Concern Separation in Model-Integrated Computing

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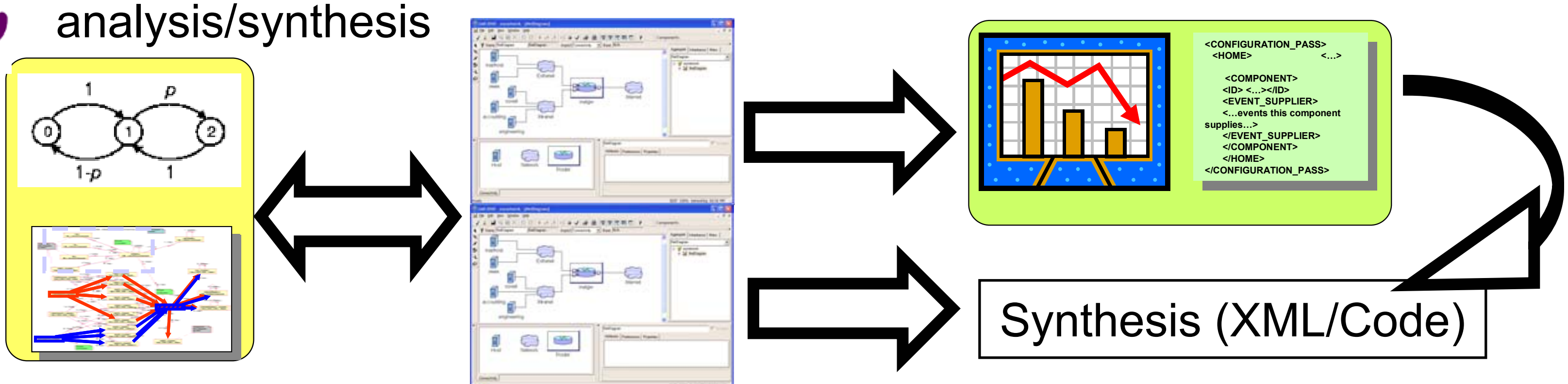
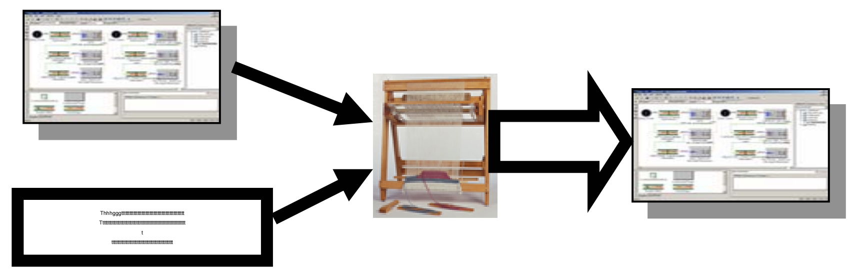
Focus Areas of this Presentation

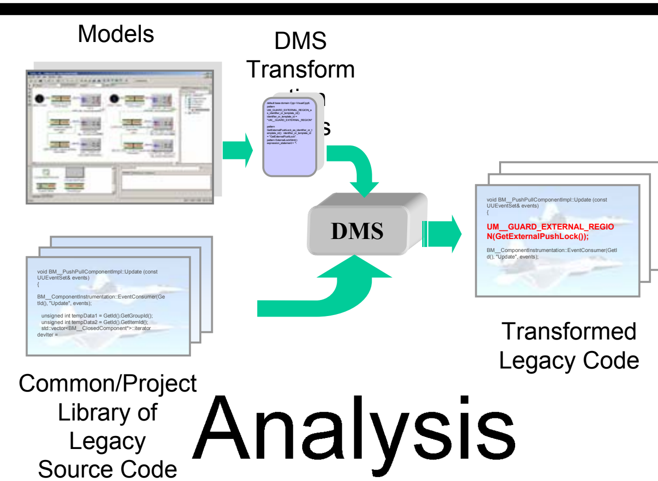
CoSMIC -- a suite of domain-specific modeling languages and tools for DRE analysis/synthesis



C-SAW – a model transformation tool for separating crosscutting properties in domain-specific models



- **Goal: Maintain the fidelity between the evolving model properties and the legacy source code**
- **Challenges: Parsing and invasively transforming legacy source code from higher-level models**
- **Solution: Model-Driven Program Transformation**
  - Based on the unification of a mature program transformation system with a meta-modeling environment

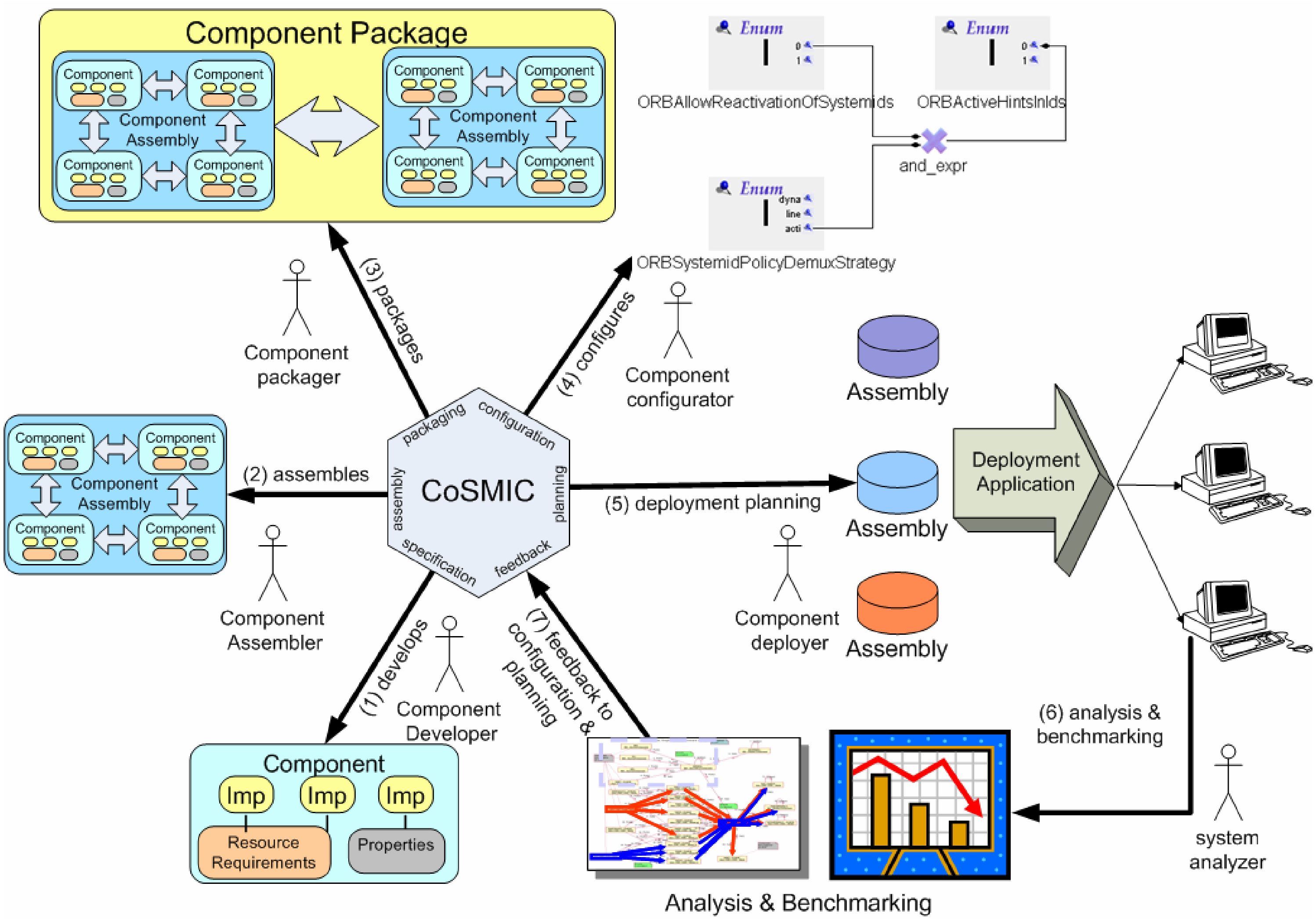


Analysis

CoSMIC:
Modeling Deployment & Configuration Crosscutting Concerns

Model-Driven Middleware for DRE Systems

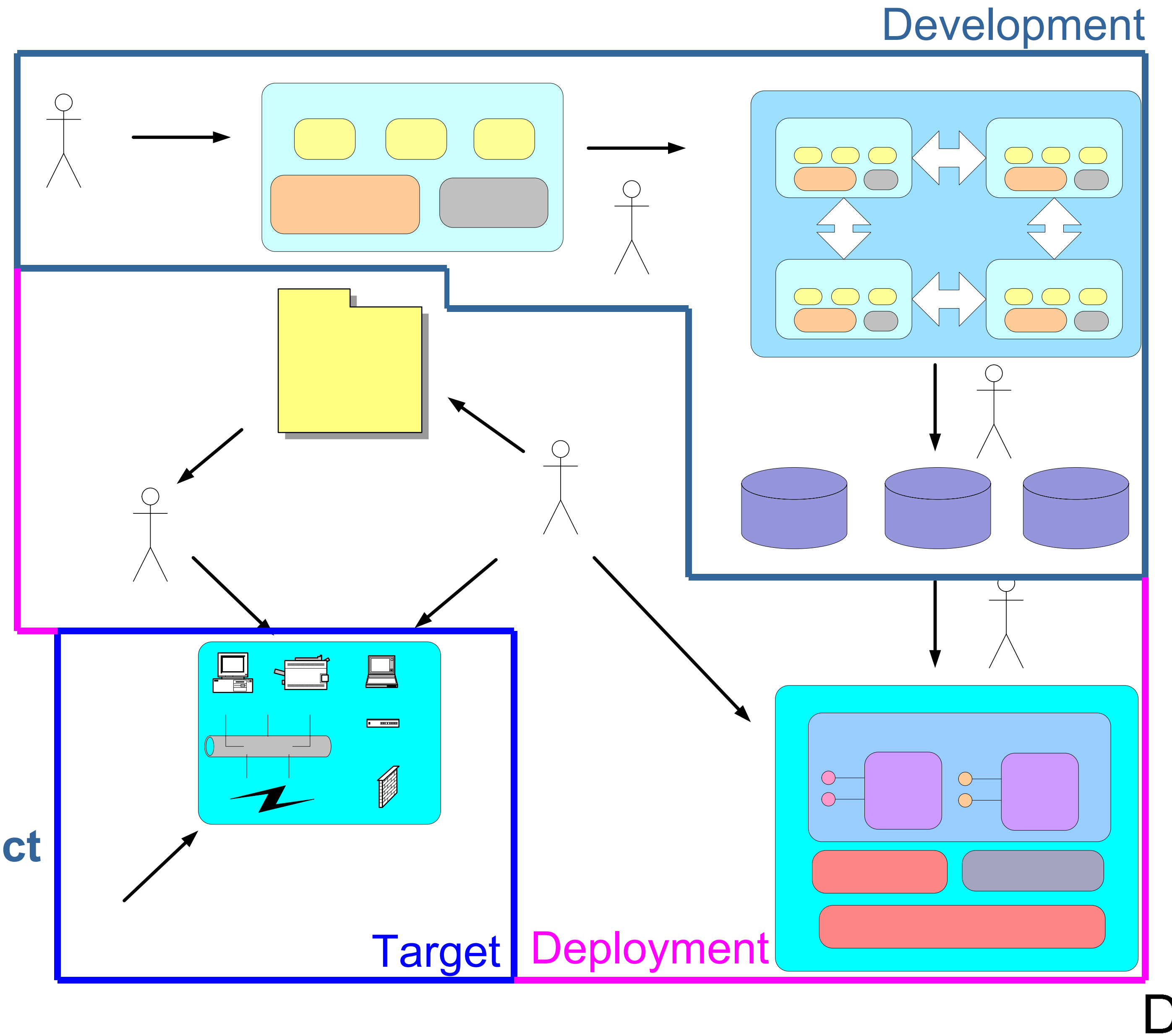
CoSMIC Model Driven Middleware Suite



- **Addresses DRE systems configuration and deployment crosscutting concerns**
- **Employs MIC technology**
- **www.dre.vanderbilt.edu/cosmic**

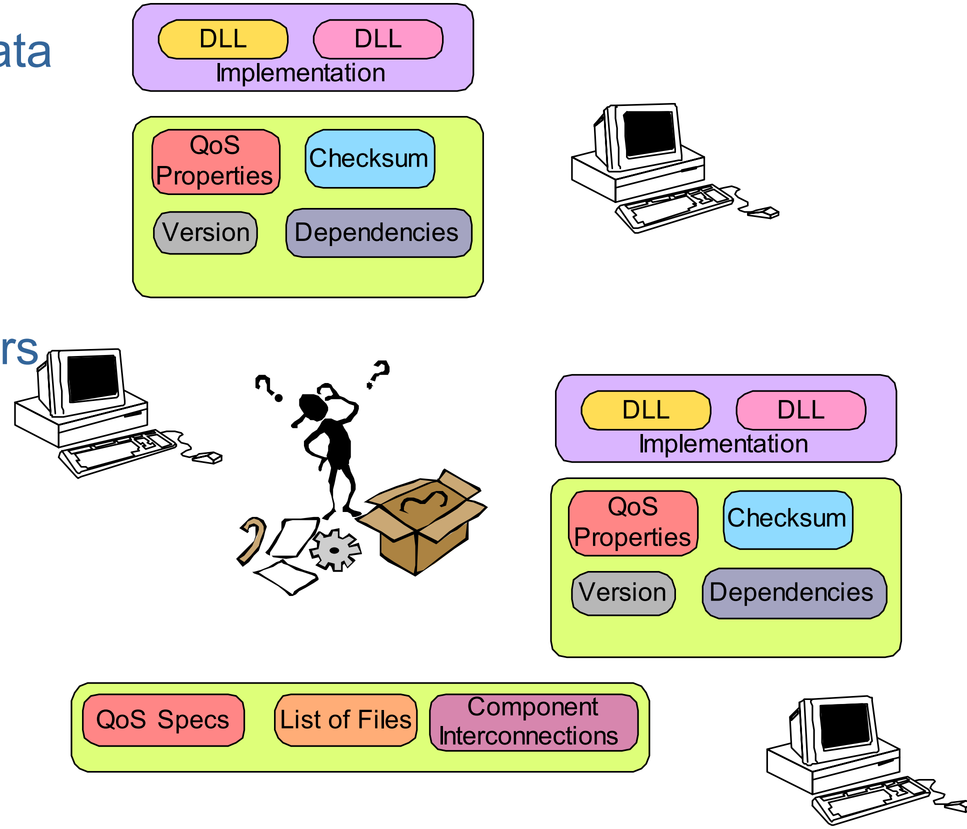
Addressing D&C Crosscutting Concerns with DAnCE

- **Different Stages**
  - *Development*
    - Developer
    - Assembler
    - Packager
  - *Target*
    - Domain Administrator
  - *Deployment*
    - Repository Administrator
    - Planner
    - Executor
- **Actors are abstract**
  - Usually human + software tool



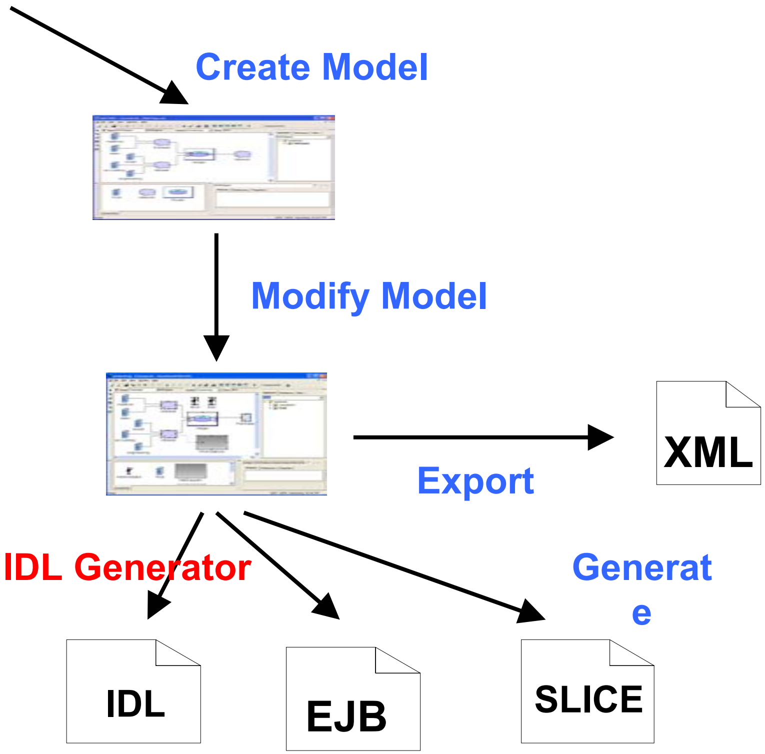
PICML: Capturing & Modeling D&C Crosscutting Concerns

- **Context**
  - Configuring & Deploying component-based applications using XML meta-data
- **Problem**
  - Meta-data split across multiple XML descriptors
  - Inter-dependencies between descriptors
  - XML is error-prone to read/write manually
  - No guarantees about semantic validity (only syntactic validation possible)
  - If meta-data is wrong, what about my application?

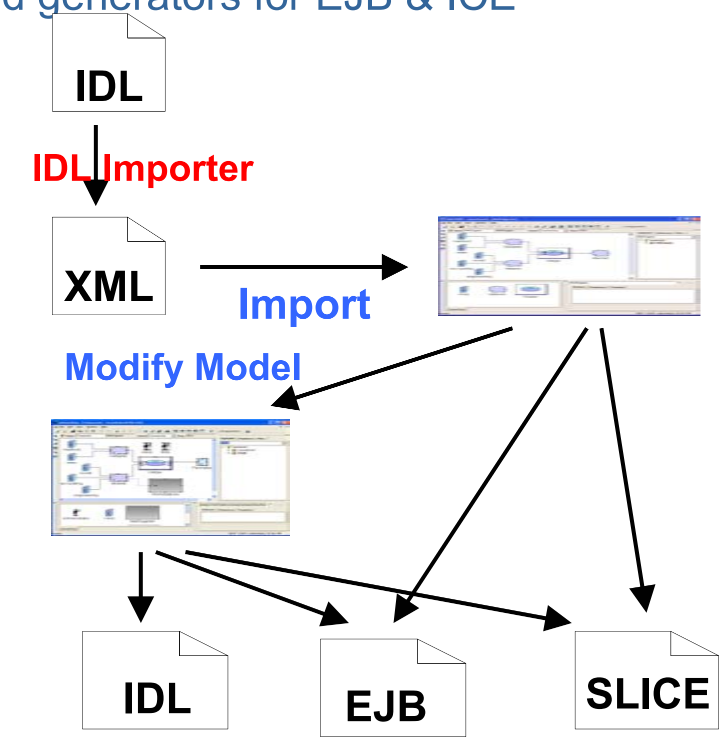


- **Solution**
  - PICML = Platform Independent Component Modeling Language
    - Modeling paradigm developed using Generic Modeling Environment (GME)
  - Capture dependencies visually
  - Define semantic constraints using Object Constraint Language (OCL)
  - Generate domain specific meta-data from models
  - Correct-by-construction

IDML: Capturing Interface Definition Aspects in PICML



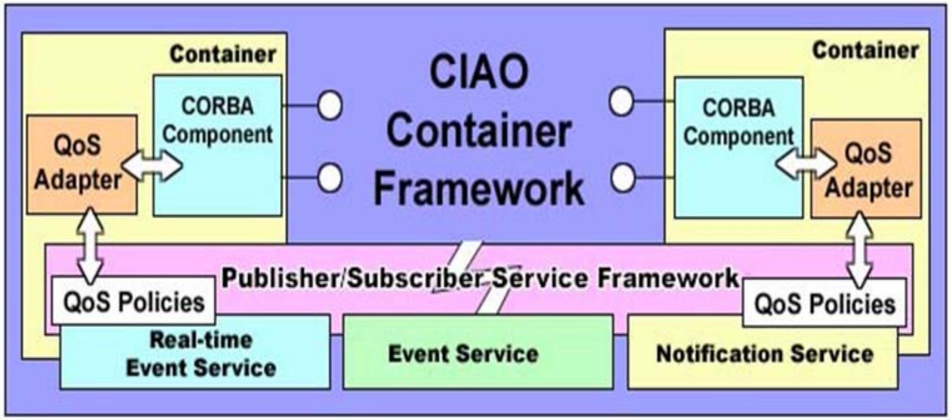
- IDML = Interface Definition Modeling Language
- Graphical modeling language.
- Component middleware building blocks.
- Integrated with PICML.
- Export model to equivalent XML format.
- Generate middleware-specific application code.
  - IDL generator finished
  - Planned generators for EJB & ICE



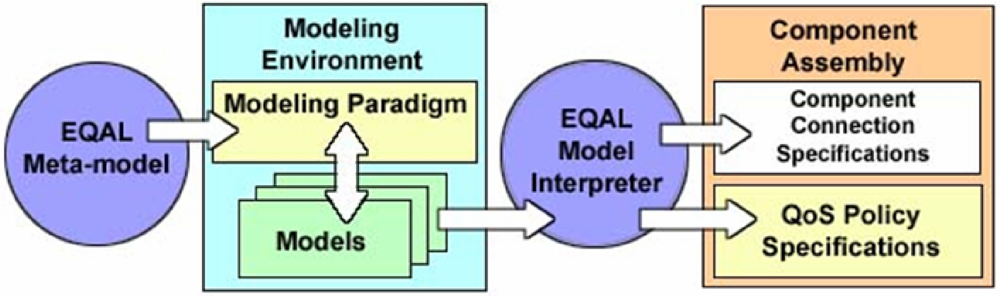
- IDL Importer translates IDL into IDML's XML format.
- Import XML into graphical modeling tool.
  - Translate to other middleware platform.
- Develop model further
  - Regenerate IDL.
  - Generate application code for a different middleware platform.

EQAL: Capturing Event QoS Aspects in PICML

- **Context**
  - Publisher/subscriber services are highly configurable
  - XML-based specification of QoS properties



- **Problems**
  - Multiple dissimilar services
  - Semantically invalid operating policies
  - Error-prone handwritten XML
- **Solution**
  - Use models to enforce policy constraints & synthesize configuration files

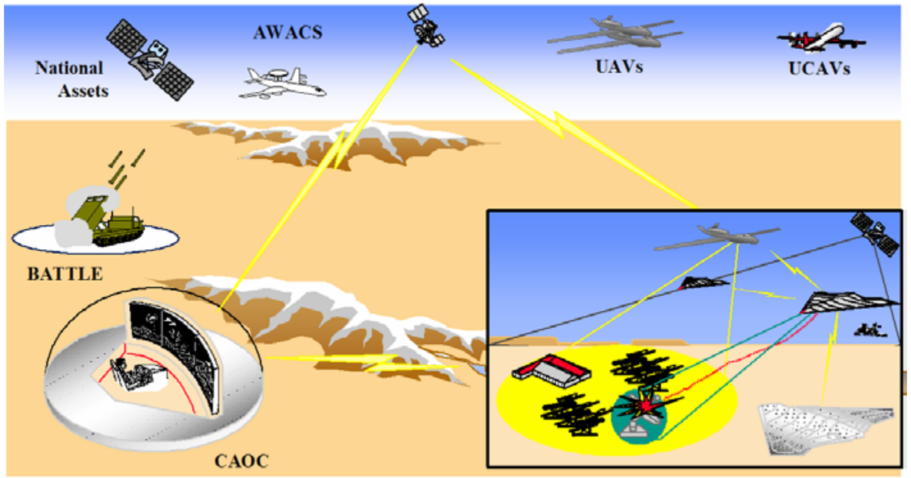


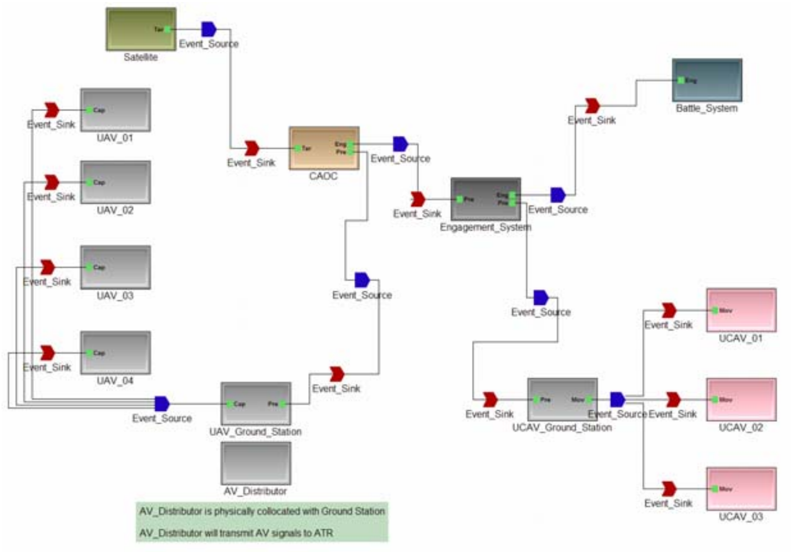
- EQAL = Event QoS Aspect Language
- EQAL is part of PICML within the CoSMIC suite
  - Built in the Generic Modeling Environment (GME)
  - Addresses publisher/subscriber service configuration and deployment challenges
    - *Models* specify service configurations and deployments
    - *Aspects* decouple D&C concerns
    - *Constraints* ensure semantic validity
    - *Interpreters* generate descriptor files

C-SAW: An Aspect Model Weaver

Separating Crosscutting Concerns from Domain-Specific Models

Scaling up to Large DRE Systems

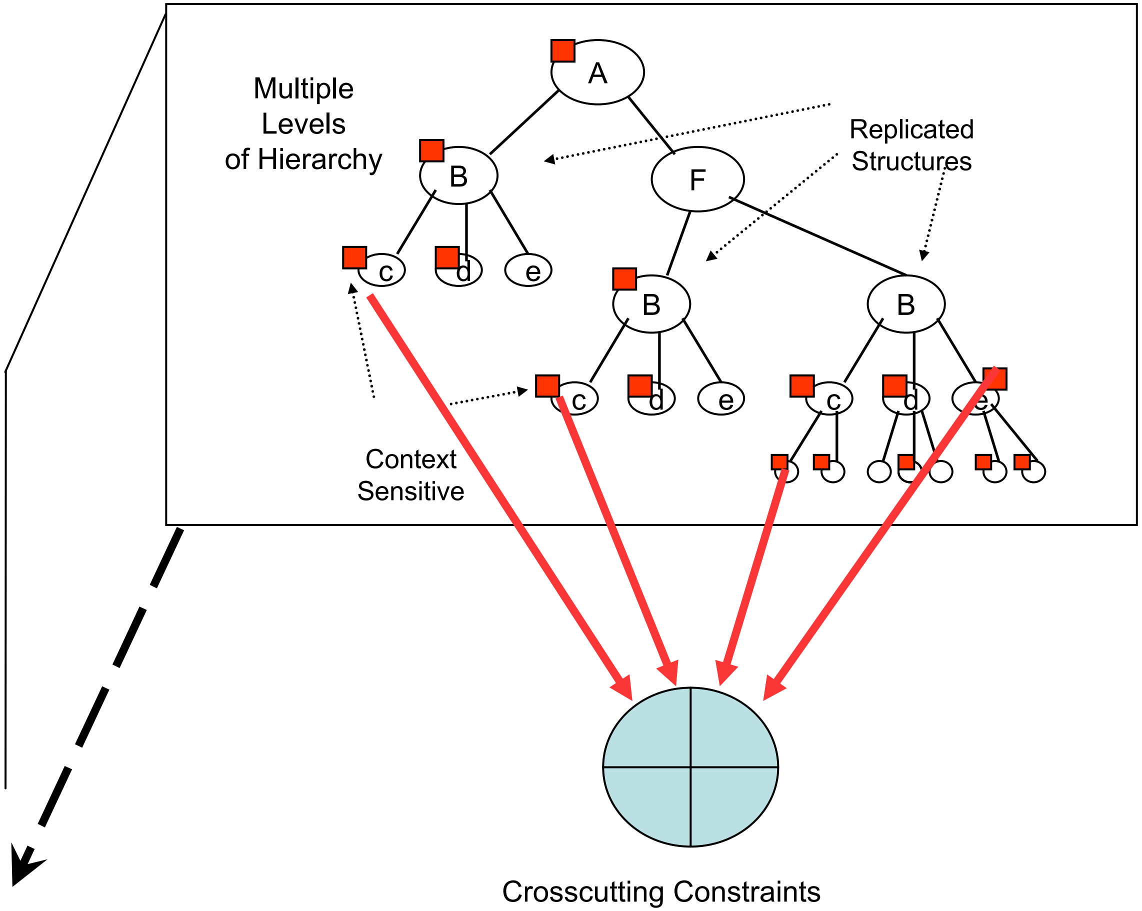




- Rich and complex interactions among modeling elements
- Changing requirements have cascading effect across multiple locations in a model
- The time to make such changes becomes infeasible to do manually; error prone nature of manual change can lead to incorrect models
- Example: Scaling a model from 3 UAVs to 30 UAVs involves a combinatorial amount of changes that becomes nearly impossible to model by hand; similar for large federations of event channels (EQAL)

Challenge: Crosscutting Constraints in Real-Time/Embedded Models

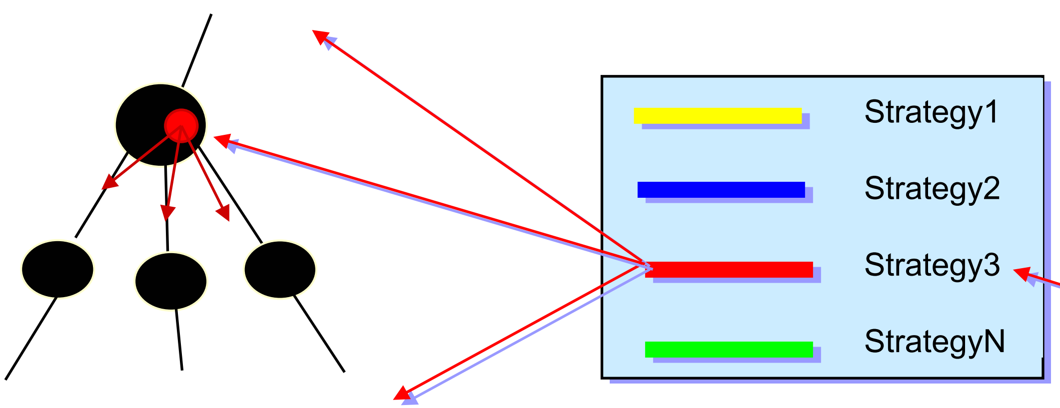
- **Base models become constrained to capture a particular design**
- **Concerns that are related to some global property are dispersed across the model**



Changeability???

Quantification Over a Domain Model

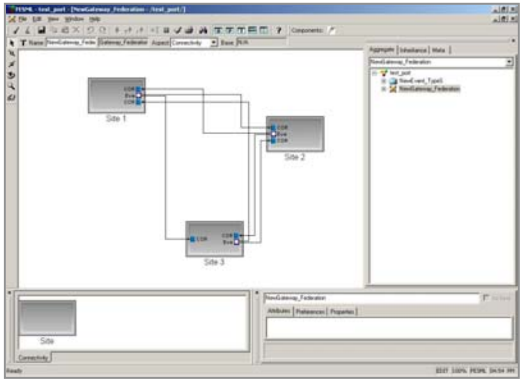
- **Apply AO Weaving concepts to Model-based systems**
  - Weavers ‘Decorate’ Models with attributes & constraints
  - Weavers compose new model constructs




```
…
select(p | p.name() == "Model*" &&
        p.kind() == "StateFlow")->Strategy3();
…
```

Using C-SAW for Aspect Weaving within EQAL Models

EQAL Model with 3 sites

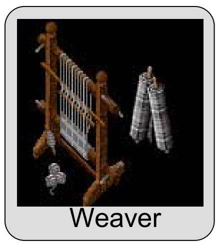


1

ECL Specifications

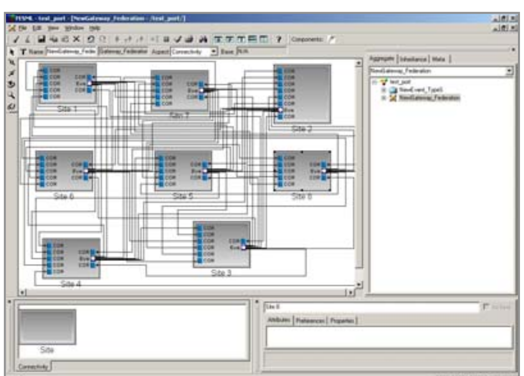
```
aspect Start( )
{  scaleUpSites(1, 8, 4); }
strategy scaleUpSites(site_id, max, idx: integer)
{
  iterateSite_r(idx-1, 1, max, idx);
  addSite_r(site_id, max, idx);
  addCon_r1(site_id, max, 1, 1, idx);
}
strategy iterateSite_r(oldmax, oldidx,
                       max, idx  : integer)
{
  declare id_str :string;
  if (oldidx <=oldmax) then
   id_str := intToString(oldidx);
   rootFolder().findModel("NewGateway_Federation").
   findModel("Site " + id_str).addGateWay_r(max, idx);
   iterateSite_r(oldmax, oldidx+1, max, idx);
  endif;
}
```

2



C-SAW

3



EQAL Model with 8 sites

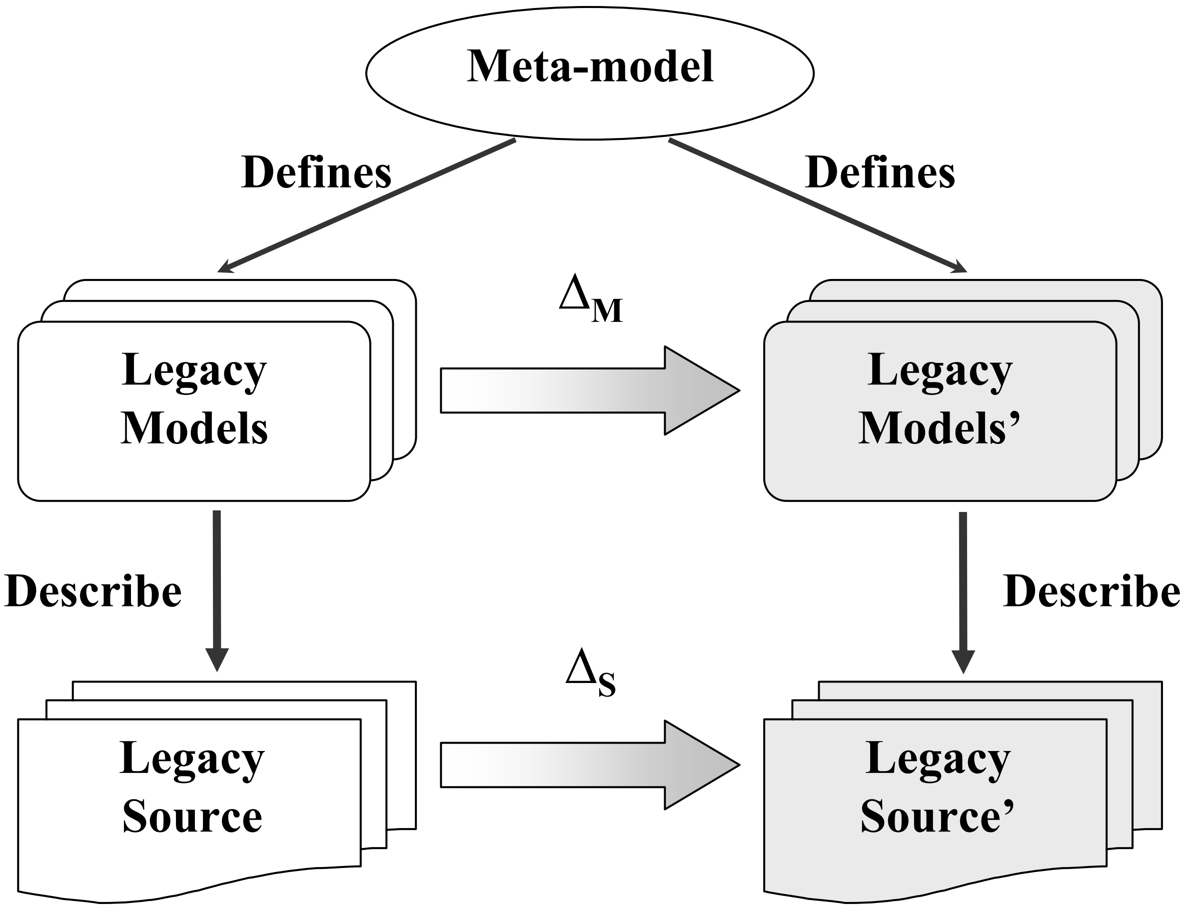
1. EQAL is used to model a federated event service with three sites
2. The ECL strategy specifications are used to scale up any site as well as the corresponding connections in the EQAL model. Three steps are included:
   - Add extra CORBA_Gateways to the existing sites
   - Repeatedly replicate the site as an instance
   - Create connections between all of the sites
3. C-SAW takes the original EQAL model and the ECL specifications, and then generates the new scaled-up EQAL model with additional sites:
   - Model weaving to explore design alternatives more rapidly
   - Design decisions crosscut model hierarchy
   - Removes manual error resulting from tedious/repetitious changes

Model-Driven Program Transformation

Ensuring a Causal Connection Between Concerns at Different Abstraction Levels

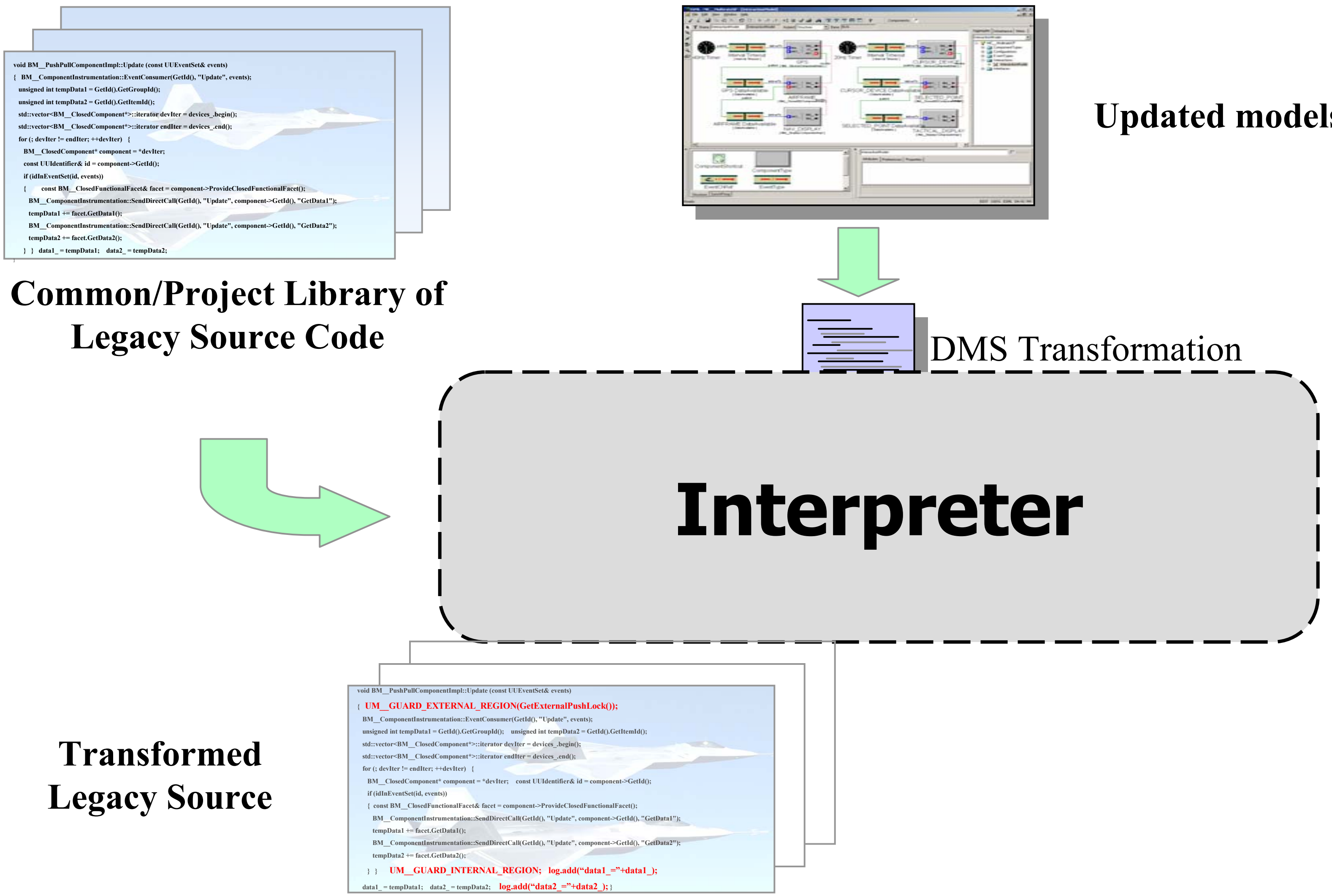
Evolution of Models and Legacy Source Code

- Goal: Maintain the fidelity between the evolving model properties and the legacy source code
- Challenges: Parsing and invasively transforming legacy source code from higher-level models
- Solution: Model-driven program transformation

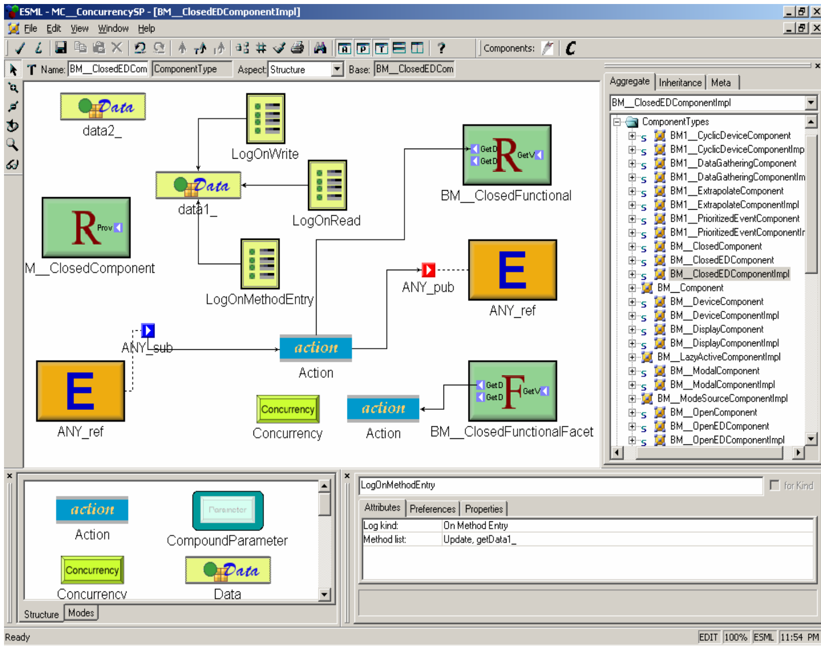


Δ_M: The changes made to the legacy models
Δ_S: The changes reflected in the legacy source

Model-Driven Program Transformation (MDPT)



Case Study : A **black box data recorder**




```
default base domain Cpp~VisualCpp6.
  pattern LogStmt() : statement = "log.add(\"data1_=\" +
data1_); ".
  pattern LogOnMethodAspect(s:statement_seq):
statement_seq = " { \s } \LogStmt\(\) ".
  pattern Update(id:identifier): qualified_id = "\id ::
Update".
  rule log_on_Update(ret:decl_specifier_seq, id:identifier,
p:parameter_declaration_clause, s: statement_seq):
function_definition -> function_definition
     = "\ret \Update\(\id\) (\p) { \s } " -> "\ret
\Update\(\id\) (\p) { \LogOnMethodAspect\(\s\) }"
   if ~[modsList:statement_seq .s matches
"\:statement_seq \LogOnMethodAspect\(\modsList\)"].
  rule log_on_Update_cv(ret:decl_specifier_seq,
id:identifier, p:parameter_declaration_clause, s:
statement_seq, cv: cv_qualifier_seq): function_definition
-> function_definition
     = "\ret \Update\(\id\) (\p) \cv { \s } " -> "\ret
\Update\(\id\) (\p) \cv { \LogOnMethodAspect\(\s\) }"    if
~[modsList:statement_seq .s matches "\:statement_seq
\LogOnMethodAspect\(\modsList\)"].
  pattern getData1_(id:identifier): qualified_id = "\id ::
getData1_".
  rule log_on_getData1_(ret:decl_specifier_seq,
id:identifier, p:parameter_declaration_clause, s:
statement_seq): function_definition -> function_definition
     = "\ret \getData1_\(\id\) (\p) { \s } " -> "\ret
\getData1_\(\id\) (\p) { \LogOnMethodAspect\(\s\) }"    if
~[modsList:statement_seq .s matches "\:statement_seq
\LogOnMethodAspect\(\modsList\)"].
  rule log_on_getData1__cv(ret:decl_specifier_seq,
id:identifier, p:parameter_declaration_clause, s:
statement_seq, cv: cv_qualifier_seq): function_definition
-> function_definition
     = "\ret \getData1_\(\id\) (\p) \cv { \s } " -> "\ret
\getData1_\(\id\) (\p) \cv { \LogOnMethodAspect\(\s\) }"
   if ~[modsList:statement_seq .s matches
"\:statement_seq \LogOnMethodAspect\(\modsList\)"].
public ruleset applyrules = { log_on_Update,
log_on_Update_cv, log_on_getData1_,
log_on_getData1__cv }.
```

- **Ensures *causal* connection between model changes and the underlying source code of the legacy system**
- **Large-scale adaptation across multiple source files that are driven by minimal changes to the model properties**
- **Model interpreters generate transformation rules to modify source**

Transformed Code fragment

```
unsigned int BM__ClosedEDComponentImpl::getData1_ () const
 {
        Addlog("data1_=" + data1_);

        UM__GUARD_INTERNAL_REGION;
        BM__ComponentInstrumentation::ReceiveDirectCall(GetId(), "GetData1");

        Addlog("data1_=" + data1_);
        return data1_;
 }

void BM__ClosedEDComponentImpl::Update (const UUEventSet& events)
 {
        Addlog("data1_=" + data1_);

        UM__GUARD_EXTERNAL_REGION(GetExternalPushLock());
        BM__ComponentInstrumentation::EventConsumer(GetId(), "Update", events);
        unsigned int tempData1 = GetId().GetGroupId();
        unsigned int tempData2 = GetId().GetItemId();

        //*** REMOVED: code for implementing Real-time Event Channel

        Addlog("data1_=" + data1_);
        data1_ = tempData1;          //*** REMOVED: actual variable names (proprietary)
        data2_ = tempData2;
 }
```

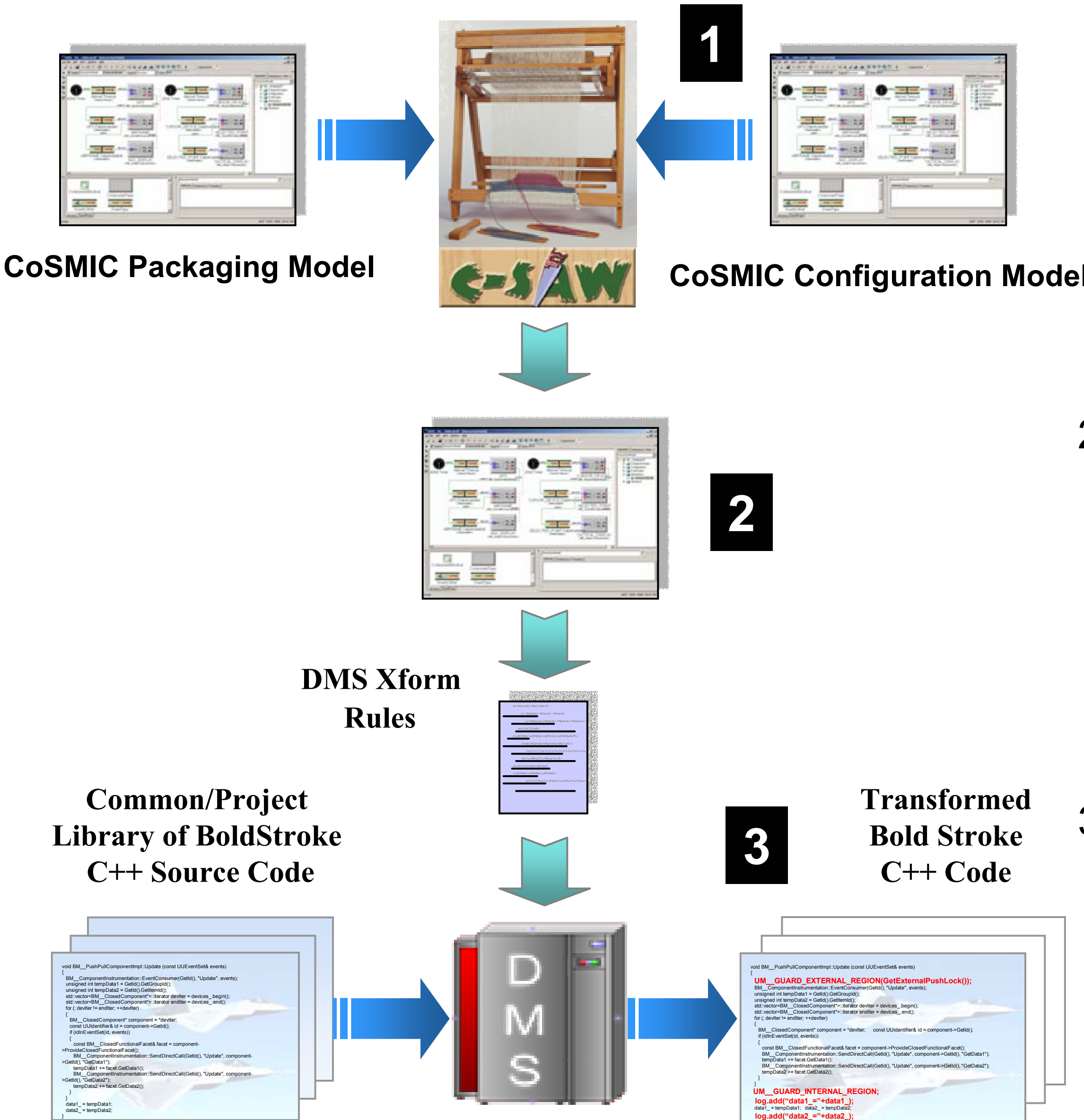
Log on getData1_() method entry

Log on reading data1_

Log on Update() method entry

Log on writing data1_

Two-Level Aspect Weaving



1. Model weaving to explore design alternatives more rapidly
   - Design decisions crosscut model hierarchy
   - Difficult to change models to new configuration
   - Design decisions captured as higher level policy strategies and weaved into models
2. Model driven program transformation
   - Ensures causal connection between model changes and represented source code of legacy system
   - Assists in legacy evolution from new properties specified in models
   - Model interpreters generate transformation rules to modify source
3. Bold Stroke Application
   - Apply original BoldStroke C++ source code and generated transformation rules to DMS; result is a transformed version of Bold Stroke that is consistent with the model specification

Video Demonstration

Project Web Pages

CoSMIC Modeling Languages and Tools

http://www.dre.vanderbilt.edu/cosmic

C-SAW Aspect Model Weaver

http://www.gray-area.org/Research/C-SAW/
Contains papers, downloads, video demos

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Backup Slides

Generalization of the control flow for the MDPT process