Institute for Software Integrated Systems

Vanderbilt University

Applying Multiple Modeling Languages to Large Scale Real-Time Systems Development

Sandeep Neema, Ted Bapty

Shweta Shetty, Steve Nordstrom, Di Yao, Shikha Ahuja

Vanderbilt Univ.

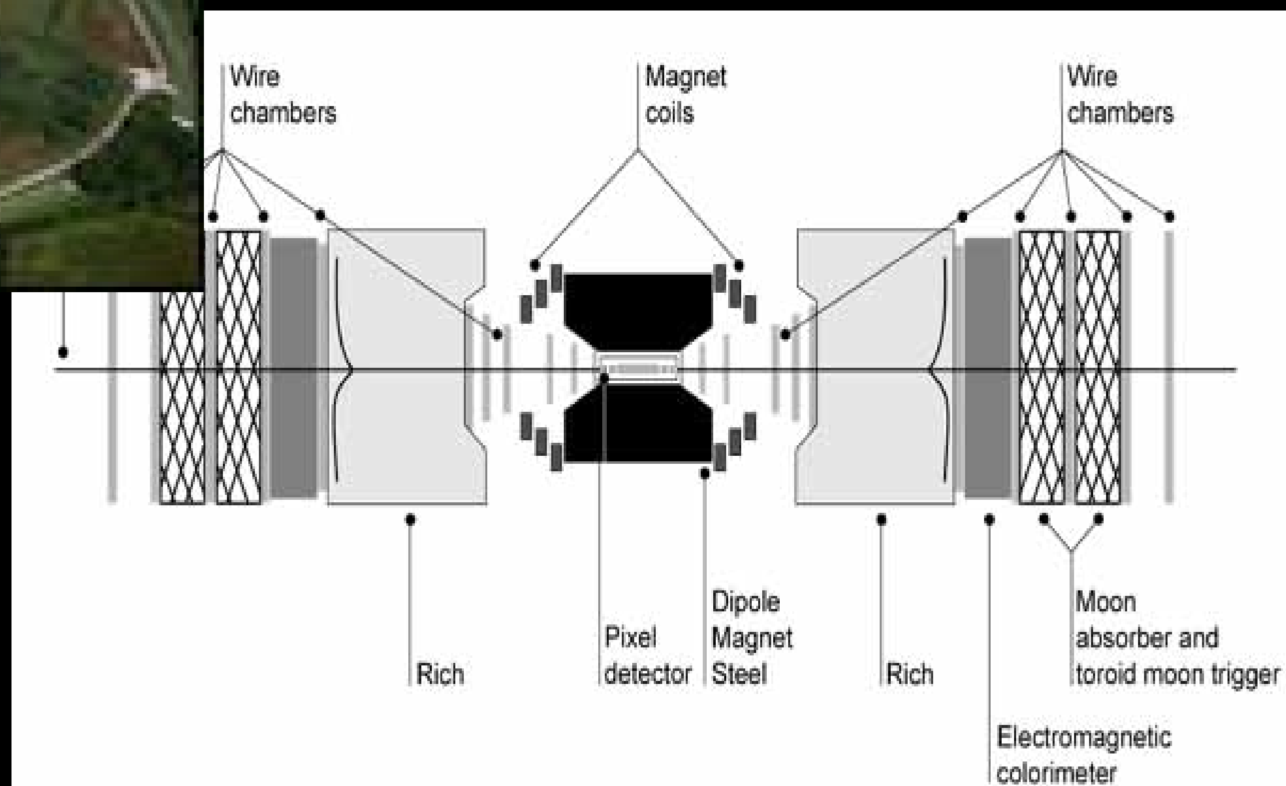
Outline

- Problem Domain
- Motivation/Challenges
- Proposed Solution
- Conclusions/Future Work

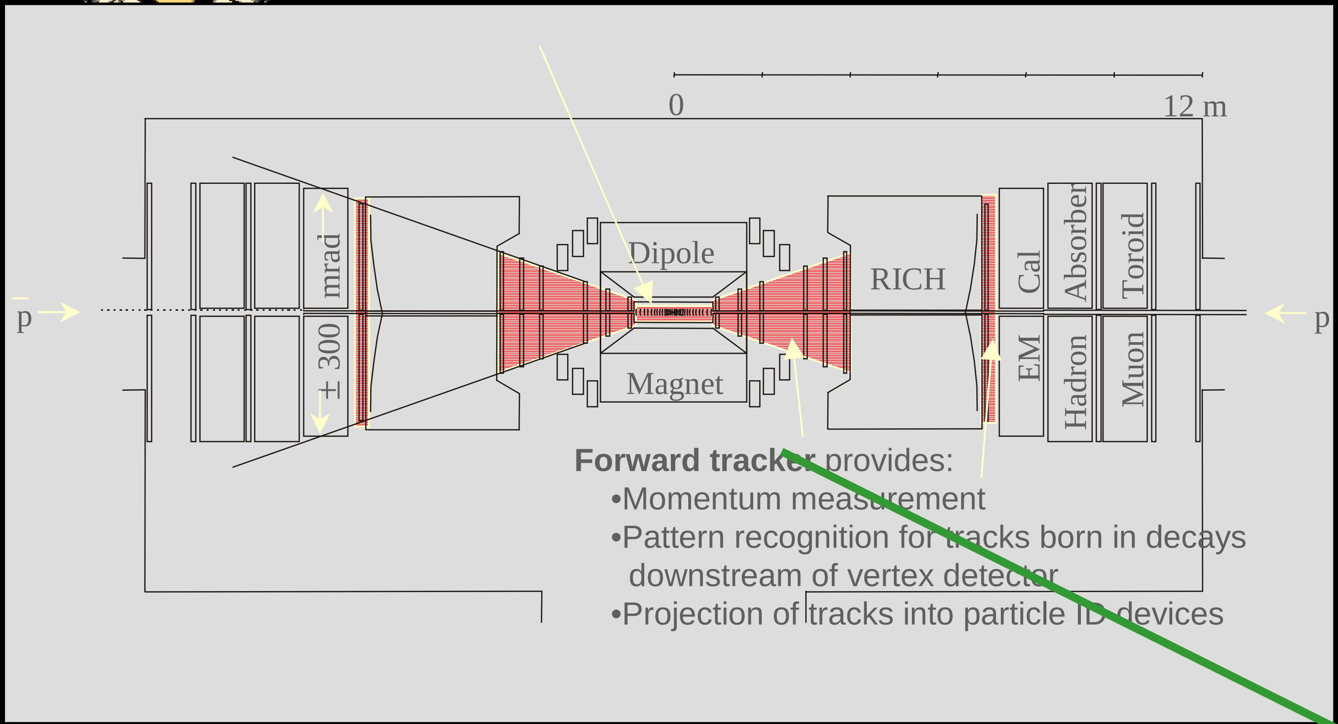
High Energy Physics


FermiLab Accelerator

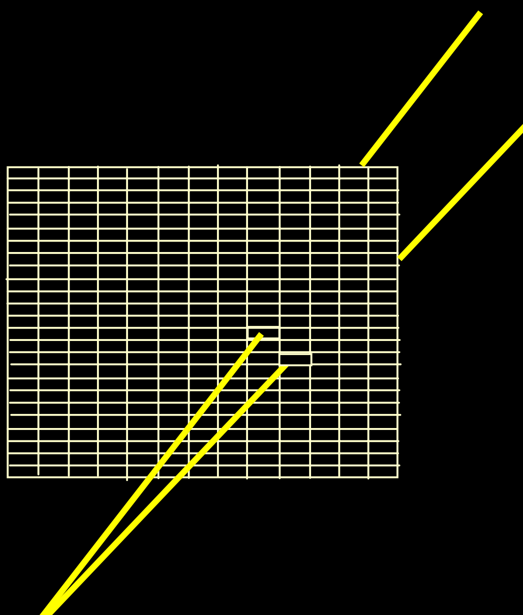
BTeV Experiment



The Trigger



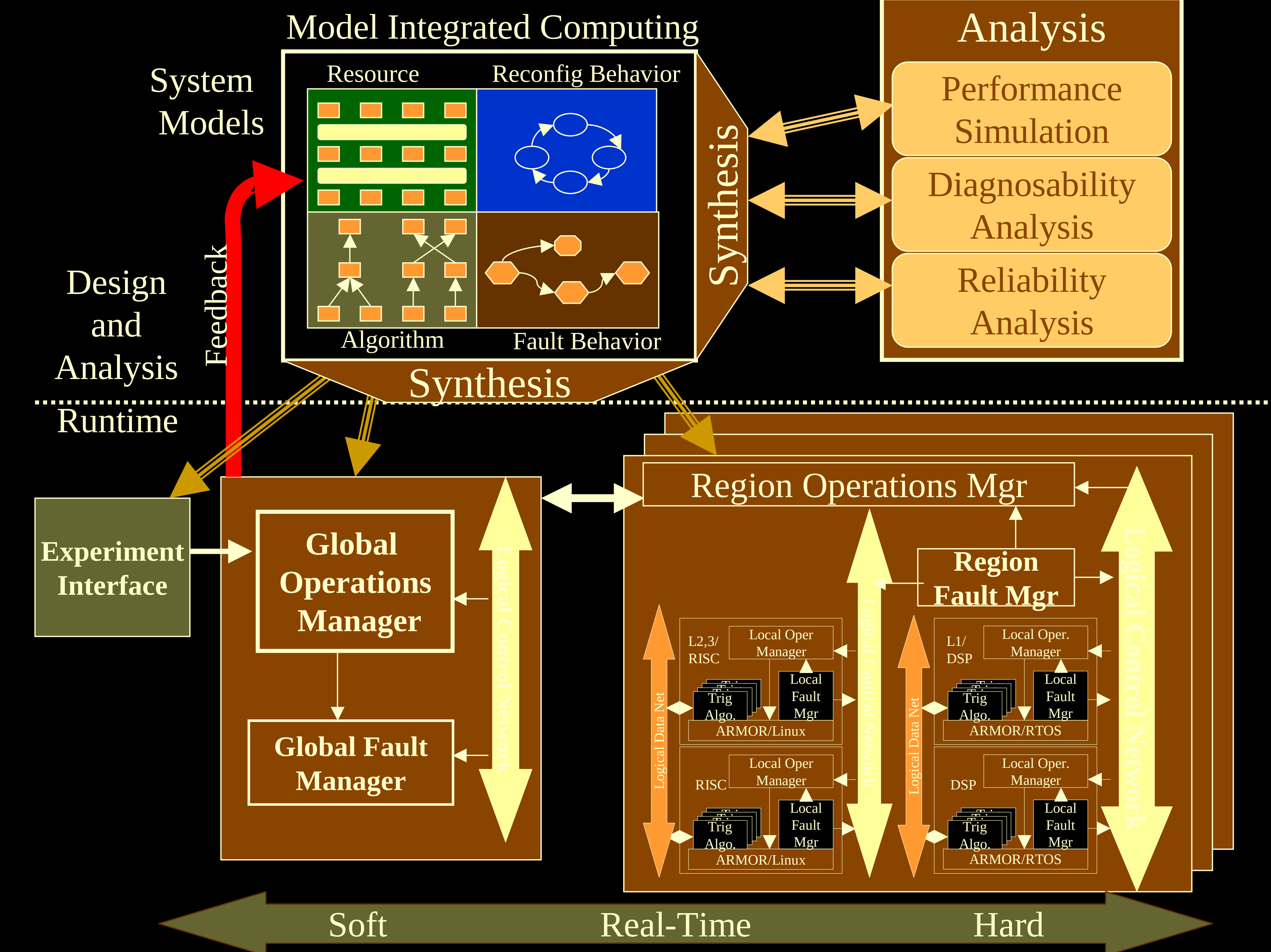
Detector Grids



Problem:
-Determine the set of particle trajectories
-Decide if it is interesting, keep or toss
-Massive amounts of data (Terabytes/Sec)
-Hardware => 2500 DSP's + 2500 PC's
-Never Fail (ok to degrade)

BTeV RTES Collaboration NSF/ITR

- Fermilab
  - Building BTeV Trigger Hardware
  - Domain Experts, Define Goals, Constraints, etc.
- Vanderbilt
  - RTES Lead (Physics)
  - Design Environment, System Synthesis, System Integration, Prototype Hardware
- UIUC
  - ARMOR, Fault Tolerant Middleware
  - Domain Expertise
- Syracuse & Pitt
  - Very Lightweight Agents, Diagnostics


Model Integrated Computing
System Models
Resource
Reconfig Behavior
Algorithm
Fault Behavior
Synthesis
Synthesis
Analysis
Performance Simulation
Diagnosability Analysis
Reliability Analysis
Design and Analysis
Feedback
Runtime
Experiment Interface
Global Operations Manager
Global Fault Manager
Logical Control Network
Region Operations Mgr
Region Fault Mgr
Logical Control Network
Logical Control Network
Logical Data Net
Logical Data Net
L2,3/ RISC
Local Oper Manager
Local Fault Mgr
Trig Algo.
ARMOR/Linux
RISC
Local Oper Manager
Local Fault Mgr
Trig Algo.
ARMOR/Linux
L1/ DSP
Local Oper. Manager
Local Fault Mgr
Trig Algo.
ARMOR/RTOS
DSP
Local Oper. Manager
Local Fault Mgr
Trig Algo.
ARMOR/RTOS
Soft
Real-Time
Hard

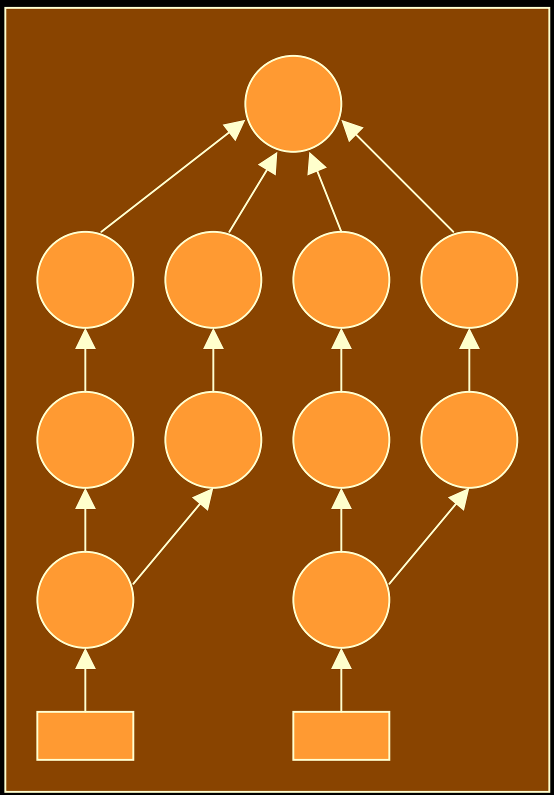
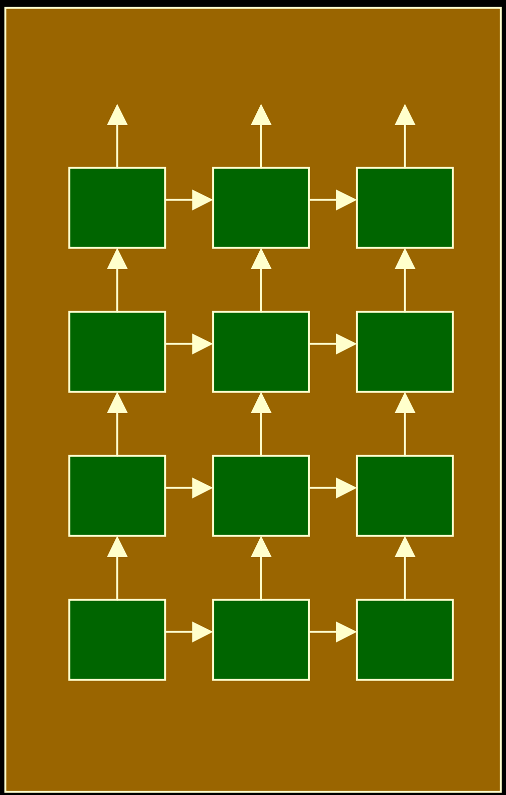
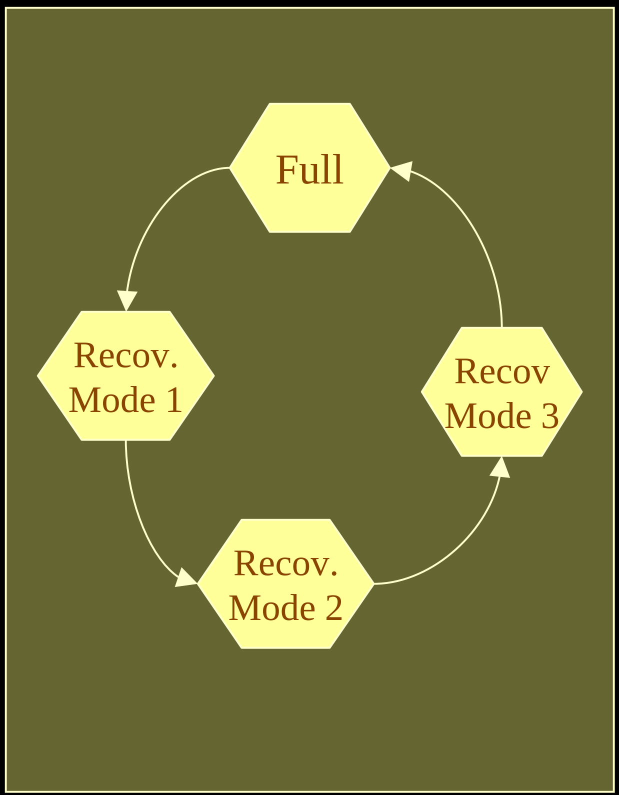
Design Issues

- Complex System
  - Thousands of Processors
  - High Data Rates
  - Real-Time Constraints
- User-Defined Behaviors
  - Domain-Specific Design Tool
  - System-Specific Implementation
- Run-Time Implementation
  - Heterogeneous Architecture
  - Real-Time - Execution & Mitigation
  - Fault-Tolerant

A First Cut MIC-based Solution

- Design a domain-specific modeling language
  - Provision concepts for all the different aspects of the system
  - Express their interactions
  - A “super” system-wide modeling language
- Implement a suite of translators
  - Generate fault-mitigation behaviors
  - Generate system build configurations
  - Link with user code/libraries

A First Cut Solution

Processing & Data Flow	Hardware Resources	Hierarchical Fault Management
		
Concepts: Processes, streams, data channels, Functions, data types, communication	Concepts: Processors, Memory, Topology, Reliability, Failure Modes,…	Concepts: Recovery Strategies, Modes of Operation, goals/importance

Problems/Challenges

- A single model file for the entire system
- Can not support multiple developers for different aspects
- A minor change in a small portion of the entire model
  - A completely new version
  - Need to regenerate the whole system
  - No partial validation due to the tight coupling
  - Extended build times due to unnecessary compiles
- Lack of modularity in design artifacts
- Where do the models fit in the versioning system?
  - What are the dependencies?
  - Should the generated code be archived in the build system?
  - Should the code-generators be part of the versioning system?

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Learn from Textual Programming Techniques

- Modularization with multiple files for storing multiple artifacts
- “import” or “include” for referencing/external linkages
- Back-end tools “pre-processors”, “linkers” for merging, validating linkages

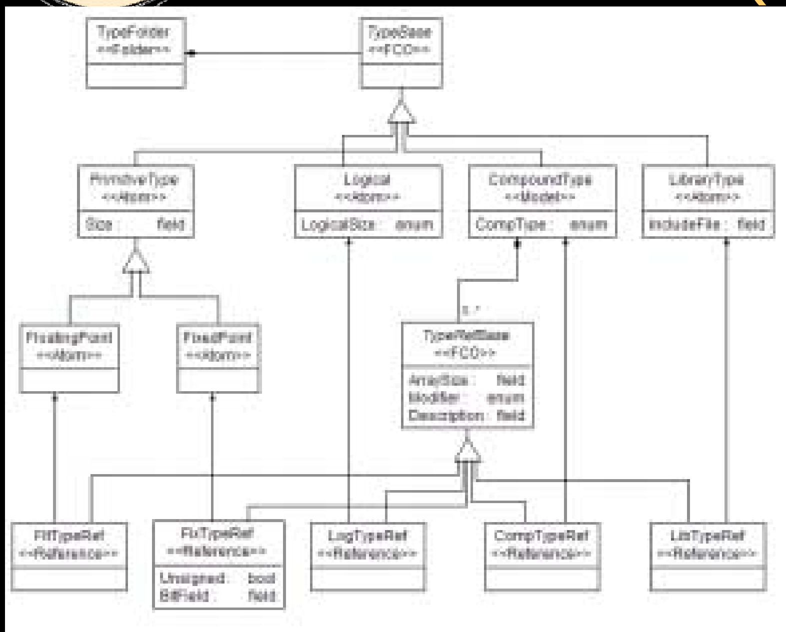
“Include” applied to MIC

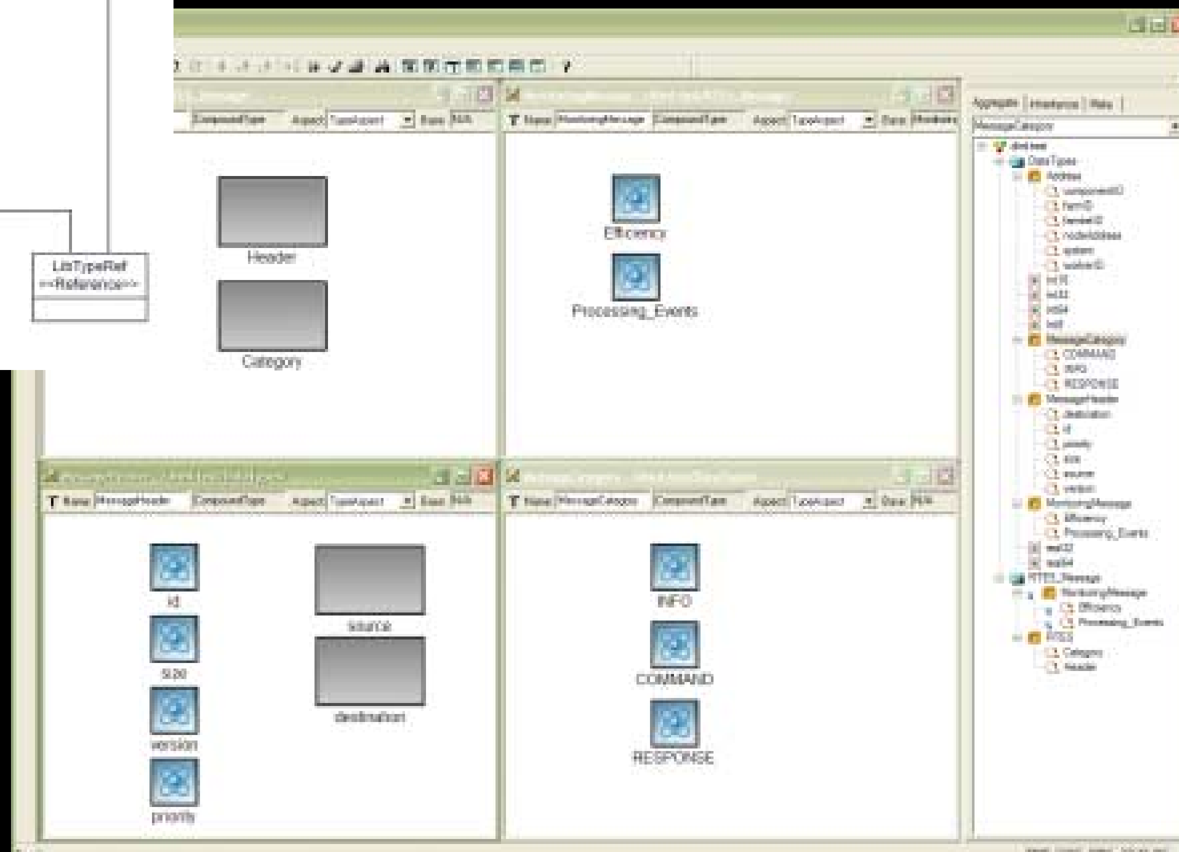
- Multiple “narrowly focused” domain-specific modeling languages
  - System Integration Modeling Language (SIML)
  - Data-Types Modeling Language (DTML)
  - GUI Config Modeling Language (GML)
  - Run Control Modeling Language (RCML)
  - Fault Mitigation Modeling Language (FMML)
- Allow expression of cross-linkages between models in different modeling languages
  - Overlapping concepts derived from a “Link” type
  - Attributes of “Link” type capture linkage specification i.e. type of linked object, location of linked object

“Include” applied to MIC (2)

- Plug-ins developed to facilitate link creation as well as link navigation
- Model interpreters, transformers evolved to navigate the links during synthesis

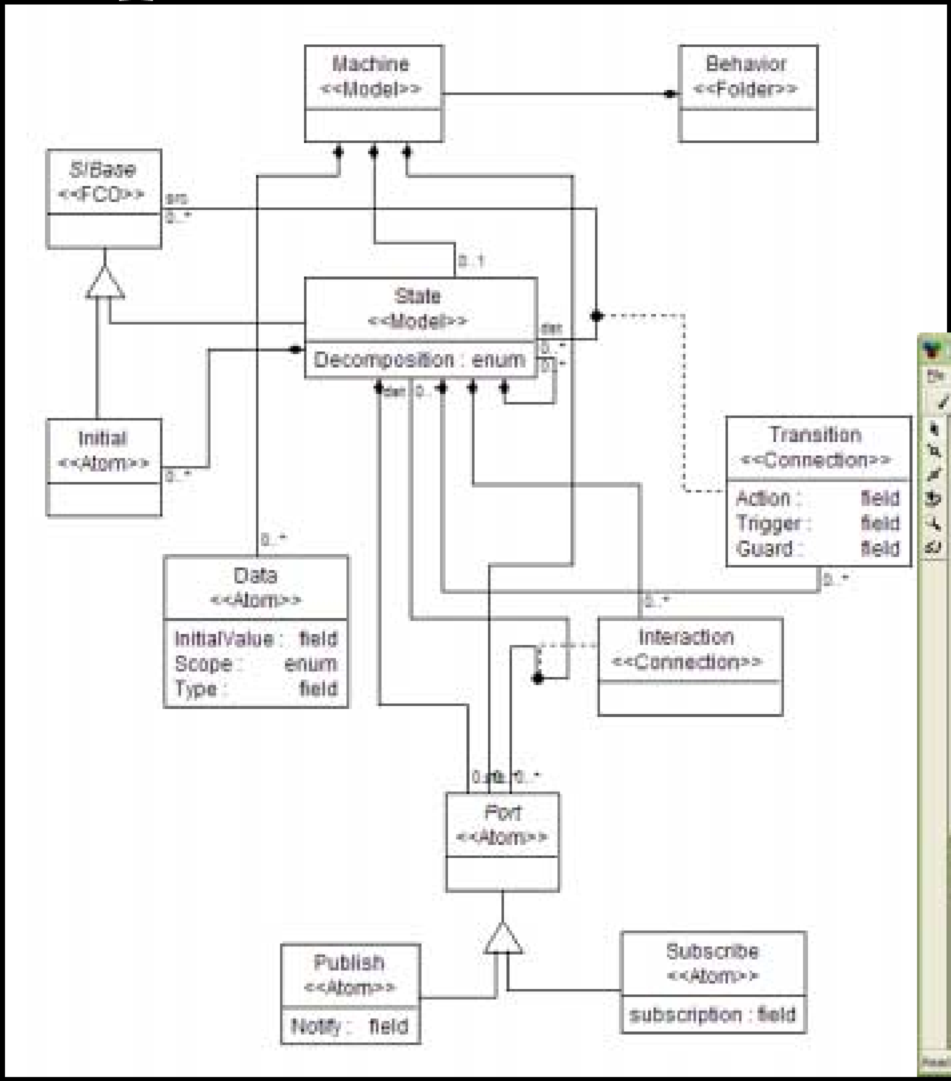
Data-Type Modeling Language (DTML)



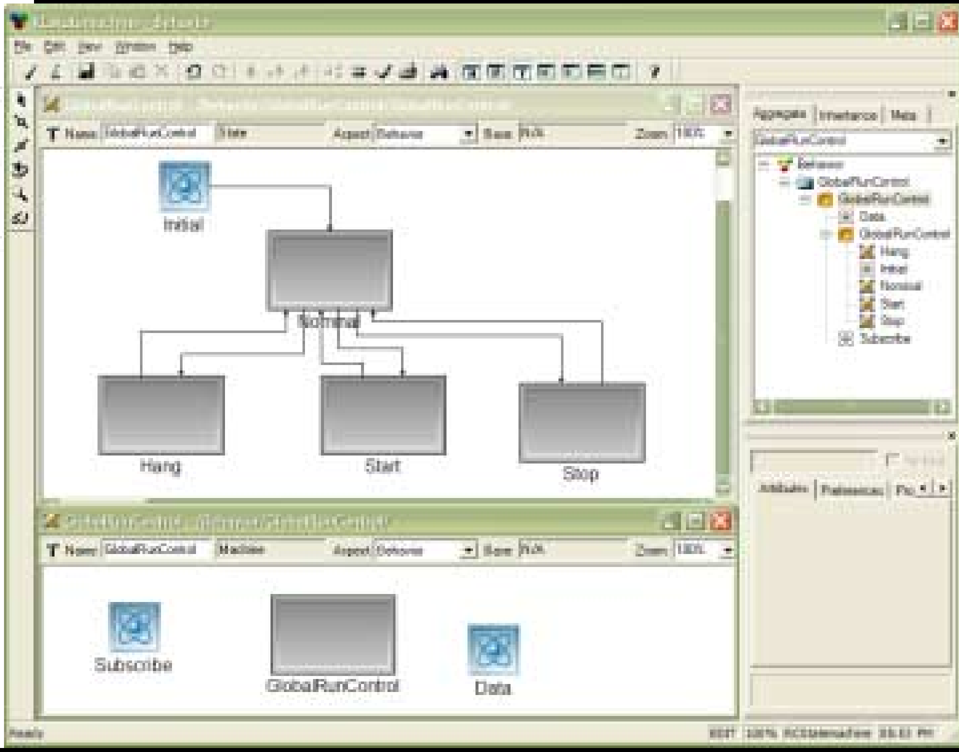


- Modeling of Data Types and Structures
- GME supported sub-typing to model type hierarchies
- Configure marshalling-demarshalling interfaces for communication

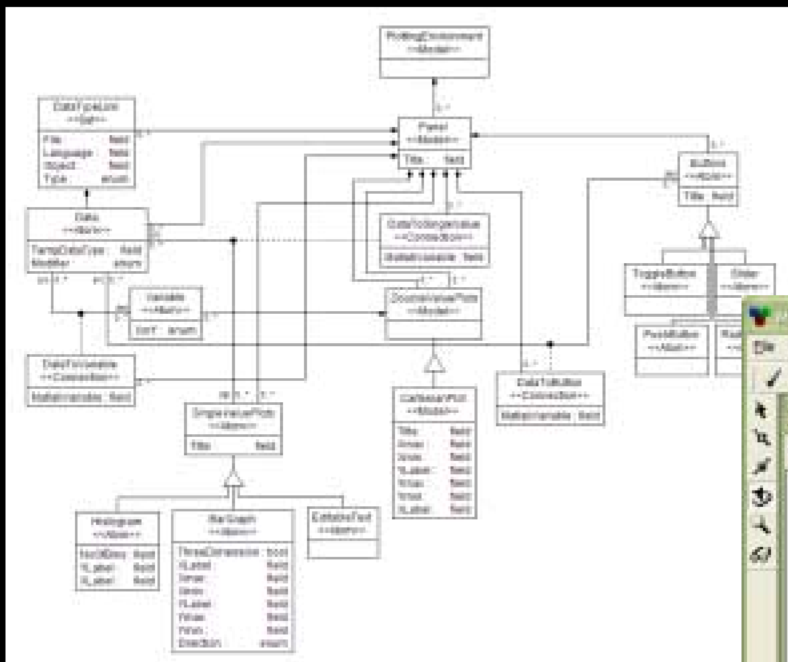
Run Control Modeling Language (RCML)

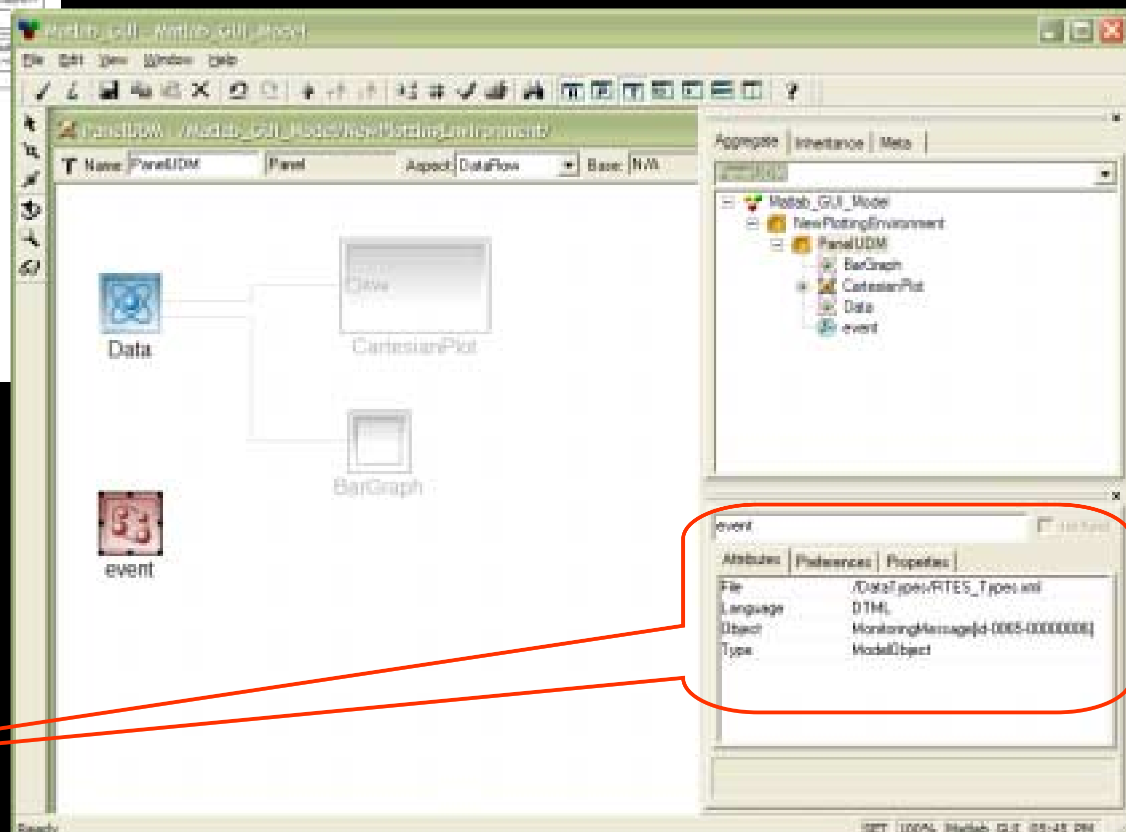


- Modeling of Experiment Run Control
- System startup, shutdown, and run states,
- Transition thru System States and associated Actions



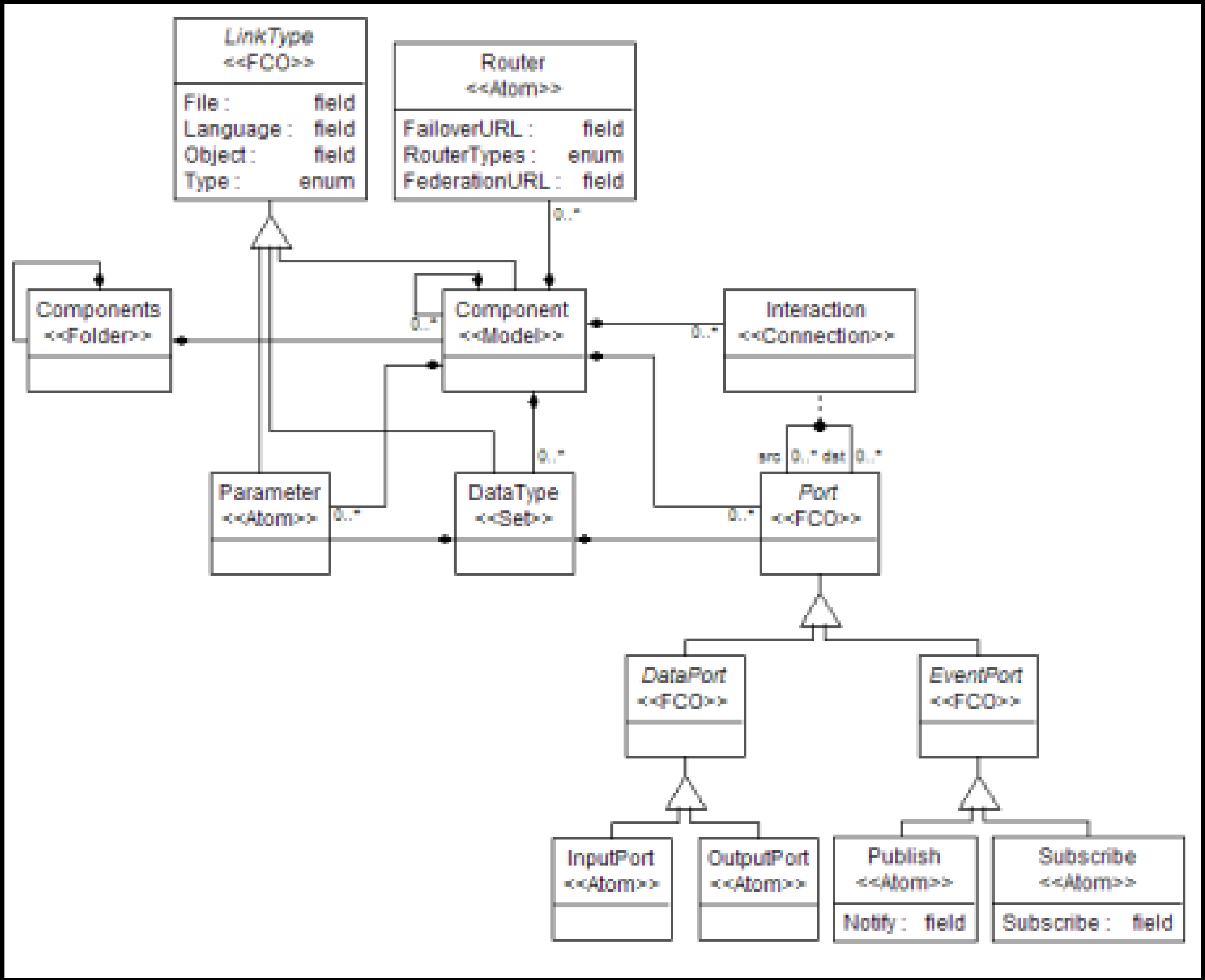
GUI Config Modeling Language (GML)





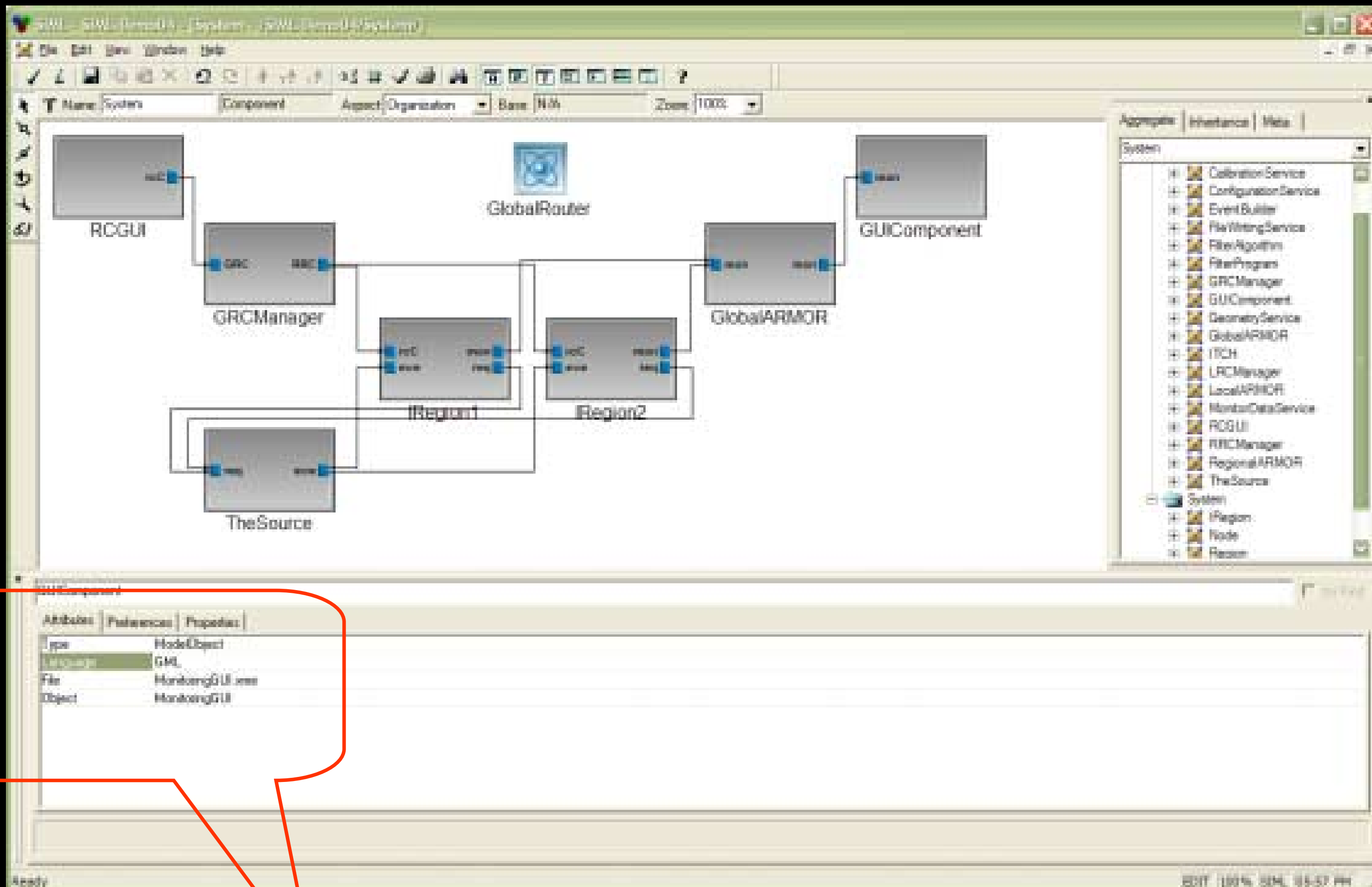
DataType Link

System Integration Modeling Language (SIML)



- Model Component Hierarchy and Interactions
- Loosely specified model of computation
- Model information relevant for system configuration

SIML Model



GUI Component Link

Versioning/Build System

- An equivalent XML representation of GME models is stored in the CVS tree
  - UdmCopy provides forward and backward translation from MGA to XML
- Model transformers developed with UDM
  - Can be built for Windows and Linux platforms
  - Transformer code is also stored in CVS
- Build system is hosted in Linux
  - Multi-stage build
  1. Compiles model transformers
  2. Makefiles invoke model transformers upon the stored models and generates code artifacts (behavior/config code)
  3. Generated codes are compiled, and linked to produce the binaries

Other solutions

- Model Library
  - Matlab Simulink
    - Model containers must specifically be constructed as libraries
  - GME
    - Libraries are inserted completely in the model
    - Updates are user demanded
- Multi-User Capability
  - GME
    - Domain-independent
    - Database backend
    - Stores models in separate files

Conclusions/Future Work

- Addressed scalability and versioning problems with MIC
- A prototype system in place experimenting with the developed concepts
- Good experience with respect to multi-user editing/maintenance of models
- Scalability concepts need to be generalized and formally structured to be applicable for a wider audience
- Consistency is weakly enforced