

OMG Modeling “Standards” for Model-Based Engineering

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About Simula Research Labs

- Research institute created by the Norwegian Ministry of Education and Research
- Objectives:
 - Basic and long-term research in networks, distributed systems, scientific computing, and software engineering
 - Promote the application of research in public and private sectors
 - Educate students at master's, doctoral, and post-doctoral levels
- Various research domains
 - Software estimation, cardiac modeling, biomedical computing, computational geoscience, networks, media
 - Certus centre: software V&V

CERTUS

- **Purpose:**
 - Develop new and improved methods and tools for modeling, certifying, and testing of critical software systems
- **Supported by:**
 - The Research Council of Norway and its Centre for Research-Based Innovation
- **Established in September 2011**
 - 8-year mandate (2011-2019)
 - ~10 MNOK/year (~US\$ 1.75M/year)
 - 7 permanent scientists, 7 PhD students, 4 adjunct researchers
- **Initiated by Prof. Lionel Briand (U. of Luxembourg) and led by Dr. Arnaud Gotlieb**

CERTUS Industry Partners

- All research projects are industry driven:
 - CISCO Systems Norway
 - ESITO
 - FMC Technologies
 - KONGSBERG Maritime
 - TOLL customs and excises



CERTUS Technical Strategy

- Use of model-based engineering (MBE) methods, tools, and standards
- Current focus on
 - Certification and verification of real-time and embedded software
 - Modeling, configuring, and testing of complex product families
 - Automated testing of data-intensive software systems
- **OMG** industry standards used:
 - Unified Modeling Language (UML)
 - Modeling and Analysis of Real-time and Embedded Systems (MARTE) - a UML profile
 - Systems Modeling Language (SysML)

WHAT IS MODEL-BASED ENGINEERING (MBE)?

Models in Engineering

■ Descriptive models

- To help us understand (i.e., reason about) complex systems
- To communicate understanding and design intent to others
- To predict the interesting characteristics of systems and system designs (e.g., safety, performance)

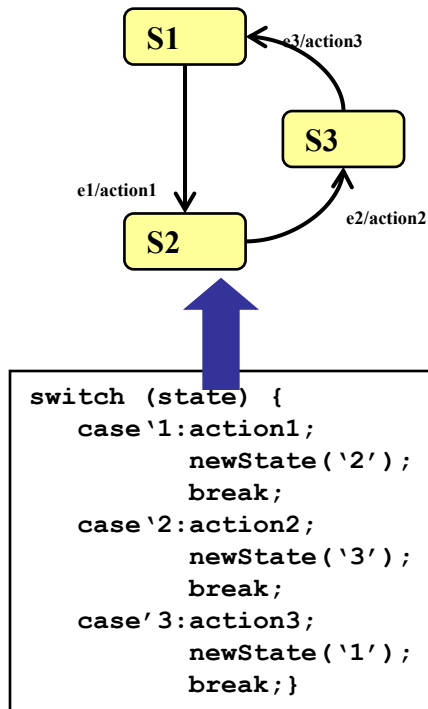
◆ Prescriptive models

- To specify systems (blueprints)
- ...and, in some cases, even to implement systems

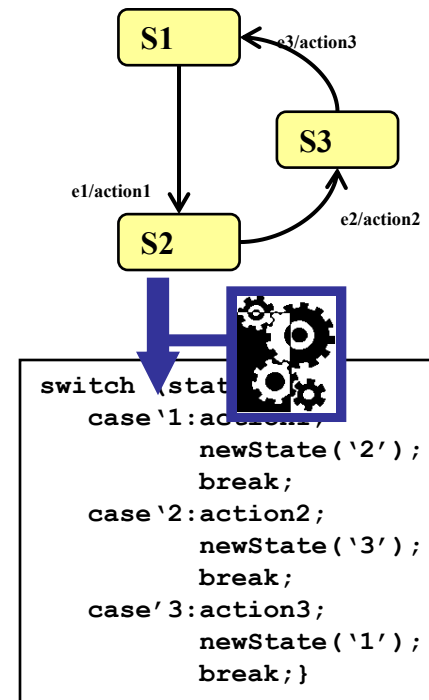
The Essence of Modern MBE

- An approach to system and software development in which computer-based models play an indispensable role
- Based on two time-proven ideas:

(1) ABSTRACTION



(2) AUTOMATION

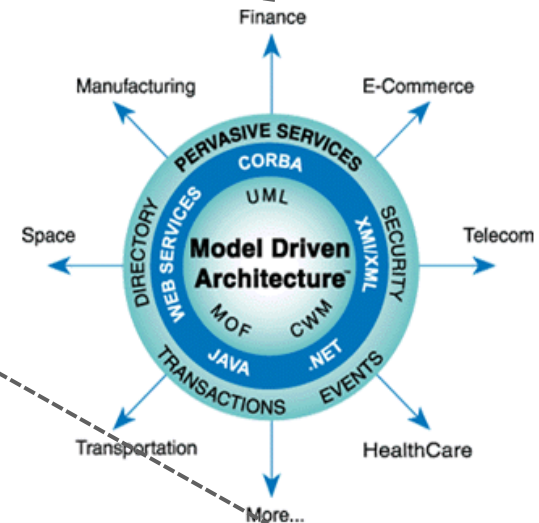
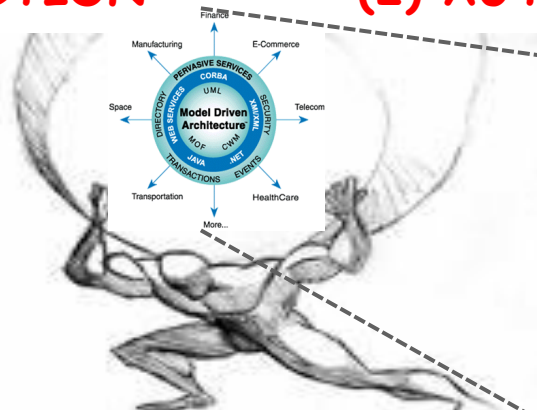


OMG's Model-Driven Architecture (MDA)TM

- In recognition of the increasing importance of MBE, the Object Management Group (OMG) is developing a set of supporting industrial standards

(1) ABSTRACTION

(2) AUTOMATION



(3) INDUSTRY STANDARDS

- UML 2
- OCL
- MOF
- SysML
- SPEM
- ...etc.

Be wary of the notion of "platform independent model" (PIM)!

OMG Modeling Standards

- Software Modeling Language: UML
- Real-Time Software: MARTE
- Modeling Language: SysML
- Metamodel: Meta Object Facility (MOF)
- Model Exchange Format: XMI
- Constraint Language: OCL
- Transformation/Mapping Language: QVT
- Representation Model: Diagram Definition
- Model Management Service: MOF Versioning
- Mapping Specification: SysML-Modelica Transformation
- Mapping Specification: Ontology Definition Metamodel (ODM)
- Architecture Framework Modeling Language: UPDM
- Business Modeling Language: BPMN

THE UNIFIED MODELING LANGUAGE (UML 2)

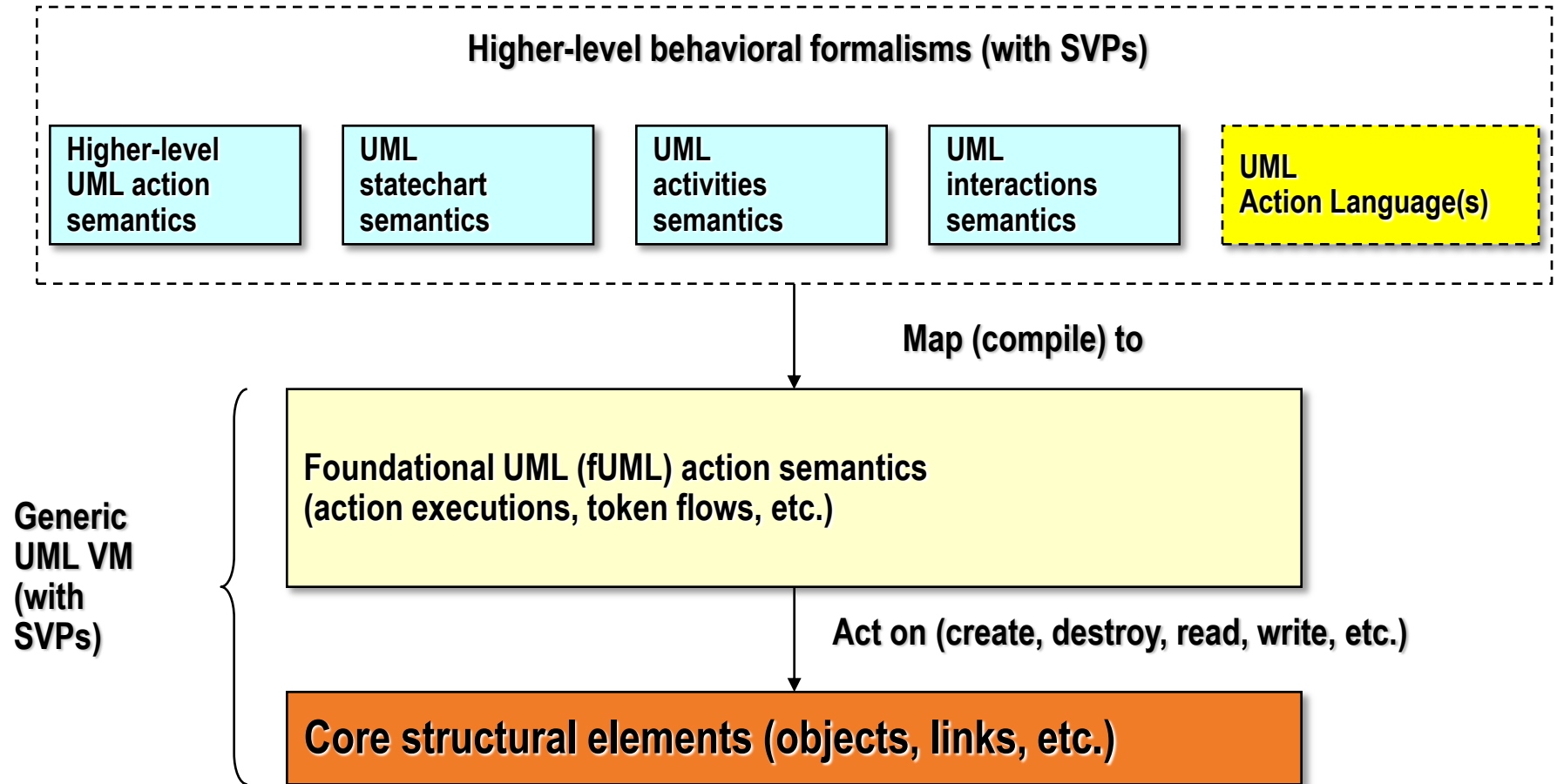
The Unified Modeling Language

- Originally conceived as a descriptive language
 - Adopted by the OMG in 1996
- Quickly became the most widely-used software modeling language
 - Supported by numerous commercial and open source tools
 - Taught in most software/computer university curricula
- Evolved into a descriptive+prescriptive language
 - 2001: UML Action Semantics - semantic foundation
 - 2003: UML 2 - refactored metamodel + ADL features + improved and extended profile mechanism
 - 2010: Executable UML Foundation (fUML)
 - 2011: Action Language (ALF) - a prescriptive UML

The "New" UML Semantics

- Executable UML Foundation specification
 - A precise formal specification of the dynamic semantics of a core subset of UML (Foundational UML = fUML)
- Enables:
 - Model execution/simulation
 - Formal (mathematical and/or programmatic) of fUML models
- <http://www.omg.org/spec/FUML/>

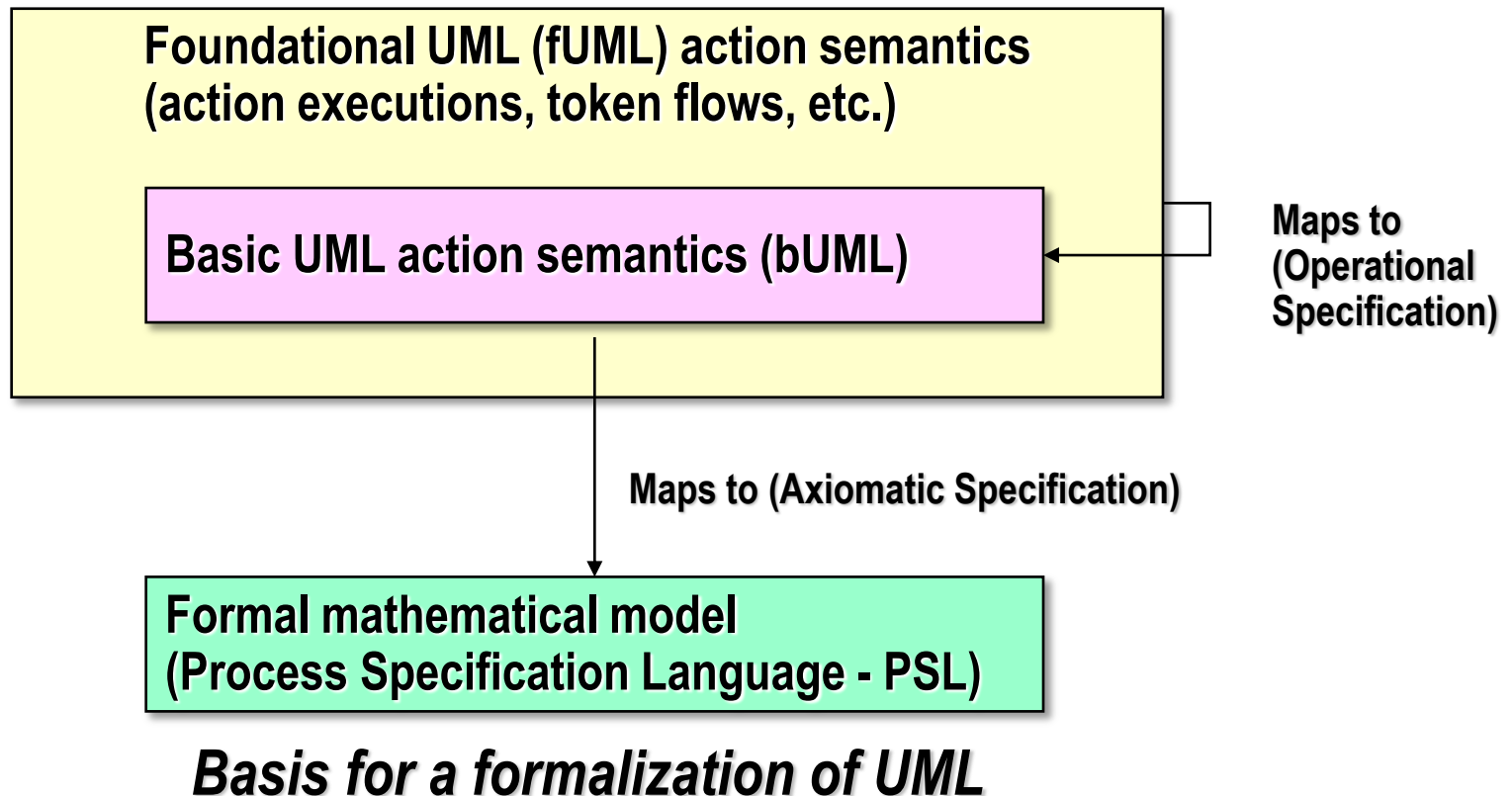
OMG Approach to Specifying UML Semantics



SVP = Semantic Variation Point

Foundational UML (fUML) and Basic UML (bUML)

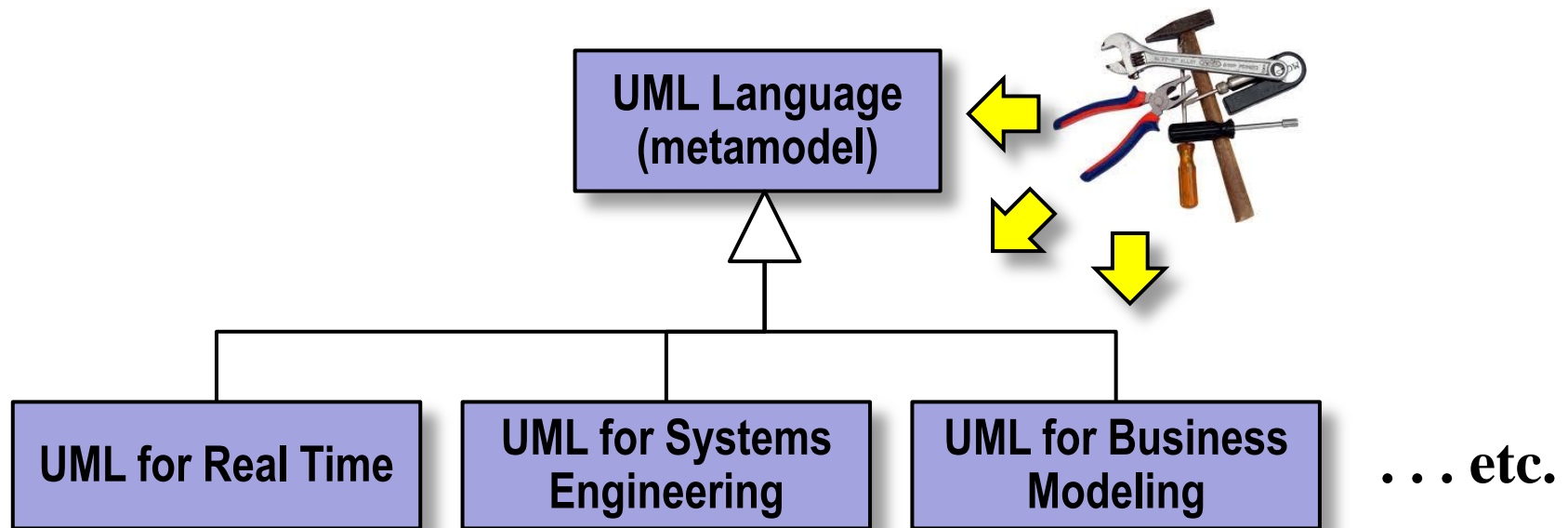
- A subset of fUML actions is used as a core language (Basic UML) that is used to describe fUML itself



THE UML PROFILE FOR MODELING AND
ANALYSIS OF REAL-TIME AND EMBEDDED
SYSTEMS
(MARTE)

Background on UML with Profiles

- Allows domain-specific interpretations of UML models
- ...which are compatible with general (standard) UML!
 - Implies the ability to reuse UML tools, expertise, etc.

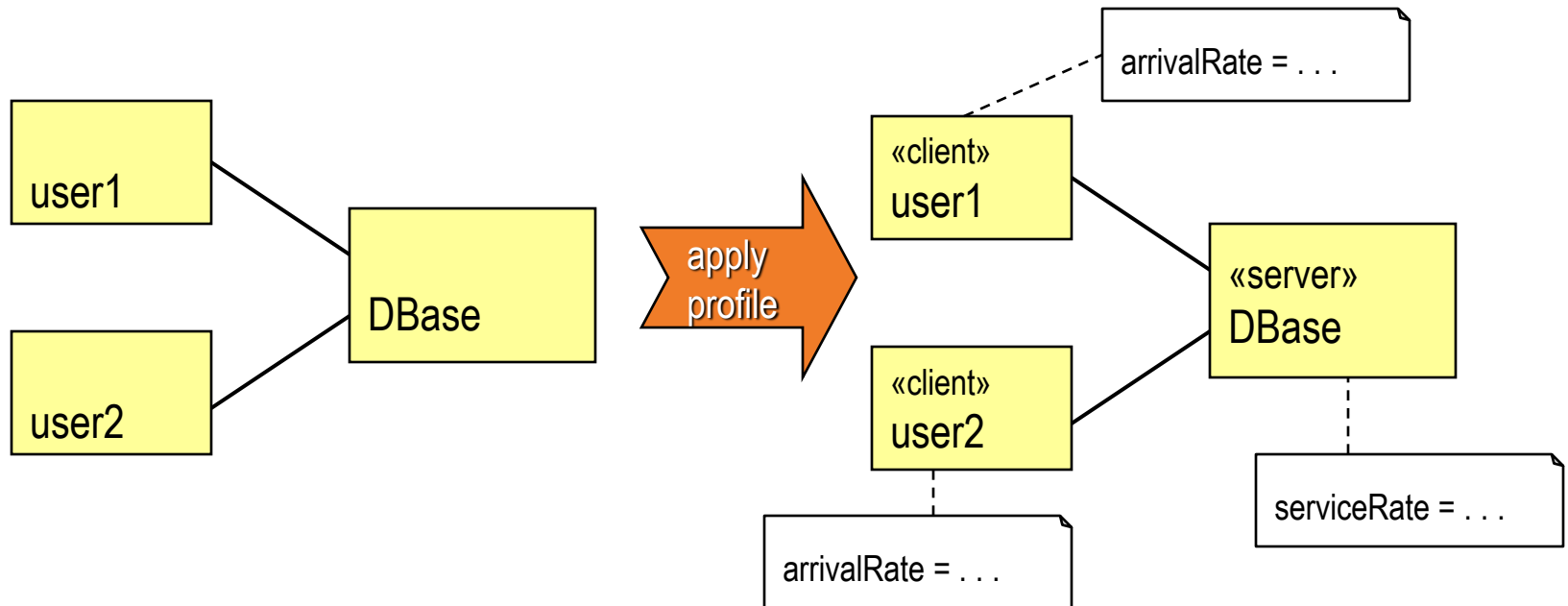


UML Profiles Types

- Language profiles
 - Define a domain-specific modeling language for specifying systems
 - E.g., an SDL profile of UML (ITU standard Z.109)
- Casting (analysis) profiles
 - For representing concern-specific interpretations and refinements of existing models
 - Used for analysis and prediction
 - E.g., performance, security, availability, safety
- **MARTE** provides both types of profiles

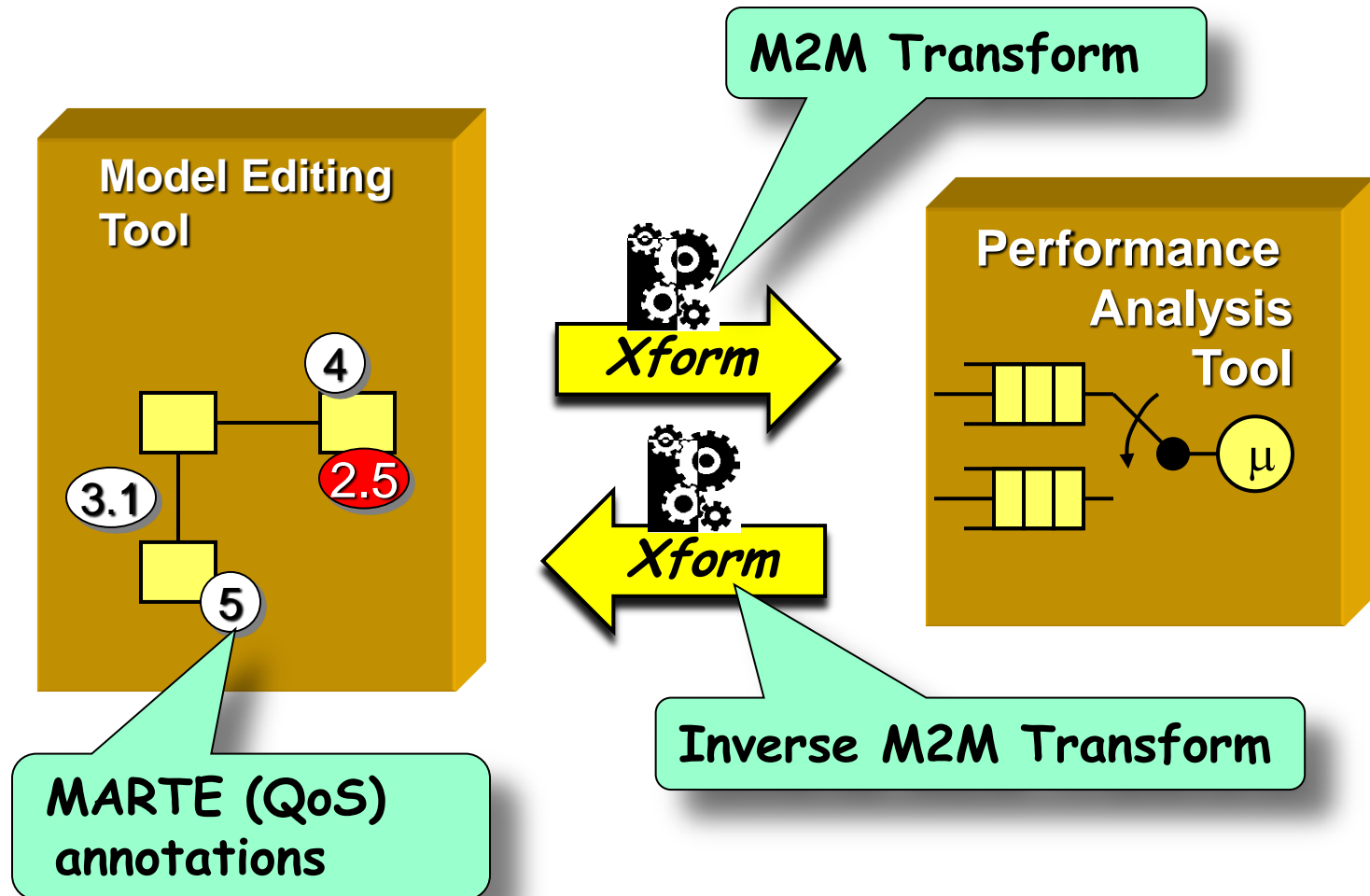
Casting Profiles

- A profile can be dynamically applied or unapplied to a given model
 - Without changing the underlying base model
 - Allows a model to be interpreted from the perspective of a specific domain
- Example: viewing a UML model as a queueing network



Example: Automated Model Analysis

- Transform a UML model into a queueing network model for performance analysis and prediction



Core MARTE Concept: Resource

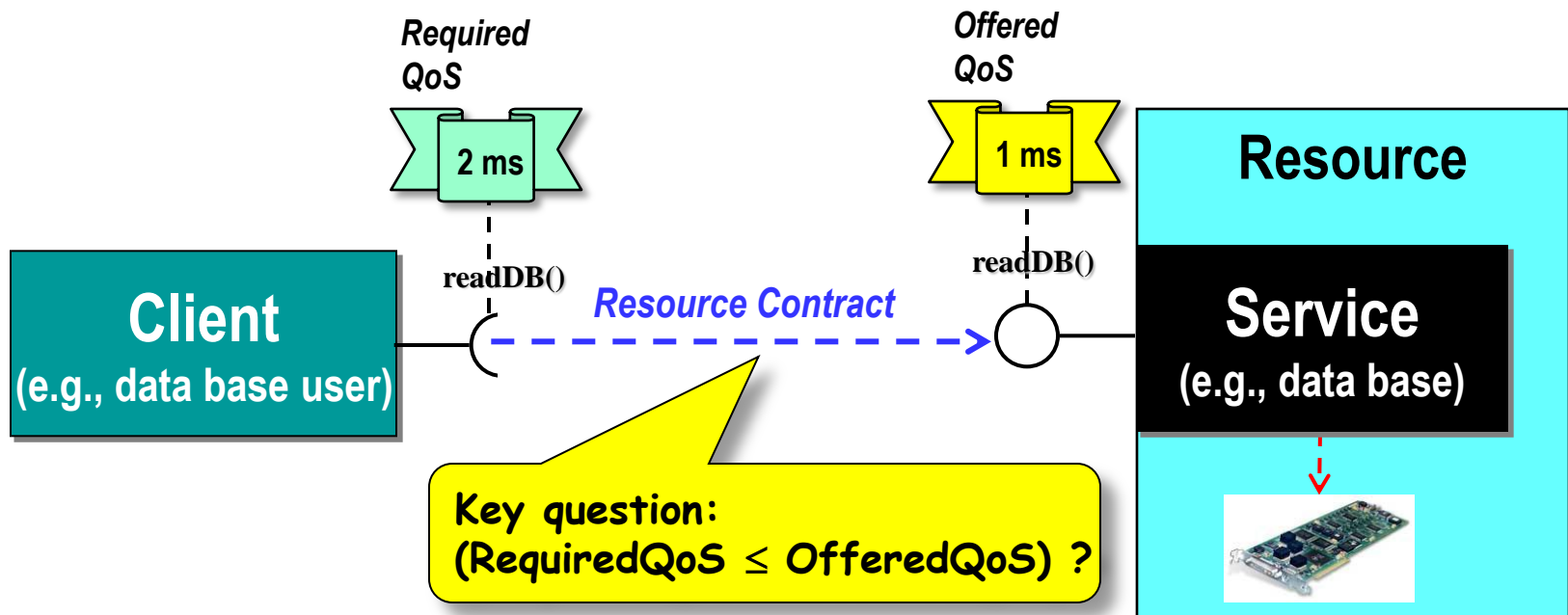
- **Resource:**
 - A facility or mechanism with limited capacity required to attain some functional objective (e.g., perform a service)
- The limited nature of resources is due to the finite nature of the underlying hardware platform(s)
 - Contention for shared resources is the primary source of complexity related to platforms
- Resources can be viewed as providers of services
 - E.g., computing power, memory storage, concurrency management, communications paths

Core MARTE Concept: QoS

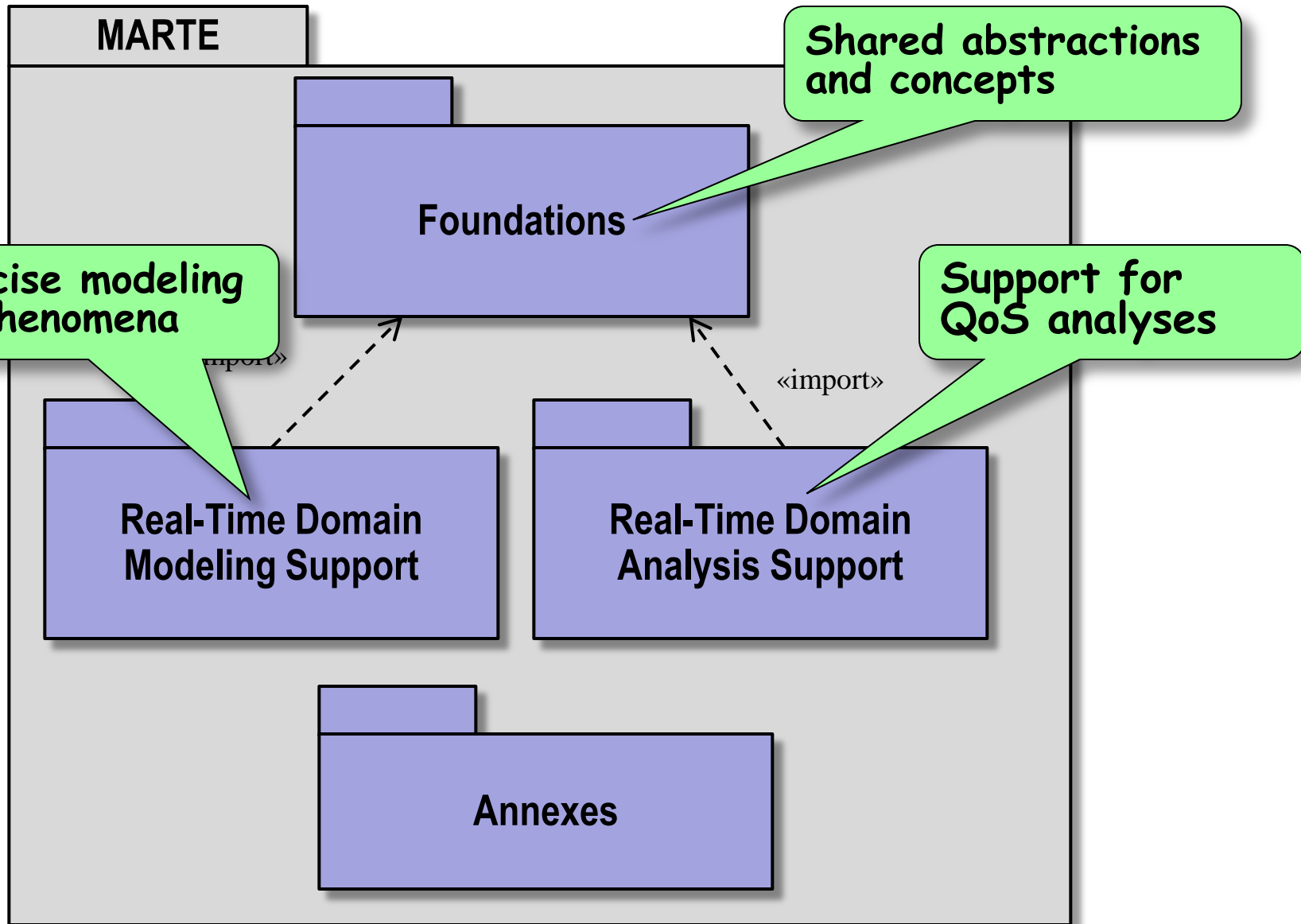
- **Quality of Service:**
 - the degree of effectiveness in the provision of a service
 - e.g. throughput, capacity, response time
- **The two sides of QoS:**
 - offered QoS: the QoS that is available (supply side)
 - required QoS: the QoS that is required (demand side)

Engineering Analyses

- *"An idea that unifies all engineering is the concept of failure. Virtually every calculation an engineer performs...is a failure calculation...to provide the limits than cannot be exceeded"*
 - Henry Petroski
- Key analysis question: Does a resource have the capacity to support its clients?
 - i.e., does supply meet demand?

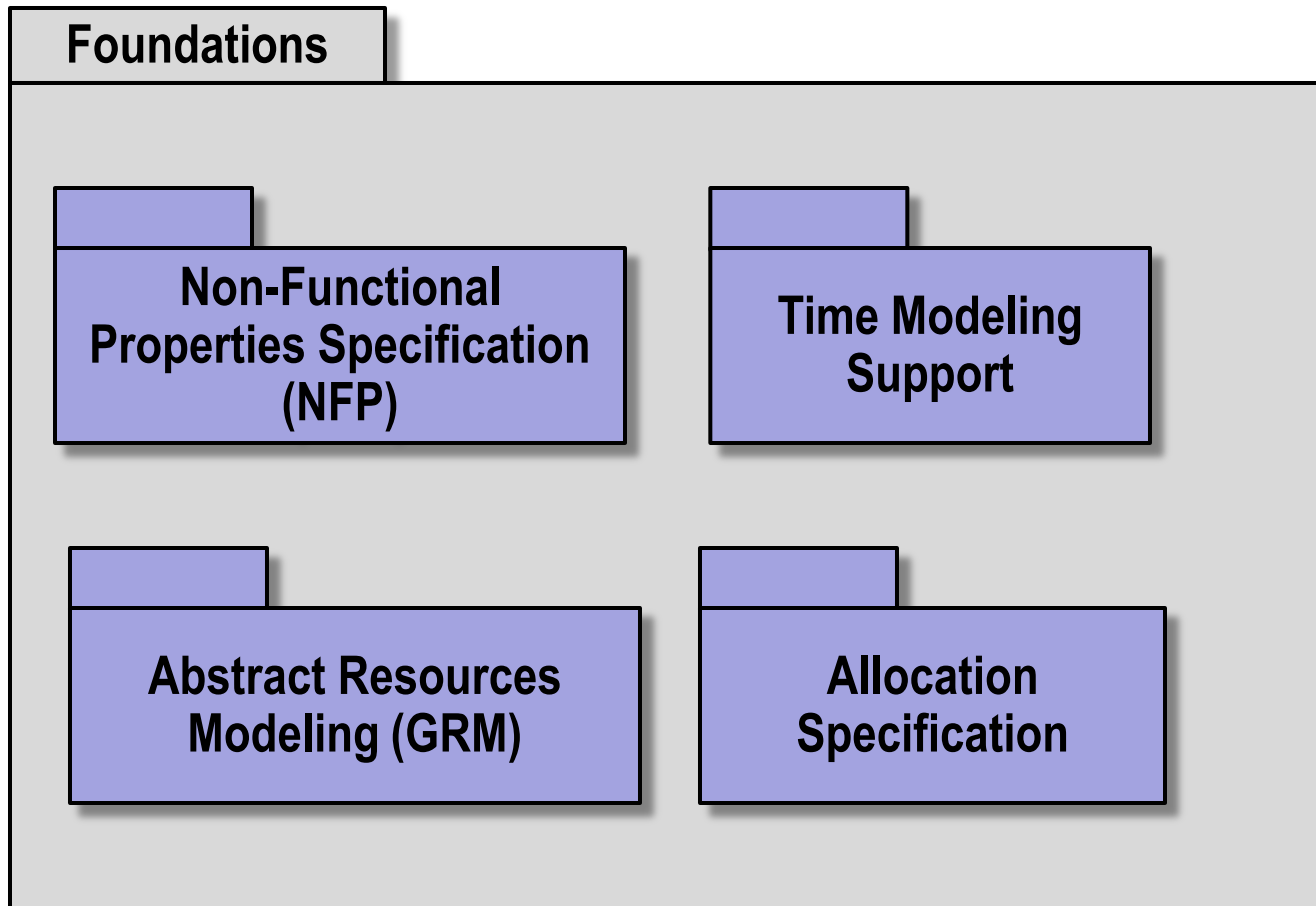


Main Elements of MARTE



MARTE Foundations

- Shared abstractions and concepts
 - Includes an abstract model of dynamic semantics (necessary for scenario modeling)

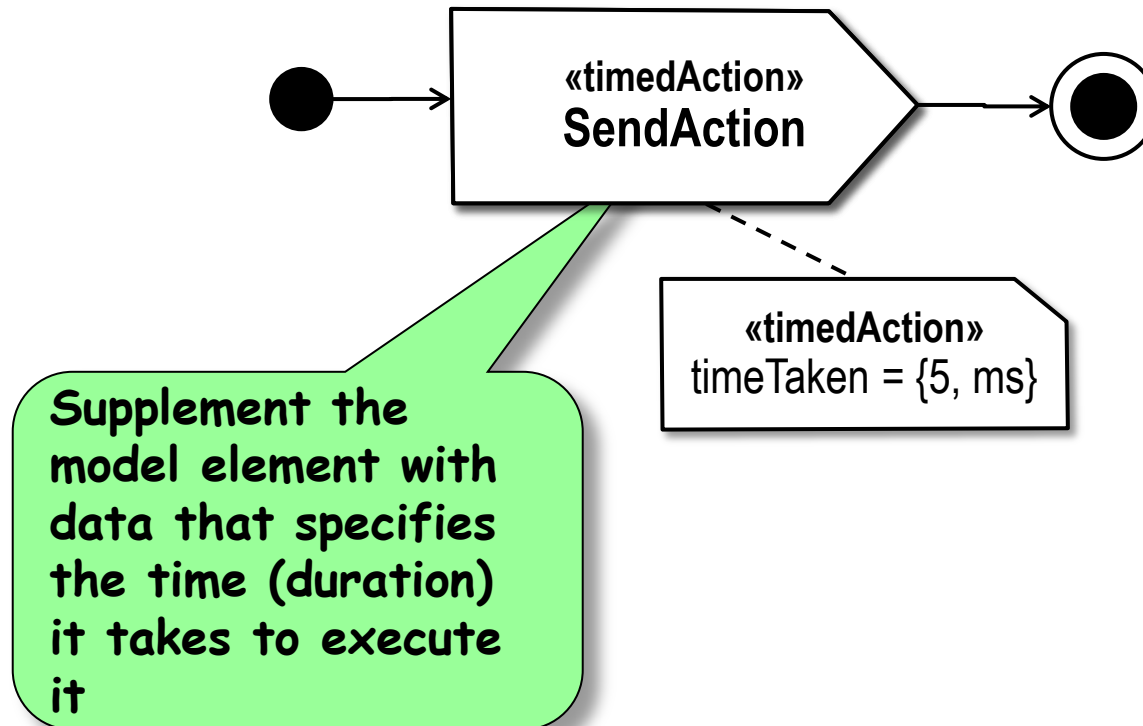


Non-Functional Properties

- Can be qualitative or quantitative
- Qualitative properties are usually enumerations
 - E.g., ROM type: {EEPROM, EPROM, flash, OTP_EPROM,...}
- Quantitative properties involve:
 - Quantity: how much/magnitude
 - Dimension: what is being measured (e.g., length, volume, duration)
 - Unit: the standard used to measure a dimension (e.g., meter, litre, second)
- Sometimes it is necessary to add a qualification to a property
 - E.g., required or provided, measured or estimated,...

Example

- Provide the ability to specify the execution time (duration) of a UML action
 - E.g.:



Value Specification Language

- Language to specify values and relationships between non-functional (QoS) properties
 - Textual language
 - Includes literals, variables and expressions
 - Expressions involving variables can capture functional relationships between values of different properties
- Examples:
 - `[1..5]` = interval literal
 - `(2, us)` = tuple literal (for structured data)
or
`(value=2, unit=us)`
 - `in $temp : Temperature = 0` = a variable declaration
 - `((temp >= 0) ? 'positive' : 'negative')` = conditional expression

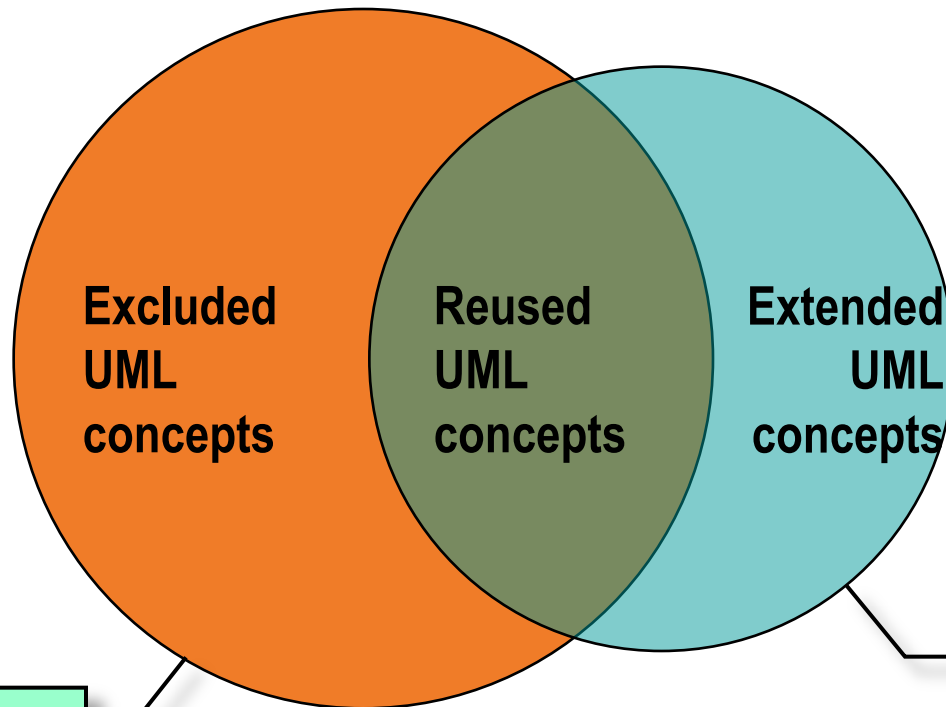
THE SYSTEMS MODELING LANGUAGE (SYSML)

The OMG SysML™ Specification

- A language for systems engineering
 - Supported by INCOSE as well as the OMG
- Current reference document (formal/10-06-01):
 - <http://www.omg.org/spec/SysML/1.2/PDF/>
 - <http://www.sysmlforum.com>
- Not a formal modeling language, but:
 - Can be specialized further using the profile mechanism
 - SysML4Modelica - an OMG standard which overlays a SysML syntax on Modelica (an executable modeling language)

UML 2 and SysML

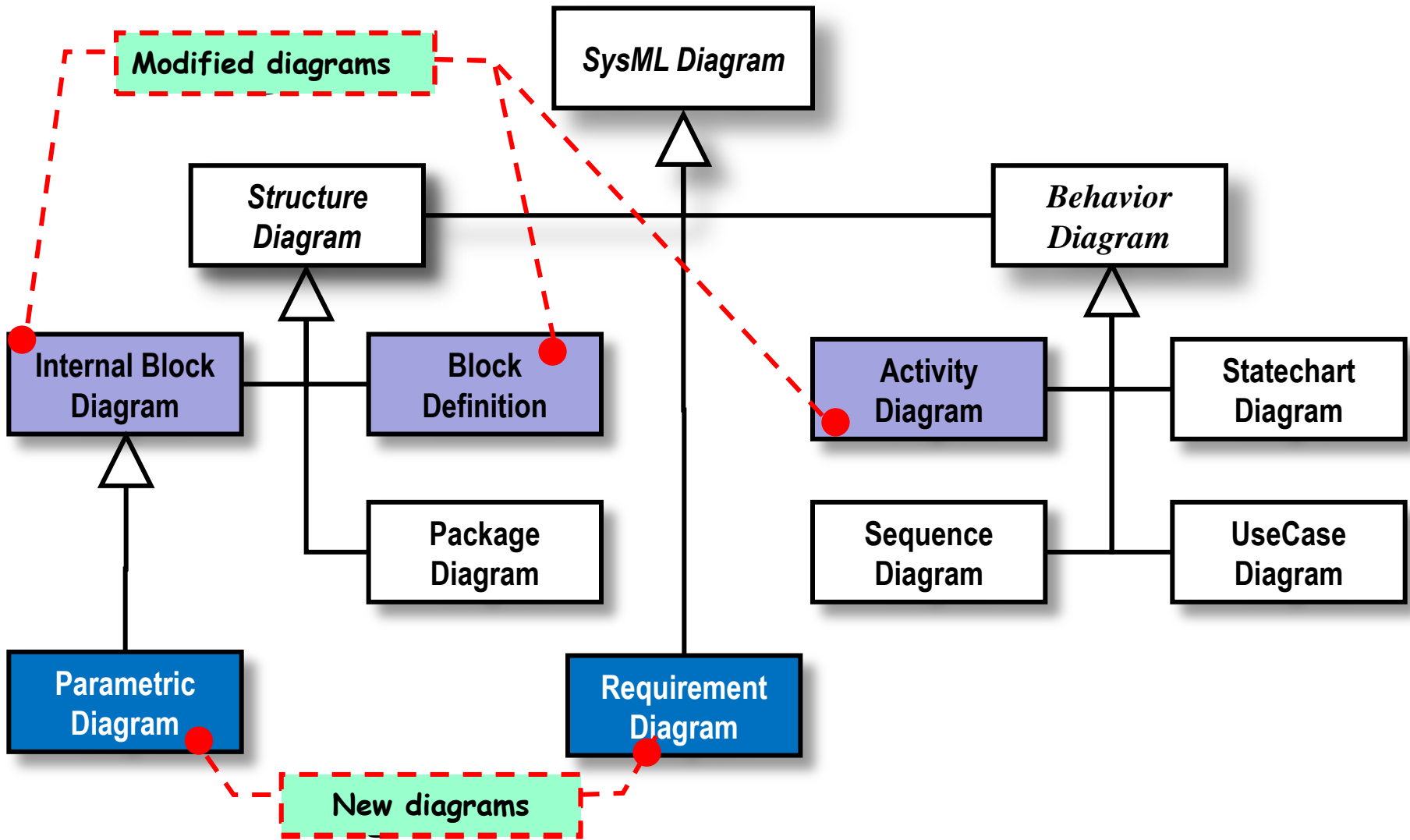
- A refinement of UML (UML profile), but
 - Some UML concepts excluded, others simplified, and others specialized for systems engineering
 - Possible to combine the excluded concepts



UML concepts

SysML concepts

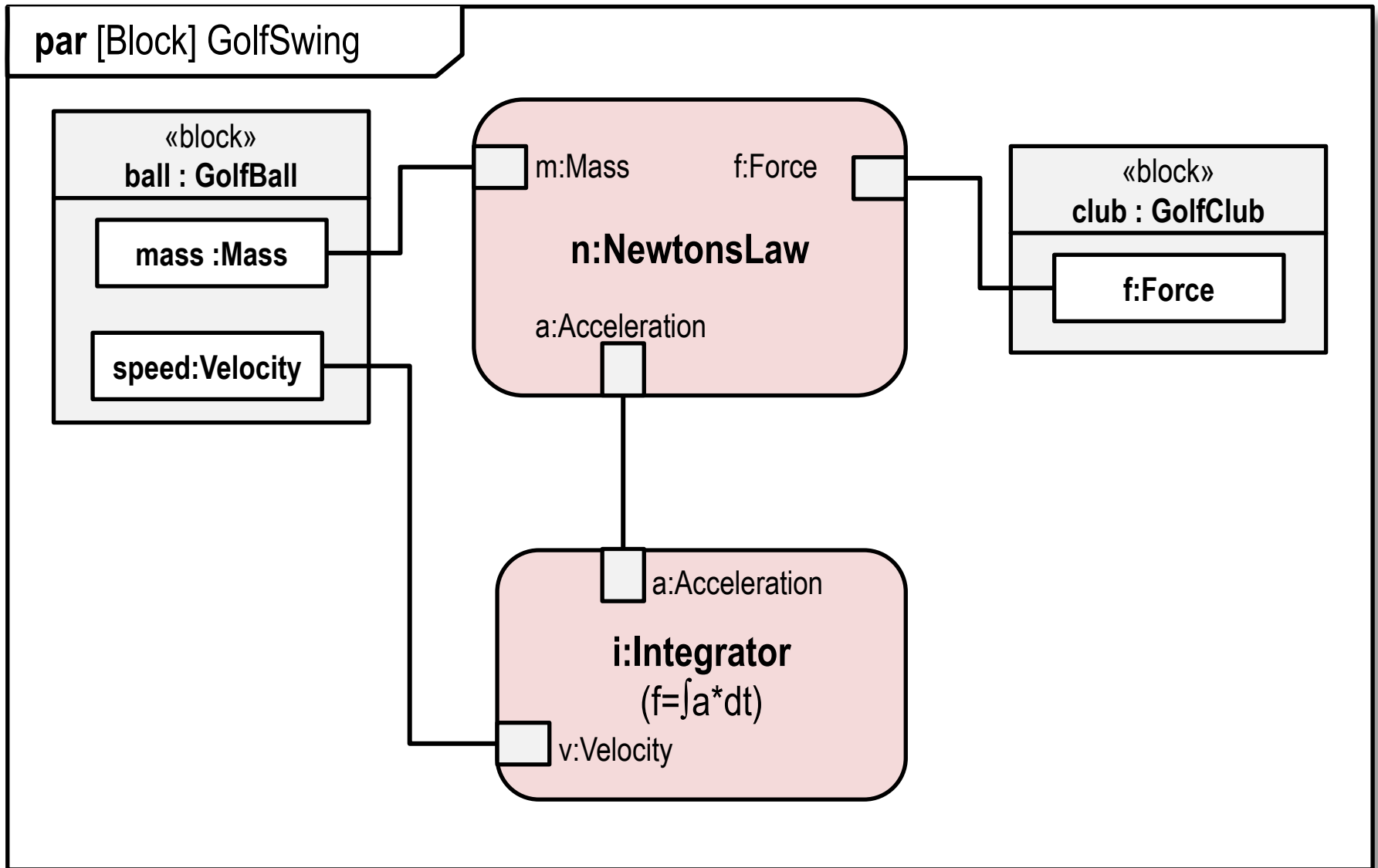
SysML Diagram Types



SysML Parametrics Modeling

- Serves two related purposes
 - For capturing functional relationships and constraints related to various system properties
 - E.g., the mass, acceleration, and force attribute of a physical element are constrained by Newton's law
 - For performing various quantitative analyses of proposed designs and comparing design alternatives
- Similar intent as the MARTE analysis (sub)profiles
 - MARTE approach is more versatile and more practical
 - Work is ongoing to merge the two

Parametric Diagram: Specifying Constraint Usage



Summary and Conclusions

- The CERTUS experience with using **OMG** standards (UML, SysML, and MARTE) for V&V of complex industrial systems has been positive
 - Including development of custom extensions via the profile mechanism
 - Used in conjunction with other standards (ISO 26262)
- The extensibility and customization capabilities of the **OMG** modeling standards have proven useful and provide an opportunity for development of new and adaptation of existing standards for MBE