From PIMs to PSMs

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Outline

MDA, xUML, and AADL

Domain Models and Bridges

xUML to AADL Translation

AADL Model Optimization

Important Abbreviations

see
omg.org/mda

The presentation describes:

A process for system development, known as

Model Driven Architecture (MDA)

which involves building

Platform-Independent Models (PIMs)

from which we derive

Platform-Specific Models (PSMs)

and/or

Platform-Specific Implementations (PSIs).

The models are represented using the notation known as the

Unified Modeling Language (UML).

Both the MDA process and the UML notation

are owned by the non-profit consortium known as the

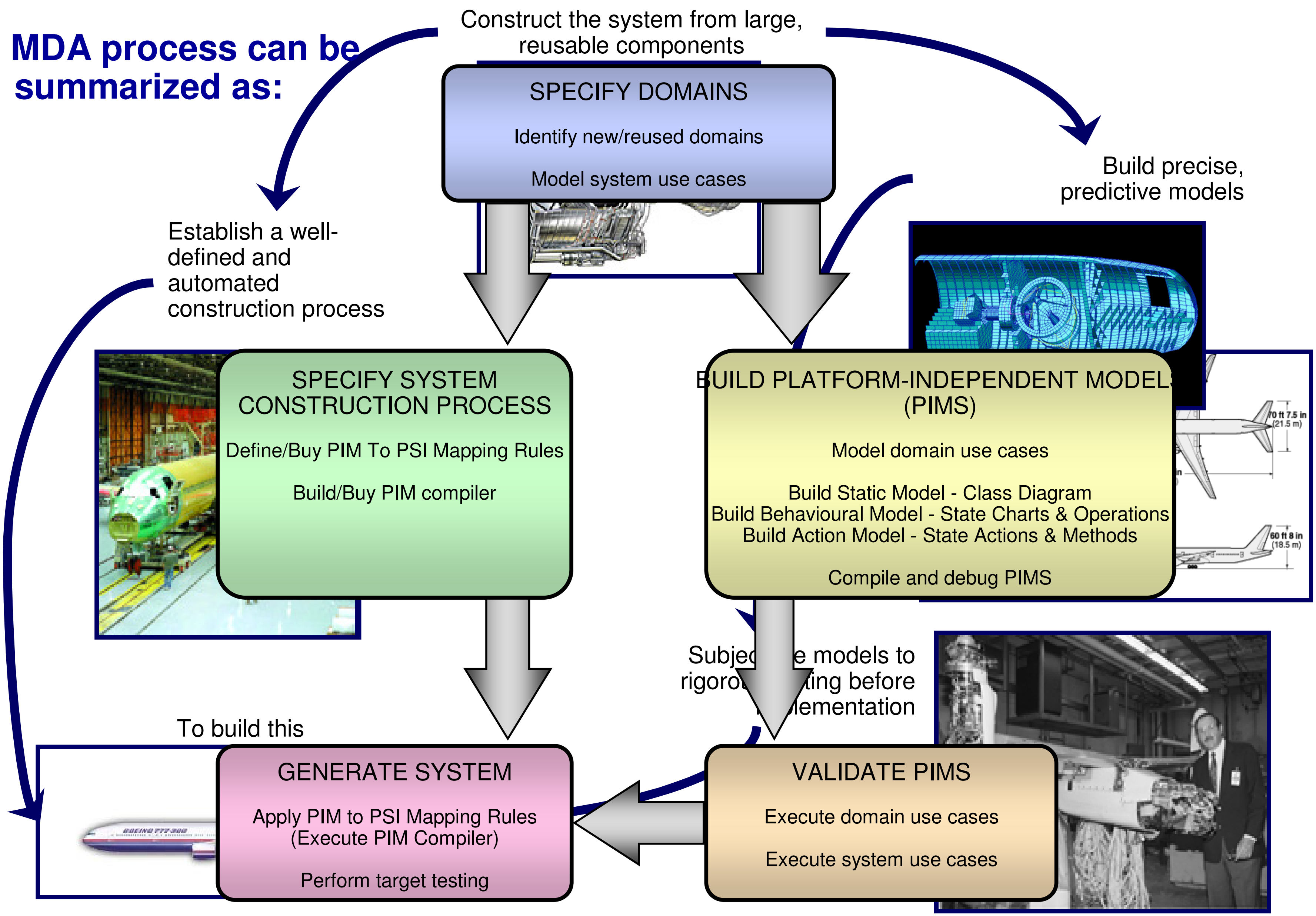
Object Management Group (OMG).

Platform Independent Model

- A Platform Independent Model (PIM) is a technology agnostic model of some aspect of the system under study.
- A PIM contains no information about any of the following:
  - Hardware Architecture
  - Operating System
  - Programming Language
  - Database Technology
  - Internal Communication Technology
- It is therefore much simpler than a Platform-Specific Model (PSM)
- Use of Executable UML (xUML) allows construction of PIMs that are:
  - Precise
  - Complete
- PIMs built using xUML can be:
  - Executed to demonstrate compliance with functional requirements
  - Automatically translated into a complete Platform Specific Implementation using a suitable model translator
  - Used as executable specifications, forming the basis for contract-based procurement

Overview of the MDA Process

The MDA process can be summarized as:



What is AADL?

- The SAE Architecture Analysis and Design Language (AADL) is an international standard for predictable model-based engineering of real- time and embedded computer systems.
- Intended fields of application are automotive systems, avionics and space applications, medical devices, and industrial process control equipment.
- The SAE AADL international standard consists of
  - a textual and graphical language with precise execution semantics for modeling the architecture of embedded software systems and their target platform;
  - a UML 2.0 profile for AADL that adds real-time embedded systems semantics of AADL to UML;
- AADL can be used to:
  - Represent embedded systems as component-based system architecture
  - Model component interactions as flows, service calls, and shared access
  - Model task execution and communication with precise timing semantics
  - Accommodate analyses such as reliability &safety- criticality through extensions

Ref: http://www.aadl.info/

xUML and AADL in the MDA Process

- xUML focuses on:
  - Service layers (domains)
  - Provided and Required services
  - Data structure (classes and attributes)
  - Processing (state machines and operations)
  - Interactions (signals and invocations)

- AADL focuses on:
  - Processors
  - Processes
  - Threads
  - Devices
  - Buses
  - Ports
  - Memory blocks

- xUML is strongly oriented towards Platform Independent Models…

  …that can be executed and analysed to assess functional capabilities…

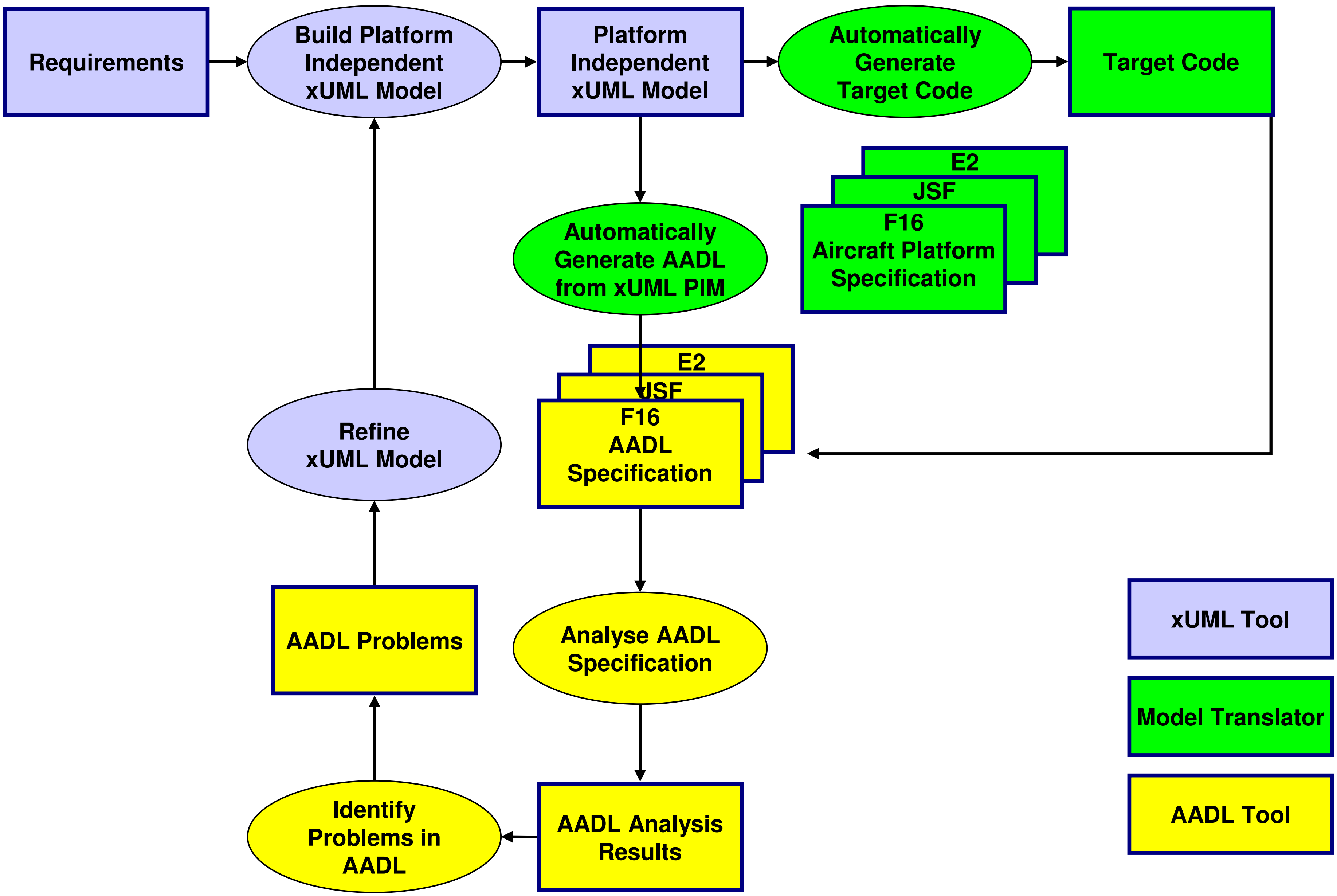
  …and used to generate several platform specific models, expressed using an appropriate language, for different aircraft types

- AADL is strongly oriented towards Platform Specific Models…

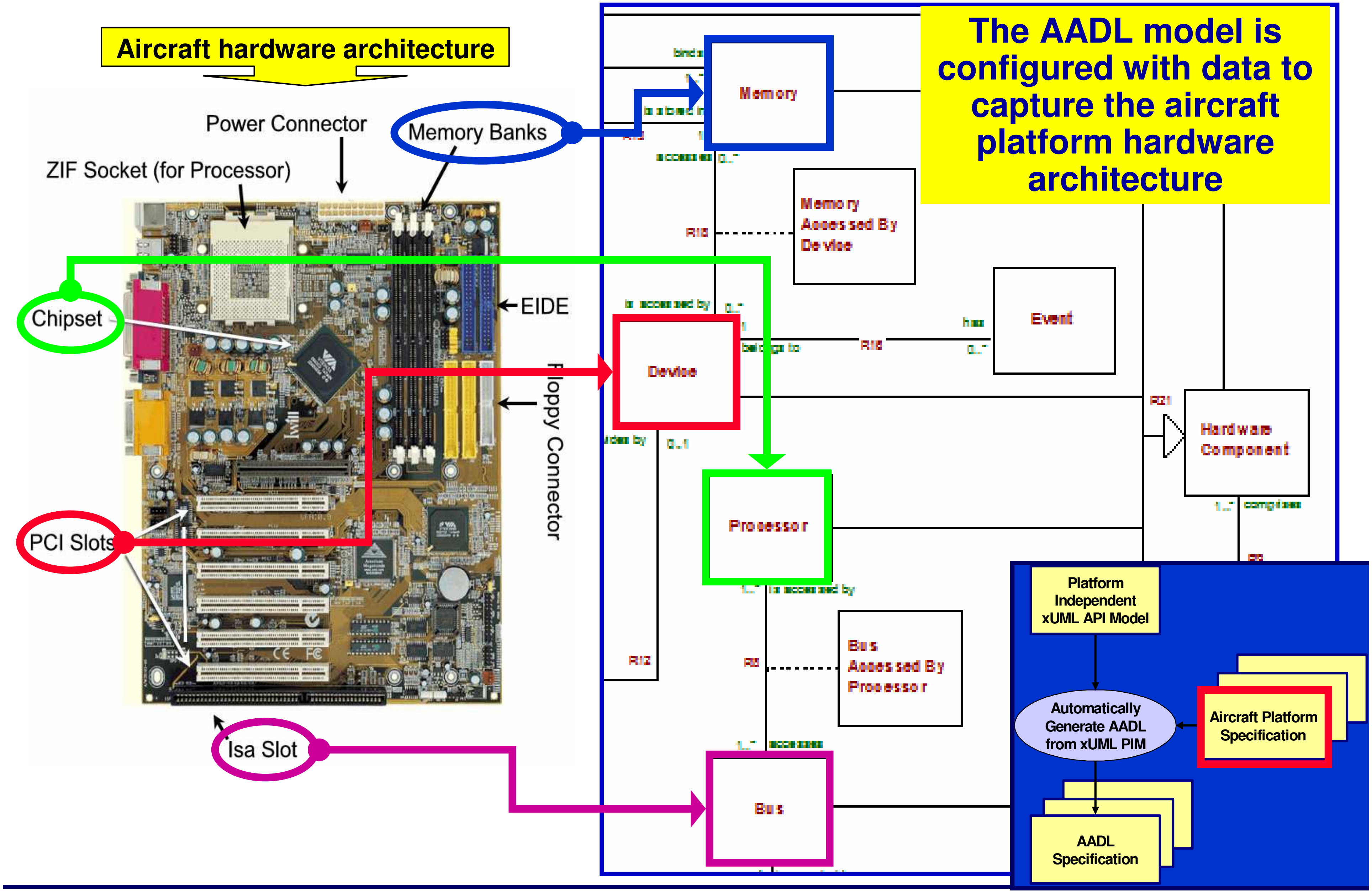
  …that can be executed and analysed to assess aircraft-specific performance characteristics…

  …and used as the basis for platform-specific implementations

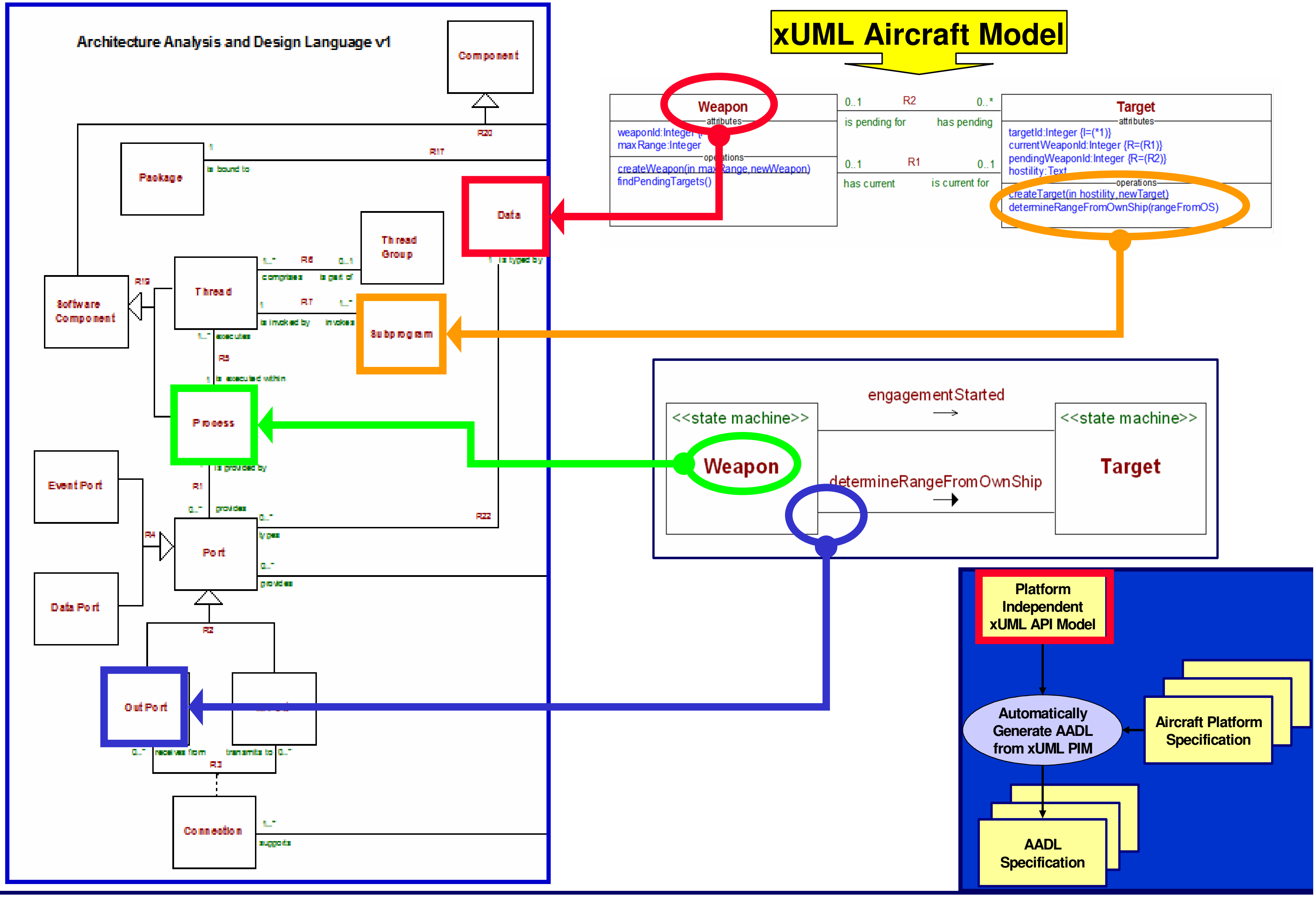
An xUML-AADL Process



Configure the AADL Model for the Hardware Components



Populate the AADL Metamodel with Software Components



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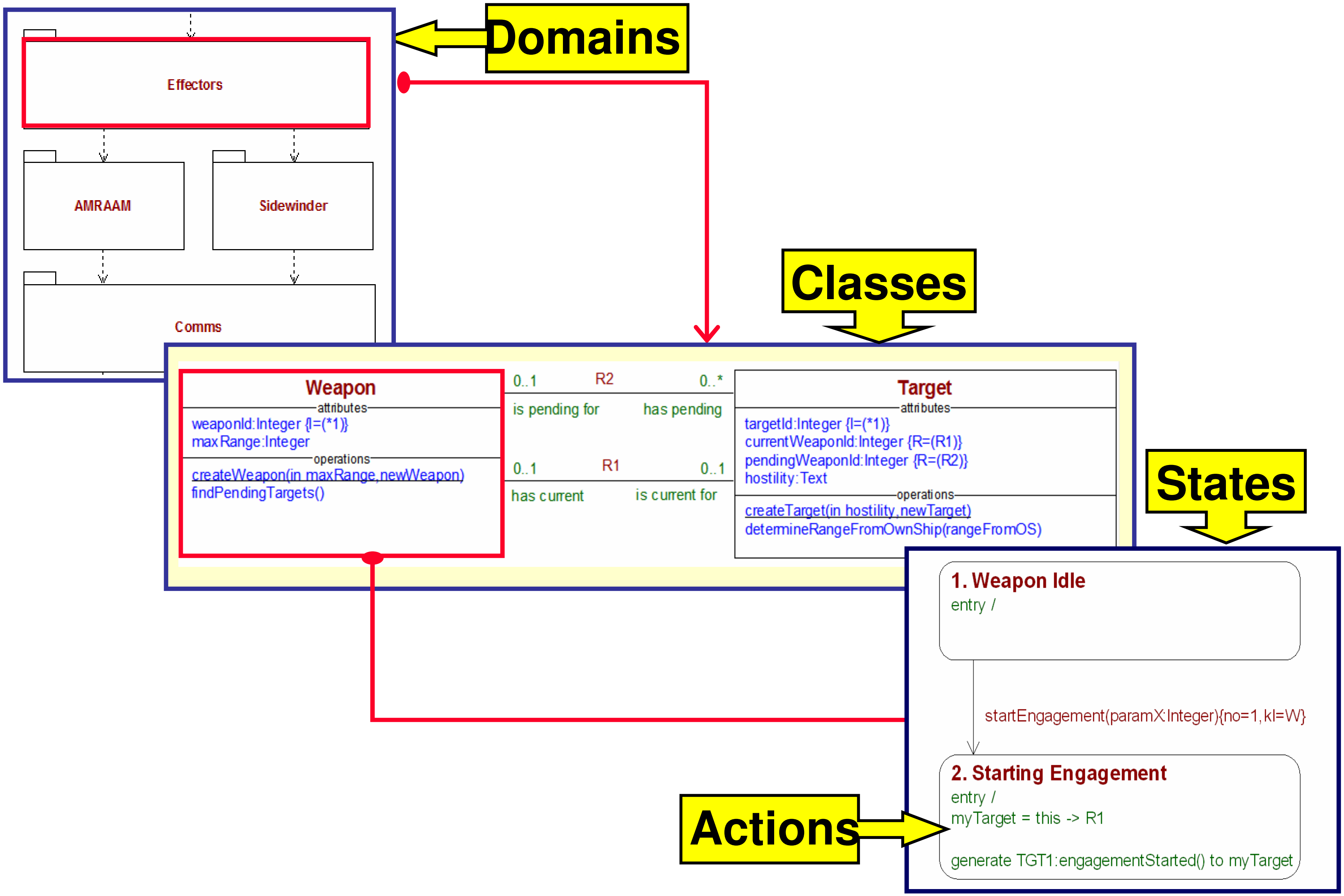
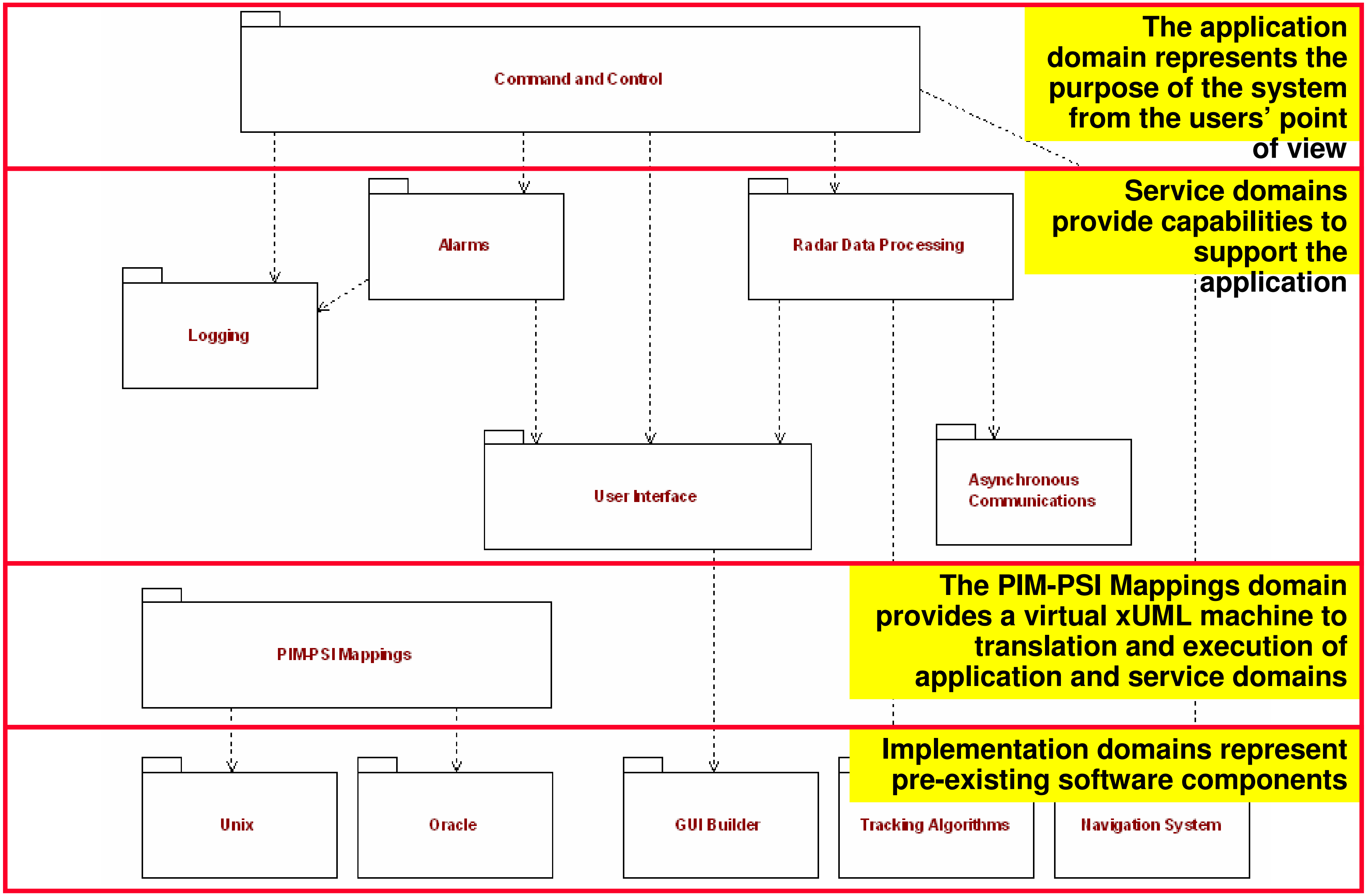
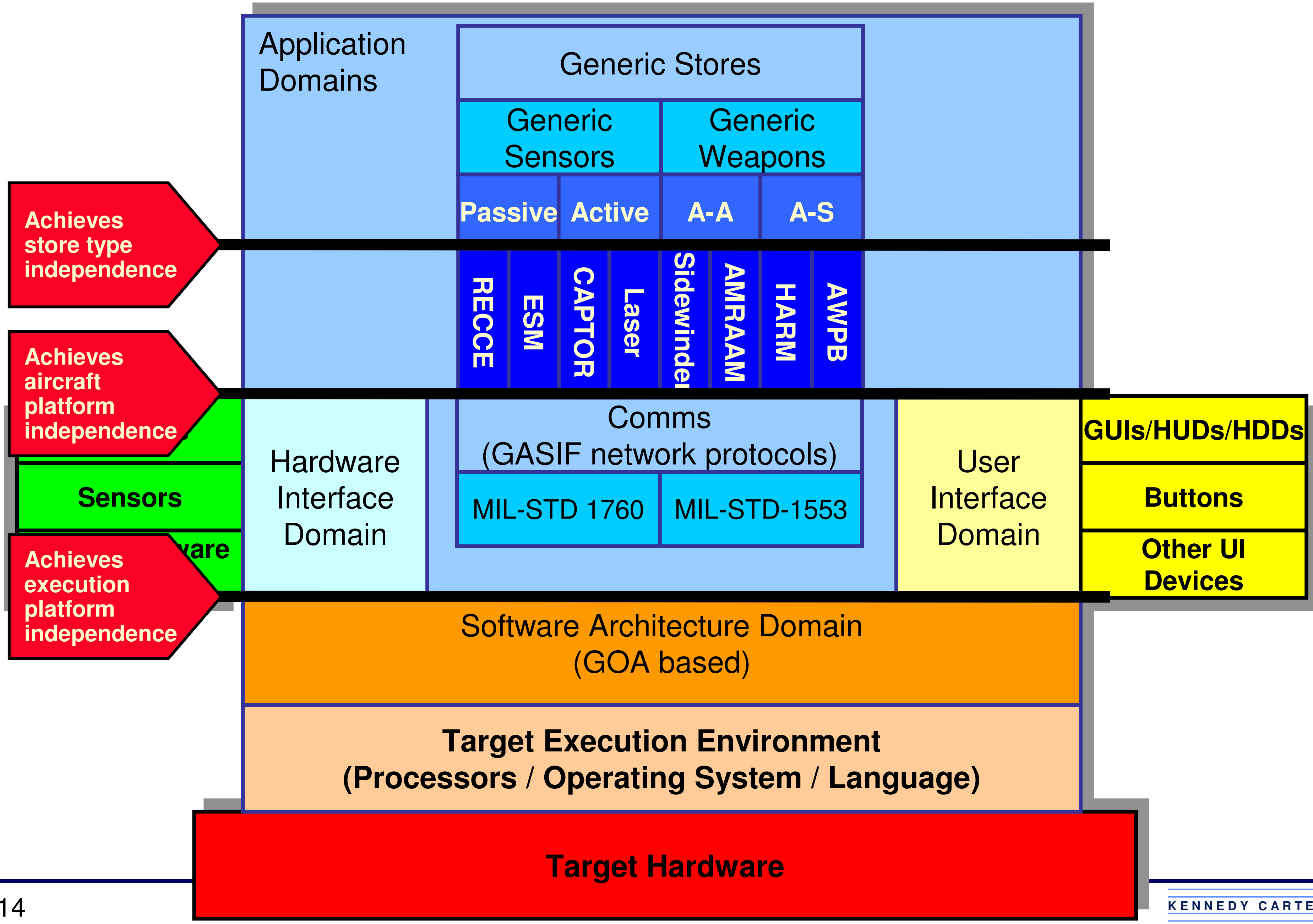
The Primary xUML Models



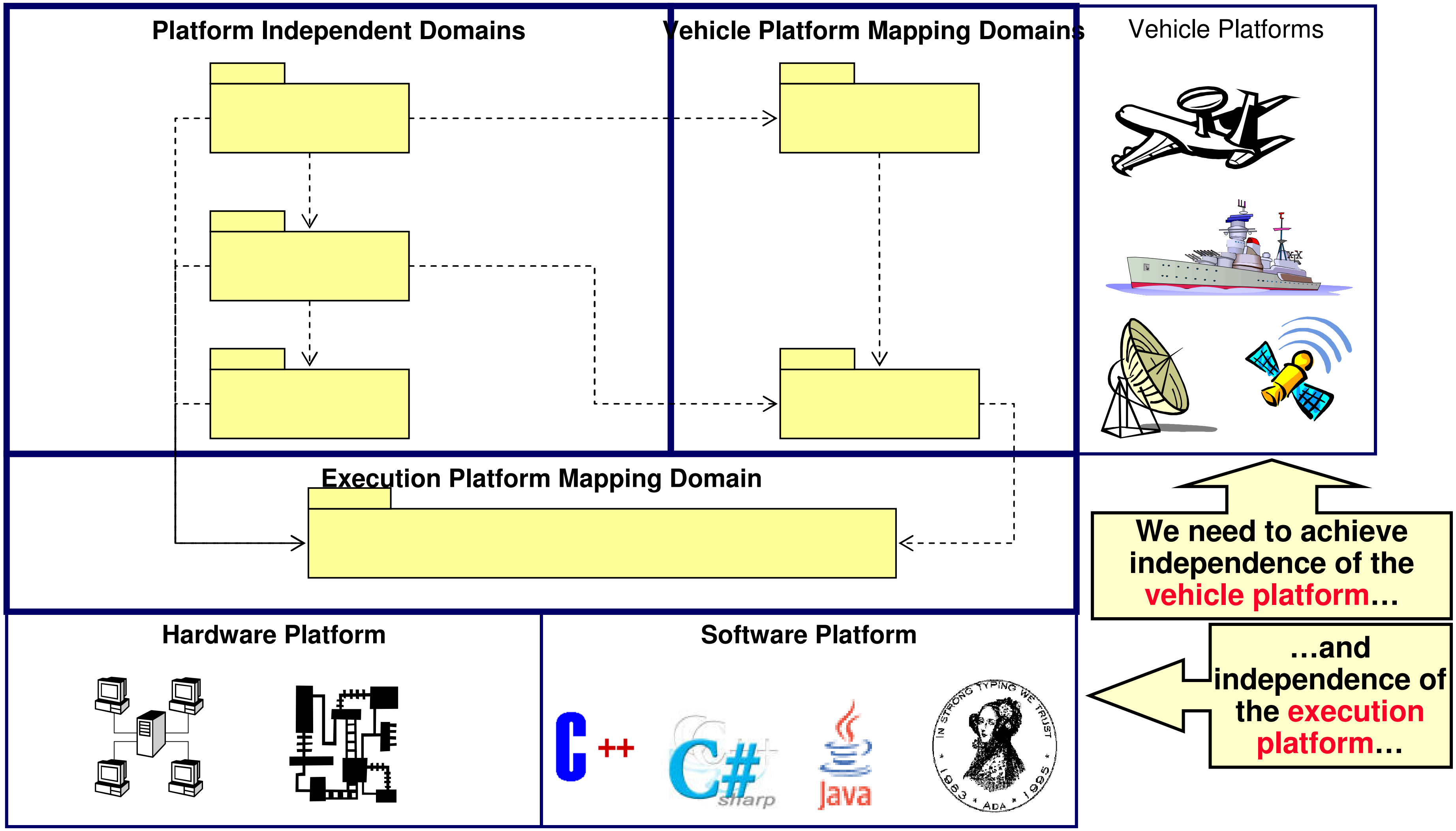
The Four Domain Layers



Use Domains to Isolate Areas of Change (or Platforms)

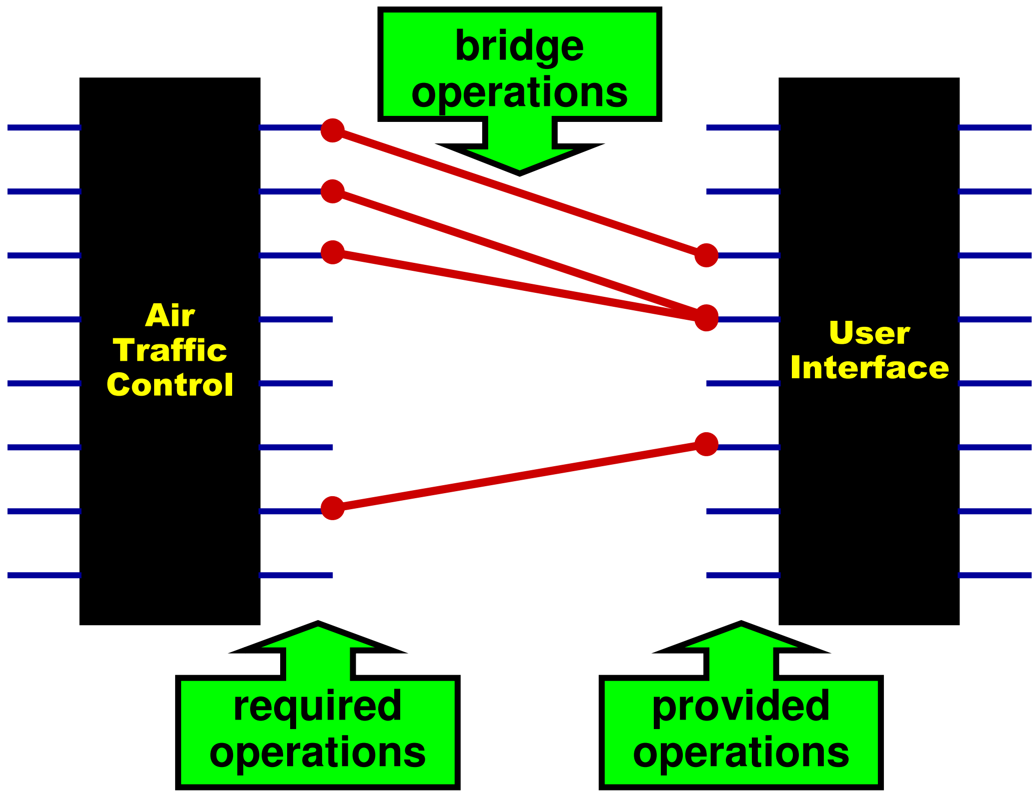


Domain Architecture for Platform Independence



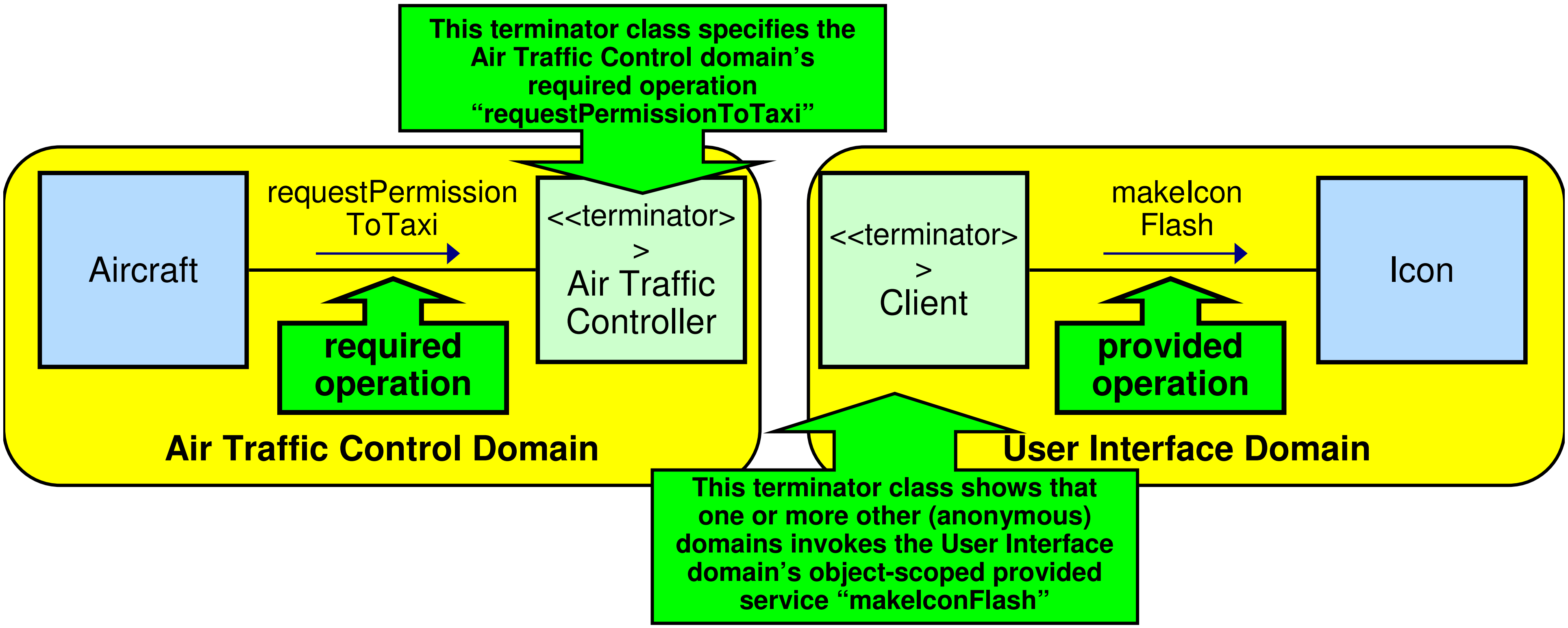
Elements of a Domain's Interfaces

Each domain can be thought of as an "integrated circuit" of classes (the black box)…
…with a set of provided and required operations (the pins)…
…that can be connected together into a system (the wiring)



The Terminator Classes Provide the Placeholders…

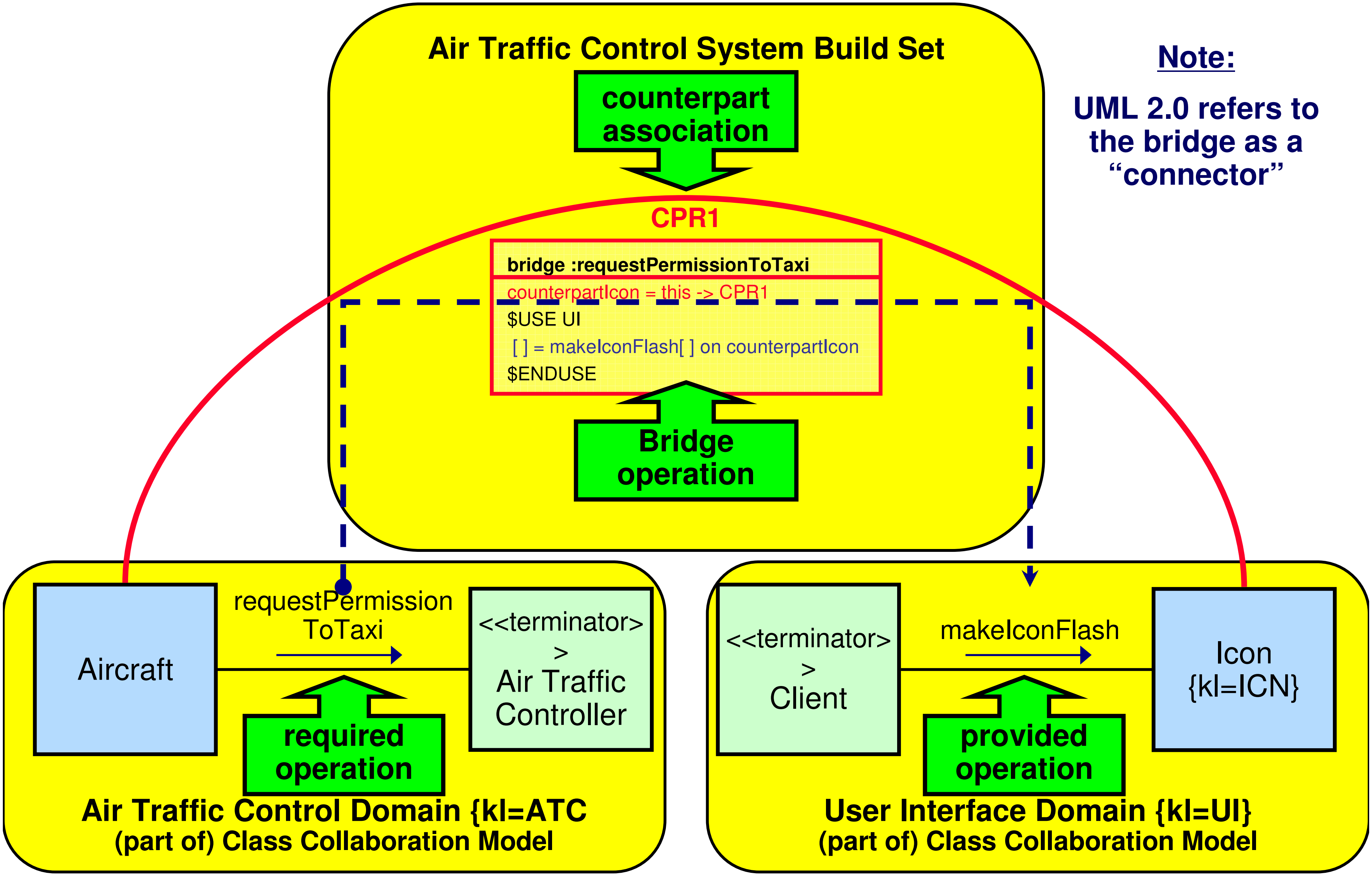
The <<terminator>> classes represent placeholders for the required operations for the domain to which they belong…
…and show which provided operations are invoked by other domains



The <<terminator>> classes are constrained such that they can only have operations. They cannot have attributes, associations, methods, state machine.

KENNEDY CARTER

The "Wiring" Is Specified in a Build Set…



Note:

UML 2.0 refers to the bridge as a "connector"

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Purpose of Translation

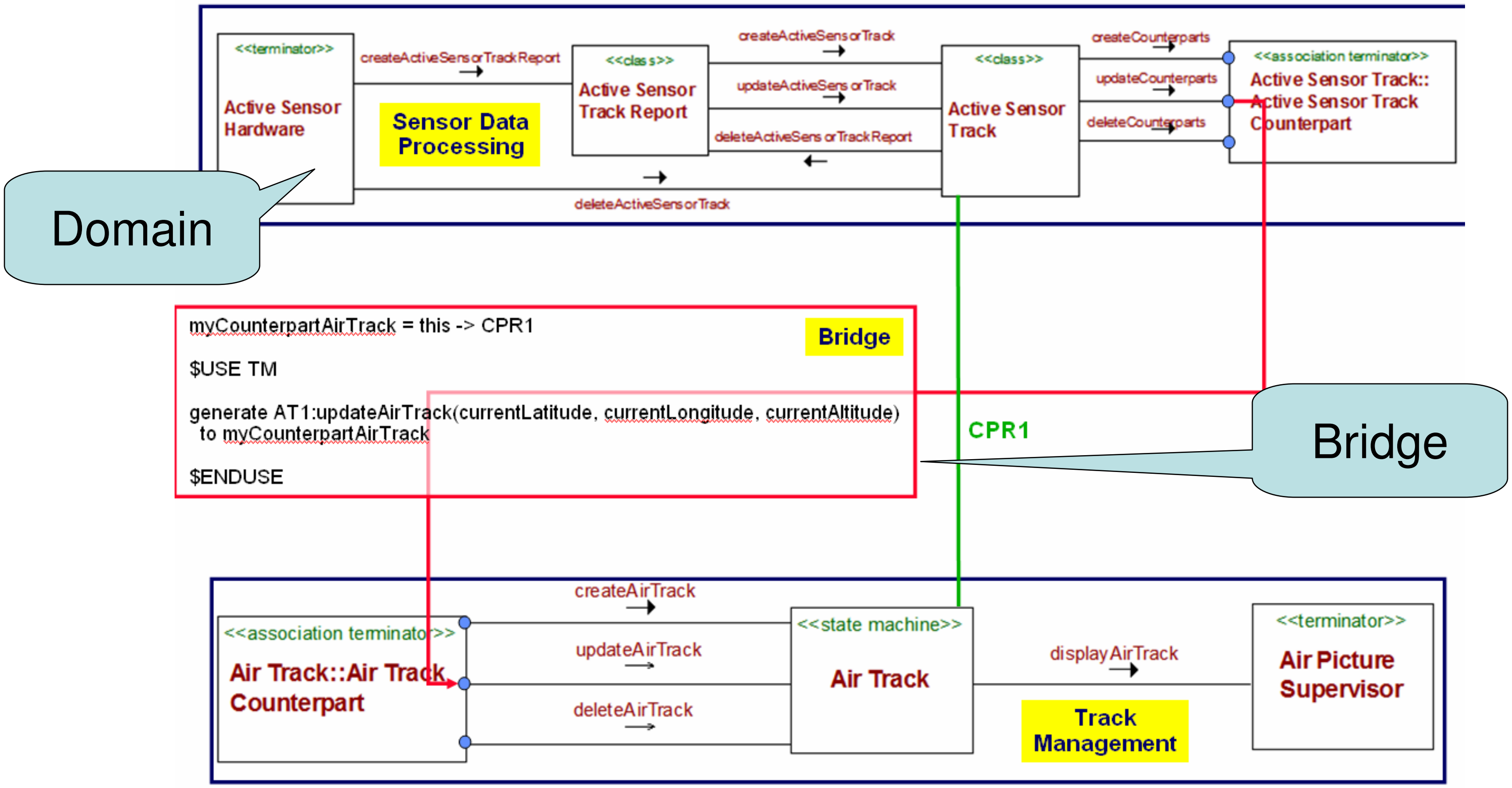
Analyze the runtime characteristics of a model expressed in xUML

Improve runtime structure

Options:

- Active object == thread (logical thread) & thread optimization to OS threads
- Define task architecture (OS threads) & active object -> thread mapping

Sample


<<terminator>>
Active Sensor Hardware
createActiveSensorTrackReport
Sensor Data Processing
<<class>>
Active Sensor Track Report
createActiveSensorTrack
updateActiveSensorTrack
deleteActiveSensorTrackReport
deleteActiveSensorTrack
<<class>>
Active Sensor Track
createCounterparts
updateCounterparts
deleteCounterparts
<<association terminator>>
Active Sensor Track:: Active Sensor Track Counterpart
Domain
myCounterpartAirTrack = this -> CPR1
$USE TM
generate AT1:updateAirTrack(currentLatitude, currentLongitude, currentAltitude)
to myCounterpartAirTrack
$ENDUSE
Bridge
CPR1
Bridge
<<association terminator>>
Air Track::Air Track Counterpart
createAirTrack
updateAirTrack
deleteAirTrack
<<state machine>>
Air Track
displayAirTrack
Track Management
<<terminator>>
Air Picture Supervisor

Mapping Domains

Domains are mapped to packages in AADL

Every definition in the public section

package xUMLBasicTypes

public

...

end xUMLBasicTypes;

package SensorDataProcessingDomain

public

...

end SensorDataProcessingDomain;

package TrackManagementDomain

public

...

end TrackManagementDomain;

Finding xUML Threads

Two Sources

- External Device Stimuli
- State Machines

In Our Example

- Active Sensor Hardware
- AirTrack State Machine

Translation of Message Semantics

xUML Semantics

- Closed Blocking. This represents a function call where the caller can send data and expects and waits for an answer from the callee before continuing its execution.
- Closed Non-Blocking. In this case the caller also expects an answer but it will not wait to get it before continuing its execution. Instead it queries for the answer at a later time.
- Open. This involves a transfer of data from the caller to the callee. The caller does not wait for the completion of the callee neither expects any answer from it.

AADL Semantics

- Closed Blocking. In this case the callee is a subprogram and the message from the caller to the callee a subprogram call.
- Closed Non-Blocking. In this case the callee is a thread (and hence the caller is another thread). The message is a data port connection from caller to callee and an event port connection from the callee to the caller to notify the completion of the execution.
- Open. In this case the caller and the callee are both thread and the message is only a event data port connection from the caller to the callee

AADL Threads for Example

```
thread ActiveSensorThread
 features
  createActiveSensorTrackReport: in event data port CreateActiveSensorTrackEvent;
  initializeAirTrack: out event data port
TrackManagementDomain::InitializeAirTrackEvent;
  updateAirTrack: out event data port TrackManagementDomain::UpdateAirTrackEvent;
  deleteAirTrack: out event data port TrackManagementDomain::DeleteAirTrackEvent;
end ActiveSensorThread;
thread AirTrackThread
 features
  initializeAirTrack: in event data port InitializeAirTrackEvent;
  updateAirTrack: in event data port UpdateAirTrackEvent;
  deleteAirTrack: in event data port DeleteAirTrackEvent;
end AirTrackThread;
```

Implicit Object Management

Objects are assumed to be managed by its class in xUML

- Find objects
- Manage object memory for creation/deletion

Need to be explicit in AADL

- In the form of “Collection”

Sample Collection

data ActiveSensorTrackReport

features

initialize: **subprogram** InitializeActiveSensorTrackReportInstance;

update: **subprogram** UpdateActiveSensorTrackReportInstance;

delete: **subprogram** DeleteActiveSensorTrackReportInstance;

end ActiveSensorTrackReport;

data ActiveSensorTrackReportCollection

features

find : **subprogram** FindActiveSensorTrackReportCollection;

create: **subprogram** CreateActiveSensorTrackReportCollection;

delete: **subprogram** DeleteActiveSensorTrackReportCollection;

update: **subprogram** UpdateActiveSensorTrackReportCollection;

end ActiveSensorTrackReportCollection;

Call Sequences

```
thread implementation ActiveSensorThread.Impl
 subcomponents
  reportCollection: data ActiveSensorTrackReportCollection;
  activeSensorTrackCollection: data ActiveSensorTrackCollection;
  airTrackCollection: data AirTrackCollection;
 calls
  createReport: { find1: subprogram ActiveSensorTrackReportCollection.find;
                create1: subprogram ActiveSensorTrackReportCollection.create;};
  updateReport: { find2: subprogram ActiveSensorTrackReportCollection.find;
                update1: subprogram ActiveSensorTrackReportCollection.update;};
  deleteReport: { find3: subprogram ActiveSensorTrackReportCollection.find;
                delete1: subprogram ActiveSensorTrackReportCollection.delete;};
 connections
  c1: event data port create1.initializeAirTrack->initializeAirTrack;
  c2: event data port update1.updateAirTrack->updateAirTrack;
  c3: event data port delete1.deleteAirTrack->deleteAirTrack;
  p1: parameter createActiveSensorTrackReport->find1.report;
  p2: parameter createActiveSensorTrackReport->create1.report;
  p3: parameter createActiveSensorTrackReport->find2.report;
  p4: parameter createActiveSensorTrackReport->update1.report;
  p5: parameter createActiveSensorTrackReport->find3.report;
  p6: parameter createActiveSensorTrackReport->delete1.report;
end ActiveSensorThread.Impl;
```

Final System

process TrackingProcess

features

createActiveSensorTrackReport : **in event data port** SensorDataProcessingDomain::CreateActiveSensorTrackEvent;

end TrackingProcess;

process implementation TrackingProcess.Impl

subcomponents

sensorThread: **thread** SensorDataProcessingDomain::ActiveSensorThread;

airTrackThread: **thread** TrackManagementDomain::AirTrackThread {xUML::Multiplicity => 100;};

connections

c1: **event data port** sensorThread.initializeAirTrack->airTrackThread.initializeAirTrack {xUML::Connection_Multiplicity => OneToOne;};

c2: **event data port** sensorThread.updateAirTrack->airTrackThread.updateAirTrack {xUML::Connection_Multiplicity => OneToOne;};

c3: **event data port** sensorThread.deleteAirTrack->airTrackThread.deleteAirTrack {xUML::Connection_Multiplicity => OneToOne;};

c4: **event data port** createActiveSensorTrackReport->sensorThread.createActiveSensorTrackReport;

end TrackingProcess.Impl;

device ActiveSensorDevice

features

createActiveSensorTrackReport: **out event data port** SensorDataProcessingDomain::CreateActiveSensorTrackEvent;

end ActiveSensorDevice;

processor MyProcessor

end MyProcessor;

system Final

end Final;

system implementation Final.Impl

subcomponents

sensor: **device** ActiveSensorDevice;

proc: **processor** MyProcessor;

trackProcess: **process** TrackingProcess;

connections

c1: **event data port** sensor.createActiveSensorTrackReport->trackProcess.createActiveSensorTrackReport;

end Final.Impl;

Performance Analysis

Properties to be added

- End-to-end latency requirements
- Periodicity of events, both external (e.g. sensor interrupts) and internal (timers – could be extracted from the xUML model)
- Execution time of subprograms
- Processor Speed
- Network Speed

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Mapping into Operating System Threads

Transformation of logical thread model

- Threads in transformed model represent OS threads
- Logical threads become subprogram calls in OS thread

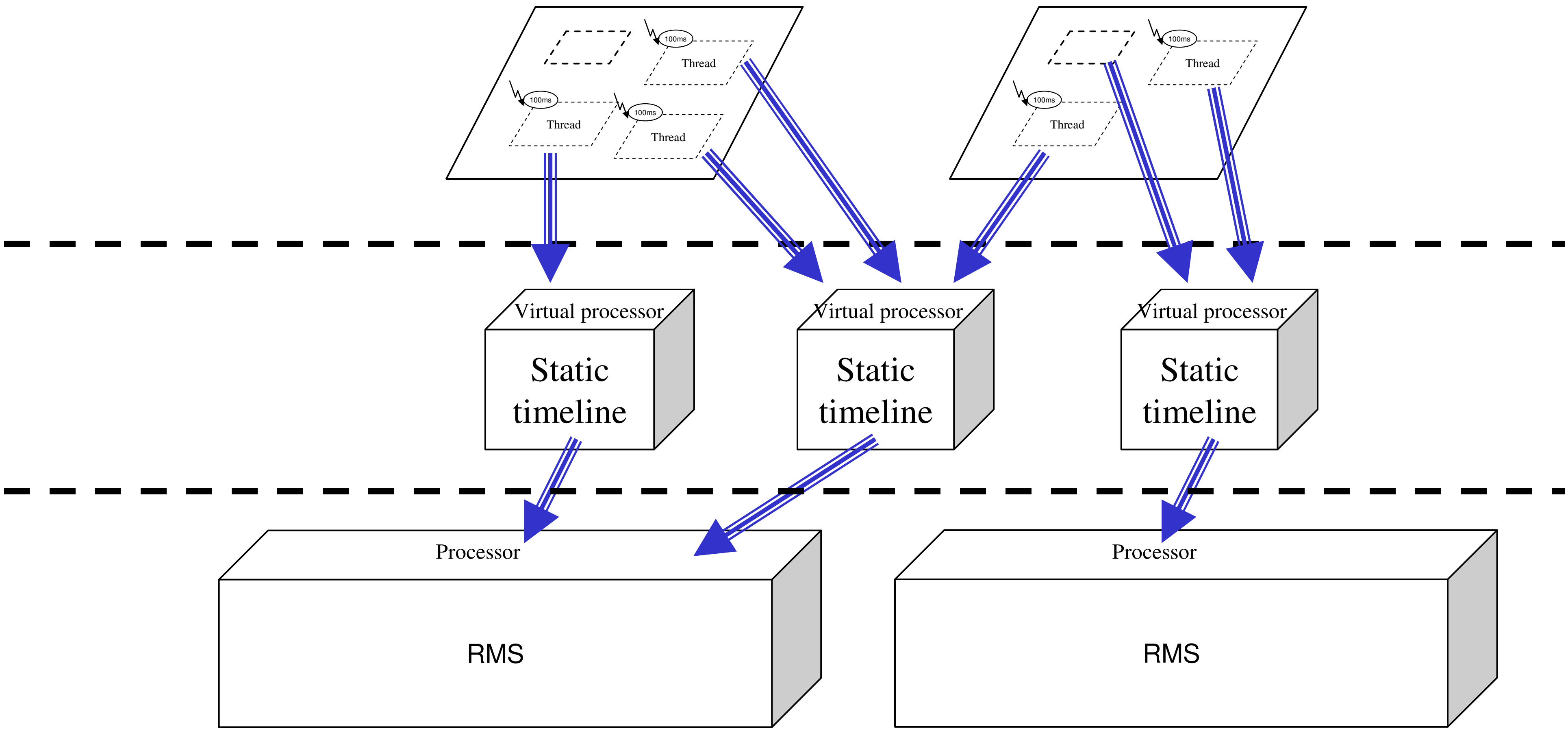
Thread groups to represent thread mappings

- Assignment by containment grouping
- Rate group optimization

Virtual processor to represent OS thread

- Virtual processor as hierarchical scheduler
- Logical thread binding to virtual processor
- Virtual processor binding or containment

Two-Level Thread Binding



Predictive Analysis Across Perspectives

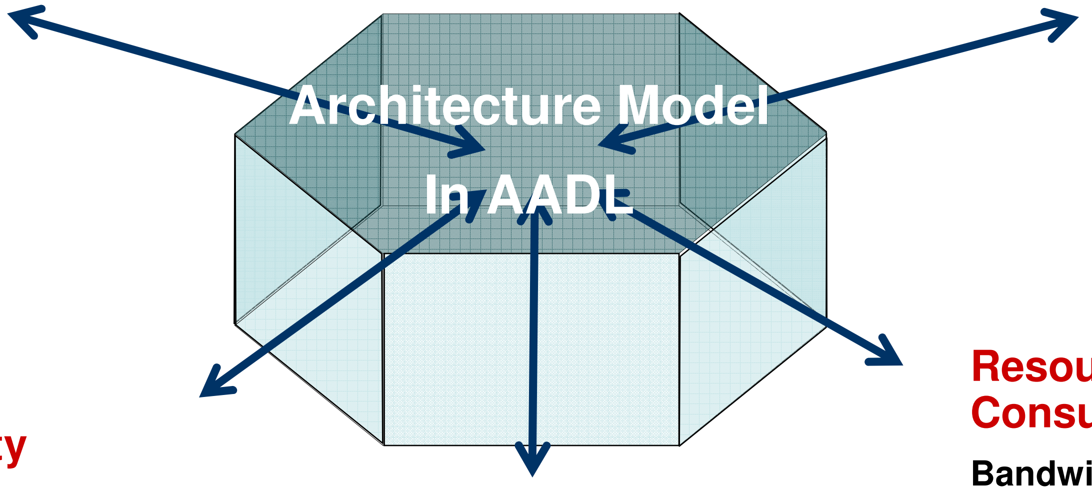
Single-Source Model Reduces Cost of Model Evolution

Availability & Reliability

- MTBF
- FMEA
- Hazard analysis

Security

- Intrusion
- Integrity
- Confidentiality



Data Quality

- Data precision/ accuracy
- Temporal correctness
- Confidence

Real-time Performance

- Execution time/ Deadline
- Deadlock/starvation
- Latency

Resource Consumption

- Bandwidth
- CPU time
- Power consumption

Observations

PSMs require more than UML offers

- AADL is targetedat runtime architecture
- OMG MARTE compatible with AADL

Mapping xUML design patterns

- Active objects, terminators, and bridges
- Functional interface
- connection semantics in bridge patterns

AADL-based runtime architecture model

- Logical thread and OS threads
- Basis of multi-dimensional multi-fidelity analysis of operational properties
- Generation of application specific runtime system implementation

Questions?

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