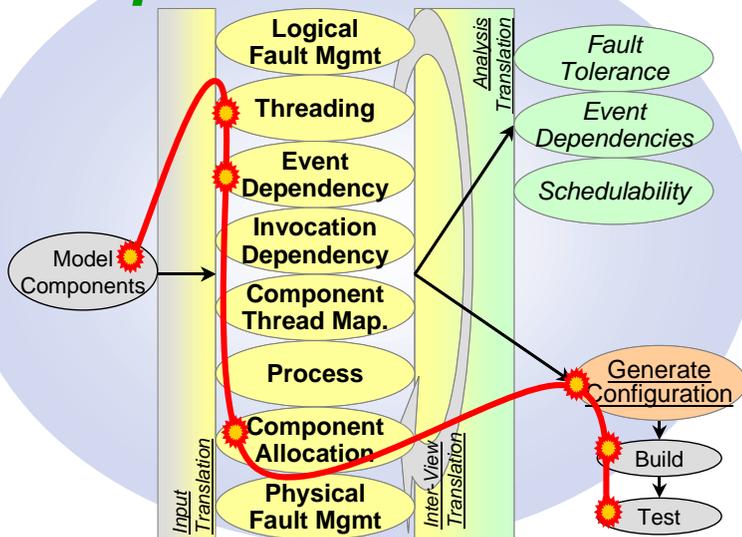
- Log in as the appropriate tool adaptor type (e.g. PRISM_PUBLISHER)
- Drag the document into the workspace area(e.g. OEP30_ACL.xml)

•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.



Development Scenarios and ...

Product Scenarios...

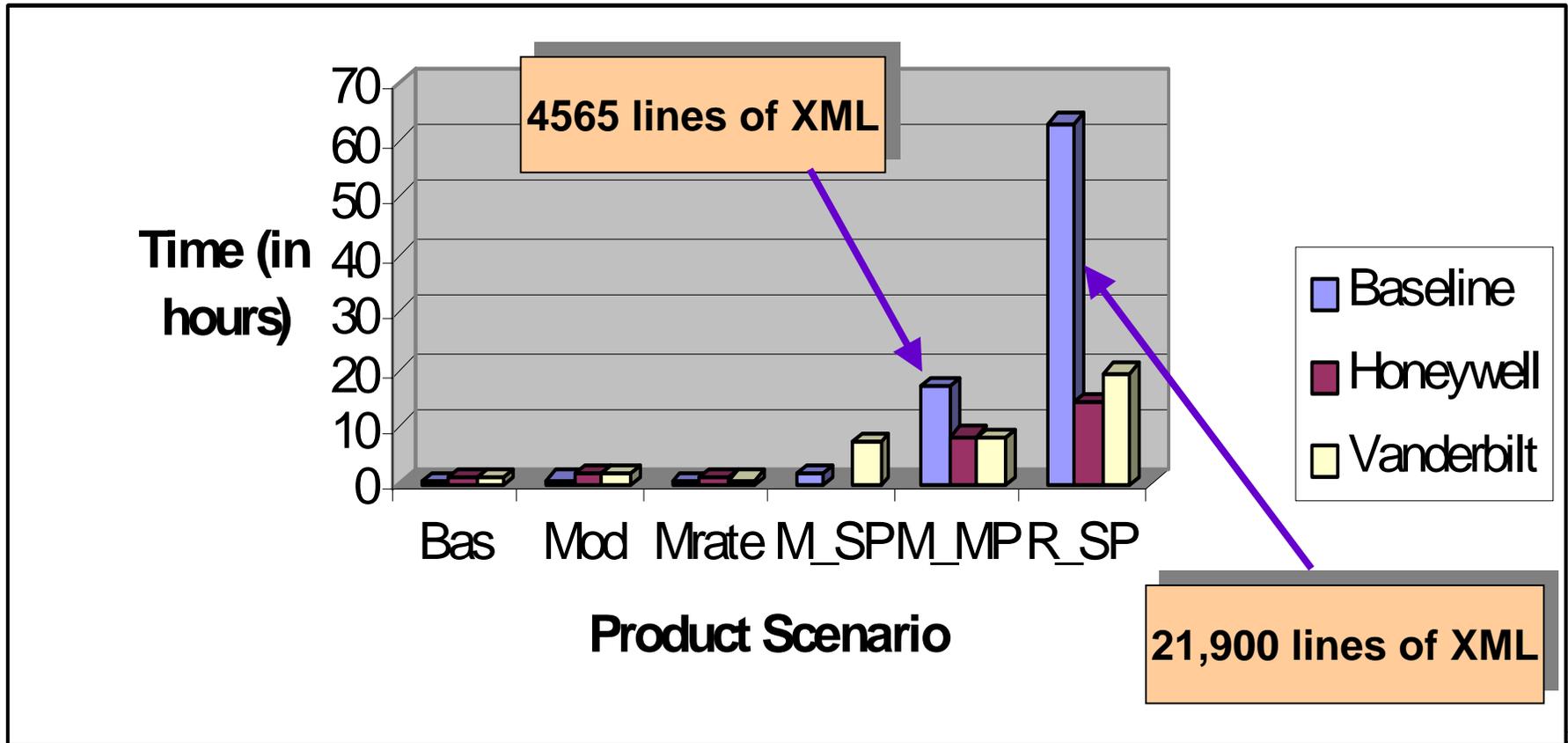


... Comprise Experiments

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

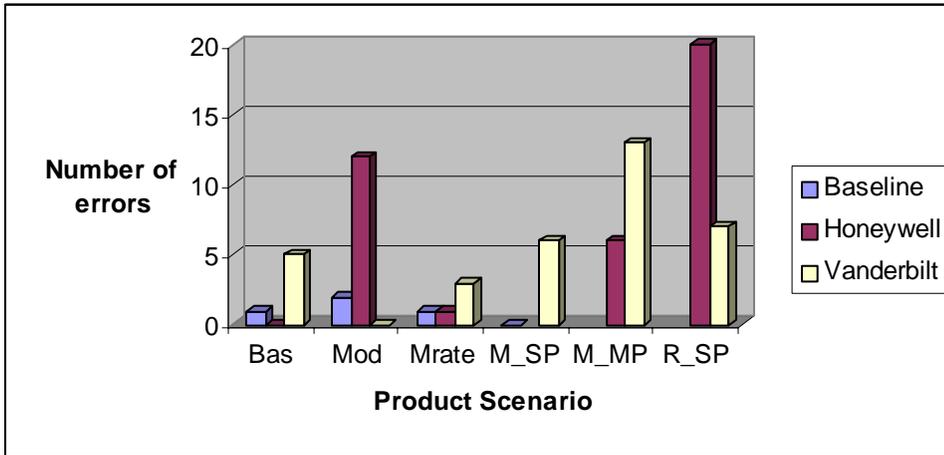
- **Validated feasibility of approach/process**
- **Integrated tool sets**
 - Bidirectional AIF and OEP Configuration Interface support
 - Incremental updates from design model changes
 - Open Tool Integrated Framework (OTIF) under investigation
 - Influence and refine interfaces via OMG MIC
- **Individual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

- 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)



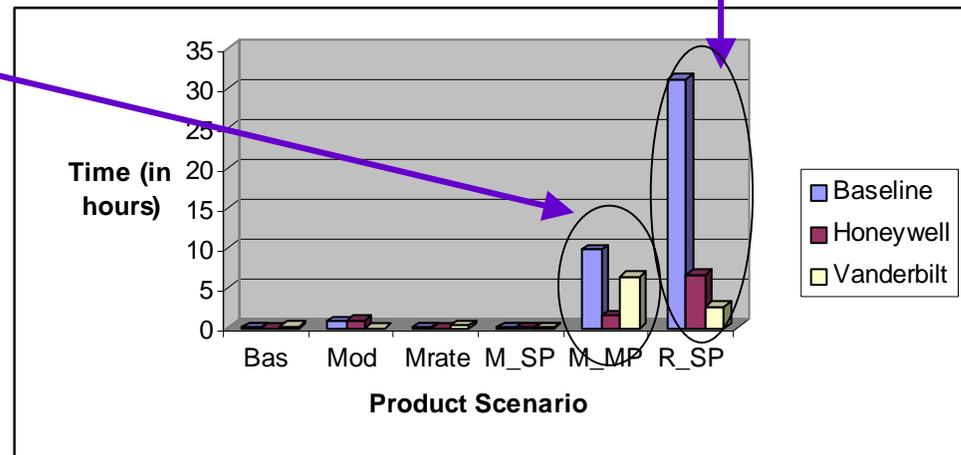
- Errors discovered (build and run)

- 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!

- **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

- **~\$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