IBM Software Group

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UML 2: A Key MDA Technology

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Agenda

- The Setting: Model-Driven Development (MDD)
- UML 2 Highlights and Related Work
- State of the Art in MDD

A Bit of Modern Software…

```
SC_MODULE(producer)
{
sc_outmaster<int> out1;
sc_in<bool> start; // kick-start
void generate_data ()
{
for(int i =0; i <10; i++) {
out1 =i ; //to invoke slave;}
}
SC_CTOR(producer)
{
SC_METHOD(generate_data);
sensitive << start;}};
SC_MODULE(consumer)
{
sc_inslave<int> in1;
int sum; // state variable
void accumulate (){
sum += in1;
cout << “Sum = “ << sum << endl;}
SC_CTOR(consumer)
{
SC_SLAVE(accumulate, in1);
sum = 0; // initialize
};
SC_MODULE(top) // container
{
producer *A1;
consumer *B1;
sc_link_mp<int> link1;
SC_CTOR(top)
{
A1 = new producer(“A1”);
A1.out1(link1);
B1 = new consumer(“B1”);
B1.in1(link1);}};
```

Can you see the architecture?

...and its Model

Can you see it now?

The Model and the Code

```
SC_MODULE(producer)
{
sc_outmaster<int> out1;
sc_in<bool> start; // kick-start
void generate_data ()
{
for(int i =0; i <10; i++) {
out1 =i ; //to invoke slave;}
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sensitive << start;}};
SC_MODULE(consumer)
{
sc_inslave<int> in1;
int sum; // state variable
void accumulate (){
sum += in1;
cout << "Sum = " << sum << endl;}
```
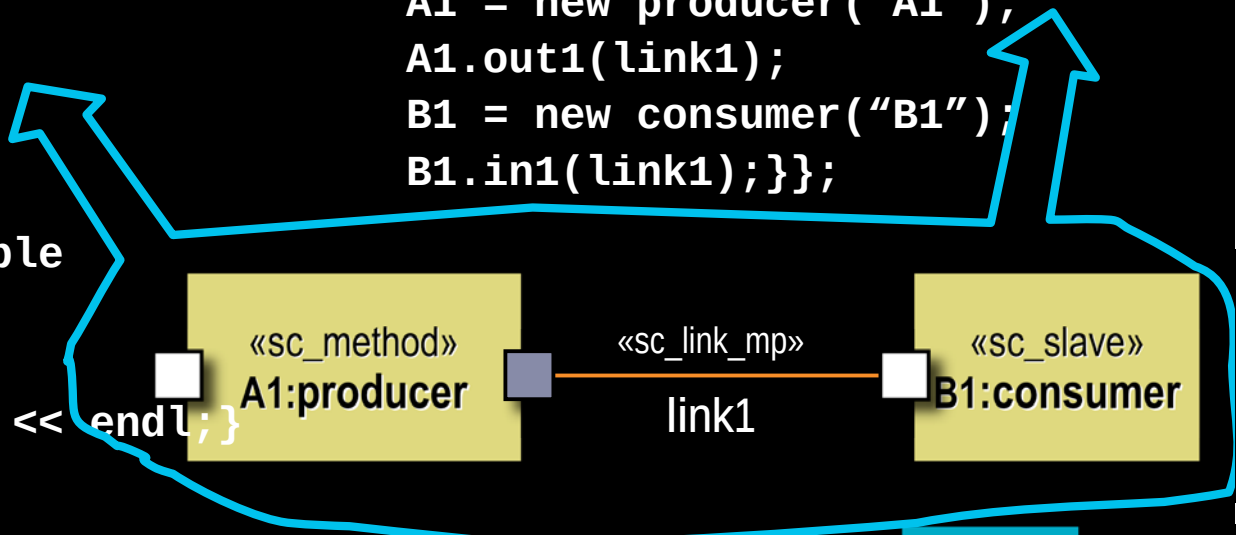

```
SC_CTOR(consumer)
{
SC_SLAVE(accumulate, in1);
sum = 0; // initialize
};
SC_MODULE(top) // container
{
producer *A1;
consumer *B1;
sc_link_mp<int> link1;
SC_CTOR(top)
{
A1 = new producer("A1");
A1.out1(link1);
B1 = new consumer("B1");
B1.in1(link1);}};
```

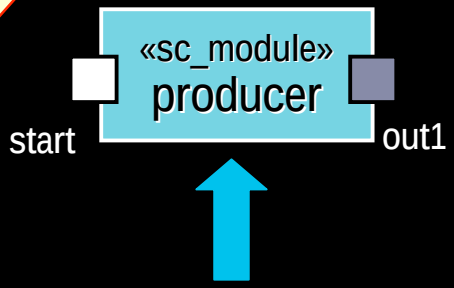


Model-Driven Development (MDD)

- An approach to software development in which the focus and primary artifacts of development are models (vs programs)
- Based on two time-proven methods:

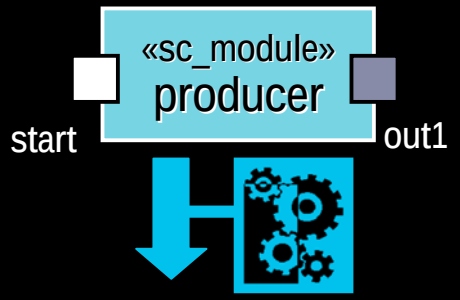
(1) ABSTRACTION

Realm of modeling languages




```
SC_MODULE(producer)
{sc_inslave<int> in1;
int sum; //
void accumulate (){
sum += in1;
cout << "Sum = " << sum
<< endl;}
```

(2) AUTOMATION



Realm of tools

```
SC_MODULE(producer)
{sc_inslave<int> in1;
int sum; //
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cout << "Sum = " << sum
<< endl;}
```
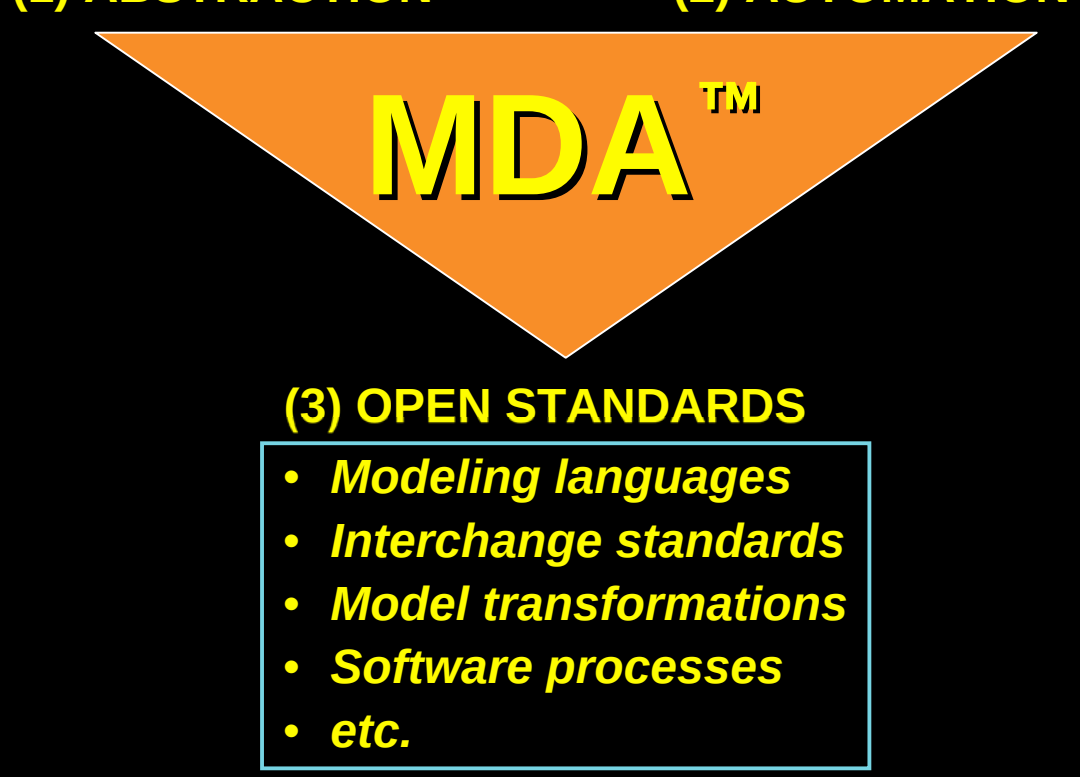
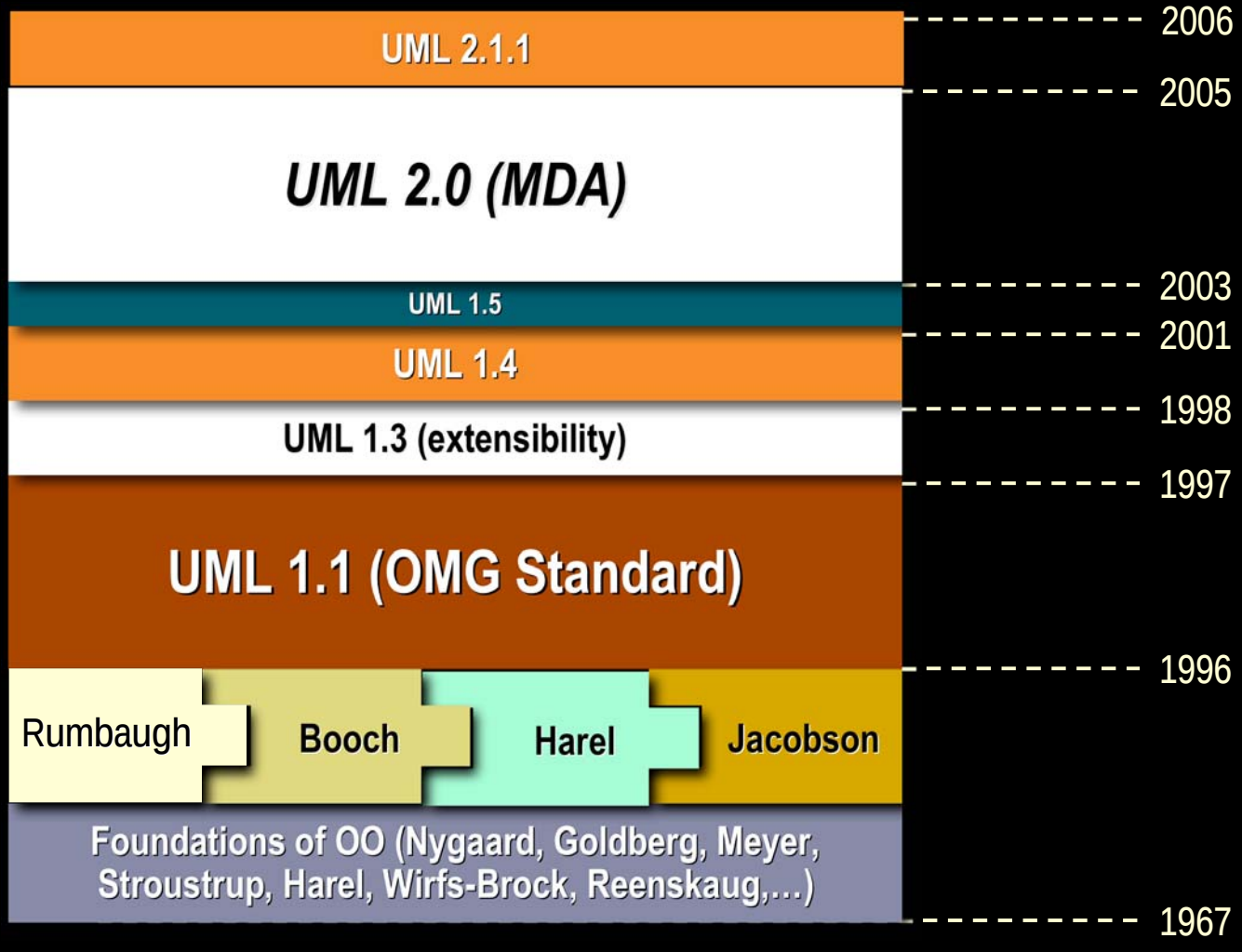

Model-Driven Architecture (MDA)

- An OMG initiative to support model-driven development through a series of open standards



UML: The Foundation of MDA



Agenda

- The Setting: Model-Driven Development (MDD)
- UML 2 Highlights and Related Work
- State of the Art in MDD

What is UML For?

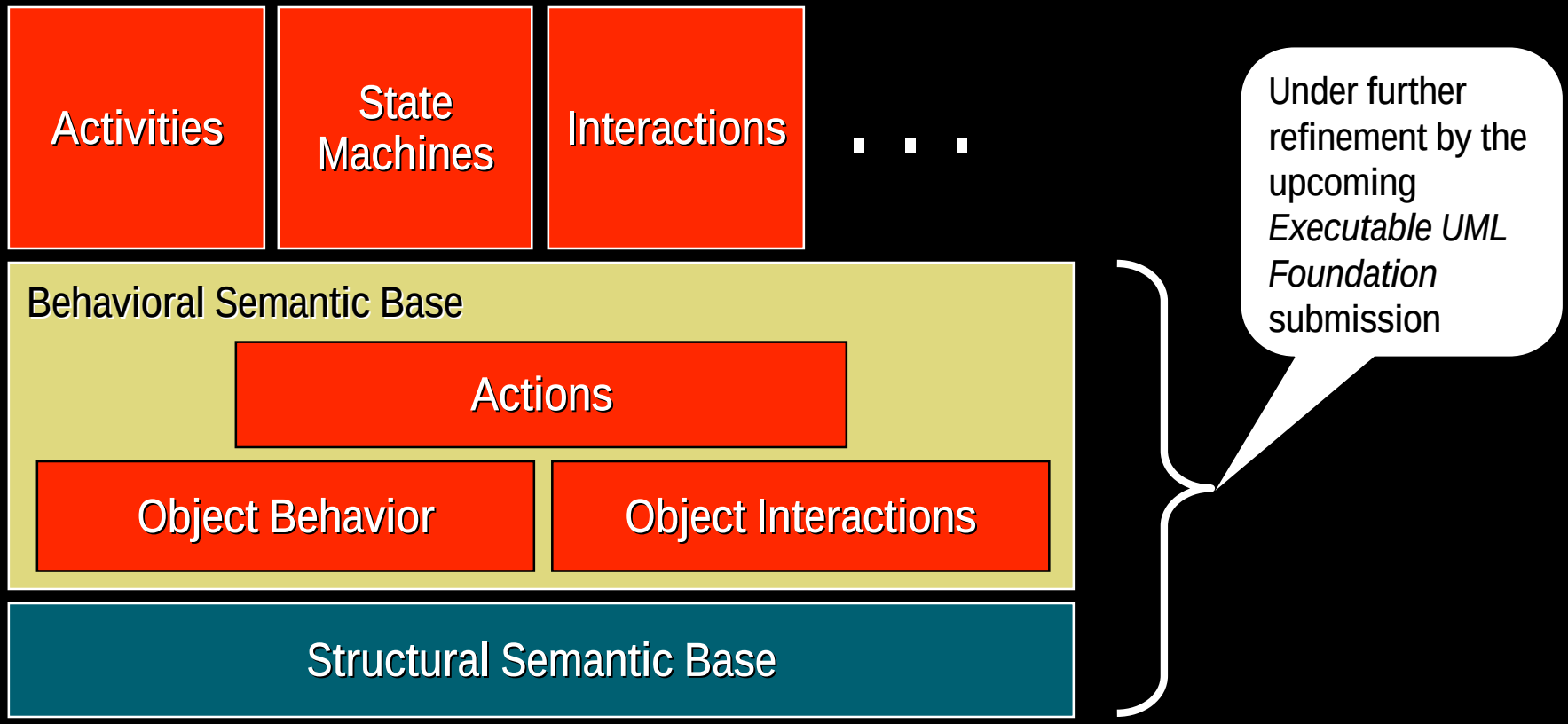
- For modeling *software systems* and their contexts
  - Using concepts from the world of object-oriented languages (class, operation, object, etc.)
- However, the general nature of these concepts makes UML suitable for extension to other and broader domains
  - E.g. systems engineering (SysML, UPDM)

UML 2 Highlights

- Greatly increased level of precision to better support MDD
  - More precise definition of concepts and their relationships
  - Extended and refined definition of semantics
- New language architecture
  - Highly modularized structure for incremental adoption
  - Greatly simplified compliance model for easier tools interchange
- Improved support for modeling large-scale software systems
  - Modeling of complex software structures (architectural description language)
  - Modeling of complex end-to-end behavior
  - Modeling of distributed, concurrent process flows (e.g., business processes, complex signal processing flows)
- Greatly improved support for defining domain-specific languages (DSLs)
- Consolidation and rationalization of existing concepts

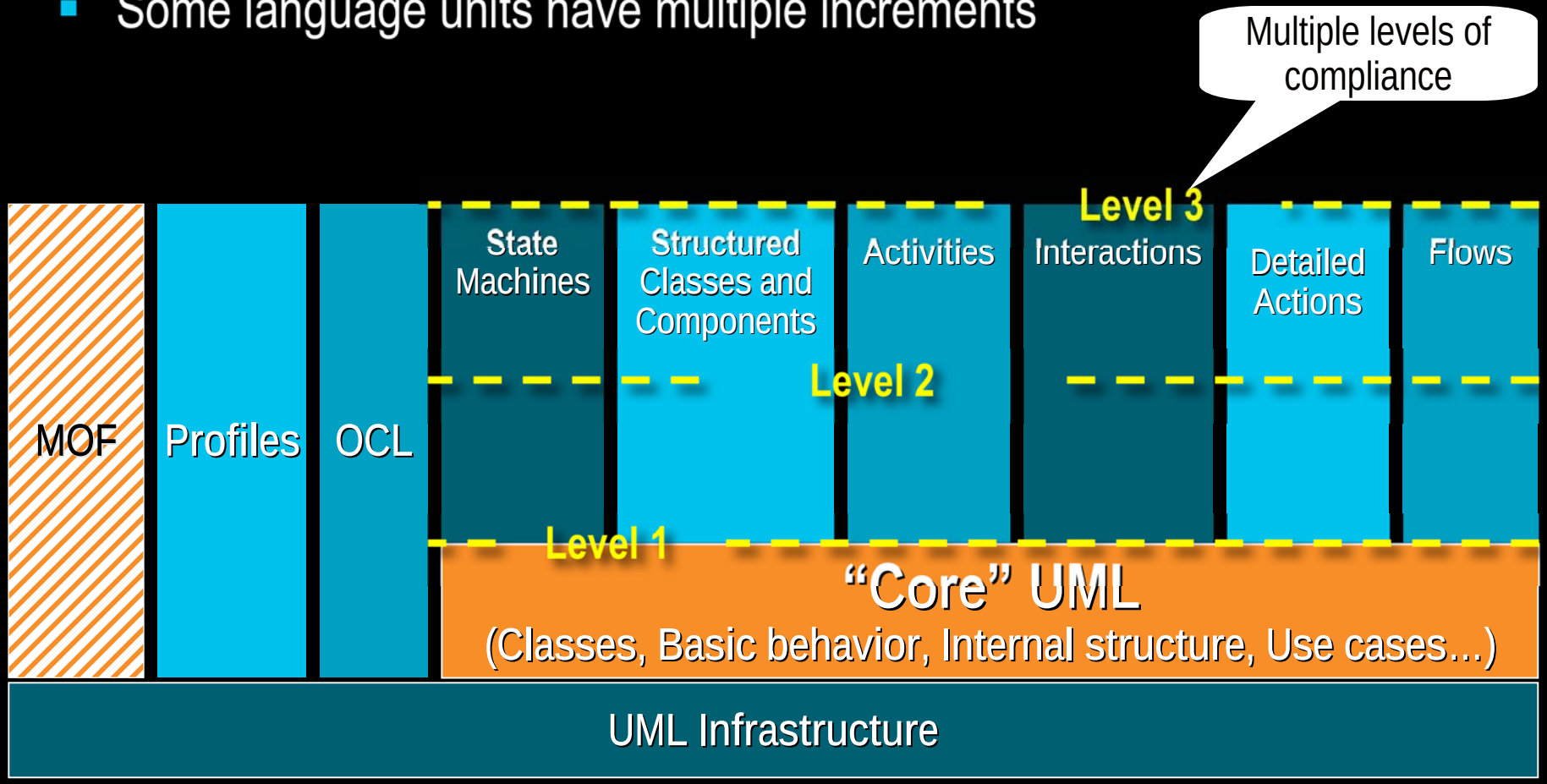
UML 2 Semantics

- A layered and modularized semantics base



The New UML 2 Language Architecture

- A core language + a set of optional "language units"
  - Some language units have multiple increments

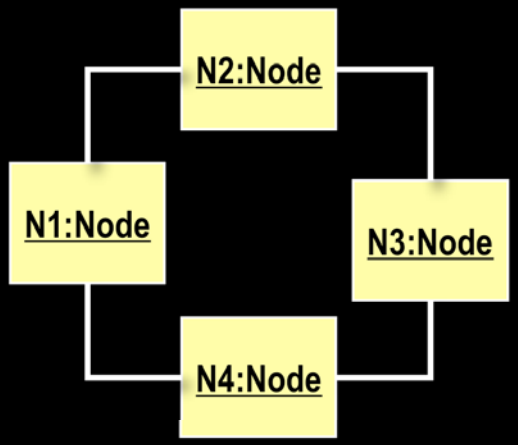


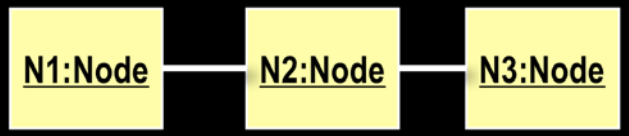
UML Compliance

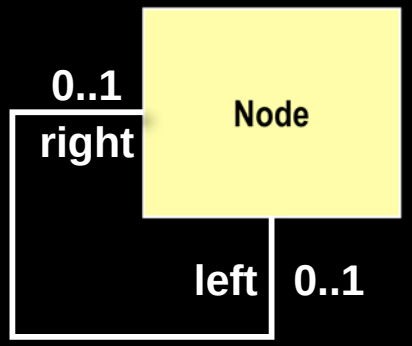
- 4 levels of compliance (L0 – L3)
  - compliance(L_x) ⇒ compliance (L_{x-1})
- Dimensions of compliance:
  - Abstract syntax (UML metamodel, XMI interchange)
  - Concrete syntax
    - Optional Diagram Interchange compliance
- Forms of compliance
  - Abstract syntax
  - Concrete syntax
  - Abstract and concrete syntax
  - Abstract and concrete syntax with diagram interchange

Are Class Diagrams Sufficient for Modeling Structure?

- Not always!
  - Because they abstract out certain specifics, class diagrams are not suitable for performance analysis
- Sometimes it is necessary to model structure at the instance level



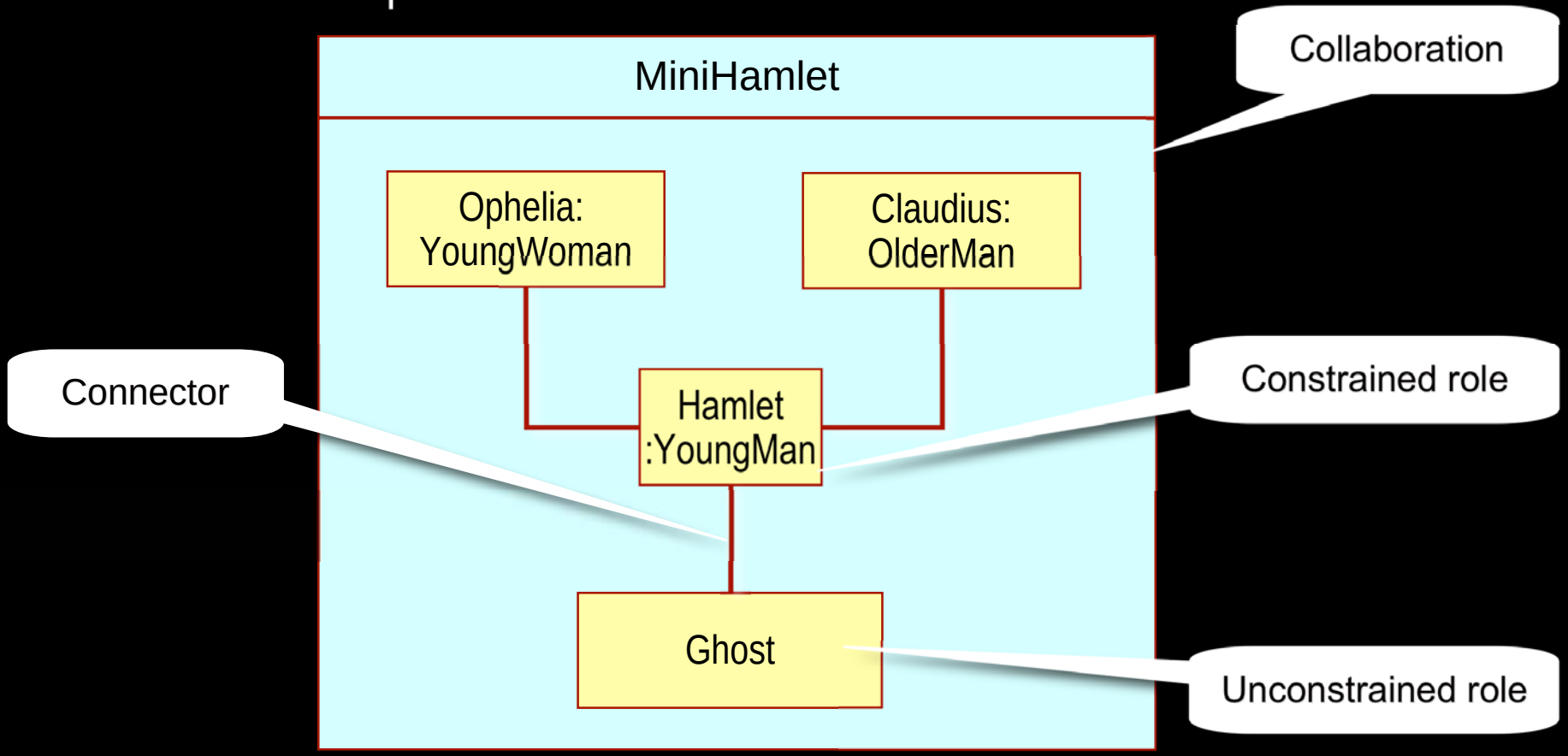




Same class diagram describes both systems!

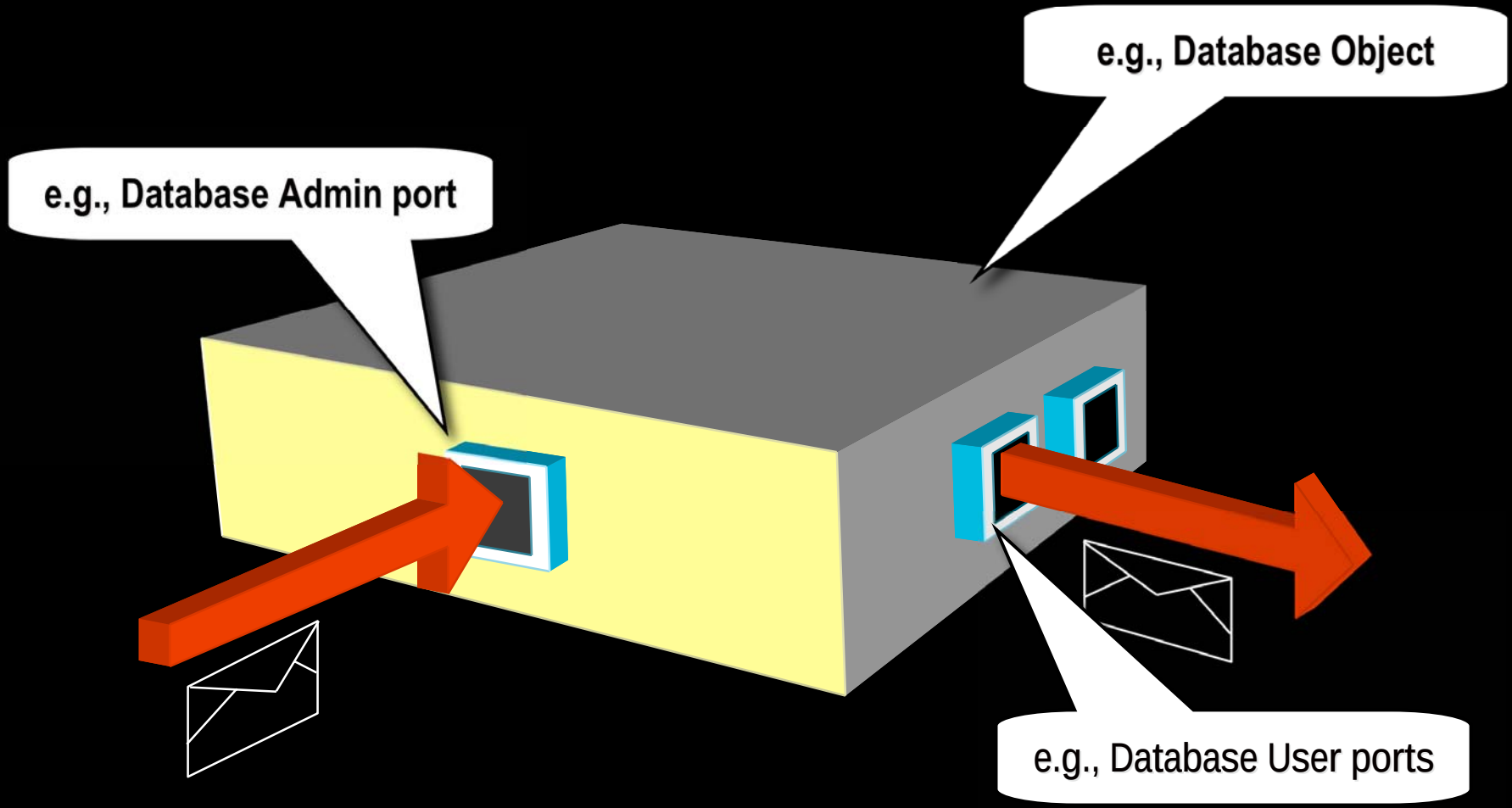
Collaboration Diagrams: Modeling Instance Structures

- A UML collaboration describes a set of communicating "roles"
  - Roles represent instances but abstract away specifics of instances
    ⟹ generic instance diagrams = *patterns*
  - Connectors represent communication links



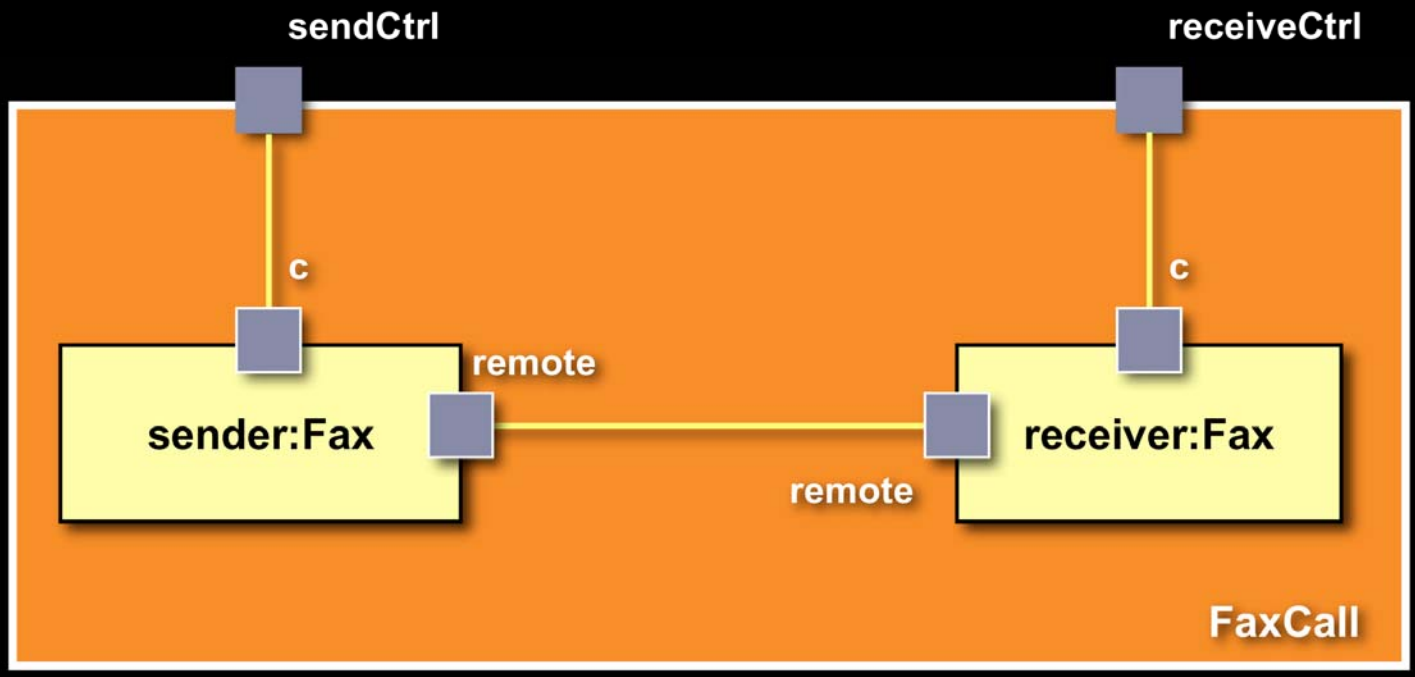
Structured Objects: External View

- Multiple points of interaction
  - Each dedicated to a particular purpose



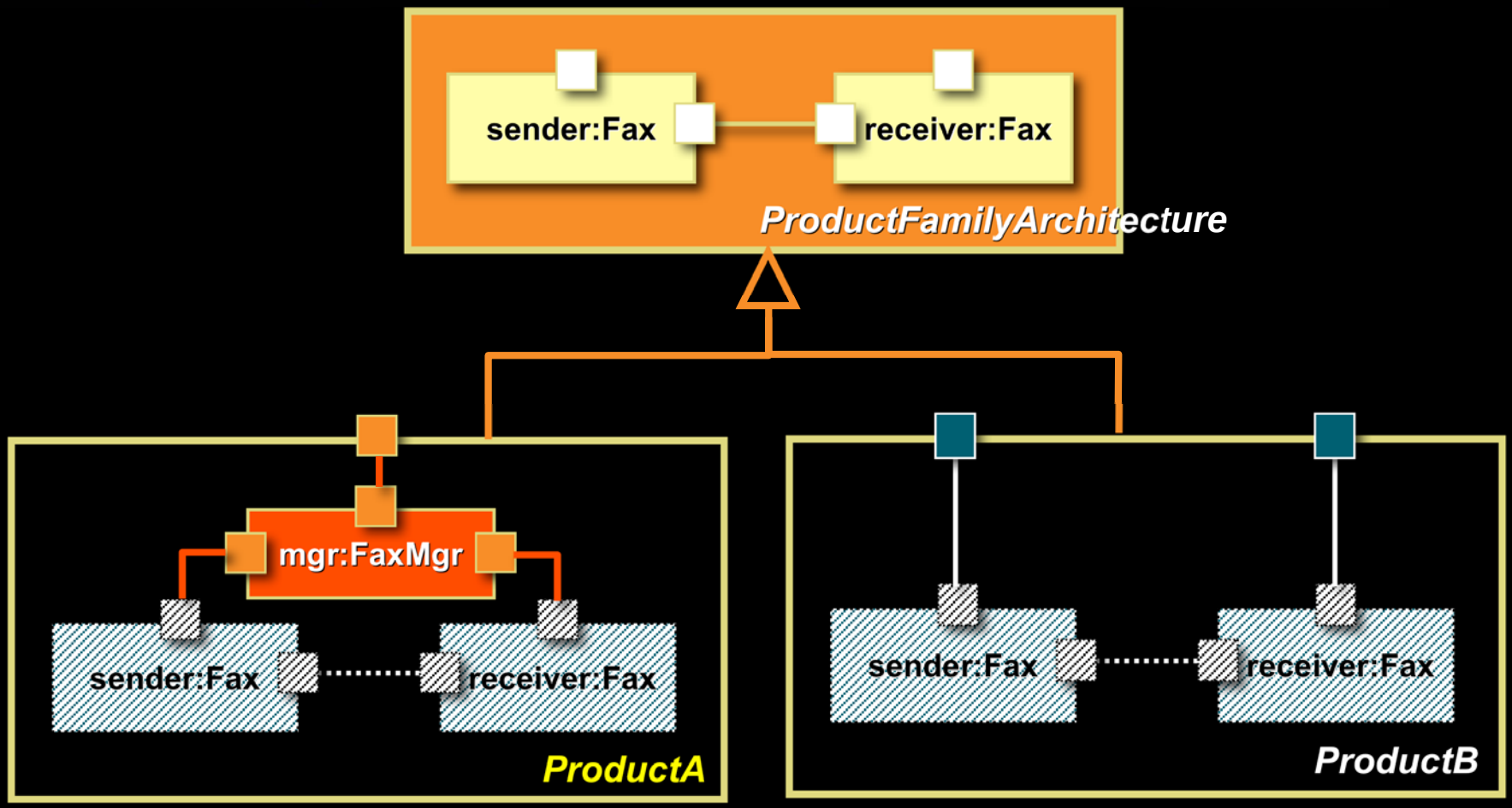
Structured Classes: Internal Structure

- Structured classes may contain an internal collaboration structure that represents its implementation



Architecture Refinement Through Inheritance

- Using standard inheritance mechanism (design by difference)

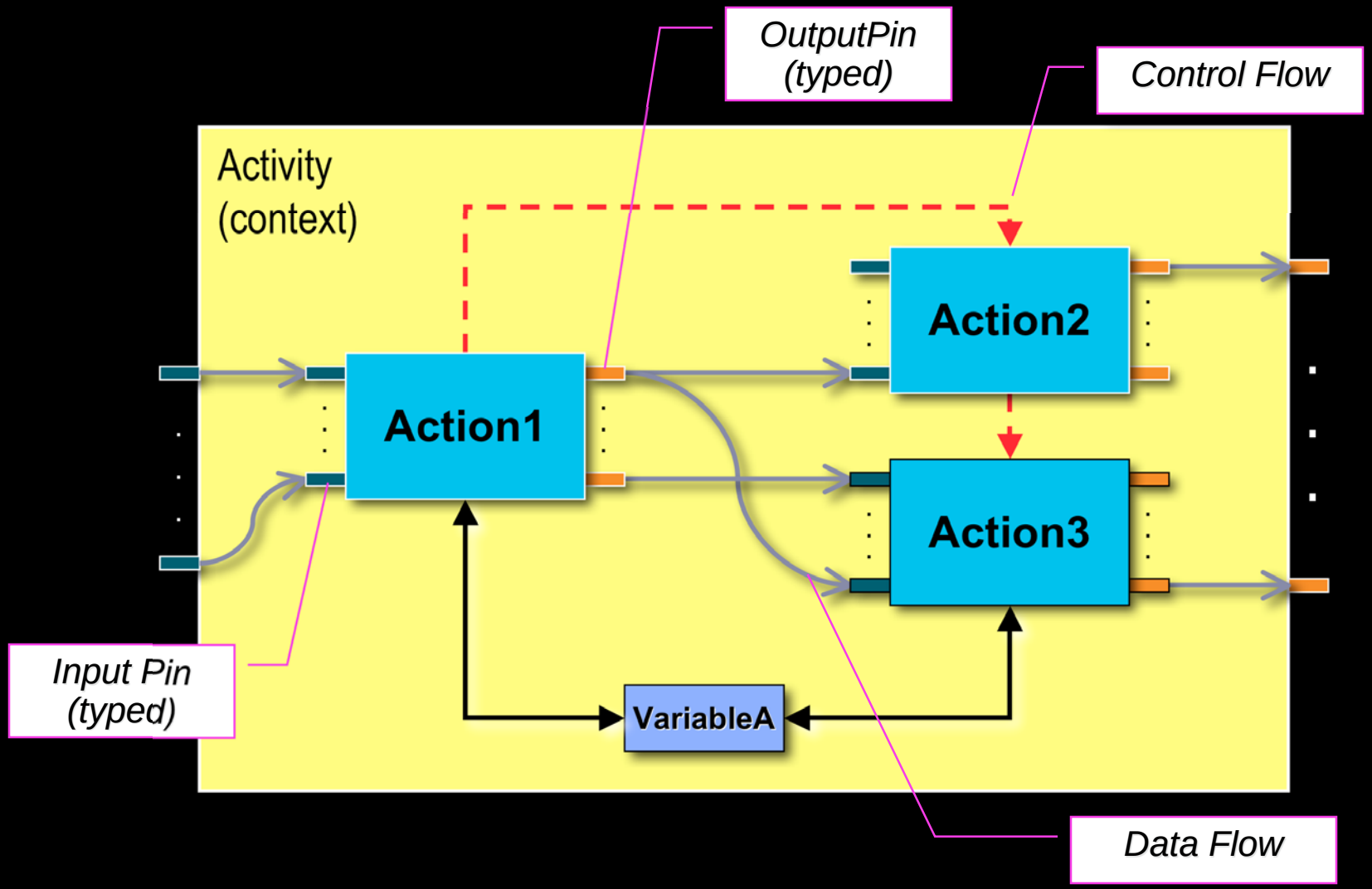


Categories of Actions

- For modeling fine-grained behavior
  - UML 2 unified the action and activity modeling paradigms
- Categories of Actions
  - Communication actions (send, call, receive,…)
  - Primitive function action
  - Object actions (create, destroy, reclassify,start,…)
  - Structural feature actions (read, write, clear,…)
  - Link actions (create, destroy, read, write,…)
  - Variable actions (read, write, clear,…)
  - Exception action (raise)

UML 2: Action and Activity Basics

- Support for multiple computational paradigms



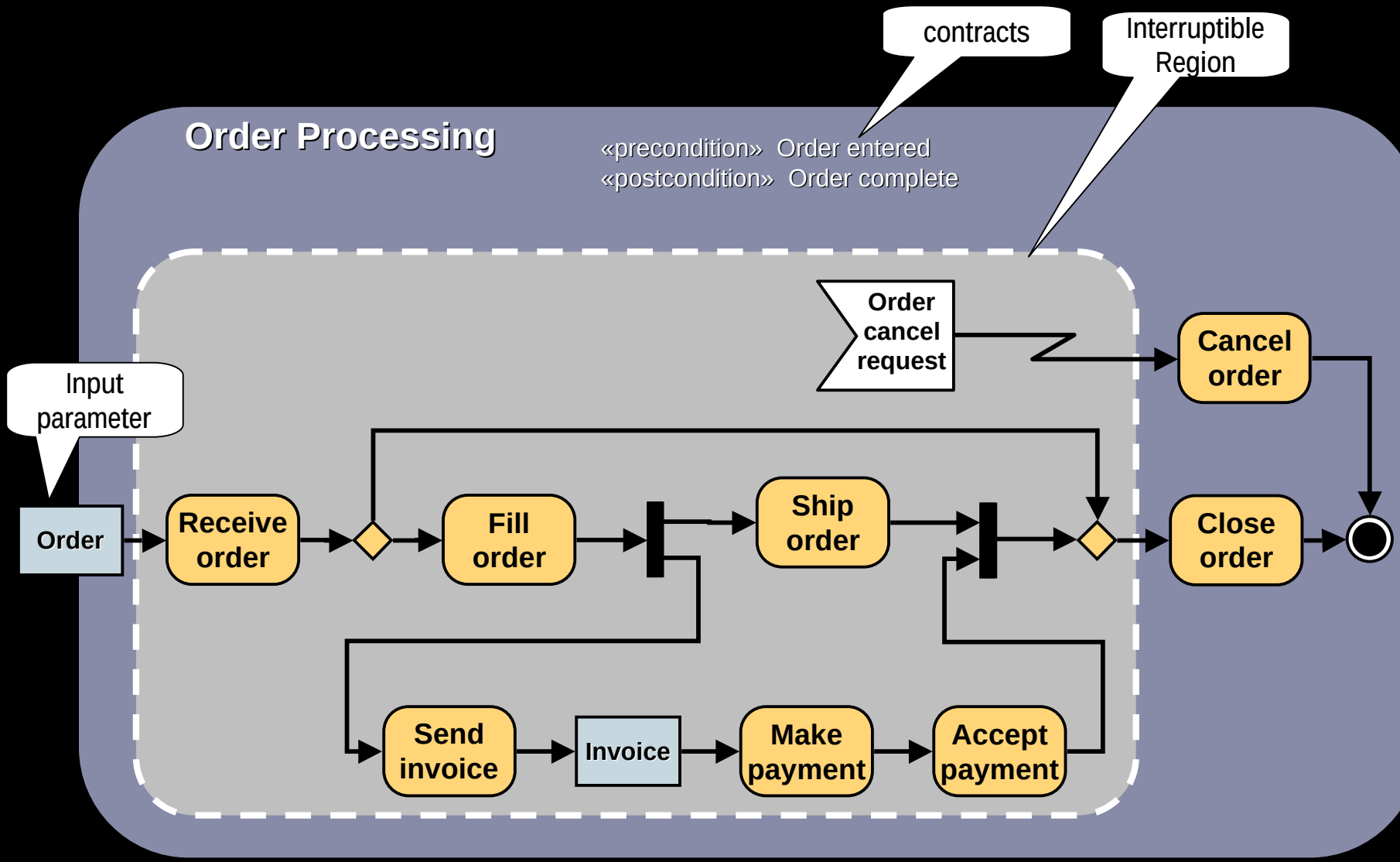
Activities

- Major influences for UML 2 activity semantics
  - Business Process Execution Language for Web Services (BPEL4WS) – a de facto standard supported by key industry players (Microsoft, IBM, etc.)
  - Functional modeling from the systems engineering community (INCOSE)
- Significantly enriched in UML 2
  - More flexible semantics for greater modeling power
  - Many new features

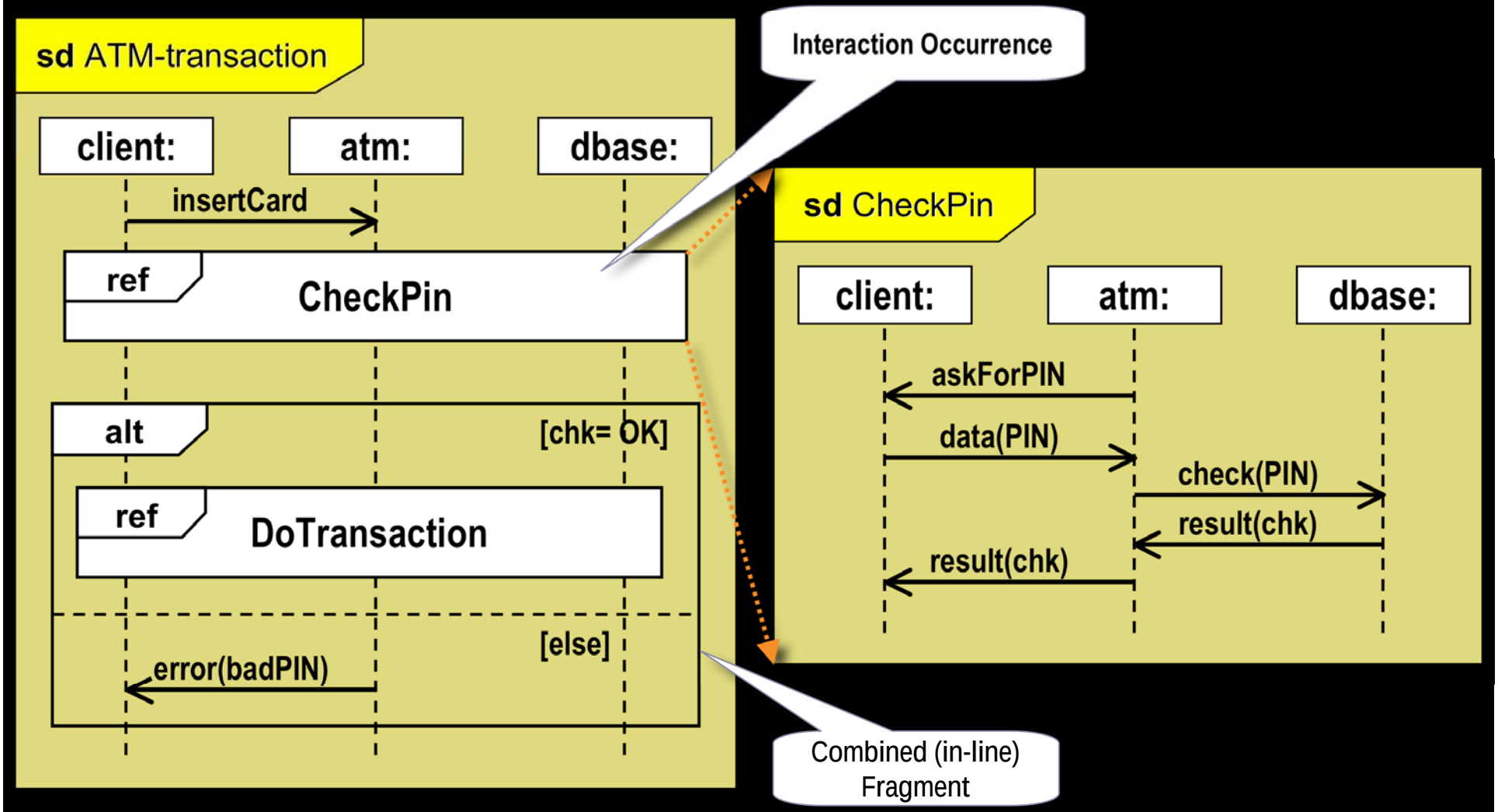
Activities

- For modeling procedural behavior
  - Similar to flowcharts, but…
  - …includes support for concurrency modeling (parallel behaviors)
  - Based on the Petri Net formalism
- "Higher-level" actions
  - Shares same conceptual model as actions:
    - Control and data flows
    - Potential concurrent execution
    - Pins (parameters)
- Can be nested hierarchically to an arbitrary depth
  - Like procedures in traditional programming languages

Activity Example



UML 2 Interactions Modeling



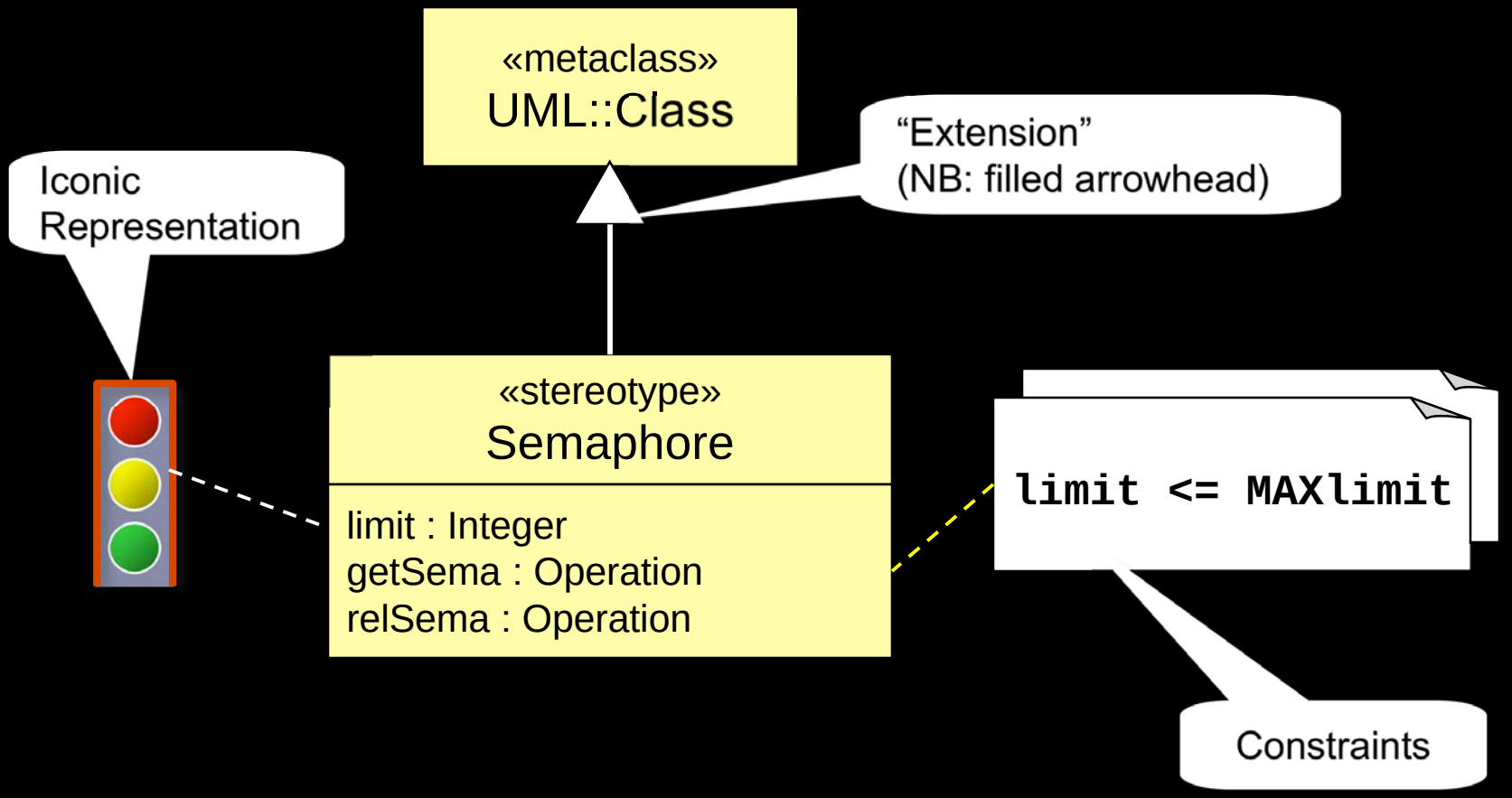
OMG's UML as a Platform for DSMLs

- Designed as a "family of modeling languages"
  - Contains a set of *semantic variation points* (SVPs) where the full semantics are either unspecified or ambiguous
  - SVP examples:
    - Precise type compatibility rules
    - Communications properties of communication links (delivery semantics, reliability, etc.)
    - Multi-tasking scheduling policies
  - Enables domain-specific customization

Success Criteria for a Computer Language

- Technical validity: absence of major design flaws and constraints (ease of writing correct programs)
- Expressiveness: ability to succinctly specify the necessary domain concepts
- Simplicity: absence of complexity (eases learning)
- Efficiency: potential to minimize space and performance overheads
- Familiarity: proximity to widely-available skills sets
- Interoperability: language compatible with other technologies
- Support: availability of the infrastructure required for effective exploitation
  - Availability of *effective* tools (editors, compilers, debuggers, static and dynamic analyzers, build tools, version control tools, merge/diff tools, etc.)
  - Availability of program libraries
  - Availability of skilled practitioners
  - Availability of textbooks and training courses
  - Institutions for evolution and maintenance

Example: Adding a Semaphore Concept to UML



UML Profiles

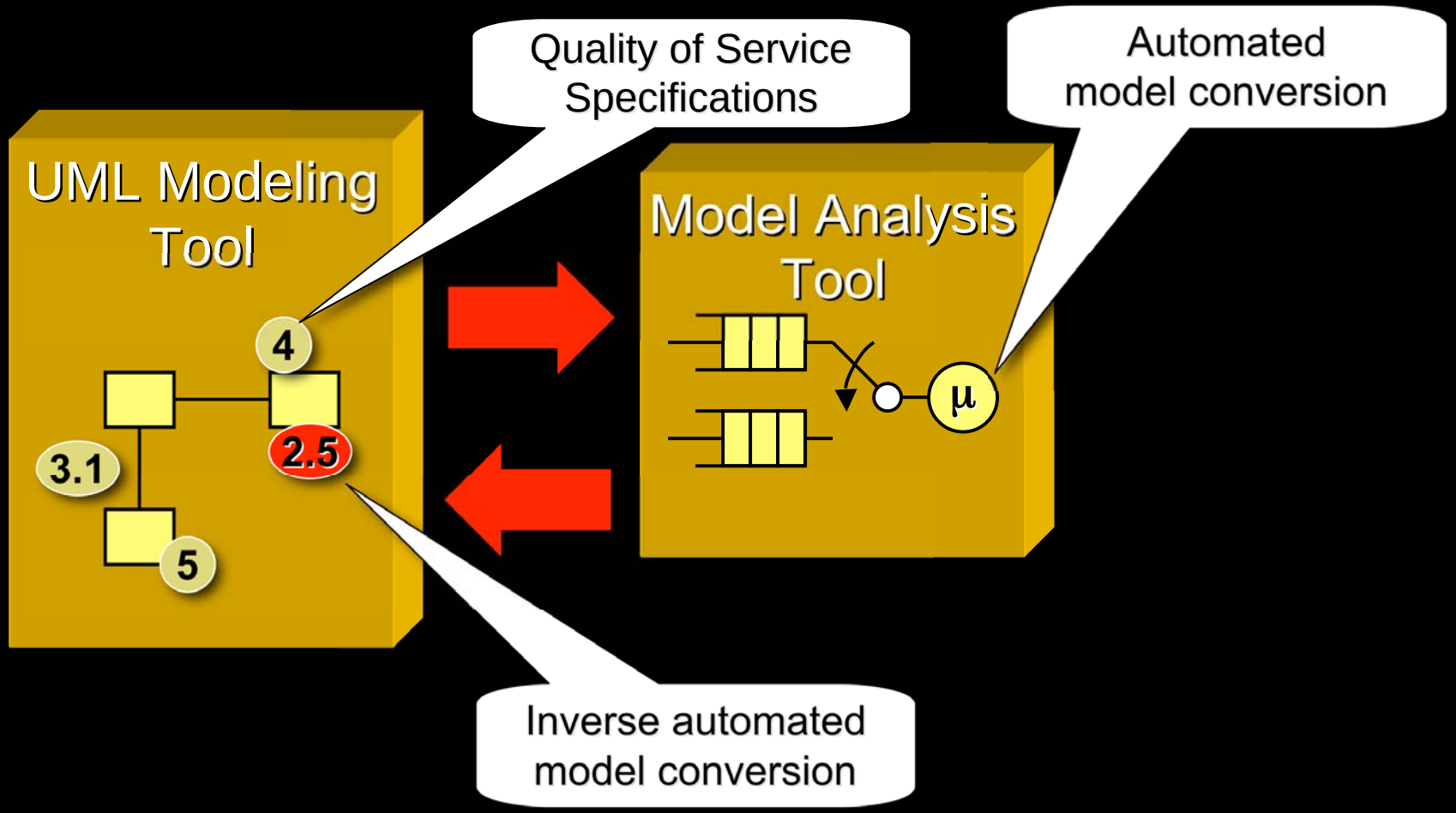
- Profile:
  - A special kind of package containing stereotypes and model libraries that, in conjunction with the UML metamodel, define a group of domain-specific concepts and relationships
  - The profile mechanism is also available in MOF where it can be used for other MOF-based languages
- Profiles can be used for two different purposes:
  - To define a domain-specific modeling language
  - To define a domain-specific viewpoint

Current Catalog of OMG Profiles

- UML Profile for CORBA
- UML Profile for CORBA Component Model (CCM)
- UML Profile for Enterprise Application Integration (EAI)
- UML Profile for Enterprise Distributed Object Computing (EDOC)
- UML Profile for Modeling QoS and Fault Tolerance Characteristics and Mechanisms
- UML Profile for Schedulability, Performance, and Time
- UML Profile for System on a Chip (SoC)
- UML Profile for Systems Engineering (SysML)
- UML Testing Profile
- New profiles
  - UML profile for Modeling and Analysis of Real-Time and Embedded Systems (MARTE)
  - UML profile for DoDAF/MoDAF (UPDM)
  - UML profile for Modeling Services (UPMS)

MARTE Usage Example

- Seamless inter-working of specialized tools based on shared standards



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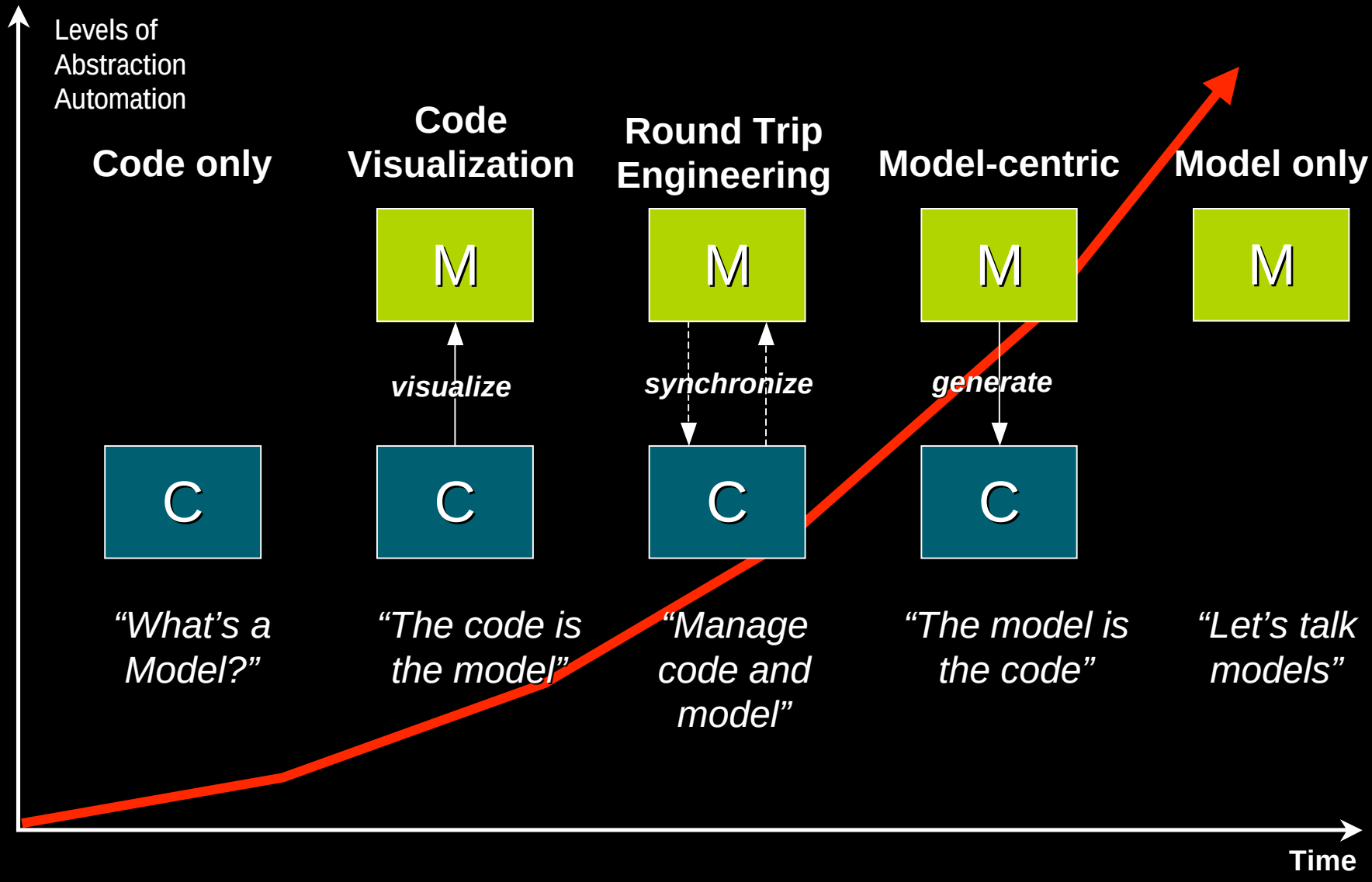
- State of the Art in MDD

The MDD Maturity Model



The State of the Art

- Model-driven development at the “Model” level
  - Higher levels of abstraction and
  - Higher levels of automation (advanced tools with full or partial automatic code generation)
- Major improvements in:
  - Product reliability
  - Developer productivity
- MDD tools have reached the critical maturity threshold:
  - Performance (tools and code)
  - Interoperability
  - Capability
  - Scalability

Automatic Code Generation: Full Generation

- State of the art:
  - All development done via the model (i.e., no modifications of generated code)
  - Size: Systems equivalent to ~ 10 MLoC
  - Scalability: teams involving hundreds of developers
  - Performance: within ±5-15% of equivalent manually coded system

Software Developed Using (Rational) MDD Tools

Automated doors, Base Station, Billing (In Telephone Switches), Broadband Access, Gateway, Camera, Car Audio, Convertible roof controller, Control Systems, DSL, Elevators, Embedded Control, GPS, Engine Monitoring, Entertainment, Fault Management, Military Data/Voice Communications, Missile Systems, Executable Architecture (Simulation), DNA Sequencing, Industrial Laser Control, Karaoke, Media Gateway, Modeling Of Software Architectures, Medical Devices, Military And Aerospace, Mobile Phone (GSM/3G), Modem, Automated Concrete Mixing Factory, Private Branch Exchange (PBX), Operations And Maintenance, Optical Switching, Industrial Robot, Phone, Radio Network Controller, Routing, Operational Logic, Security and fire monitoring systems, Surgical Robot, Surveillance Systems, Testing And Instrumentation Equipment, Train Control, Train to Signal box Communications, Voice Over IP, Wafer Processing, Wireless Phone

Major Telecom Equipment Manufacturer

- Adopted MDD Tooling
  - Rose RealTime, Test RealTime, RUP
- Example 1: Radio Base Station
  - 2 Million lines of C++ code (87% generated by tools)
  - 100 developers
- Example 2: Gateway
  - 300,000 lines of C++ code (83% generated by tools)
  - 30 developers
- Example 3: Network Controller
  - 4.5 Million lines of C++ code (80% generated by tools)
  - 400 developers

Major Telecom Equipment Manufacturer

- Adopted MDD Tooling
  - Rose RealTime, Test RealTime, RUP
- Example 1: Radio Base Station
  - 2 Million lines of C++ code (87% genera
  - 100 developers
- Example 2: Gateway

Benefits

80% fewer bugs

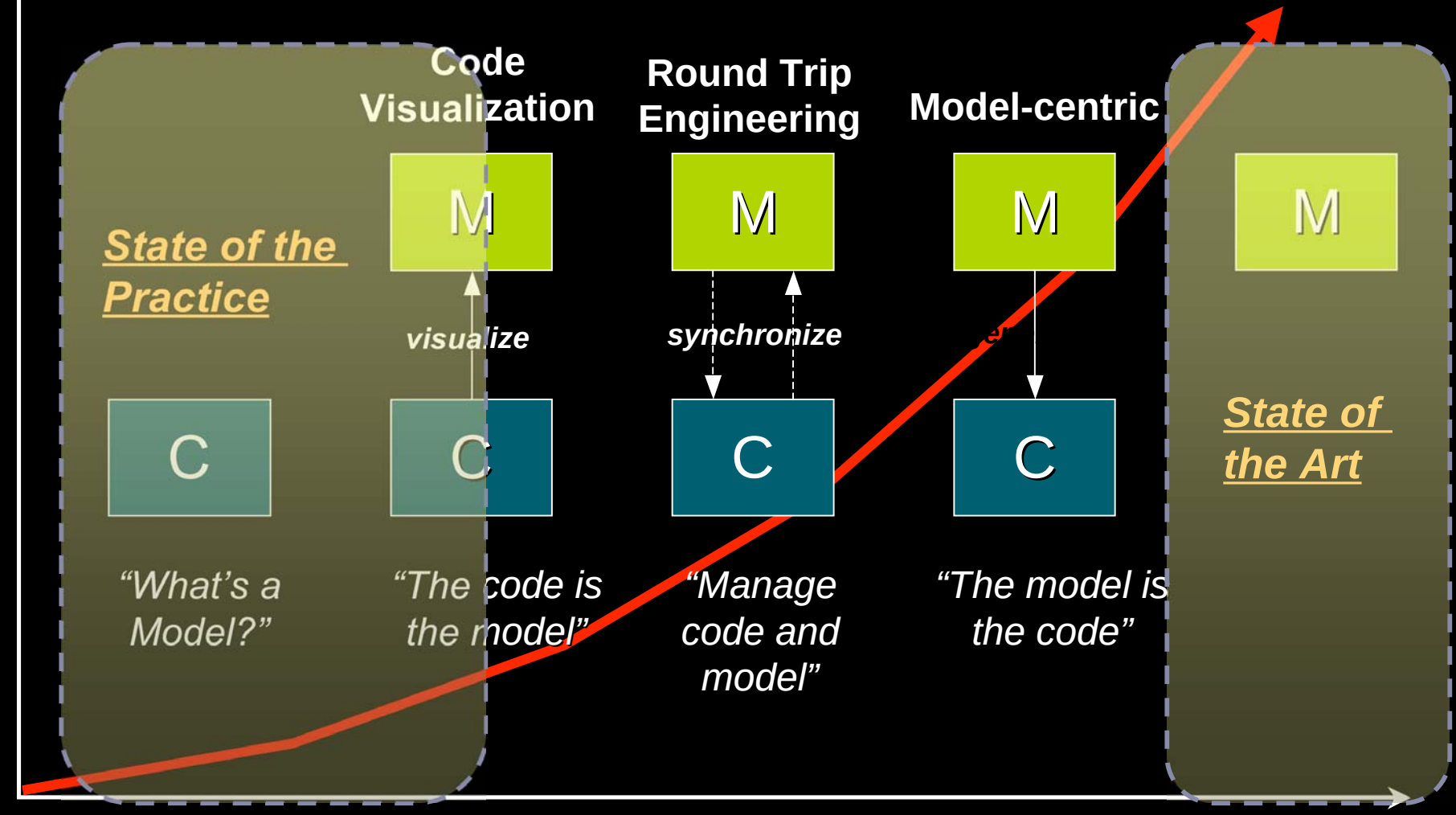
30% productivity increase

30% reduction in required documentation

"*I can't see how we could have done it in the given timeframe without Rational Rose RealTime*" Project Manager, Telecommunications Equipment Manufacturer

"We cut production time from 16 to 12 months.The quality was dramatically improved." Corporate Director, Software Technology Development

The MDD Maturity Model vs State of the Practice



Conclusions

- Model-Driven Development (MDD) has a *proven* potential to make a significant difference in productivity and quality of software development
  - The OMG is supporting MDD through its MDA standardization initiative
- UML 2 is a key member of the MDA standards family
  - As a core modeling language positioned for MDD
  - As the foundation for a set of standard domain-specific modeling languages
- The first generation of MDD-based products and supporting tools and methods are available
  - It has proven the effectiveness of this highly automated approach to software development

UML References

- General modeling specs:
  - http://www.omg.org/technology/documents/modeling_spec_catalog.htm
- UML 2 specs:
  - Superstructure: http://www.omg.org/cgi-bin/doc?ptc/2006-04-02
  - Infrastructure: http://www.omg.org/cgi-bin/doc?ptc/2004-10-14
- Books:
  - Rumbaugh, J., Jacobson, I., and Booch, .G., "Unified Modeling Language Reference Manual," (Second Edition), Addison Wesley, 2004
  - Pilone, D. and Pitman, N., "UML 2.0 in a Nutshell," O'Reilly, 2005
  - Eriksson, H.-E., et al., "UML 2 Toolkit," OMG Press & John Wiley, 2004
  - Fowler, M., "UML Distilled," (3rd Edition), Addison Wesley, 2004