MDA Distilled

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What's the problem?

Software is expensive, and productivity is low for many reasons. Amongst them:

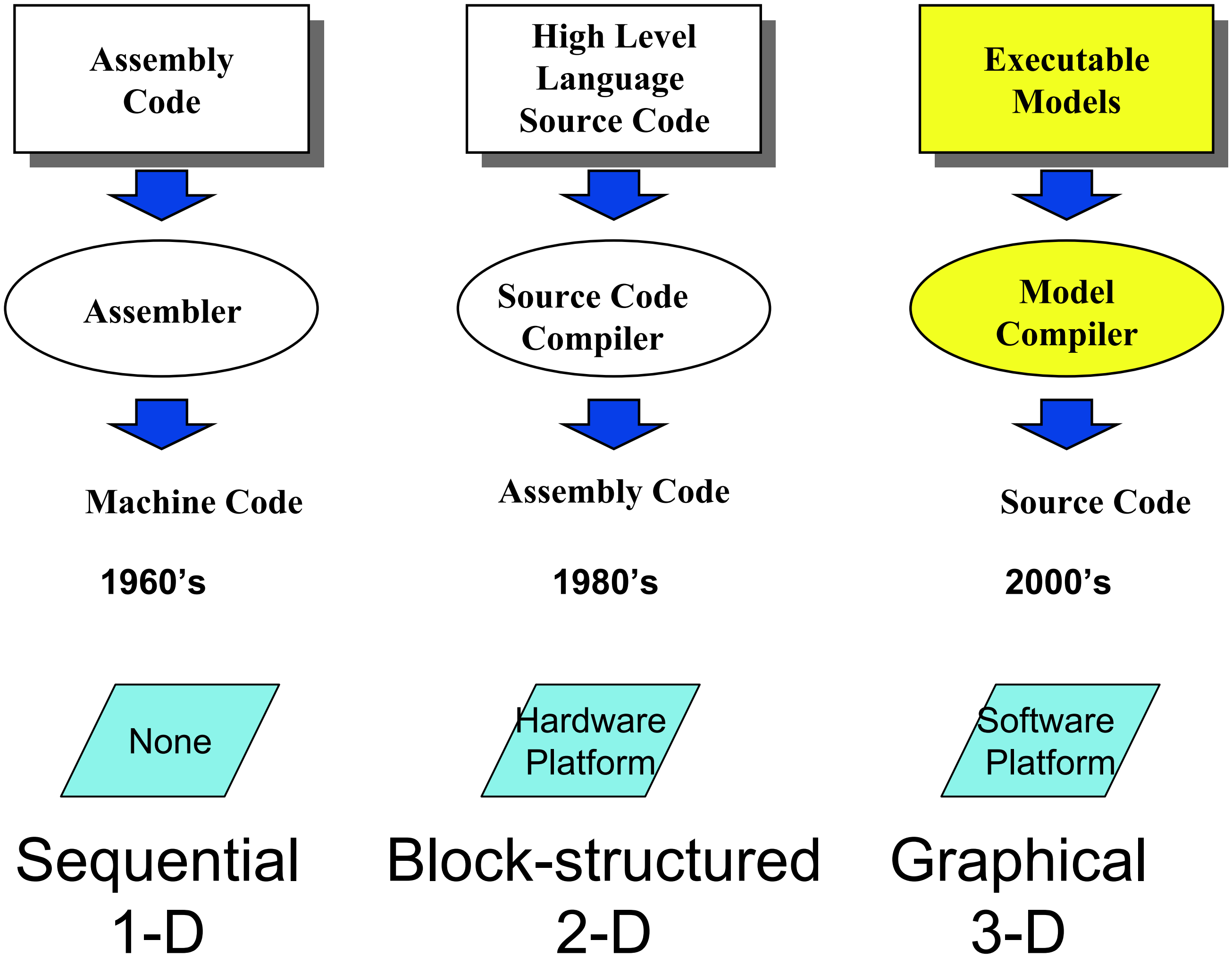
- Code is at too low level of abstraction
- Reuse occurs (to the extent it does at all) at too low a granularity
- Any code is glued together (at great expense) to its infrastructure (also expressed as code)
- Mapping information (design expertise) is applied—then lost

No wonder!

Expensive and hard-to-find!

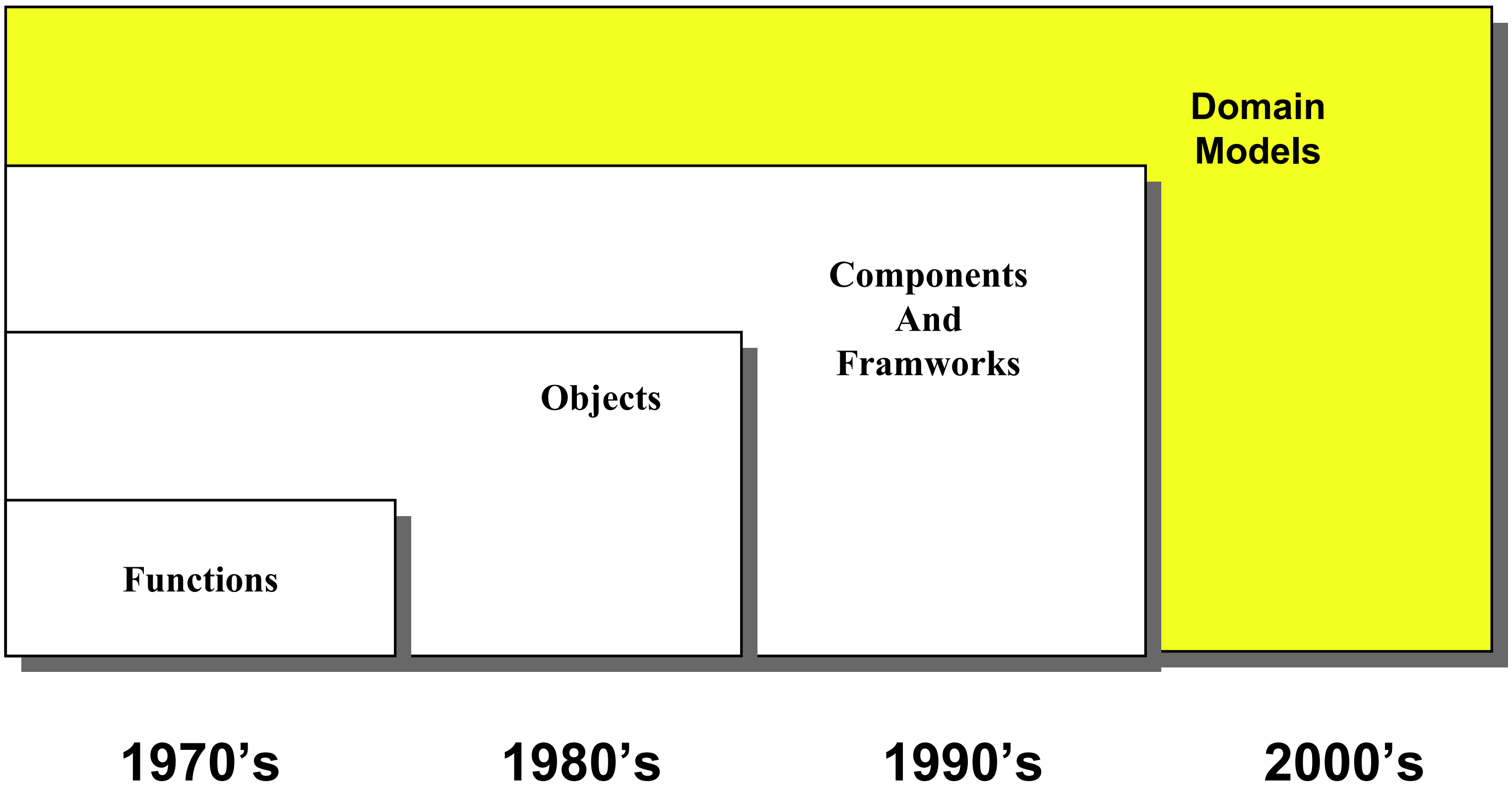
Language abstraction

High-level language source code is two-dimensional.



Reuse granularity

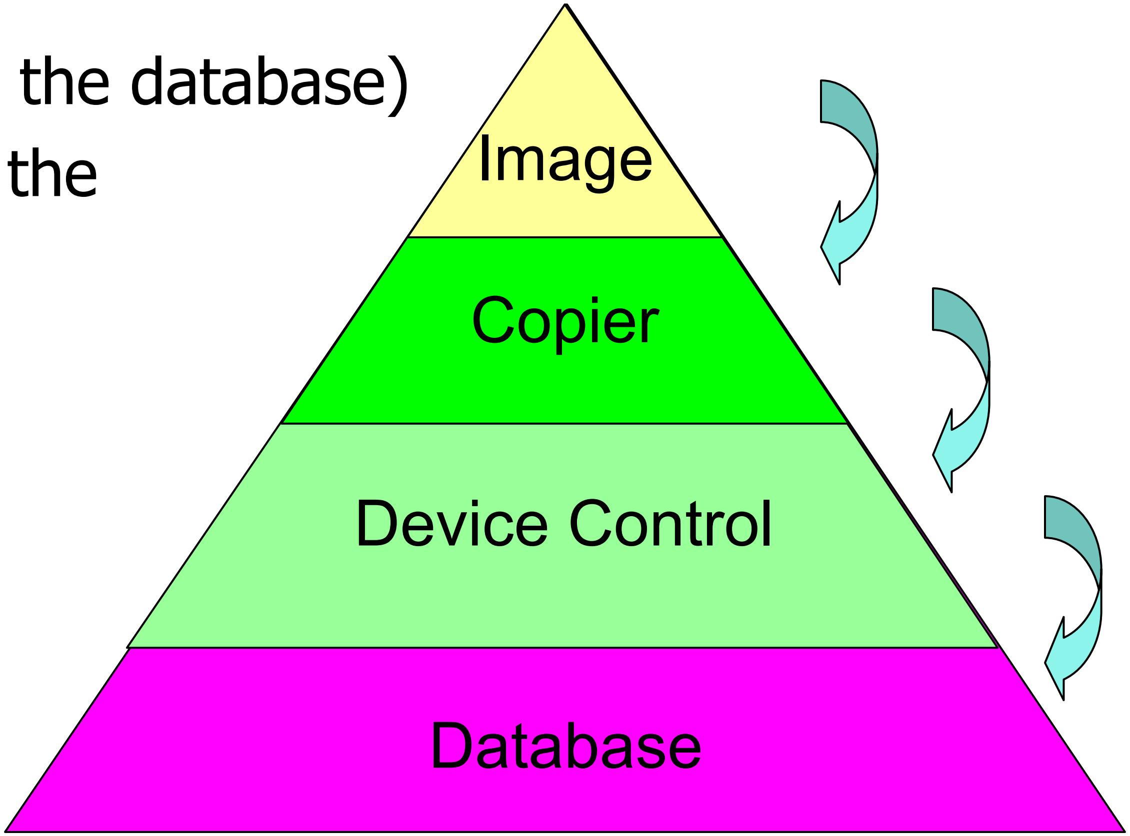
Components and frameworks require common infrastructure.



Code binds

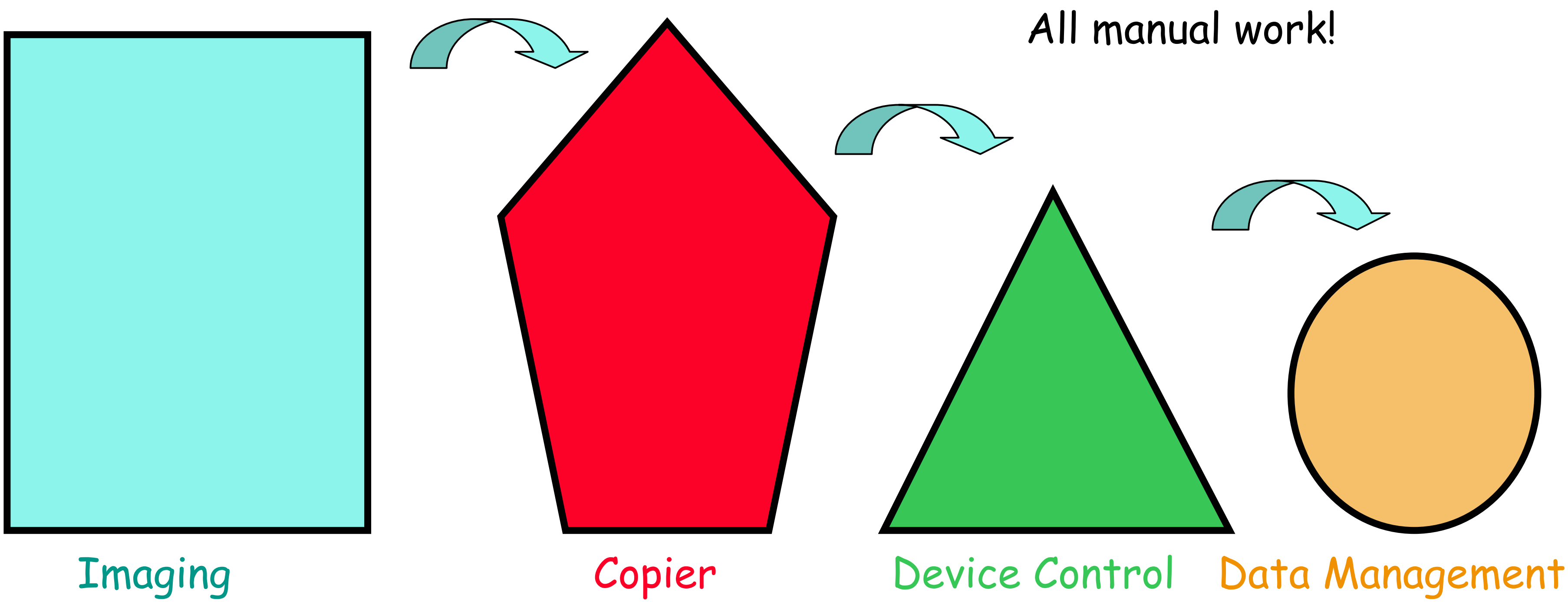
Code is glued to its infrastructure:

- Binds device control to the database
- Binds the copier to
  (device control and the database)
- Binds the image to the
  (copier and
  (device control and
  the database))…

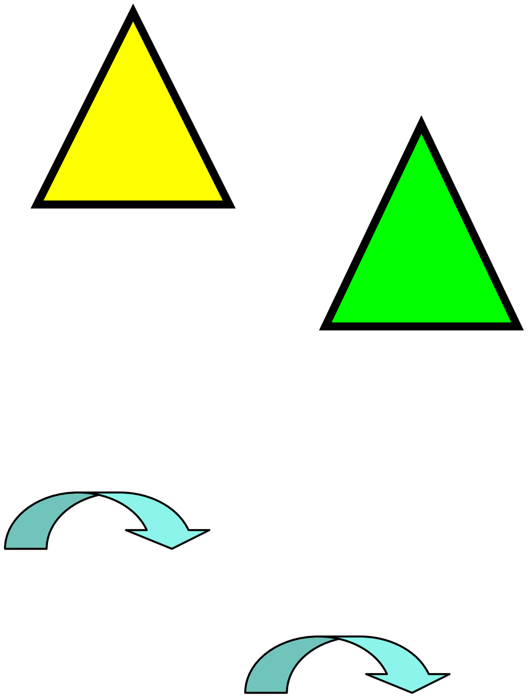


Mapping information is lost

- Mapping between layers is all skilled manual labor.
- And once a mappings is 'found,' it is applied by hand
- When a change is made, the mappings are not repeatable.



Components of an MDA solution



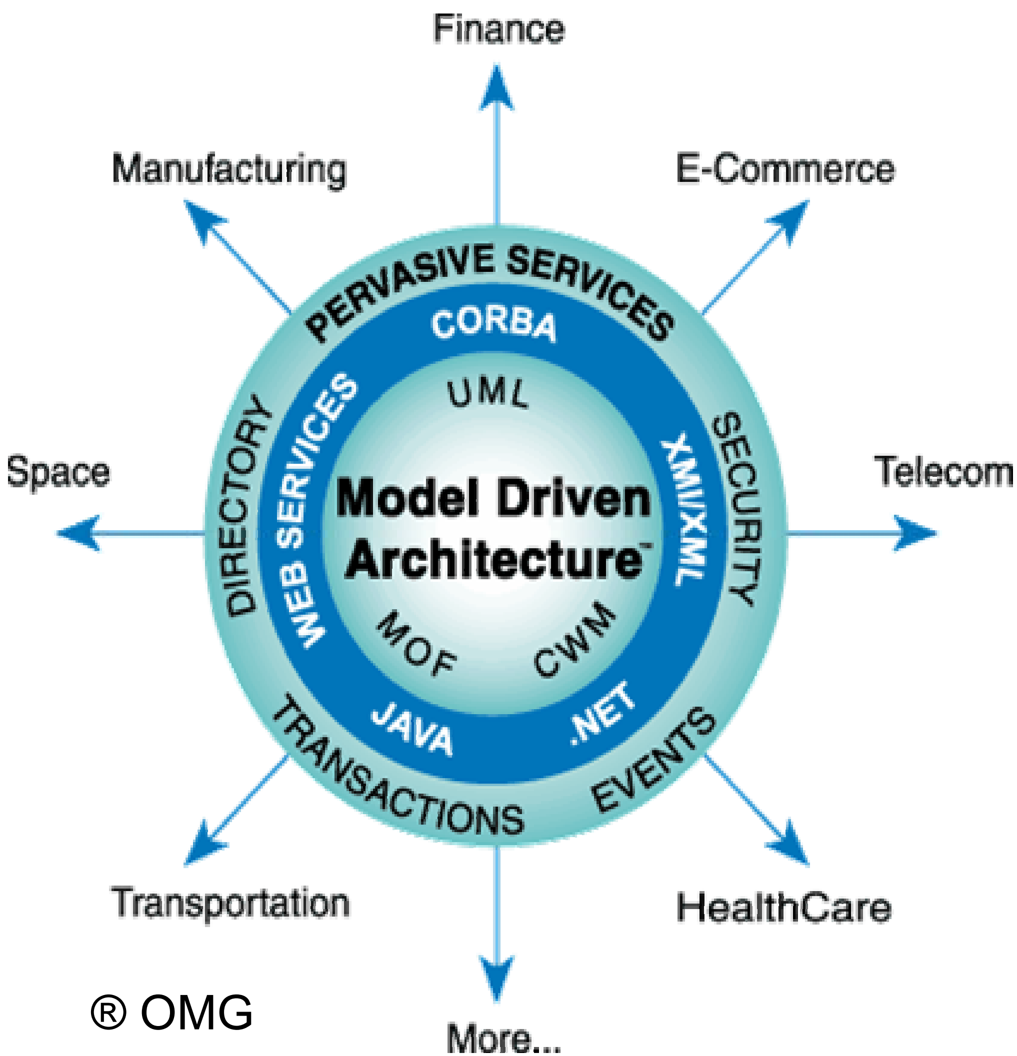
Capture *each layer* in a platform-independent manner as intellectual property.

Capture *the mappings* to the implementation as intellectual property (IP).

Layer by layer.

Models and mappings become assets.

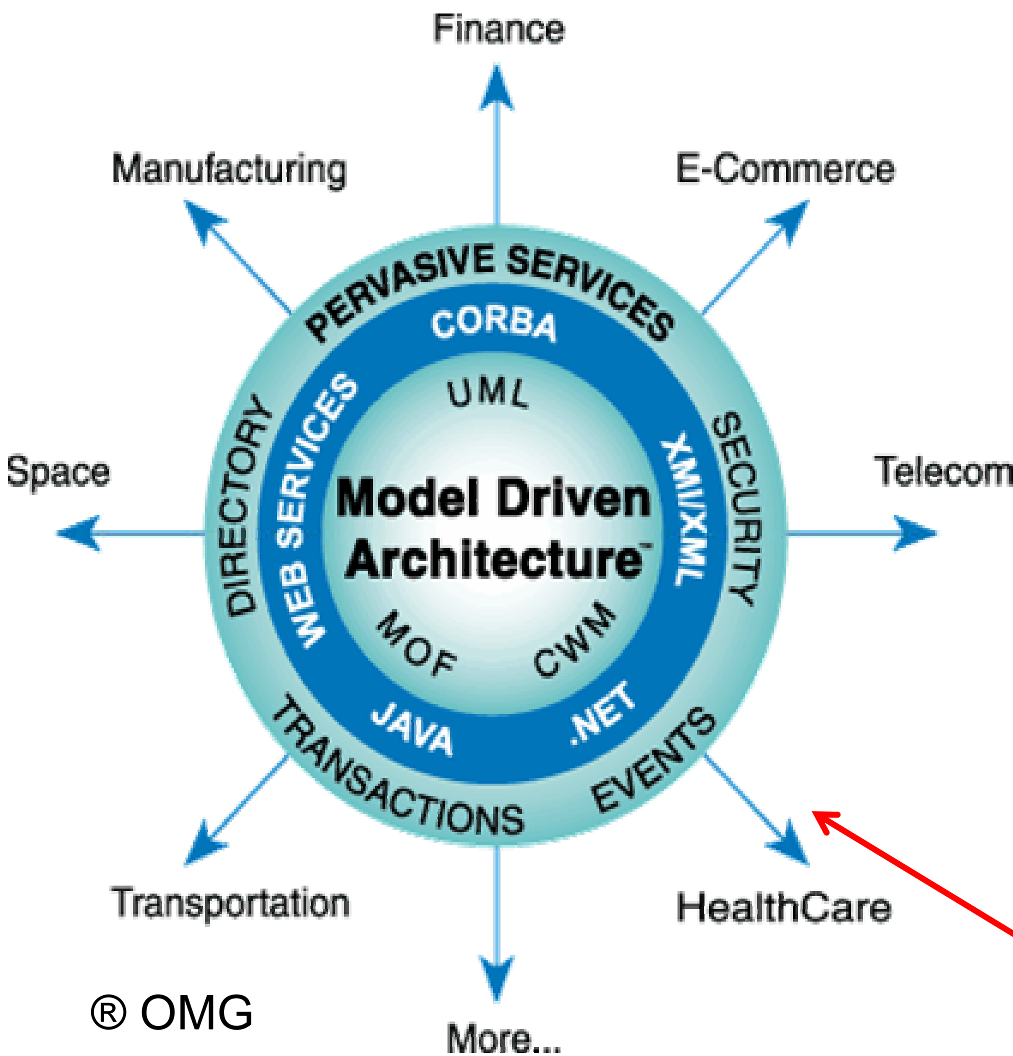
Enter Model-Driven Architecture



MDA: an interoperability standard for combining models at design-time.

This enables a market for IP in software.

Enter Model-Driven Architecture



® OMG

MDA:

- Captures IP as models and enables protection of them
- Allows IP to be mapped automatically
- Allows multiple implementations
- Makes IP portable

This enables a market for IP in software.

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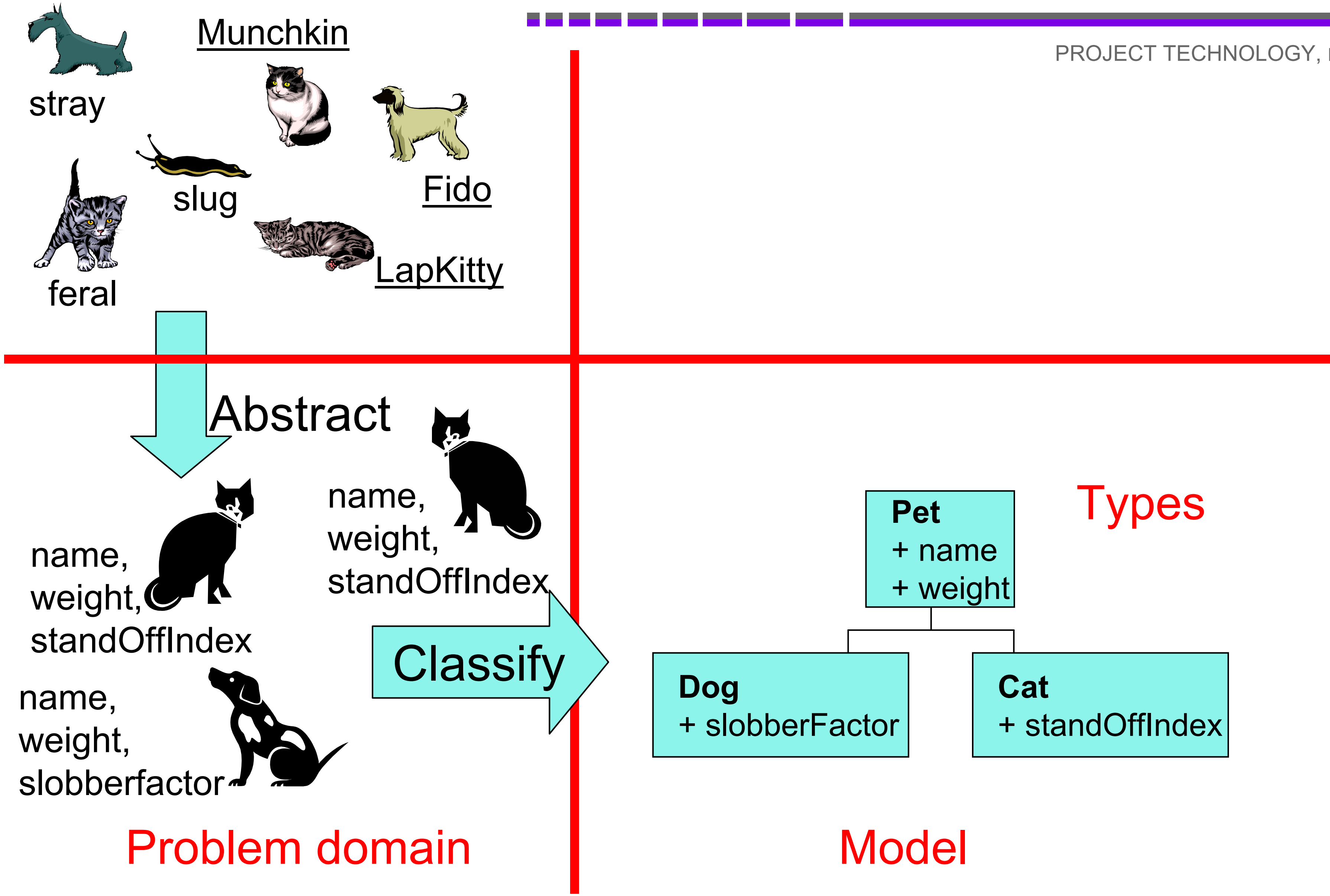
Modeling language for software

"The Unified Modeling Language is a language for specifying, constructing, visualizing, and documenting the artifacts of a software-intensive system."

The UML Summary

® Object Management Group

Abstraction and classification



Why model?

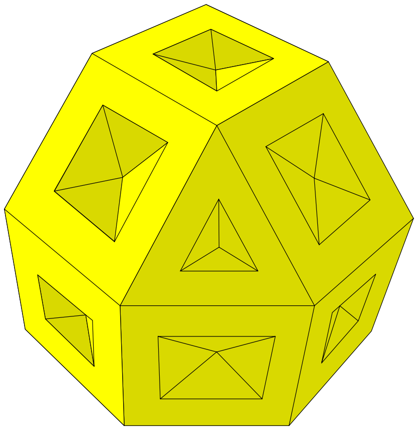
A good model:

- Abstracts away not-currently-relevant stuff
- Accurately reflects the relevant stuff, so it…
- Helps us reason about our problem
- Is cheaper to build than code
- Communicates with people
- Communicates with machines

What is a model?

A model is coherent set of elements that:

- Covers some subject matters
  - Doesn’t have to cover all subject matters
- At some level of abstraction
  - Doesn’t have to define realizations
- That need not expose everything
  - Doesn’t have to show everything at once
- That need not be complete in itself
  - Doesn’t have to include “code”



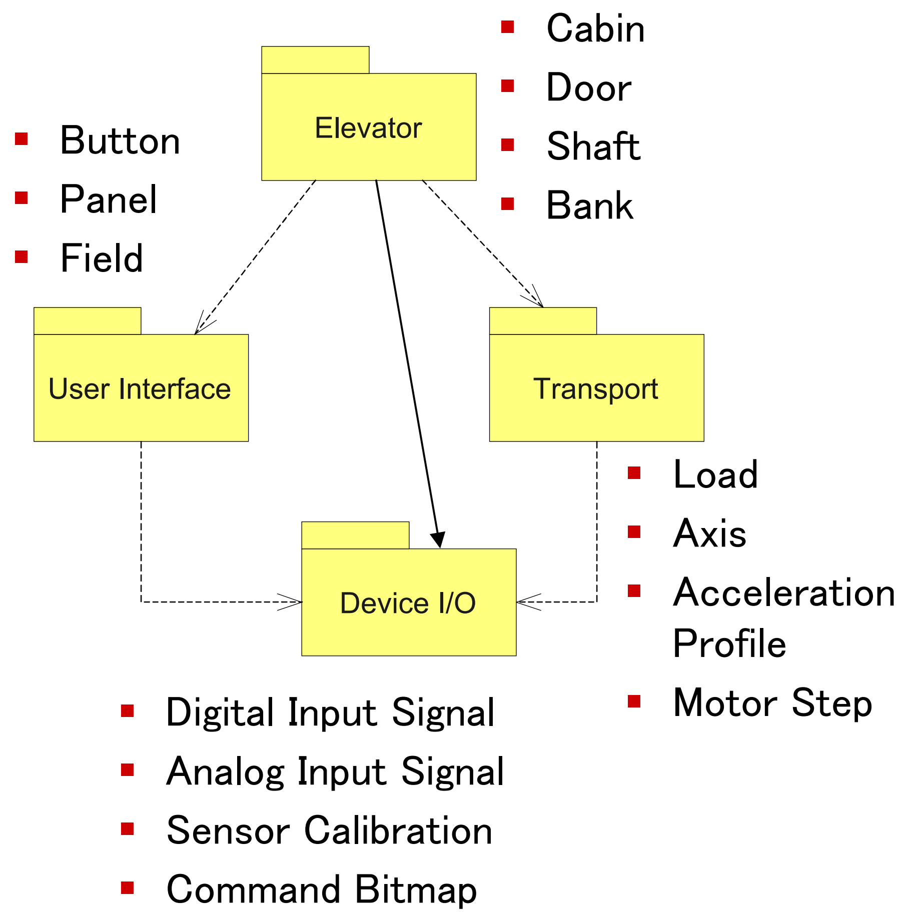
Seating plan?
Materials?
Interior?
No engine yet!

Subject matters

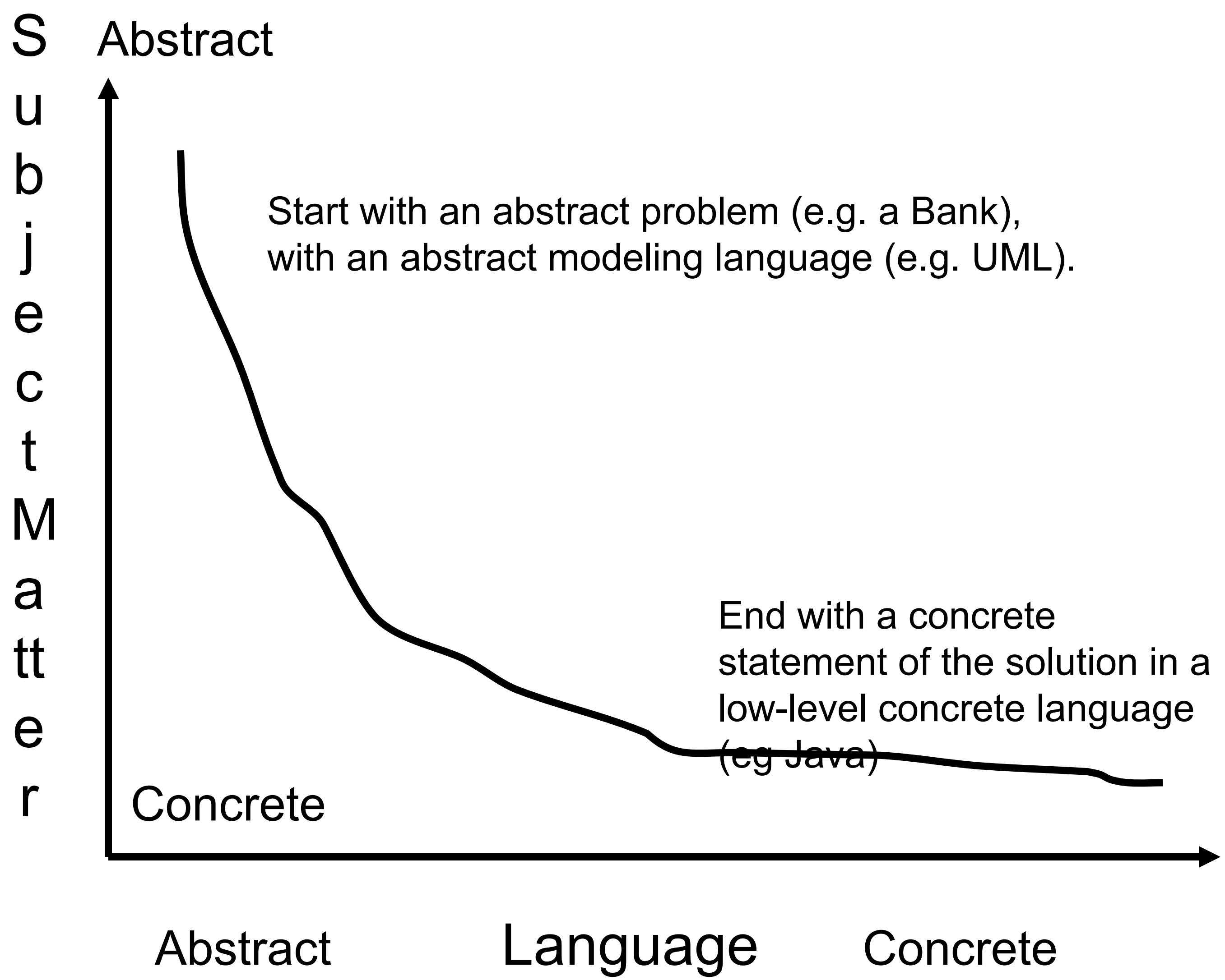
Good models come from separating layers by subject matter, so that each one is *platform independent.*

A change to models in one subject matter should not necessitate reconstruction of models in another subject matter.

A "PIM"

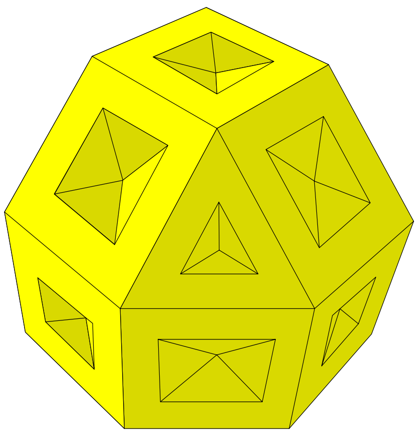


Language Abstraction

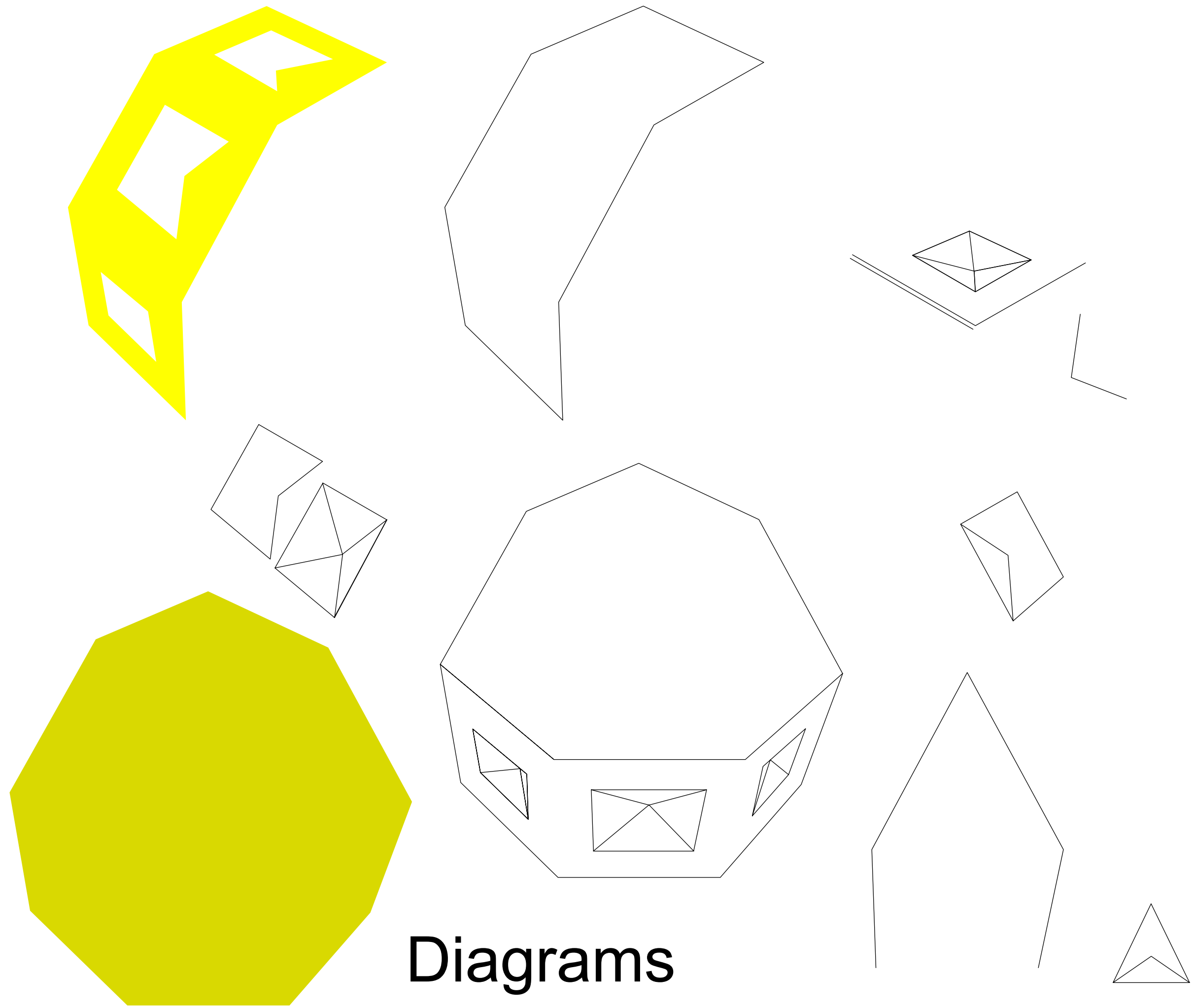


Model Views

A diagram is a coherent view on a model.



Model



Diagrams

Incompleteness

Code can be added to a model later.

Executable UML models

UML can be used as a semantic modeling language, if we:

- Define actions
- Define the context
- Define execution rules

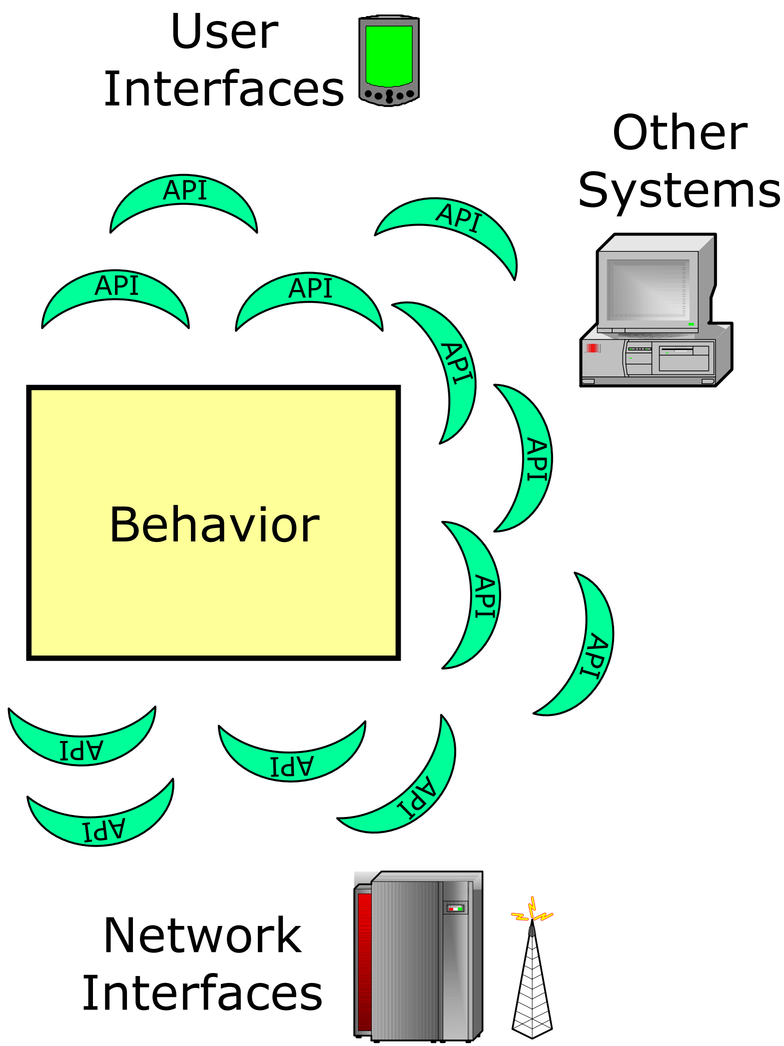
for an underlying semantic model.

The underlying semantic model is an:

executable
translatable

UML.

Defining behavior using UML



- UML can now be used to define behavior
  - UML 1.5/2.0 now has Action Semantics
- Use an executable translatable profile of UML ($^{X}{}_{T}$UML)
- $^{X}{}_{T}$UML defines behavior without making premature design decisions

Three primary diagrams

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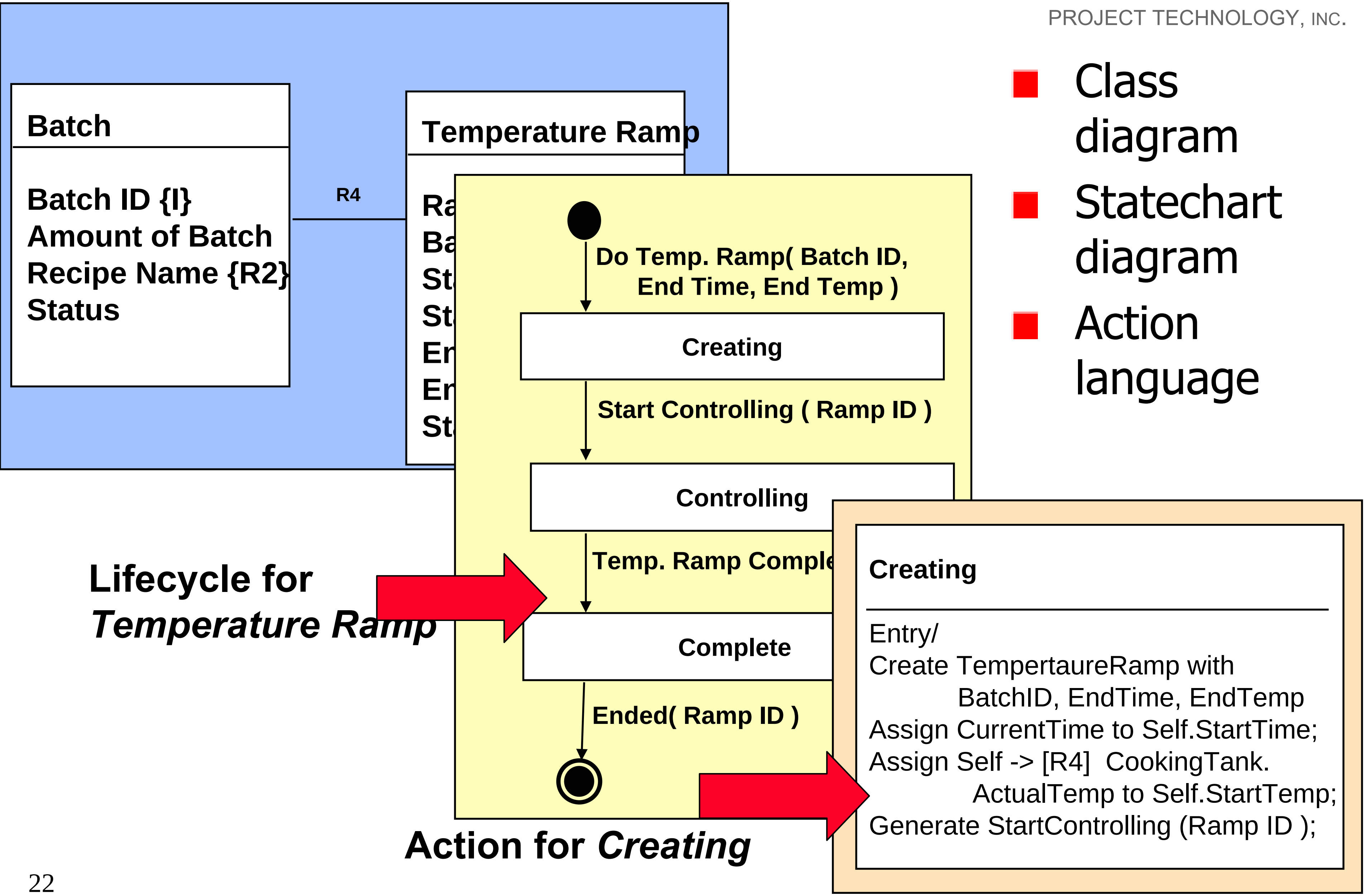
- Class diagram
- Statechart diagram
- Action language



Lifecycle for *Temperature Ramp*

Action for *Creating*

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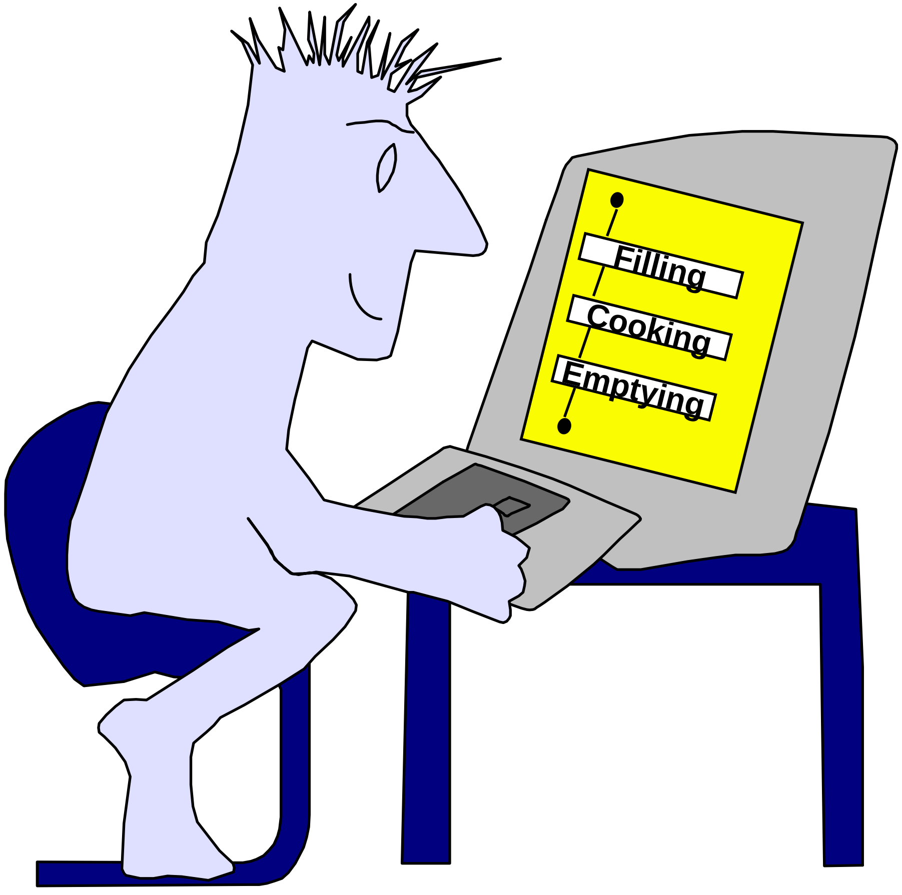
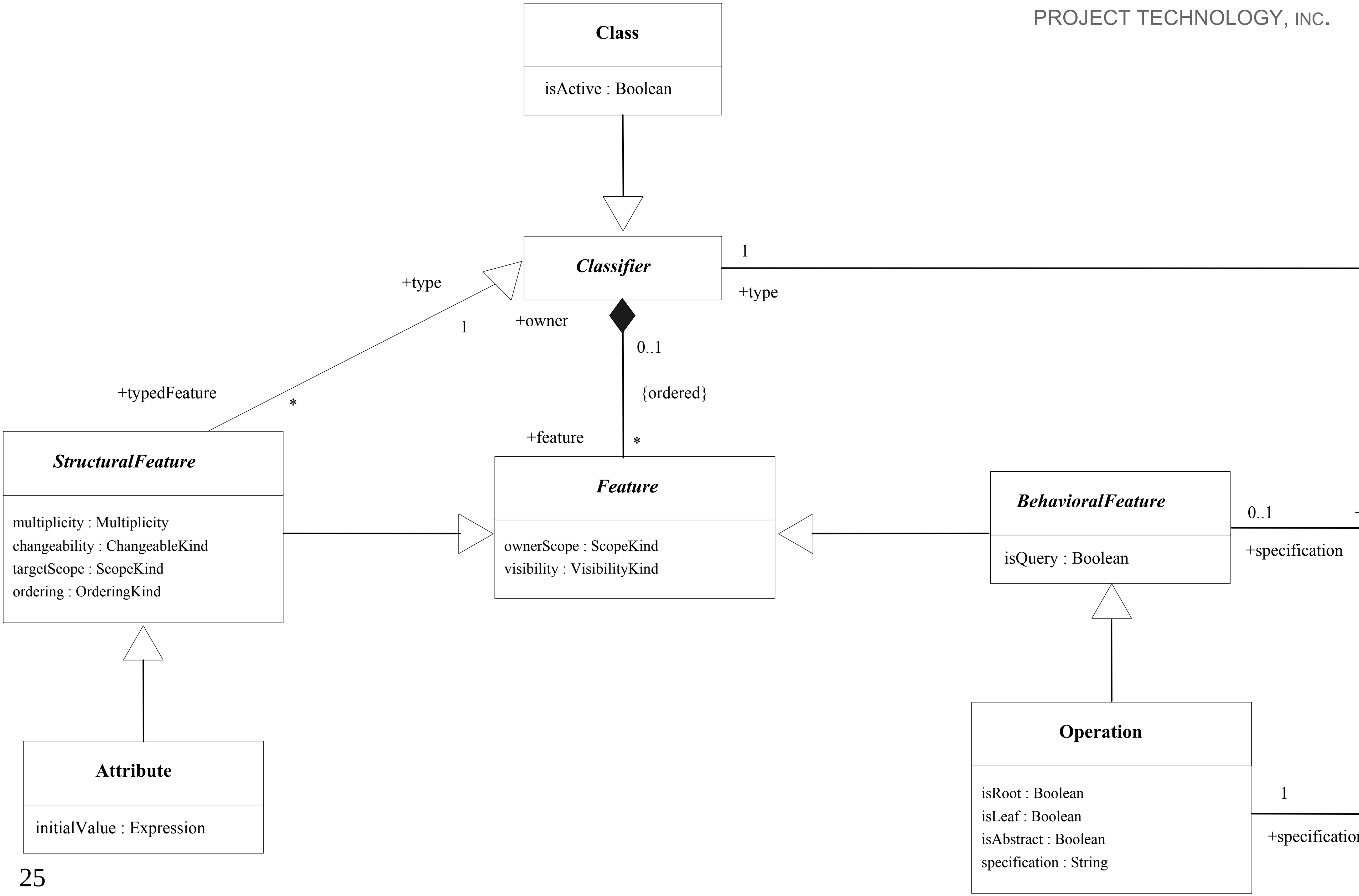
What is a metamodel?

A metamodel captures developer models in a model repository.

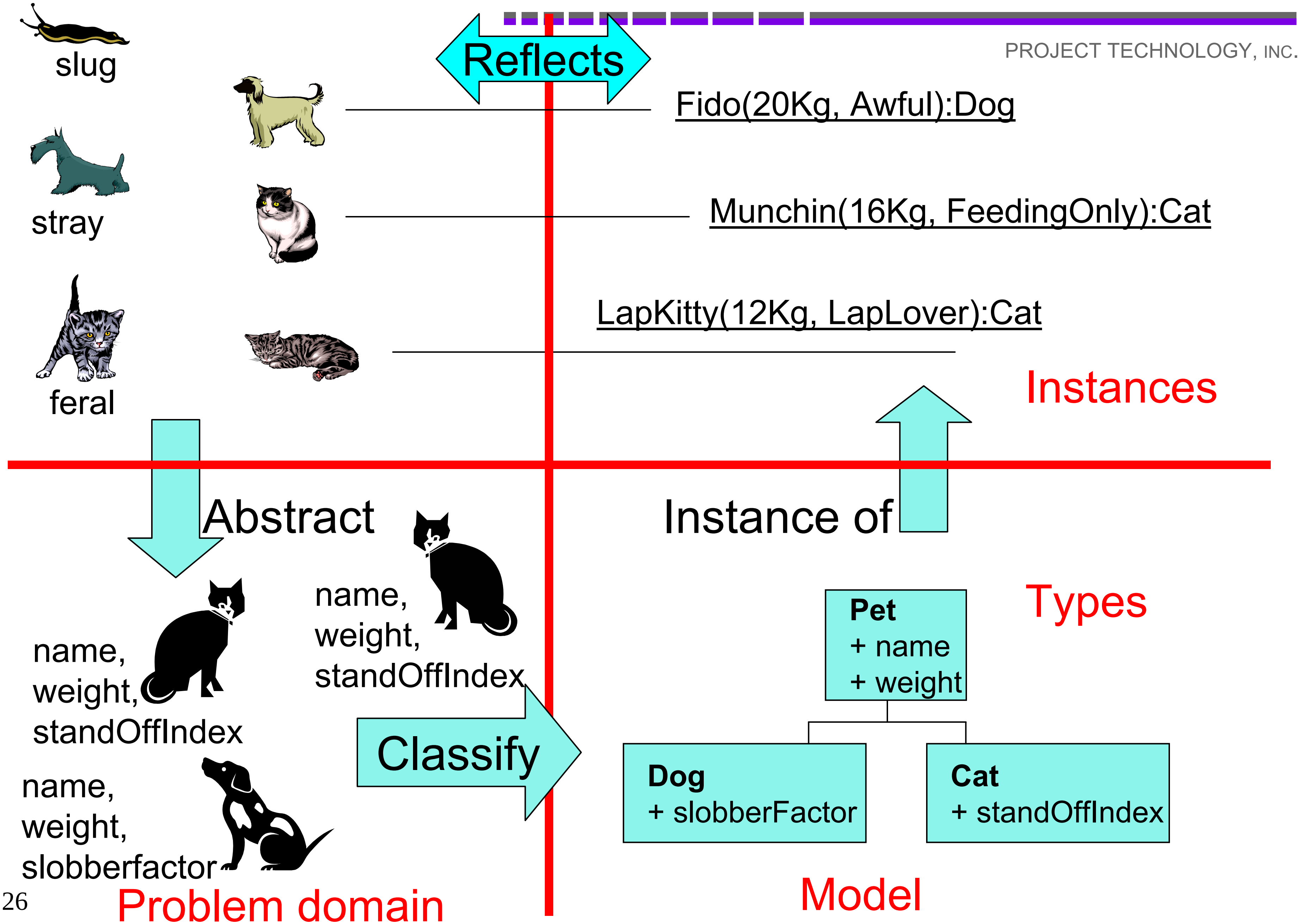
What is the structure of the repository?



UML metamodel



Instance-of


slug
stray
feral
Reflects
Fido(20Kg, Awful):Dog
Munchin(16Kg, FeedingOnly):Cat
LapKitty(12Kg, LapLover):Cat
Instances
Abstract
Instance of
name, weight, standOffIndex
name, weight, standOffIndex
name, weight, slobberfactor
Classify
Types
Pet
+ name
+ weight
Dog
+ slobberFactor
Cat
+ standOffIndex
Problem domain
Model

The relationship to the metamodel

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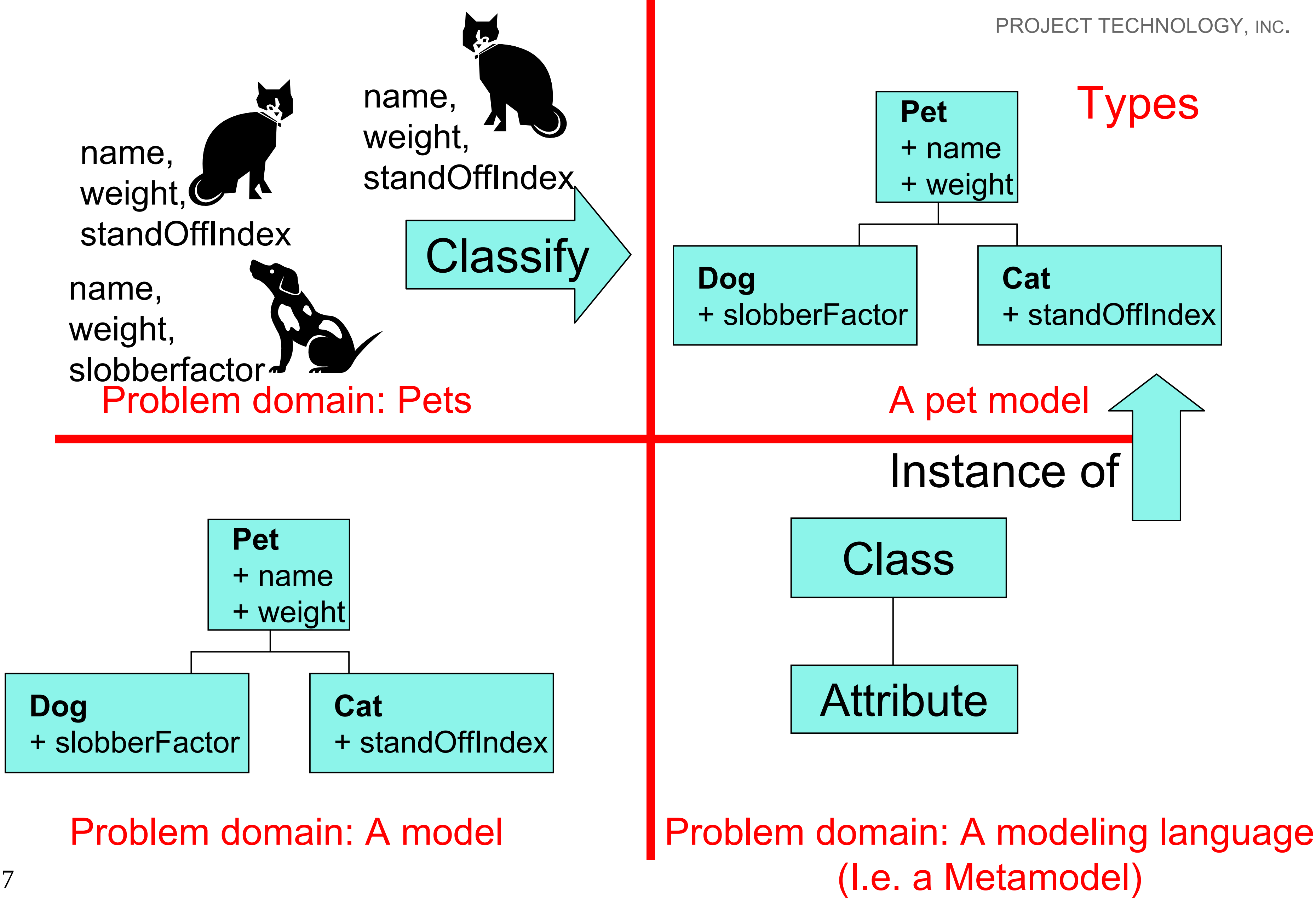
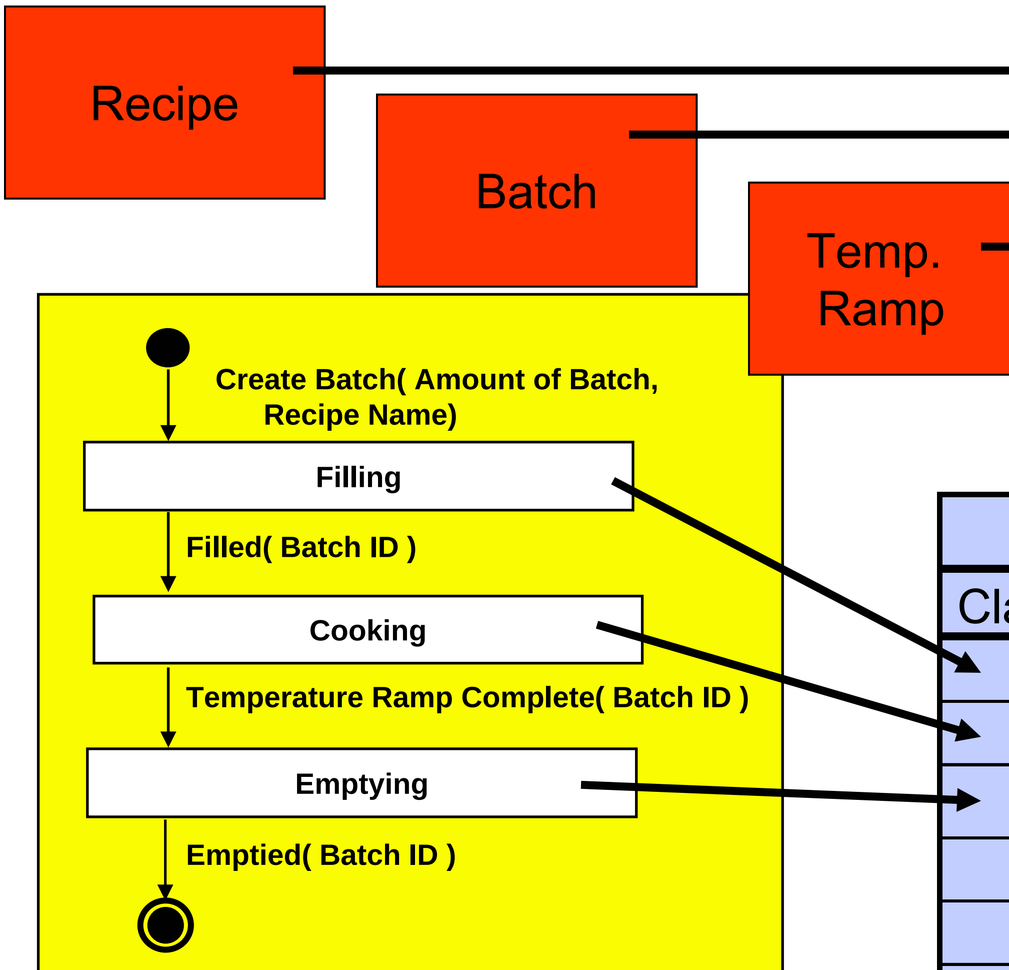


Metamodel instances

Just like an application model,
the meta-model has instances.

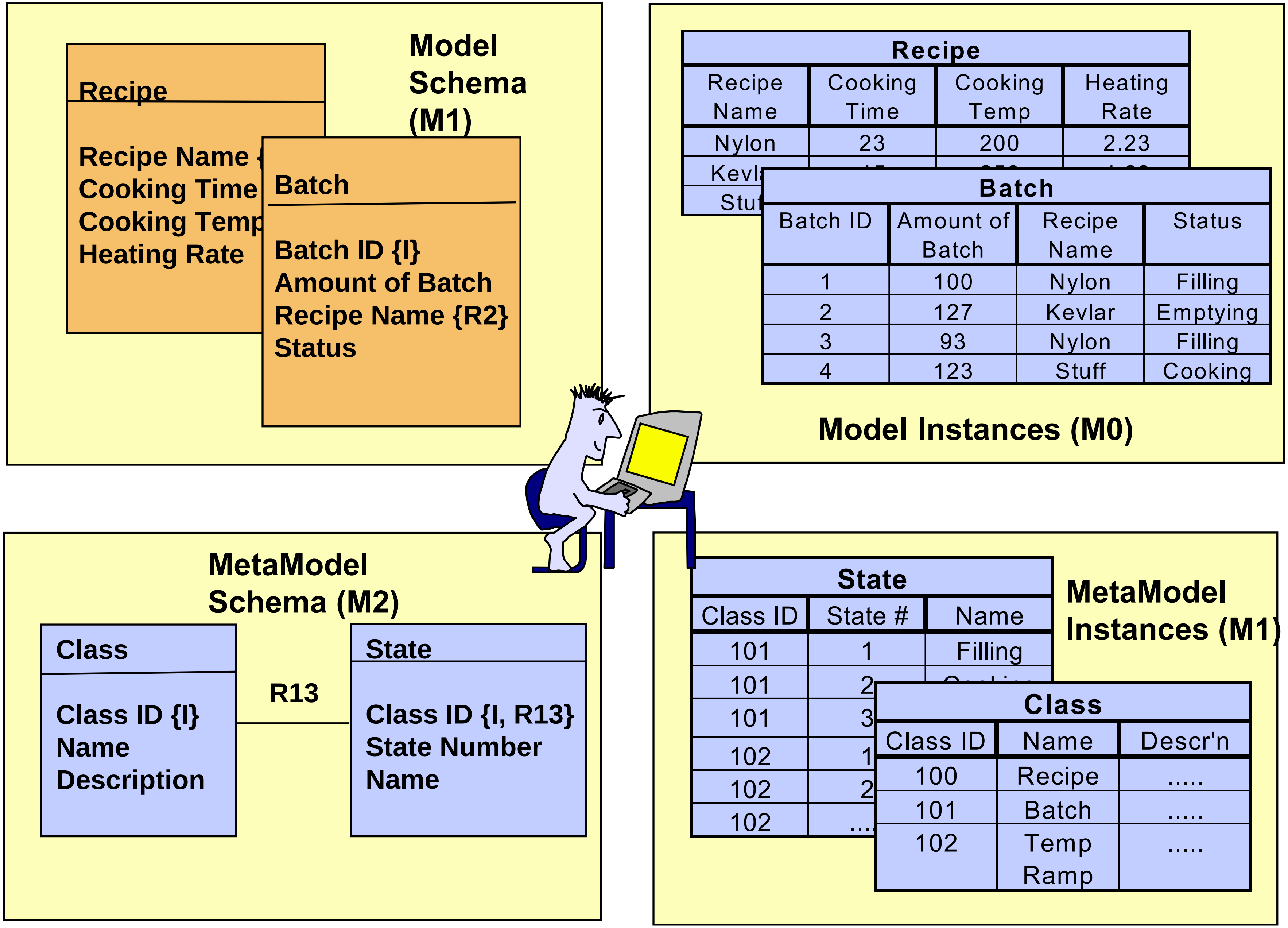


Class

Class ID	Name	Descr'n
100	Recipe	.....
101	Batch	.....
102	Temp Ramp	.....

State

Class ID	State #	Name
101	1	Filling
101	2	Cooking
101	3	Emptying
102	1	....
102	2	.....
102	.....	.....

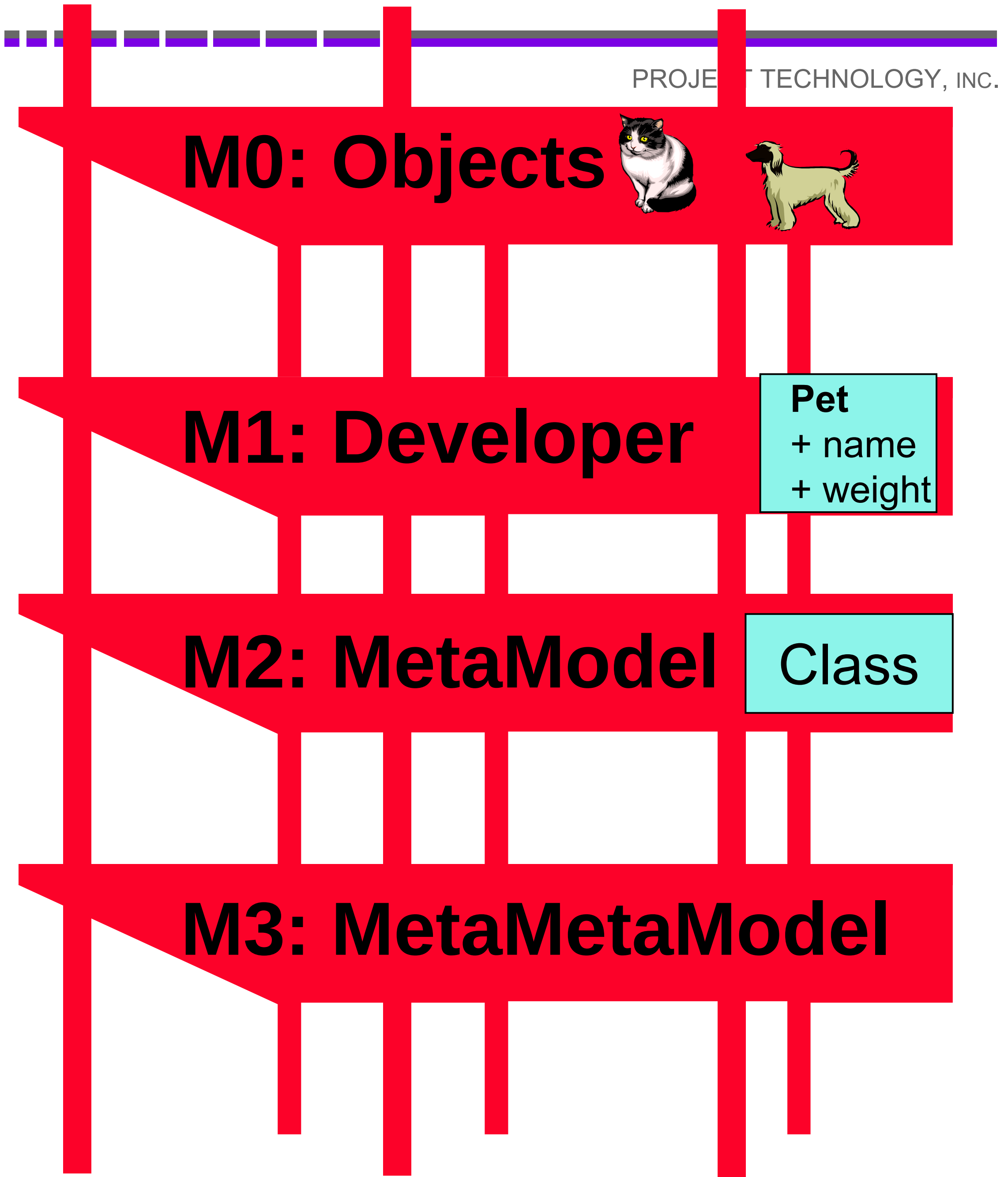


Model Schema (M1)
Recipe
Recipe Name {
Cooking Time
Cooking Temp
Heating Rate
Batch
Batch ID {I}
Amount of Batch
Recipe Name {R2}
Status
Recipe
Recipe Name
Cooking Time
Cooking Temp
Heating Rate
Nylon
23
200
2.23
Kevla
Stuf
Batch
Batch ID
Amount of Batch
Recipe Name
Status
1
100
Nylon
Filling
2
127
Kevlar
Emptying
3
93
Nylon
Filling
4
123
Stuff
Cooking
Model Instances (M0)
MetaModel Schema (M2)
Class
Class ID {I}
Name
Description
R13
State
Class ID {I, R13}
State Number
Name
State
Class ID
State #
Name
101
1
Filling
101
2
101
3
102
1
102
2
102
...
MetaModel Instances (M1)
Class
Class ID
Name
Descr'n
100
Recipe
.....
101
Batch
.....
102
Temp Ramp
.....

Four-layer architecture

The "four-layer architecture" is a simple way to refer to each layer.

(In reality, meta-levels are relative.)

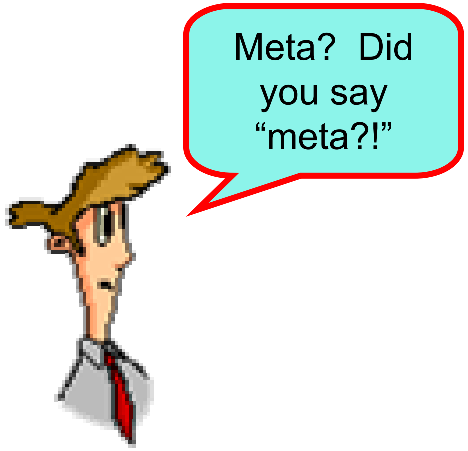


Fourth Layer

The fourth layer is a *model of the metamodel*, which yields a "meta-meta-model." It is the simplest model that can model the metamodel.

A metamodel of the "meta-meta-model" (i.e. the "meta-meta-meta-model") would have the same structure as the meta-meta-model. This layer is:

- Reflective
- Normally associated with the MOF



MOF

The Meta-Object Facility is an OMG standard that defines the structures for M3.

Any metamodel can be captured in MOF (not just UML), which makes it the basis

- for defining standards that …
- *…map between metamodels*.

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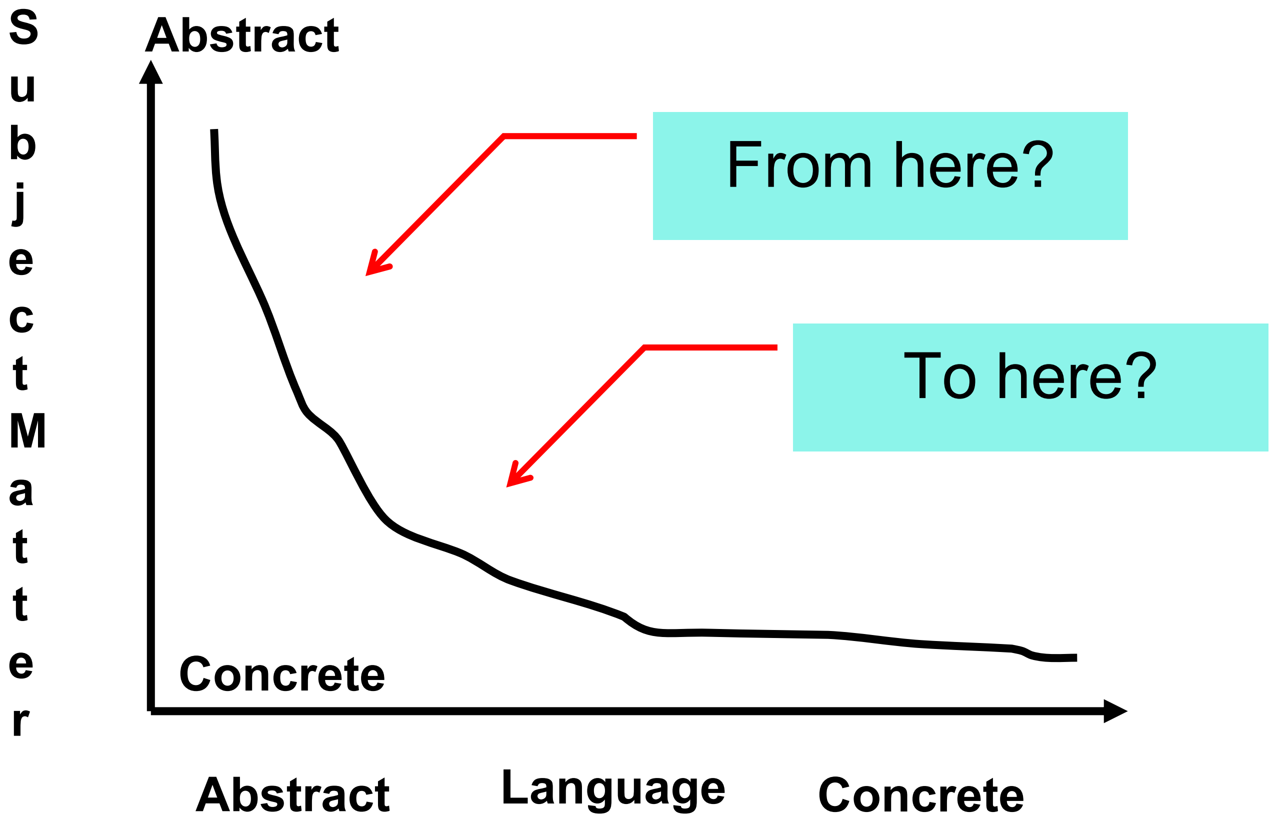
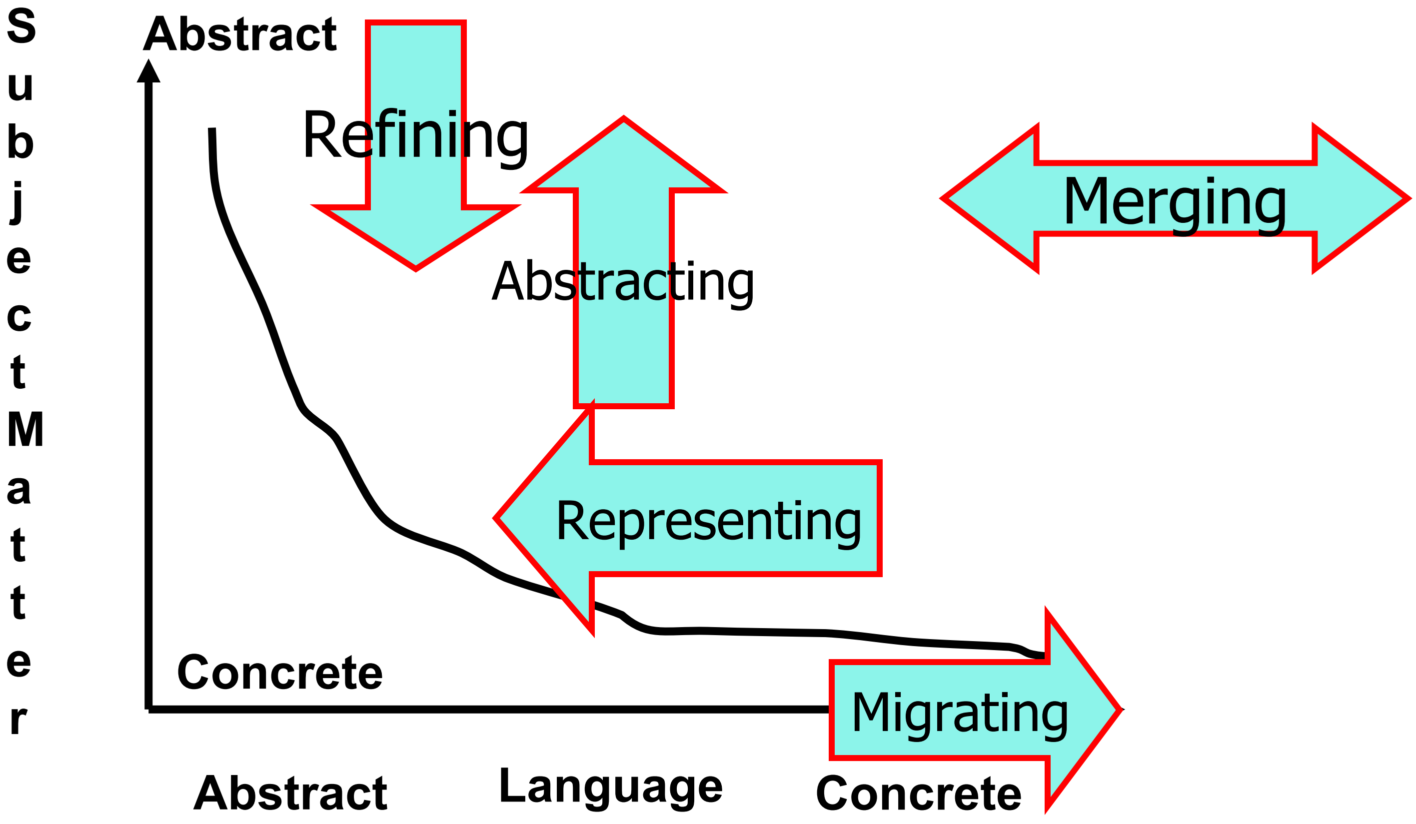
Mapping functions

A mapping function transforms one model into another.

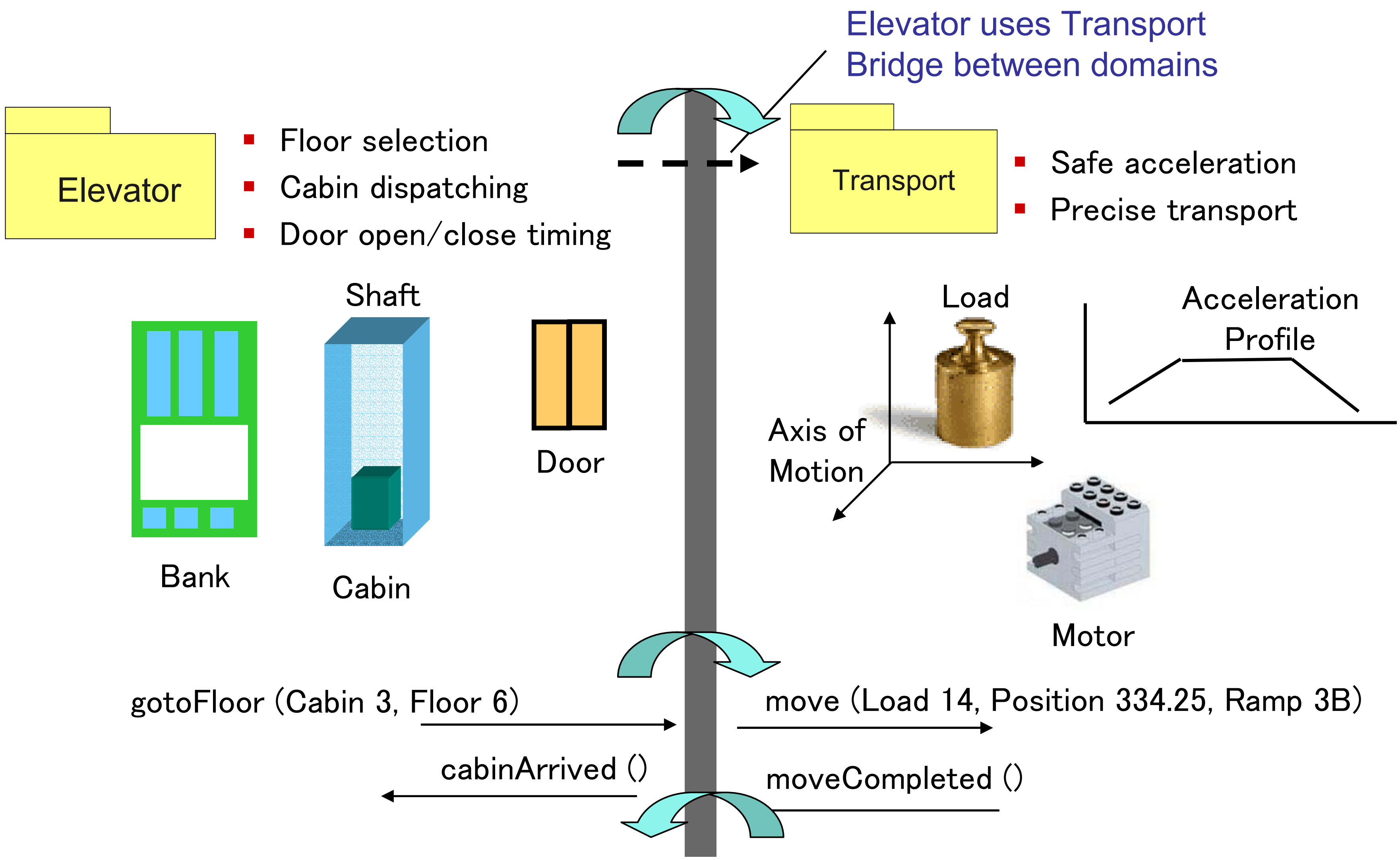


Types of mappings

In general, a mapping can be:



Example of merging mapping



Metamodel-metamodel mappings

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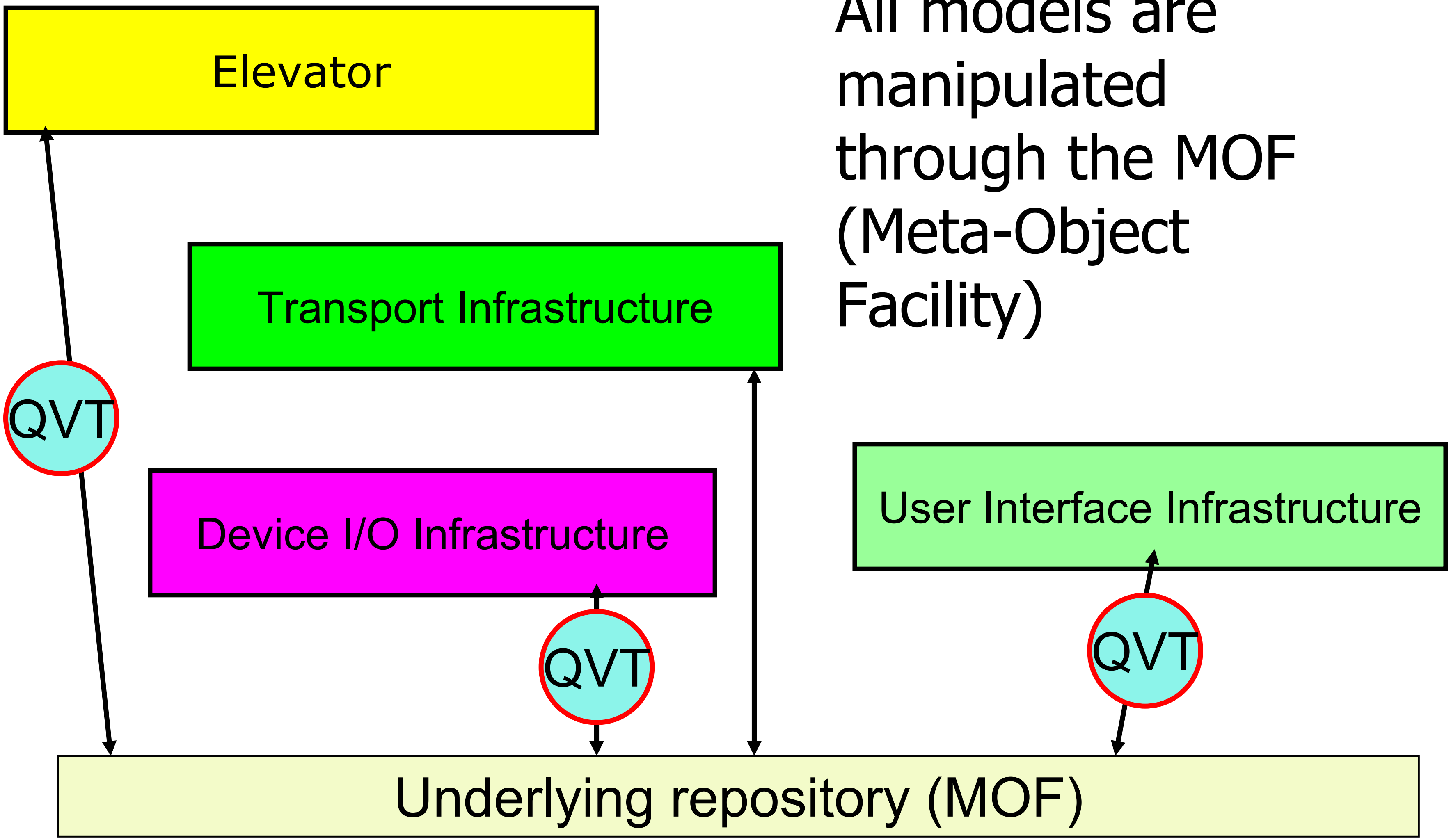

All models are manipulated through the MOF (Meta-Object Facility)

Why MOF?

A metamodel (as stored in MOF) allows us to state mapping rules.

- For each Class….
- For each Structural Feature…
- For each Attribute…
- For each Action

rather than manipulate specific classes in the developer model.

This means a standard “mapping tool” can be defined: QVT.

Metamodel-metamodel mappings


```
.function Transform
.param inst_ref class
.open OOA, Arch;
.select many PDMs related by
      class->attribute[R105] in OOA
.for each PDM in PDMs
Insert PDM in PDMTable in Arch;
.endfor
.end function
```

QVT is a standard approach for defining *mapping functions* that map between metamodels

Inserts element ("attribute") in target metamodel.

- Query
- View
- Transform

QVT

There is presently no standard, but three approaches present themselves:

- Imperative,
- Template,
- Declarative.

The RFP explicitly demands declarative, but alternatives have been proposed.

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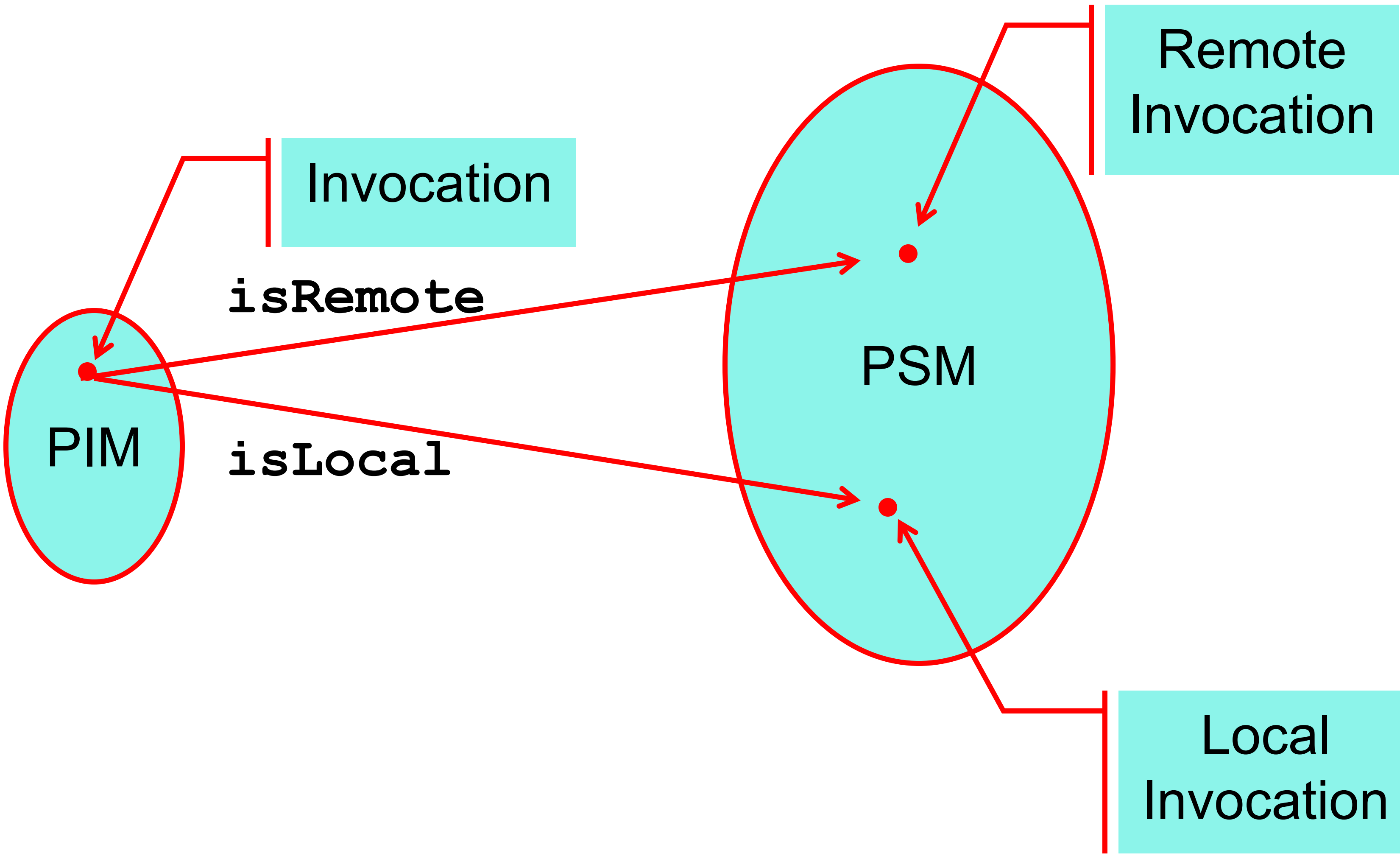
Why marks?

A *mark* distinguishes multiple possible targets.



Kinds of marks

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- Discriminators and enumerators
  ```
  [ isRemote | is Boolean ]
  ```
- Quantities
  ```
  (if numInstances < Q and
    frequencyOfAccess < F ?
          LinkedList |
                HashTable )
  ```
- Inputs
  ```
  (Append "db_" to all database operation names)
  ```
- Other marks

Marking models

A *marking model* is a way to declare:

- Names of marks
- Where they belong in the metamodel
- Their types.

```
Invocation: Accessibility ::=
      [ isRemote | is Boolean ] = isRemote

ClassExtent: StorageType ::=
      (if numInstances < Q && frequencyOfAccess < F
            ? LinkedList
                  | HashTable ) : int
```

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Profiles

A *profile* is a UML mechanism used to define and extend metamodels.

- Profiles may be used to define metamodels for PIMs and PSMs
- Profiles may be used to define marking models

A profile is defined in terms of:

- *Stereotypes* that extend “meta-”classes, and
- *Constraints*, defined using OCL

Example

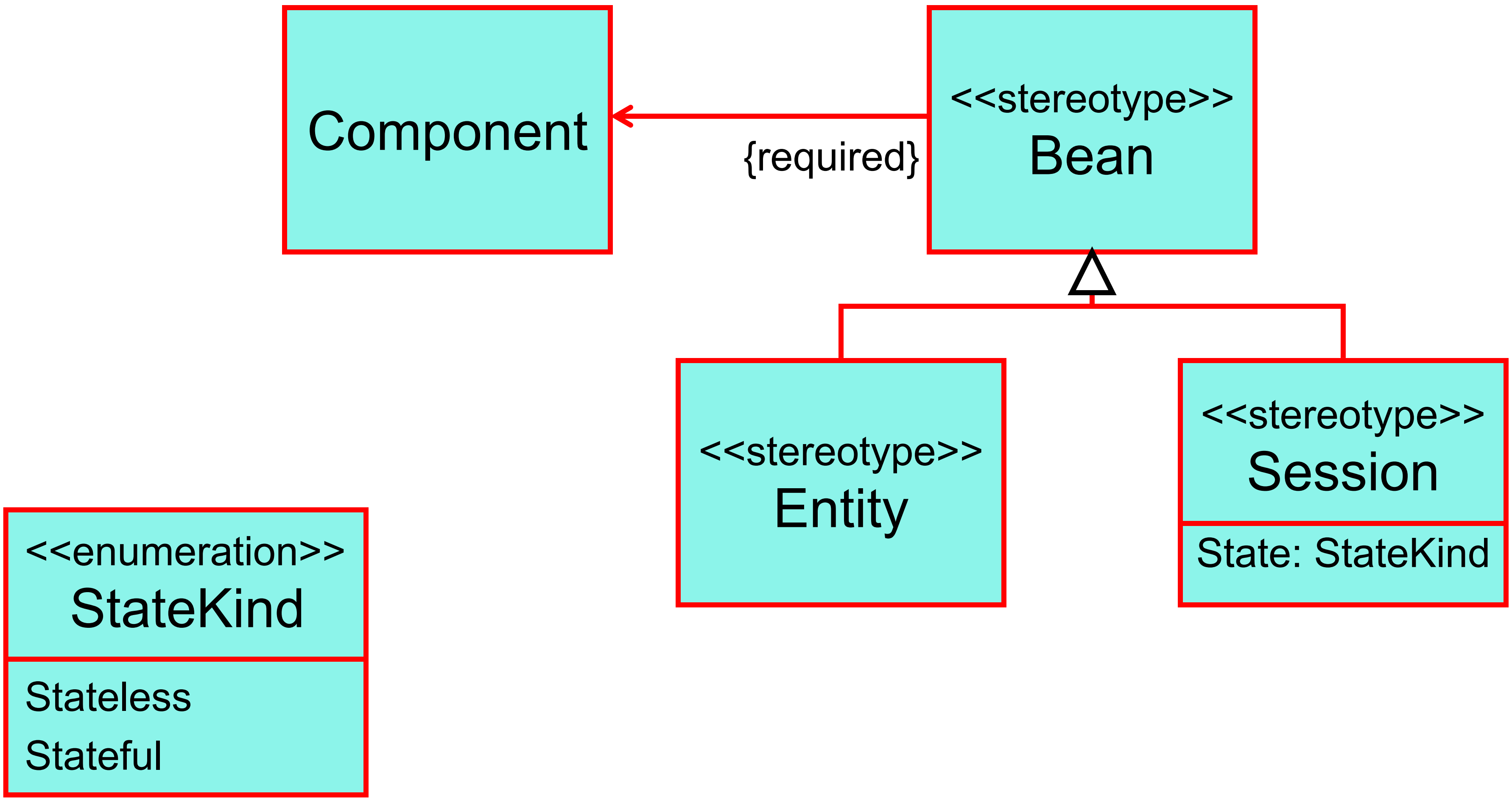

Figure 12-99: A simple EJB profile
Superstructure submission

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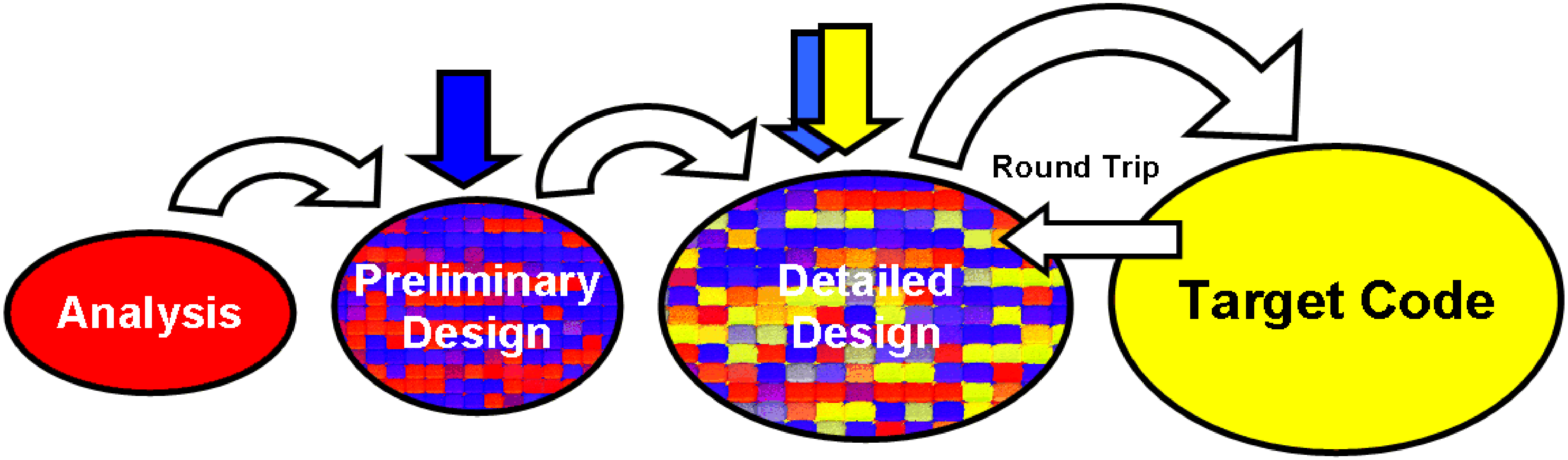
Elaborative development

Design and Architecture Details

Implementation Details and Code Bodies

Code Generation



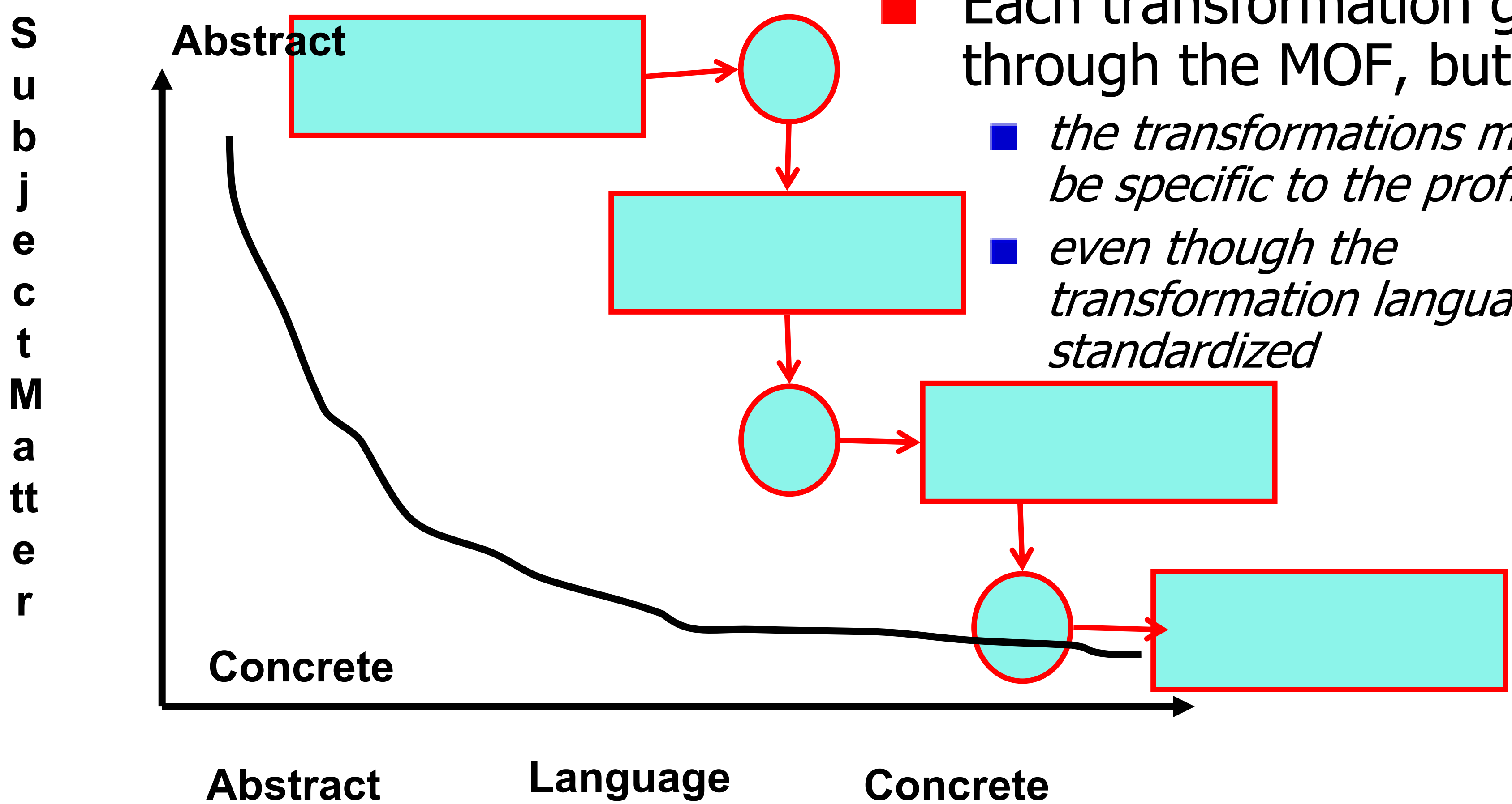
Intermixed Application and Design

Manually Created Code Bodies and Implementation Details Required for Model Execution and Code Generation

Target Code assembled from Hand-Coded Bodies inserted into a generated framework

What's wrong with that?

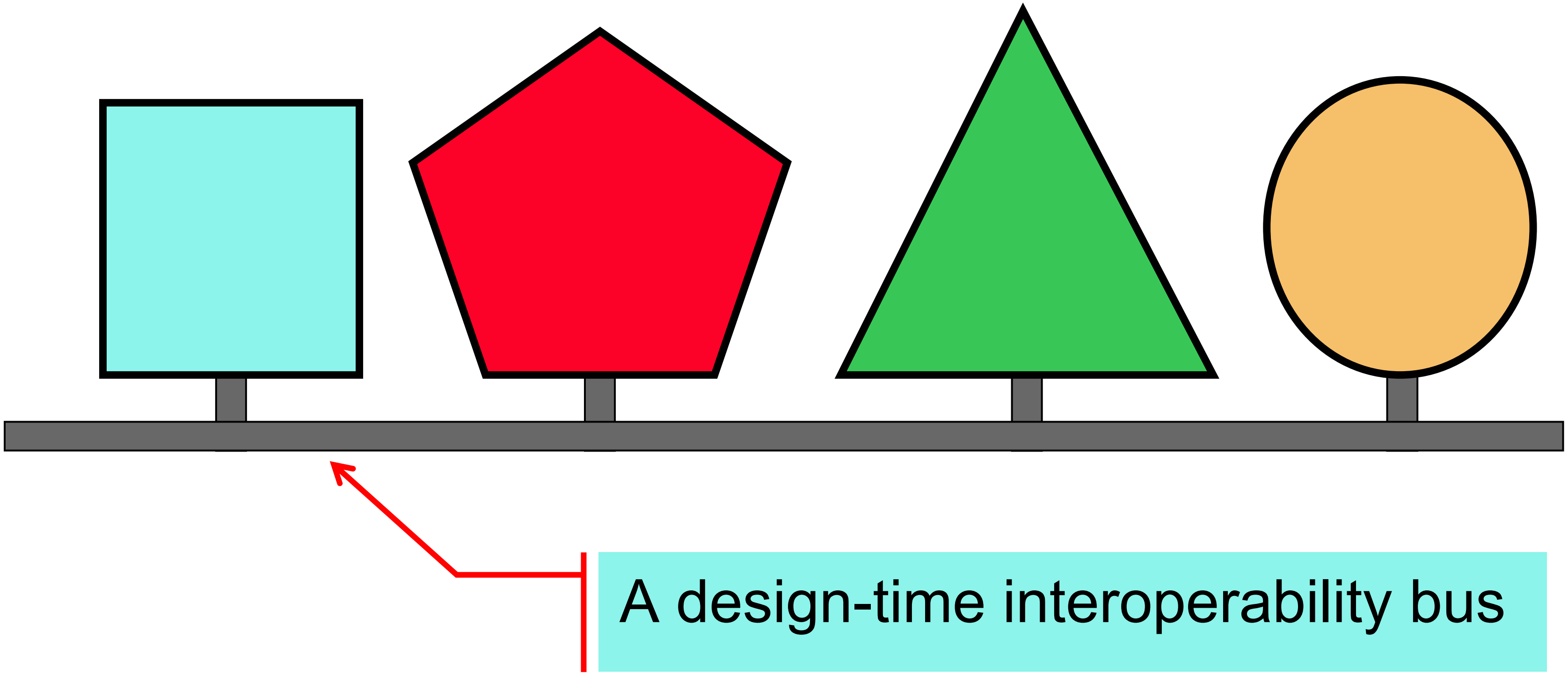
- Each meta-model demands its own profile.
- Each transformation goes through the MOF, but
  - *the transformations must be specific to the profile*
  - *even though the transformation language is standardized*



What's the solution?

Model each domain using a:

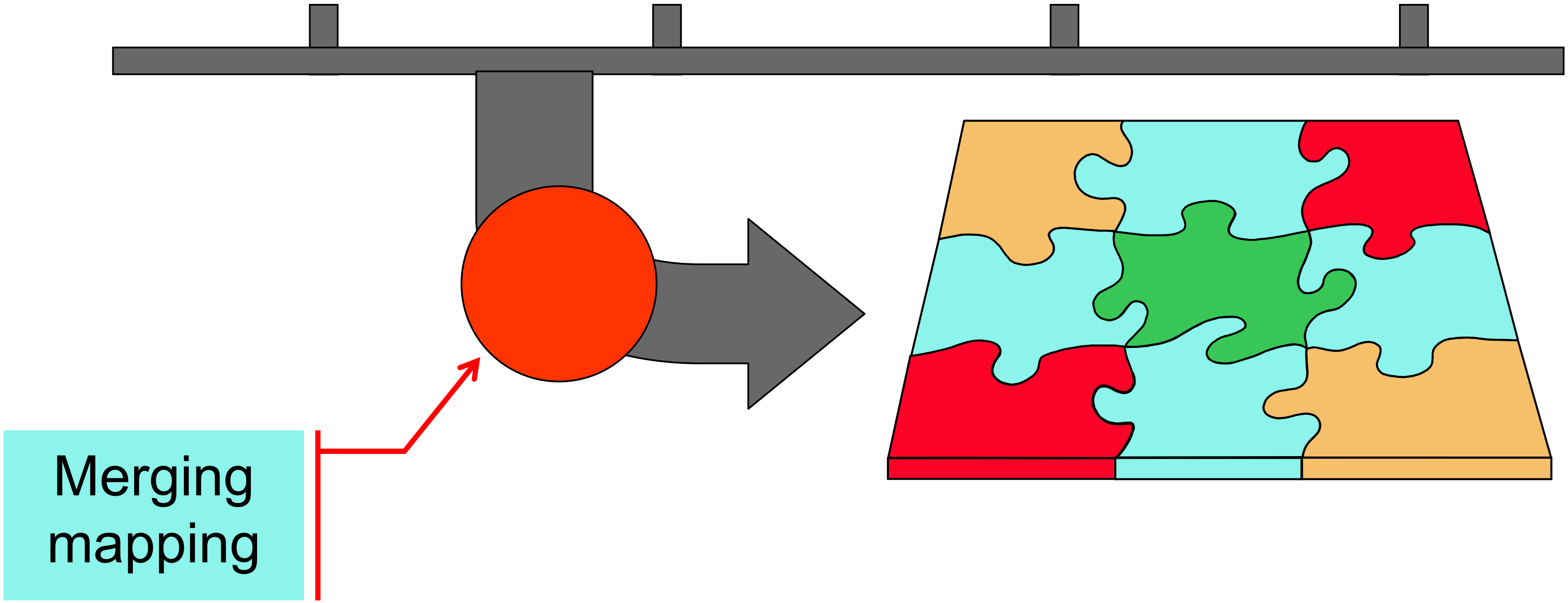
- single neutral formalism that
- (perforce) conforms to the same metamodel



What's the solution?

Connect up the models according to:

- a single set of mapping rules that
- operate on to the same metamodel



Metamodel-to-text mappings

MDA needs a way to map data from a metamodel into text.

```
.function PrivateDataMember
.param inst_ref class
.select many PDMs related by
     class->attribute[R105]
.for each PDM in PDMs
${PDM.Type} ${PDM.Name};
.endfor
.end function
```

```
.function ClassDef
.param inst_ref class
class ${class.name} :
     public ActiveInstance {
        private:
          .invoke PrivateDataMember( class )
}
...
.end function
```

We call them "archetypes".

Example

The archetype language produces text.

```
.select many stateS related to instances of
        class->[R13]StateChart ->[R14]State
            where (selected.isFinal == FALSE)
public:
  enum states_e
    { NO_STATE = 0 ,
.for each state in stateS
        .if ( not last stateS )
            ${state.Name } ,
        .else
            NUM_STATES = ${state.Name}
        .endif
.endfor
};
```

```
public:
  enum states_e
    {  NO_STATE = 0 ,
       Filling ,
       Cooking ,
       NUM_STATES = Emptying
    };
```

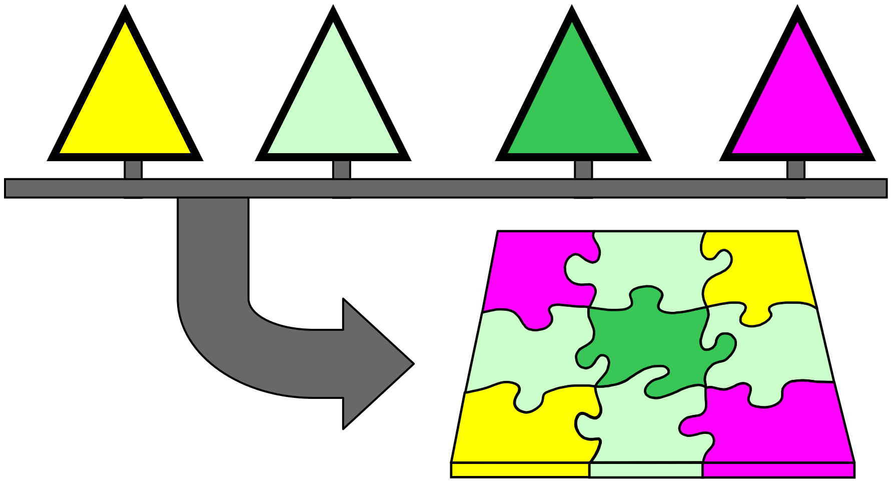
Agile MDA

- Each model we build covers a single subject matter.
- We uses the same *executable* modeling language for all subject matters.
- The executable model does not imply an implementation.
- Compose the models automatically.

This last is *design-time composability—a bus.*

Model compilers

A model compiler compiles each model according to a single set of architectural rules so that the various subject matters *are known to fit together*.

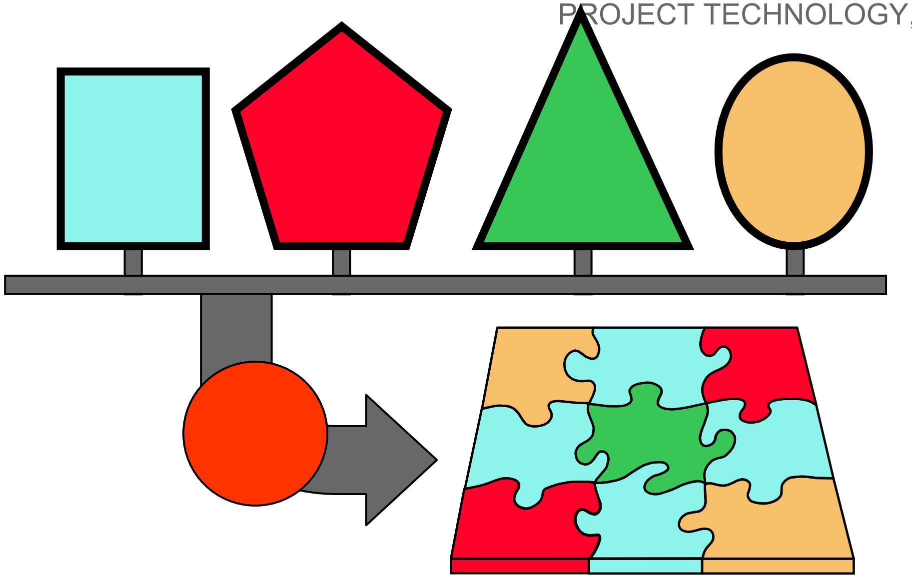


A design-time interoperability bus

A model compiler

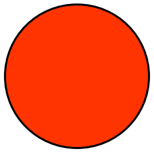
- Normalizes models to the infrastructure
- Combines models at design time.

Model compilers



System dimensions include:

- Concurrency and sequentialization
- Multi-processing & multi-tasking
- Persistence
- Data structure choices
- Data organization choices



= model compiler

Examples

Financial system

- Highly distributed
- Concurrent
- Transaction-safe with rollback
- Persistence, with rollback
- C++

Embedded system

- Single task
- No operating system
- Optimized data access and storage
- C

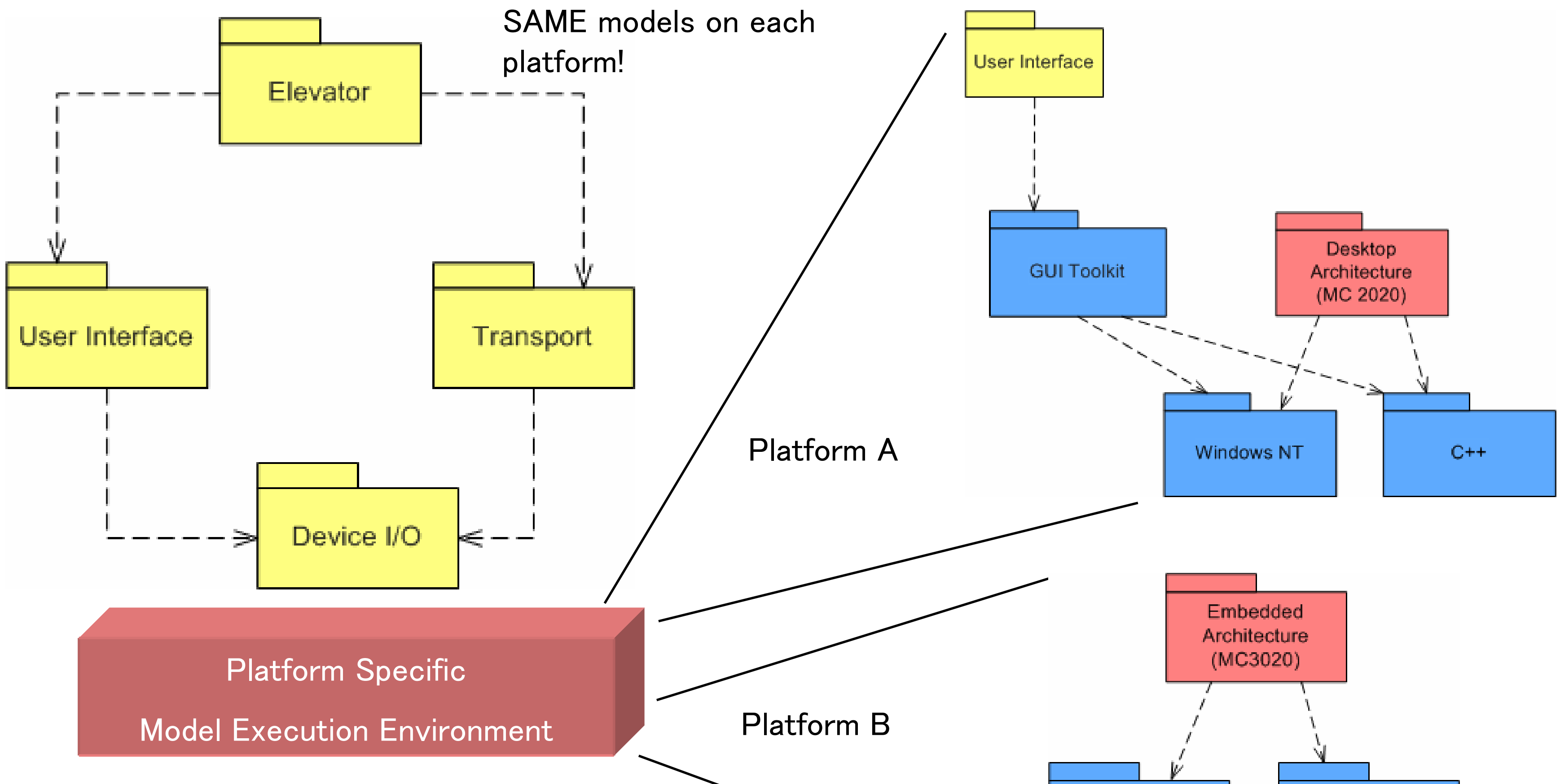
Telecommunication system

- Highly distributed
- Asynchronous
- Limited persistence capability
- C++

Simulation system

- Mostly synchronous
- Few tasks
- Special-purpose language: “Import”

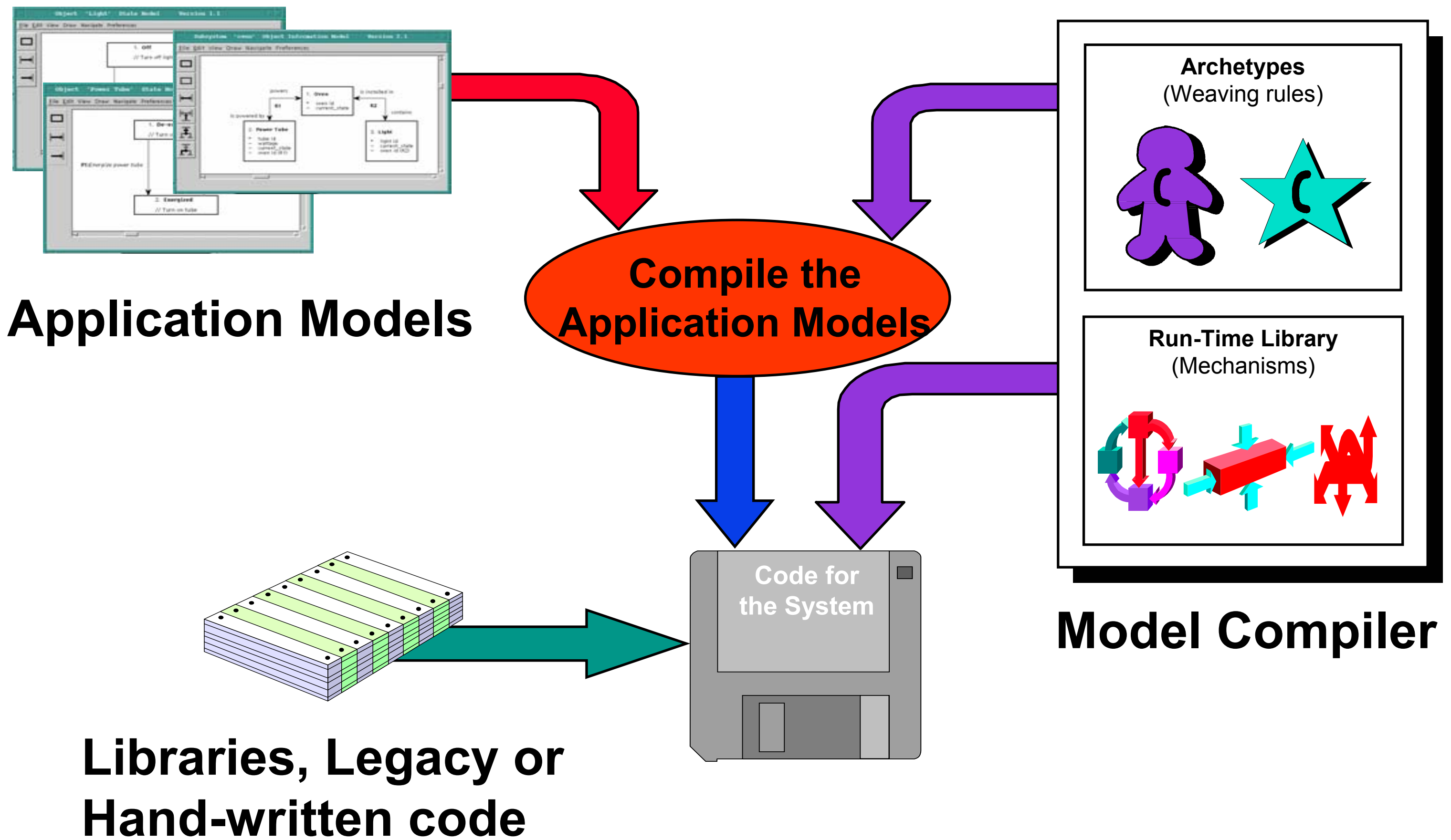
All domains are translated



Design is specific to category of platforms

Building the system

Generate deliverable production code.



Retargeting the environment

Realized in
thin
systems

Realized in
General
Purpose
Computers

Realized in
Silicon

MDA models can have multiple implementations depending on the target environment.

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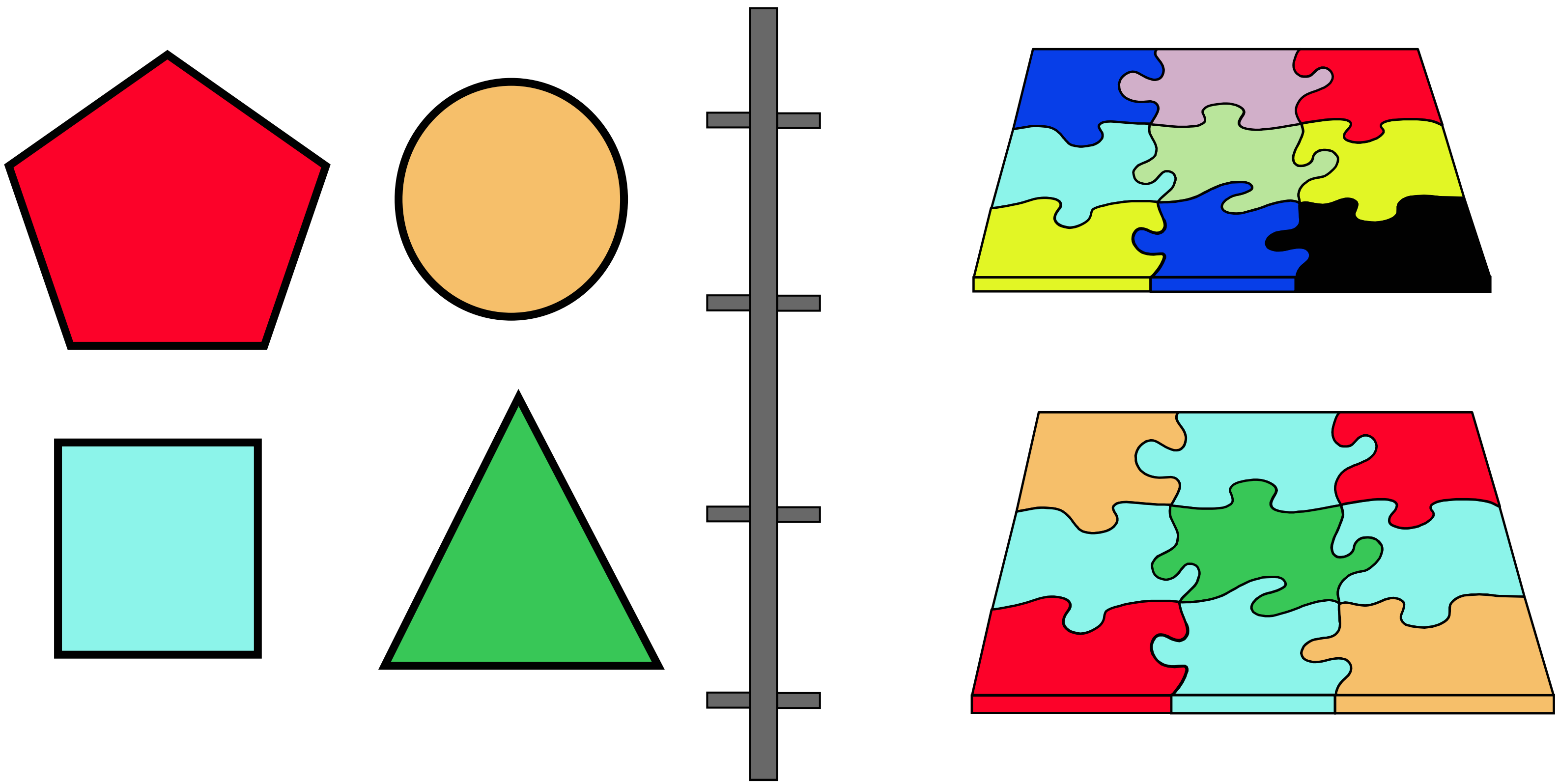
1. What’s the problem?
2. Models
3. Metamodels
4. Mappings
5. Marks
6. Representing models
7. Agile MDA
8. Conclusion

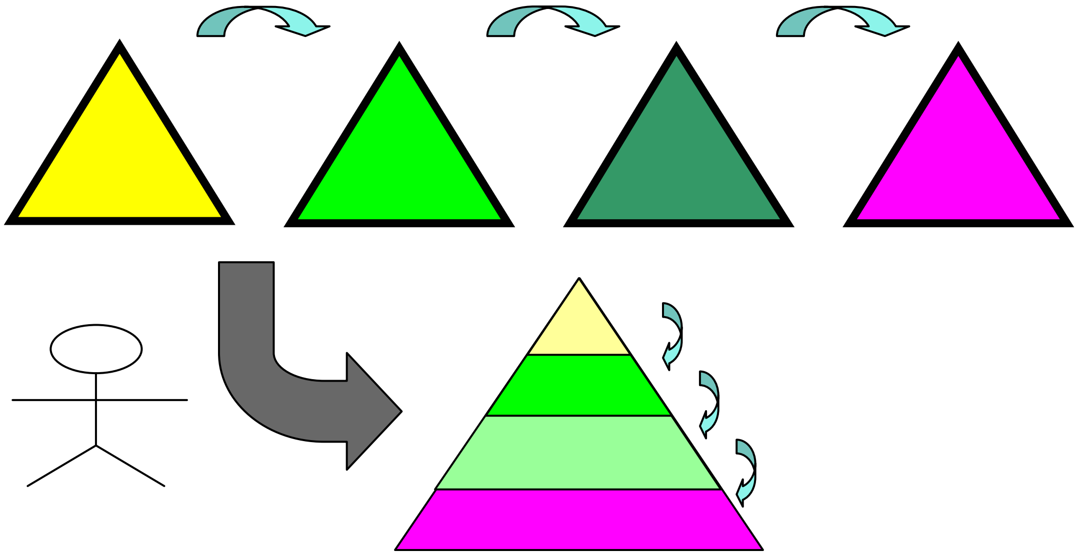
Building a market

Design time composability:

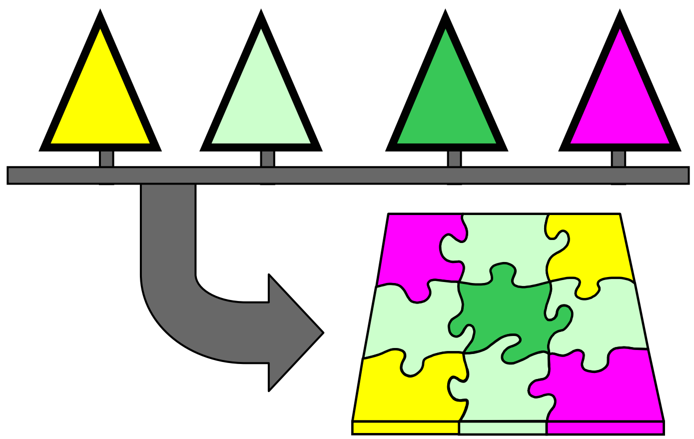
- protects IP
- allows IP to be mapped to multiple implementations
- <u>enables a market in IP in software</u>



MDA enables a market for IP in software!



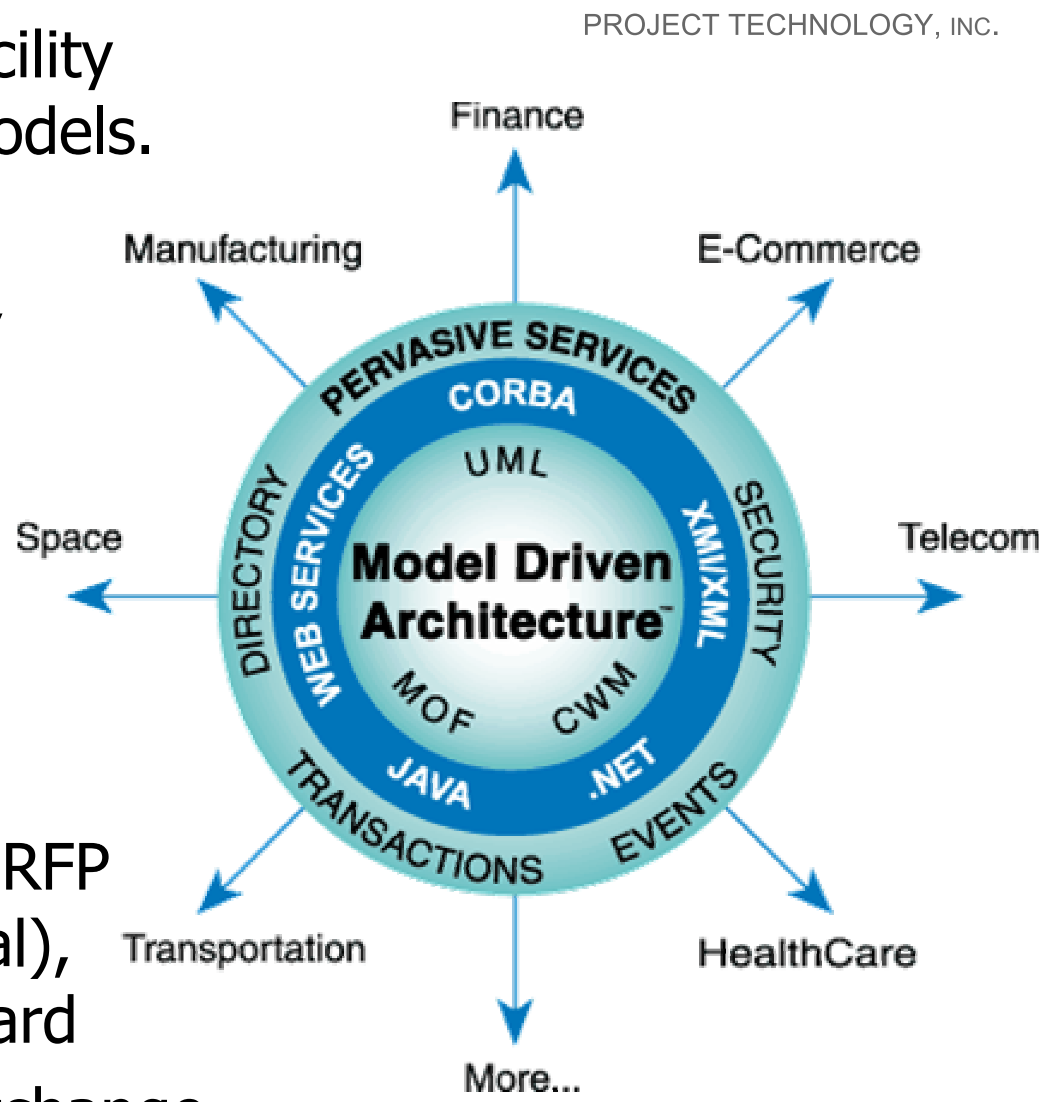
Code-driven development produces expenses.



Model-driven development produces assets.

OMG TLAs

- MOF = Meta-Object Facility
a repository for metamodels.
- CWM = Common Warehouse Metamodel, which can map between models
- QVT = Query/View/ Transform, a standard for mapping between (MOF) metamodels
  - This is presently an RFP (request for proposal), and not yet a standard
- XMI = XML Model Interchange



MDA standardization

UML 2.0 Infrastructure	Jan 2003
QVT (metamodel-metamodel)	Mar 2003
Marks	Understood
Action Language	Necessary?
Archetypes (metamodel-text)	Not yet

The ADTF and the MDA WG proposes these RFPs.

See also

MDA Distilled, Mellor, Scott, Uhl and Weise
Addison-Wesley, 2003

Executable UML, Mellor and Balcer,
Addison-Wesley, 2003

www.omg.org

www.projtech.com

MDA Distilled

MDA Distilled

- Started in earnest in March 2002
- First four chapters sent for review in July 2002
- Chapters 5-9 sent for review February 2003
- Meeting to complete last five chapters June 2003
- Review complete by July 2003
- `“I have scheduled your book to go into production on 8/1/03.”`
  `(i.e. 2003-08-01)`

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