The Software Engineering Institute

Extending the Open Source SAE AADL Toolset

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Outline

- Background: SAE AADL Standard
- XML-based tool interoperability and AADL extension
- An enriched embedded system engineering environment
- Open source toolset extension: an example
- Summary

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SAE Architecture Analysis & Design Language

- Notation for specification of task and communication architectures of Real-time, Embedded, Fault-tolerant, Secure, Safety-critical, Software-intensive systems
- Fields of application: Avionics, Automotive, Aerospace, Autonomous systems, …
- Based on 15 Years of DARPA funded technologies
- Standard approved by SAE in Sept 2004
- www.aadl.info

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Model-Based Engineering

System Analysis
- Schedulability
- Performance
- Reliability
- Fault Tolerance
- Dynamic Configurability

System Integration
- Runtime System Generation
- Application Composition
- System Configuration

Software System Engineer

Model the Architecture
Abstract, but Precise

SAE AADL

Predictive System Engineering
Reduced Development & Operational Cost

Application Software

Execution Platform

Composable Components

Target Recognition

Guidance & Control

Supply

Mec

Ambulat

& Signal Processing

Information Fusion

GPS	DB	HTTPS	Ada Runtime

. . . . . .

Devices	Memory	Bus	Processor

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The AADL Standard

- Requirements document SAE ARD 5296
  - Input from aerospace industry
  - Balloted and approved in 2000
- SAE AADL document SAE AS 5506
  - Core language approved by SAE Sept 2004
- In review to be balloted late 2004
  - Graphical AADL notation
  - UML profile of AADL for UML1.4 and UML 2.0
  - XMI domain model, XML schema
  - Ada and C Annex
- In development
  - Error Model Annex
  - ARINC 653 Annex

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Two-Tier Tool Strategy

- Open Source AADL Tool Environment (OSATE)
  - Developed by SEI
  - Low entry cost solution (no cost CPL)
  - Multi-platform based on Eclipse 3.0
  - Prototyping environment for project-specific analysis
  - Architecture research platform
- Commercial Tool Support
  - UML tool environment extension based on UML profile
  - Extension to existing modeling environment with AADL export/import
  - Analysis tools interfacing via XML or XML to native filter
  - Runtime system generation tools

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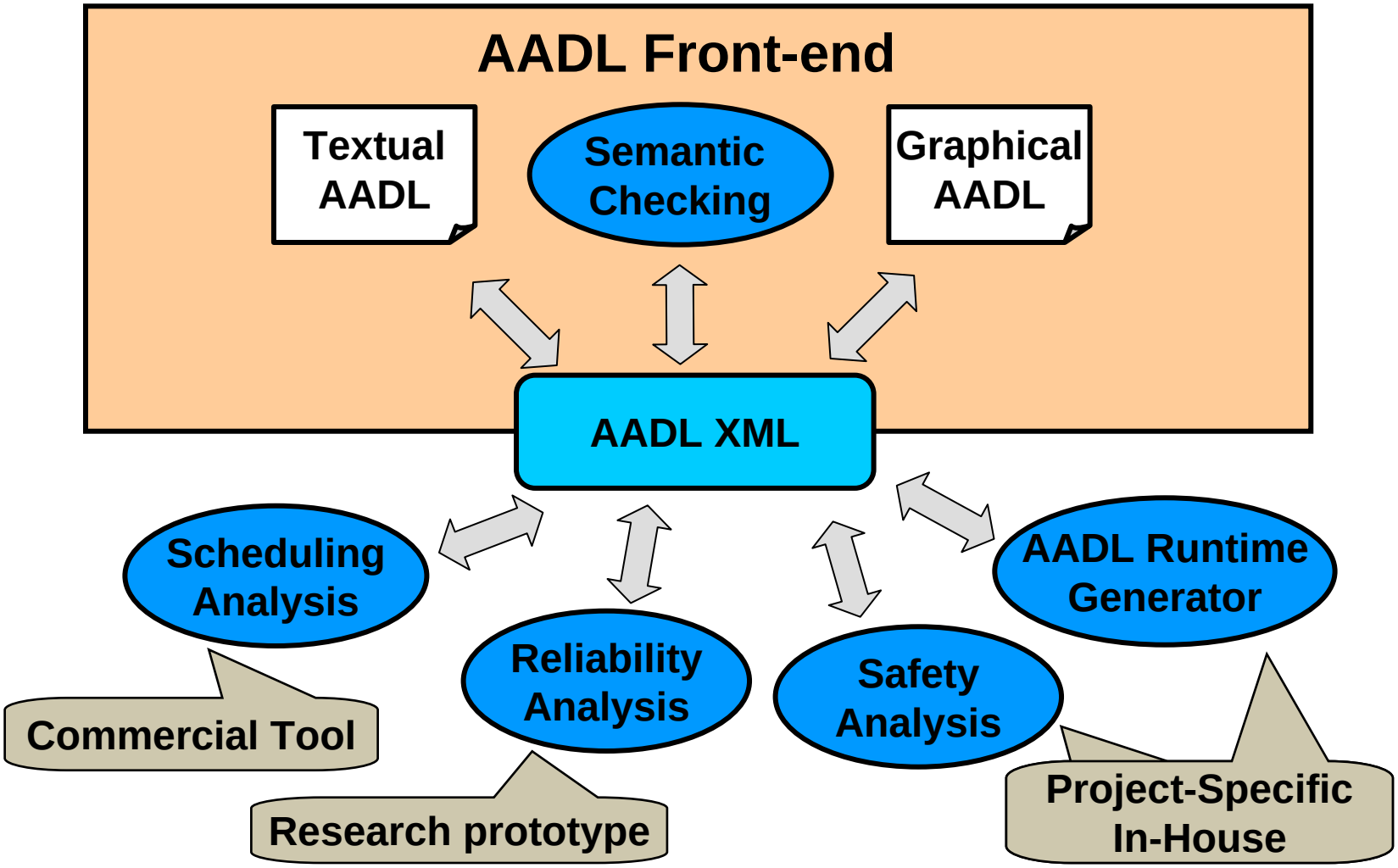
An XML-Based Tool Strategy



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AADL Meta Model

- Defined in Eclipse Modeling Framework (EMF)
  - Collection of meta model packages with graphical views
  - Separate from, but close to UML profile of AADL
- XML as persistent storage
  - XMI specification from Ecore meta model
  - Generated XML schema
- In-core AADL model
  - Generated methods for AADL model manipulation
  - Edit history, deep copy, object editor, graphical editor
  - Methods to support
    - AADL extends hierarchy
    - feature “inheritance”
    - property value “inheritance”

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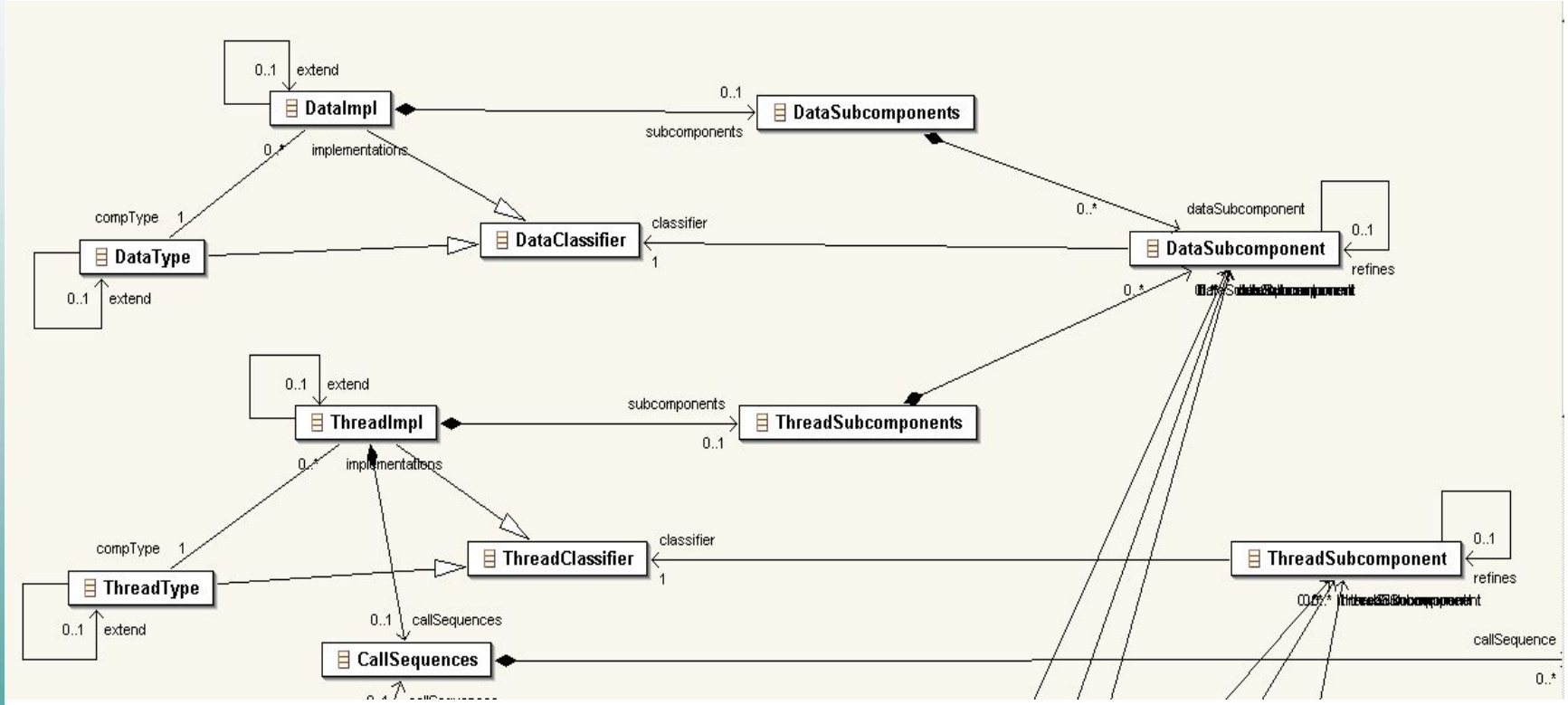
AADL Meta Model Fragment



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Extensible Language & Toolset

- Extensible language
  - New properties through property sets
  - Sublanguage extension
  - Project-specific & approved annex extensions
  - Examples
    - Error model for dependability modeling
    - ARINC 653 profile
- Extensible tool environment
  - Eclipse plug-in architecture
  - Integrated analysis capability
  - XML-based interface to external tools
  - Filter to external tool representations

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OSATE Capabilities

- OSATE Release 0.3.0 based on Eclipse Release 3
- Online help
- Text to XML & XML to text
- Syntax-sensitive text editor
- Parsing & semantic checking of approved AADL
- AADL property viewer
- AADL to MetaH translator
- Syntax-Sensitive AADL Object Editor
- Model instantiation
- Model consistency checking

Over 150 downloads

Processed 21000 line AADL model

Next release Nov 2004
Graphical editor
Multi-file support
Analysis plug-in development

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Architecture Consistency

Systemic issues discovered in architecture analysis
Issue detection codified as OSATE extensions

- Expected component connectivity
  - Required and optional port connections
- Miss rate of data stream
  - Accommodates incomplete sensor readings
  - Allows for controlled deadline misses
- State vs. state delta communication
  - Data reduction technique
  - Implies requirement for guaranteed delivery
- Data accuracy
  - Reading accuracy
  - Computational error accumulation
- Priority inversion
  - Manually assigned thread priorities

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An Illustrative Example

- Pilot display response time
  - Determined by flow latency
- Analysis of high-level architecture
  - Abstract but precise
- Leverage timing characteristics of subsystems
  - Subsystems as partitions
  - Partition execution semantics

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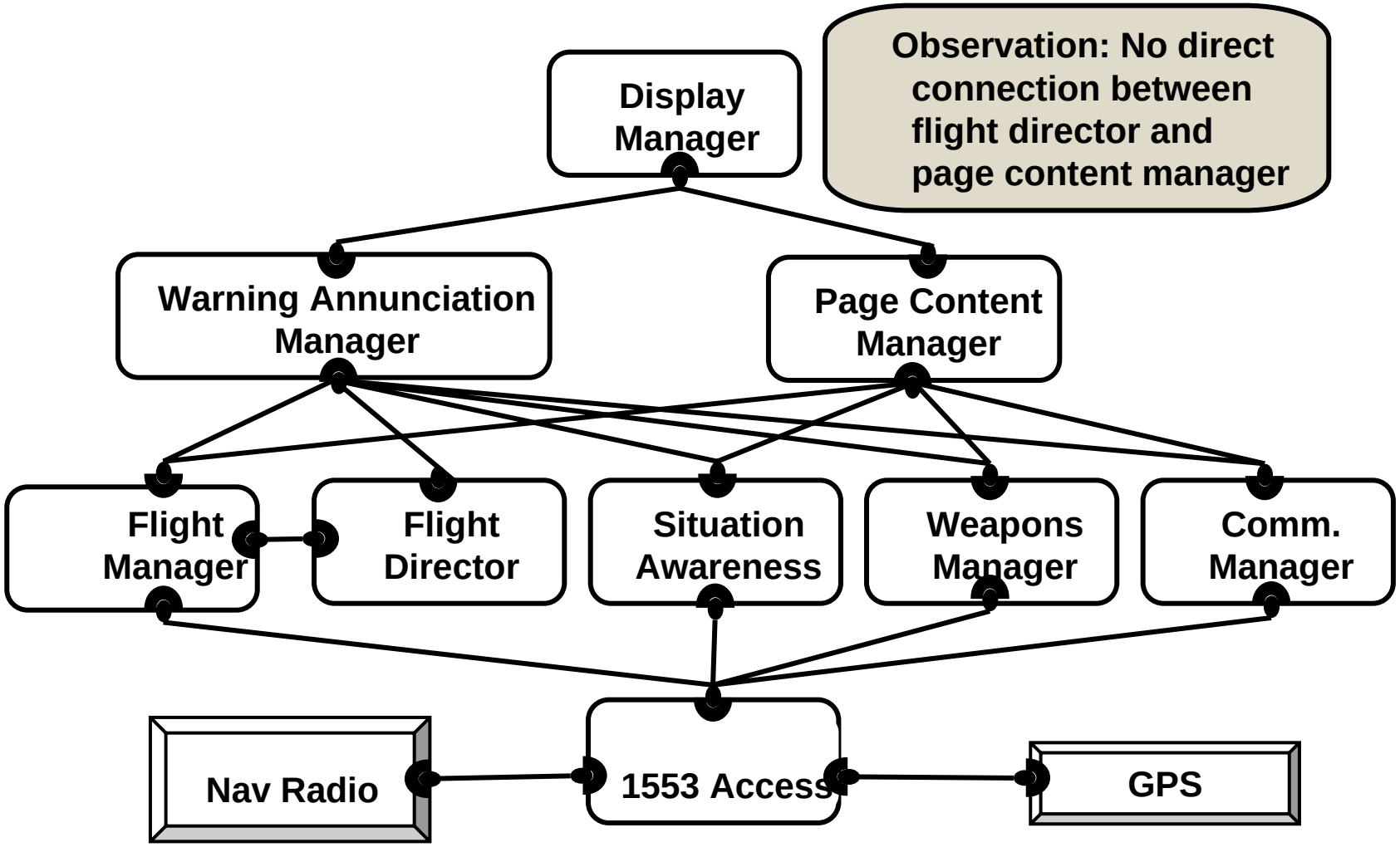
Avionics Subsystem Architecture



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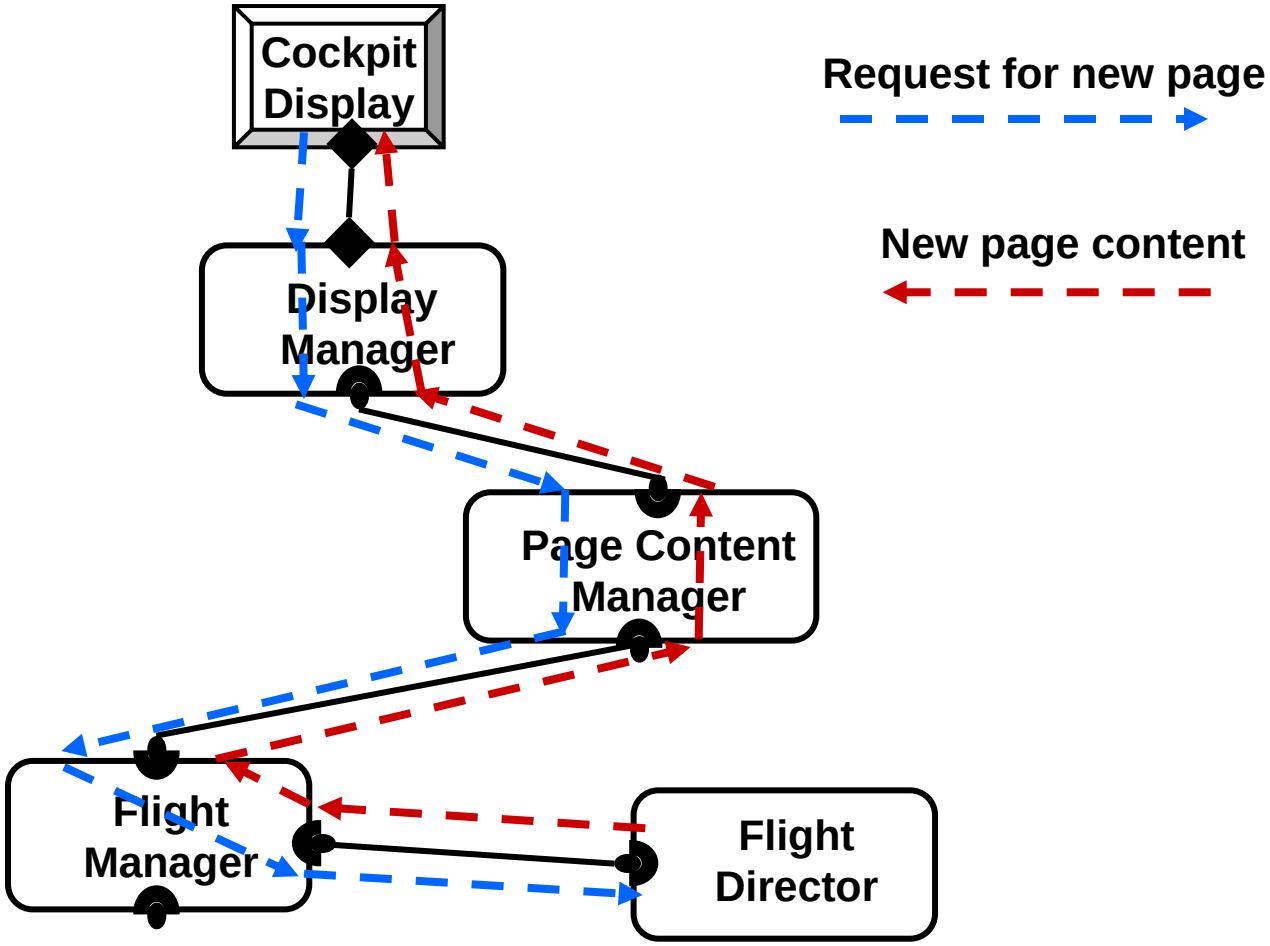
Flight Director Command Flow



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Response Time Analysis

- Worst-case scenario
  - Period delay per partition communication
    - DM sampling latency (max. = partition period)
    - Six periods of partition communication latency
    - DM execution latency (max. = partition period)
    - 0.4 seconds worst case response time
    - 0.3 seconds best case response time
- Single processor static timeline
  - One direction immediate, opposite direction phase delayed
  - Reduces partition communication latency to three periods
- Multiple processor synchronous system
  - Take into consideration bus/network latency
- Multiple processor asynchronous system
  - Asynchronous sampling with max. sampling latency = period

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Response Time Plug-in

```
public Object caseEndToEndFlow(EndToEndFlow etef)  {
    int responsetime = 0;
    for(Iterator it = etef.getFlowElement().iterator(); it.hasNext()){
        FlowElement fe = (FlowElement) it.next();
        Subcomponent sub = fe.getFlowContext();
        IntegerValue ppv = getSimplePropertyValue("ARINC653","Partition_Period");
        if (ppv == null )
            errorReporter.reportError(sub,"Subcomponent is missing partition period");
        else
            responsetime =+ ppv.getScaledValue(PredeclaredProperties.MICROSEC);
    }
    etef.setSimplePropertyValue("Actual_Latency",responsetime);
    IntegerValue epv = etef.getSimplePropertyValue("Expected_Latency");
    if (responsetime > epv.getScaledValue(PredeclaredProperties.MICROSEC))
        errorReporter.reportWarning(etef,"Actual latency exceeds expected latency");
    return DONE;
}
```

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Response Time Analysis Command

```
public class CalcAllEndToEndResponseTime extends AaxlModifyAction {
-- action to perform analysis on all end to end flows
public void doAaxlAction(AObject obj){
    AObject as = obj.getAObjectRoot();
    AadlSwitch responseTimeSwitch = ResponseTime.createResponseTimeSwitch();
    connectionSecuritySwitch.processPreOrderAll(as);
    errorReporter.reportInfo(as,“Response Analysis done");
}
}

public class CalcSelectedEndToEndResponseTime extends AaxlModifyAction {
-- action to perform analysis selected end to end flow
public void doAaxlAction(AObject obj){
    if (! obj instanceof EndToEndFlow) return;
    AadlSwitch responseTimeSwitch = ResponseTime.createResponseTimeSwitch();
    connectionSecuritySwitch.processPreOrderAll(obj);
    errorReporter.reportInfo(obj,“Response Analysis done");
}
}
```

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OSATE and External Tools

Embry-Riddle
Reliability Analysis

Architecture Extraction

System Verification Manager (CMU)
Simulink/Matlab, Dymola models

AADL Extensions
Error model
Concurrency behavior

Architecture Import
SVM

Concurrency Analysis

Company
In-house tools

XML

Architecture Export
MetaH, *TTA*

MetaH Toolset (Honeywell)
Scheduling analysis
Reliability analysis
Isolation analysis
Runtime system generation

OMNET++
Network simulation

Object Model Interface
Network model

Model Export Filters
Timing model

TimeWeaver (CMU)
Distributed resource allocation
Multi-platform runtime system generation

TimeWiz Commercial Tool
Scheduling analysis
Execution trace analysis

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Final Observations

- Industry-standard architecture modeling notation for embedded systems
  - Abstract but precise modeling
  - Early and repeated predictable analysis
- Industry-standard XML interchange format
  - Model interchange between contractors
  - Interoperability of analysis and generation tools
- Low entry cost open source tool set
  - Prototyping environment for project-specific analysis
  - Architecture research platform
  - Capture of engineering insight

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