Architecture-based Online Capacity Management: Modeling, Monitoring, and Adaptation

D3S Seminar/Department Meeting
Department of Distributed and Dependable Systems
Charles University, Prague

André van Hoorn

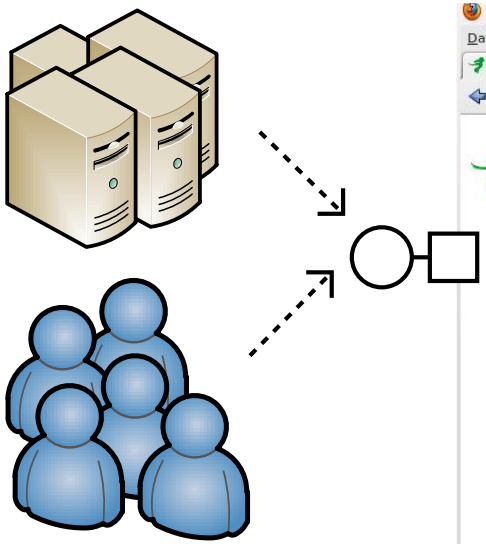
Software Engineering Group
University of Kiel, Germany

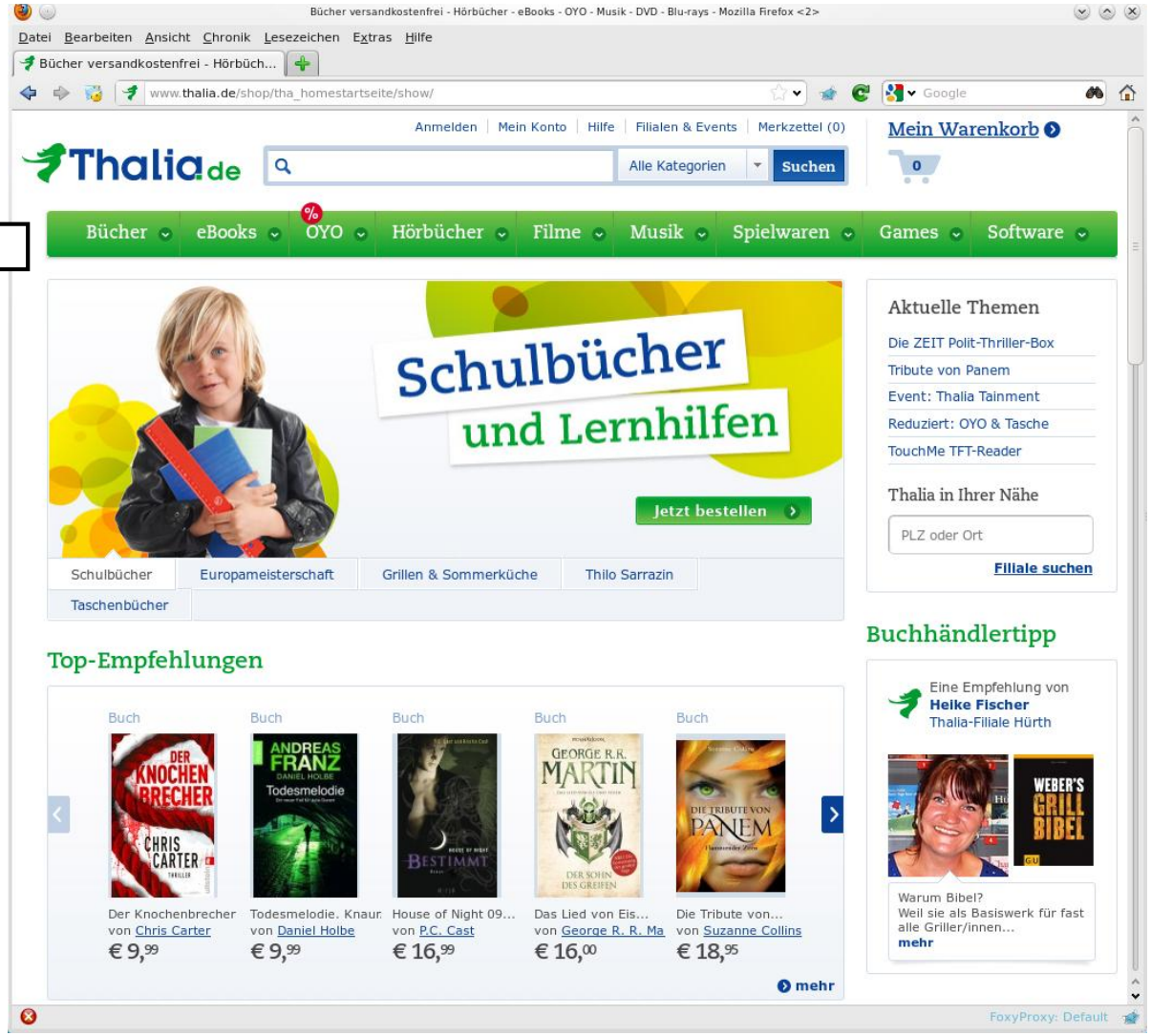
avh@informatik.uni-kiel.de

June 20, 2012 @ Prague

Motivation & Overall Goal

Christian-Albrechts-Universität zu Kiel





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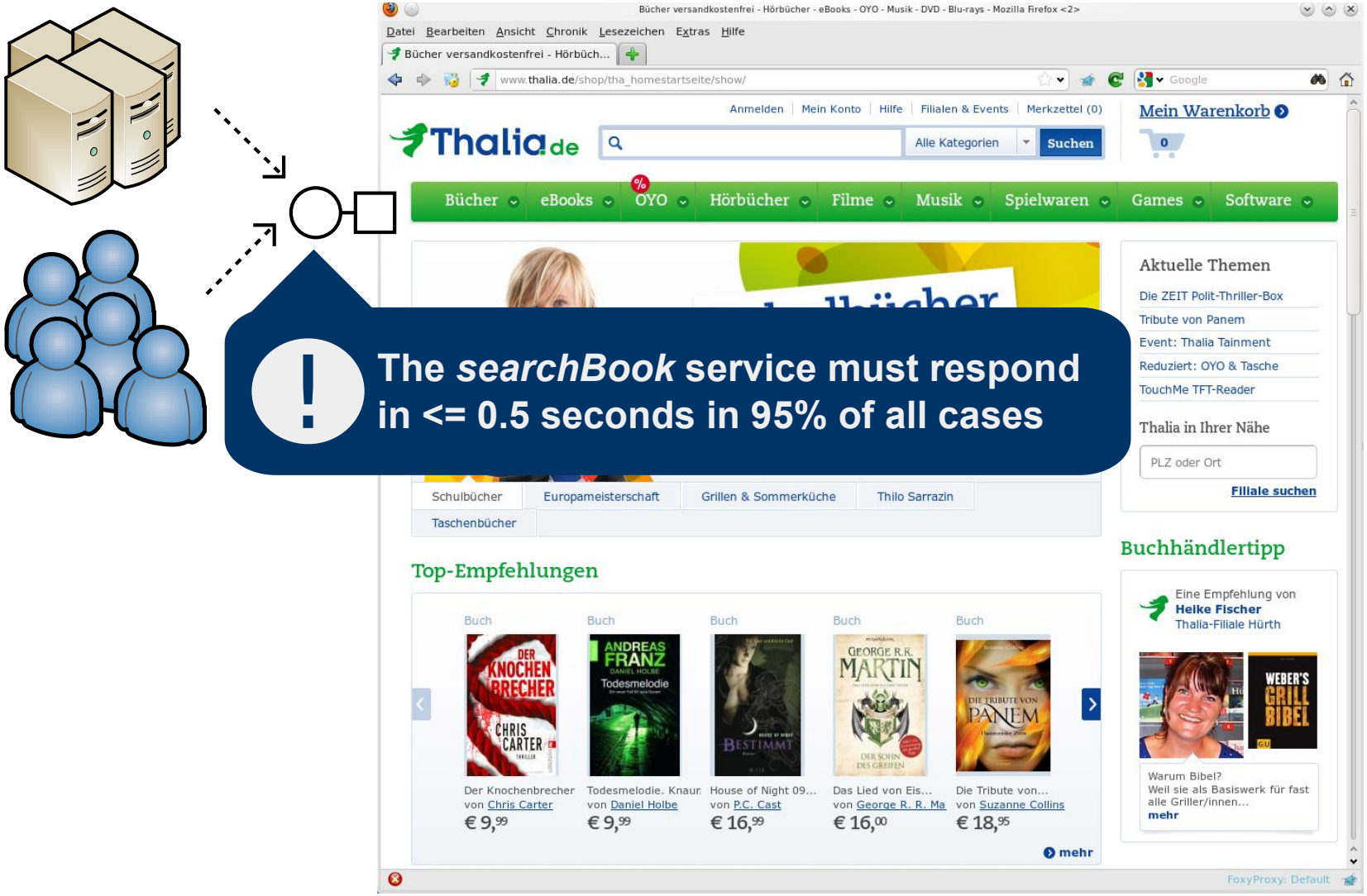

The *searchBook* service must respond in <= 0.5 seconds in 95% of all cases

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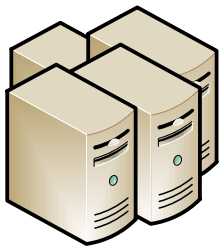

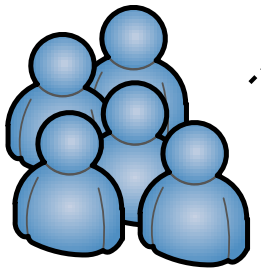

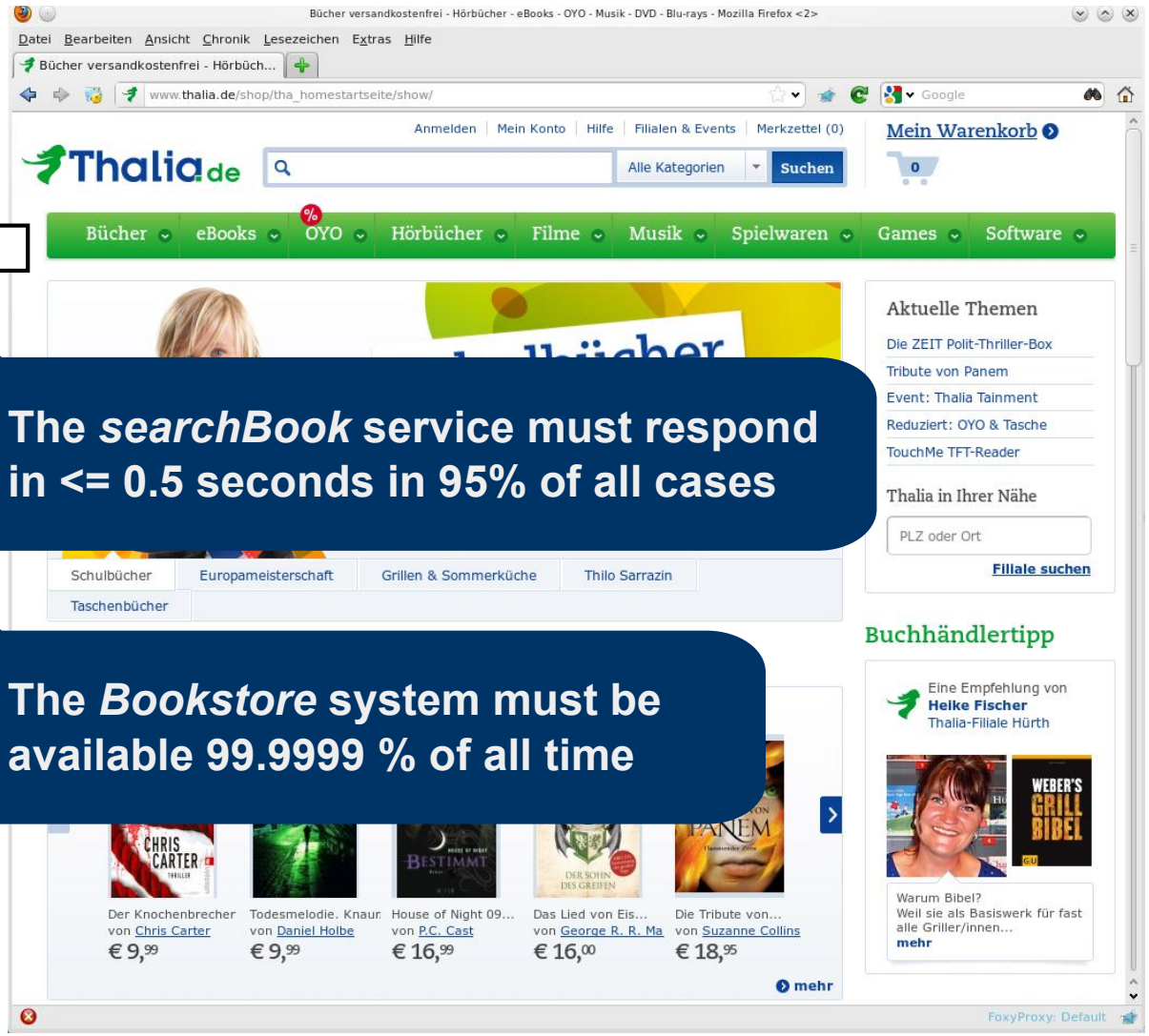

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The *Bookstore* system must be available 99.9999 % of all time

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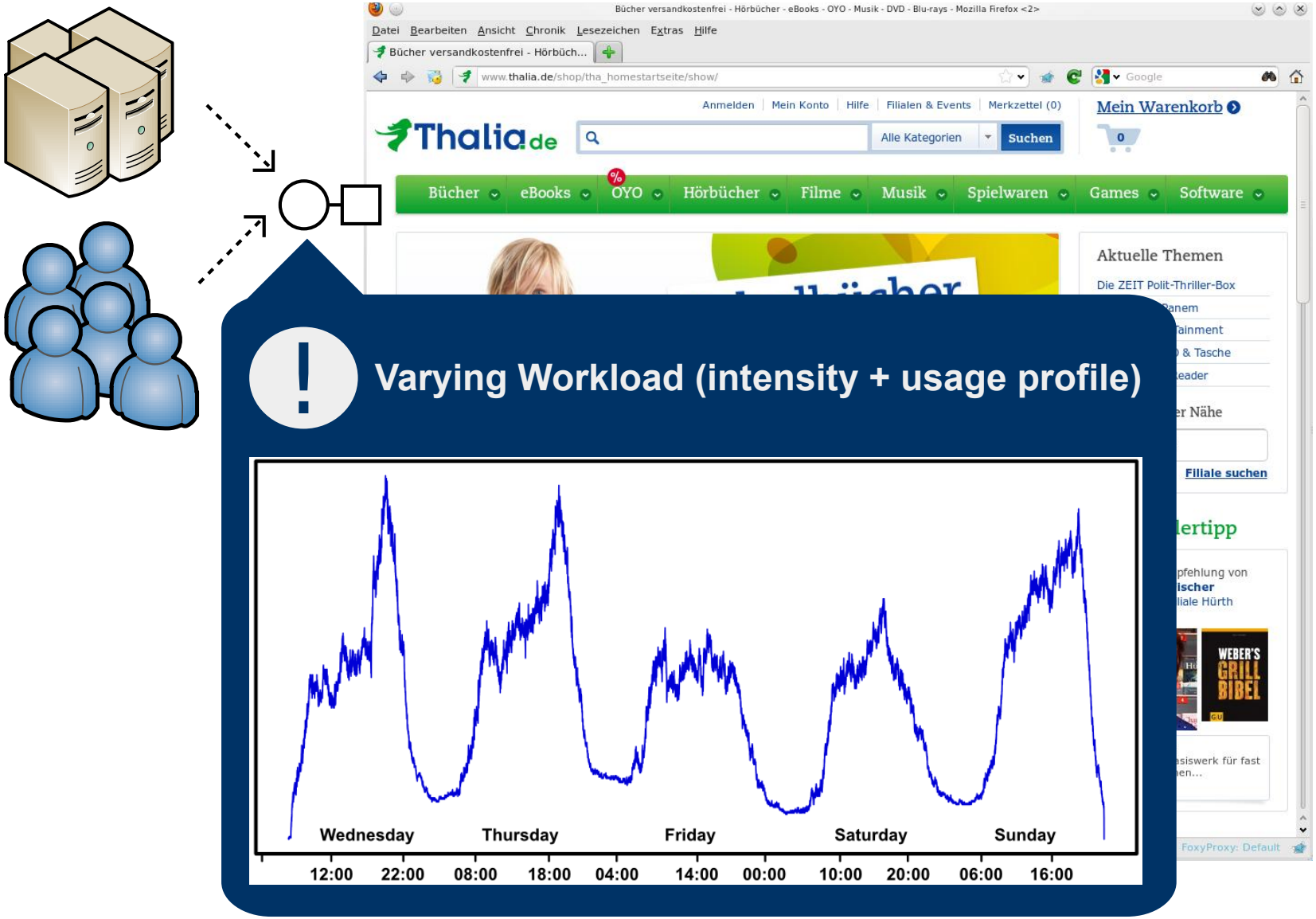

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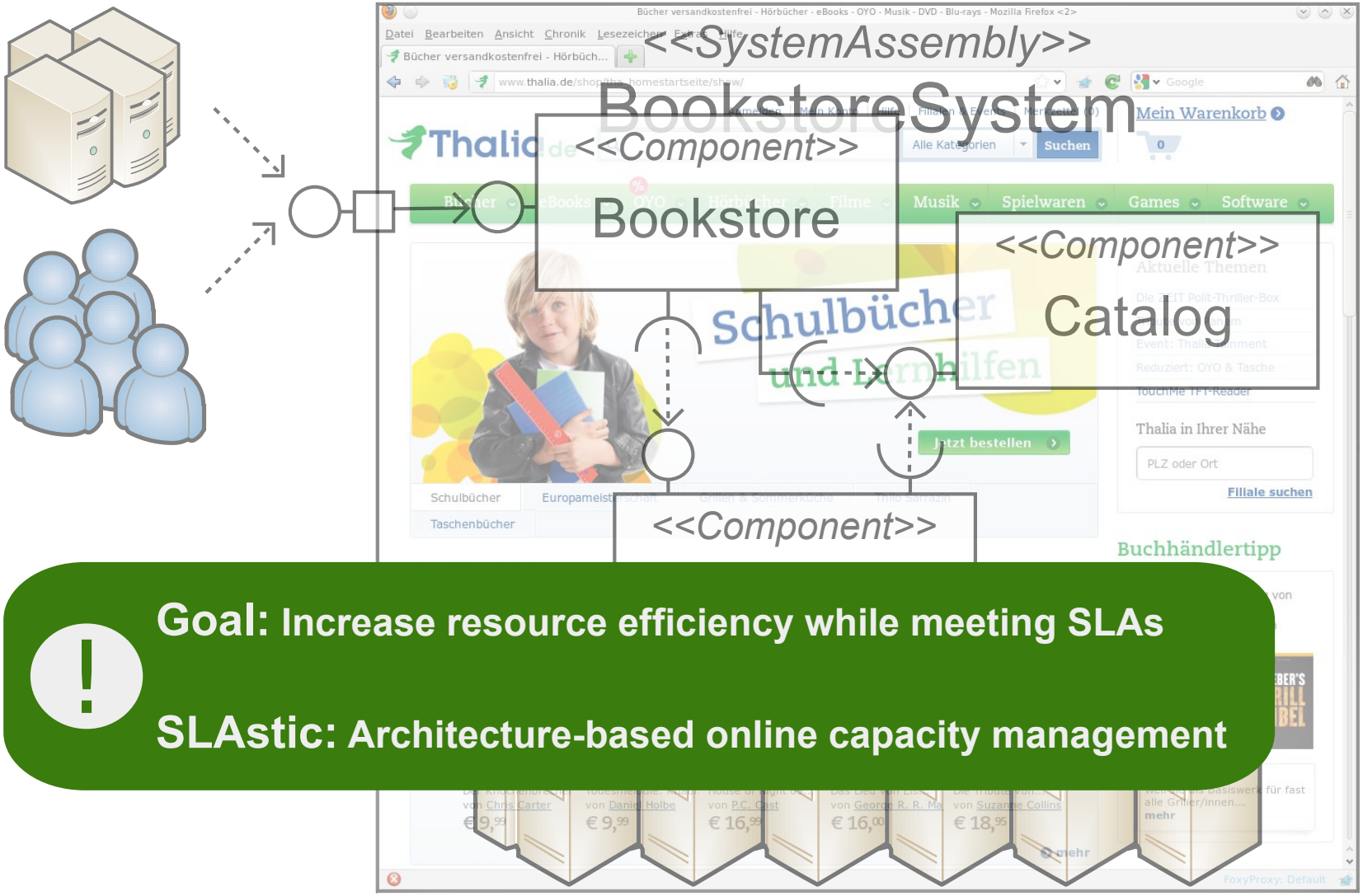

Goal: Increase resource efficiency while meeting SLAs

SLAstic: Architecture-based online capacity management

Scientific Context

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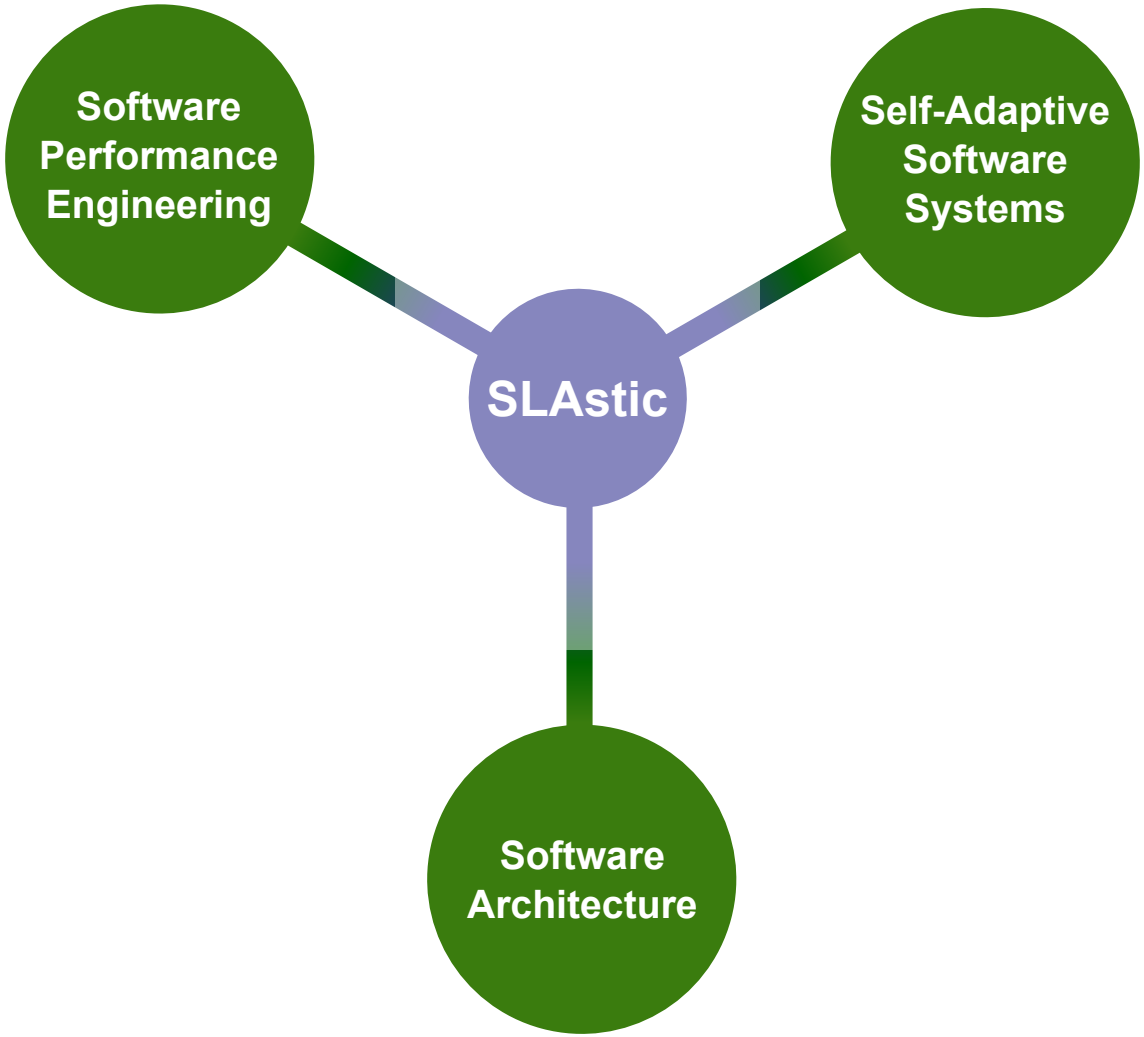
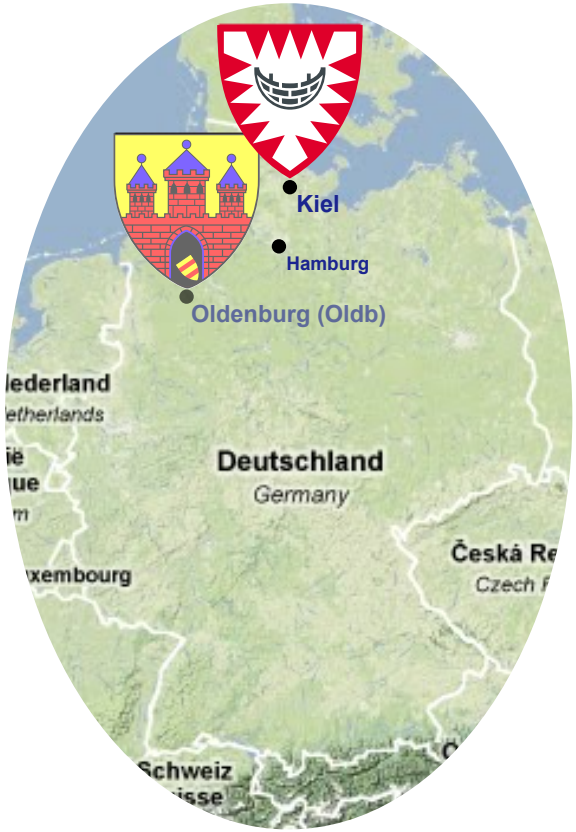


About Me

Affiliation

- **University of Kiel, Software Engineering Group**
- Before: University of Oldenburg (DFG RTG TrustSoft)



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Research Interests

1. **Software performance engineering & self-***
   - {Model,Architecture}-{based,driven} SPE techniques (+ tools)
   - Online performance management (monitoring, analysis)
   - (Architectural) performance models @ runtime
2. **Software architecture**
   - Component- & service-based software systems, MDSD
   - QoS (particularly, performance and resource efficiency)
   - Runtime reconfiguration/adaptation, self-*

Current Projects

1. **SLAstic** — Model-Driven Online Capacity Management for C-B Software Systems
2. **Kieker** — Application Performance Management and Dynamic Software Analysis

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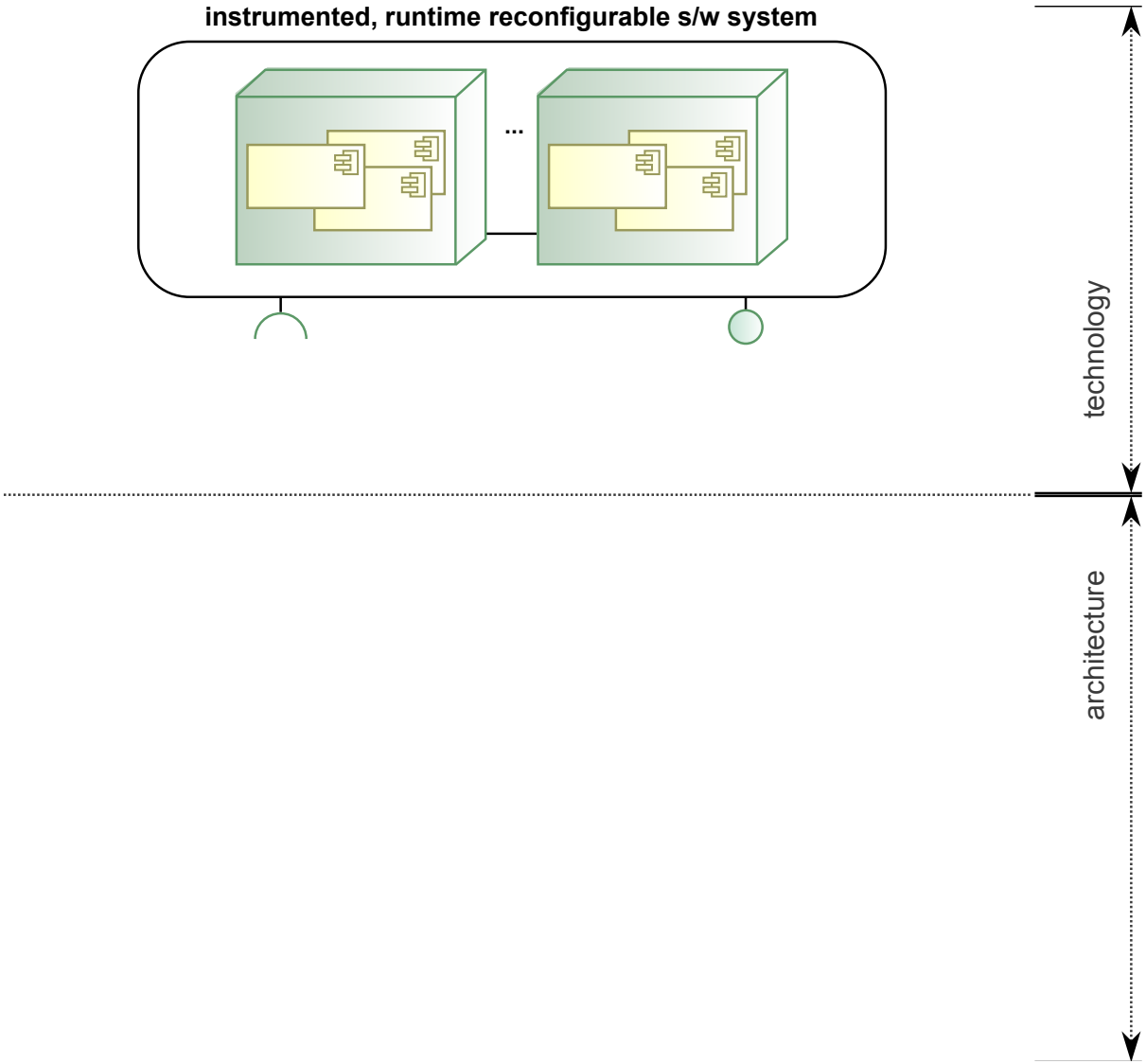
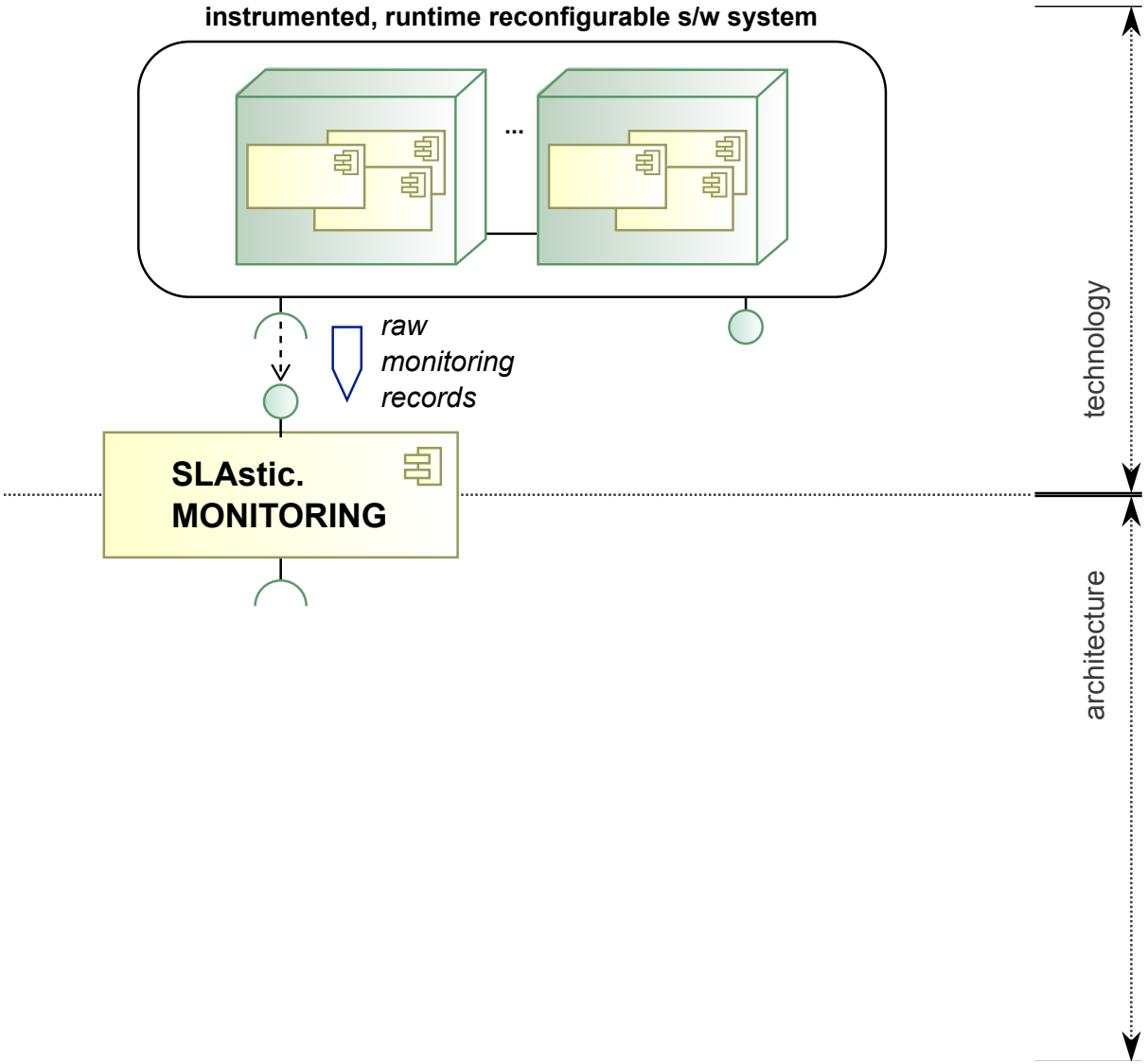
   - Component- & service-based software systems, MDSD
   - QoS (particularly, performance and resource efficiency)
   - Runtime reconfiguration/adaptation, self-*
3. **Software re(verse)-engineering**
   - Dynamic and hybrid (legacy) software analysis
   - Extraction of architectural models and usage profiles
   - Architecture-based software modernization

Current Projects

1. **SLAstic** — Model-Driven Online Capacity Management for C-B Software Systems
2. **Kieker** — Application Performance Management and Dynamic Software Analysis
3. **DynaMod** — Dynamic Analysis for Model-Driven Software Modernization

Architecture-based Online Capacity Management: Modeling, Monitoring, and Adaptation


instrumented, runtime reconfigurable s/w system
...
technology
architecture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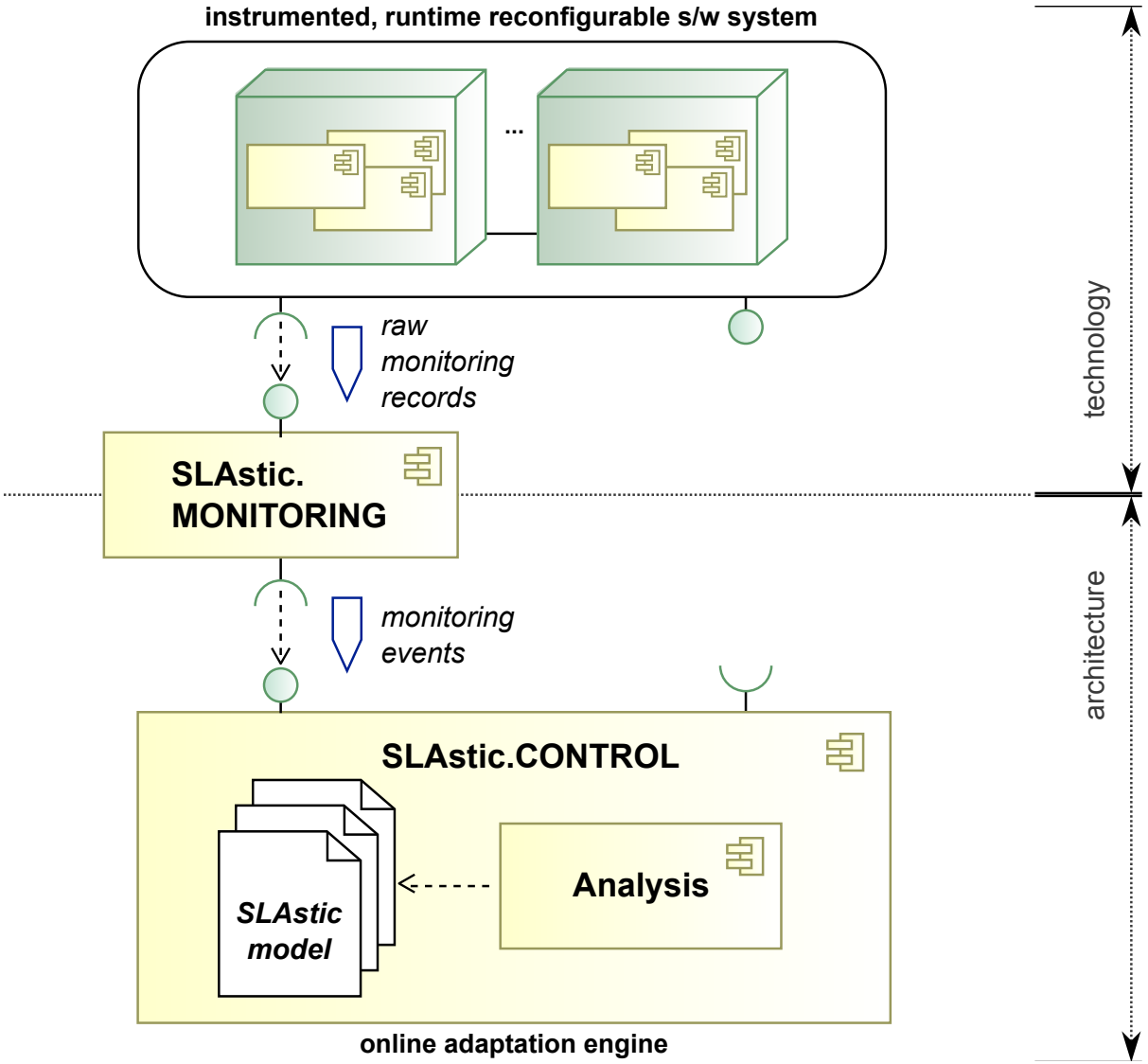
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SLAstic.CONTROL
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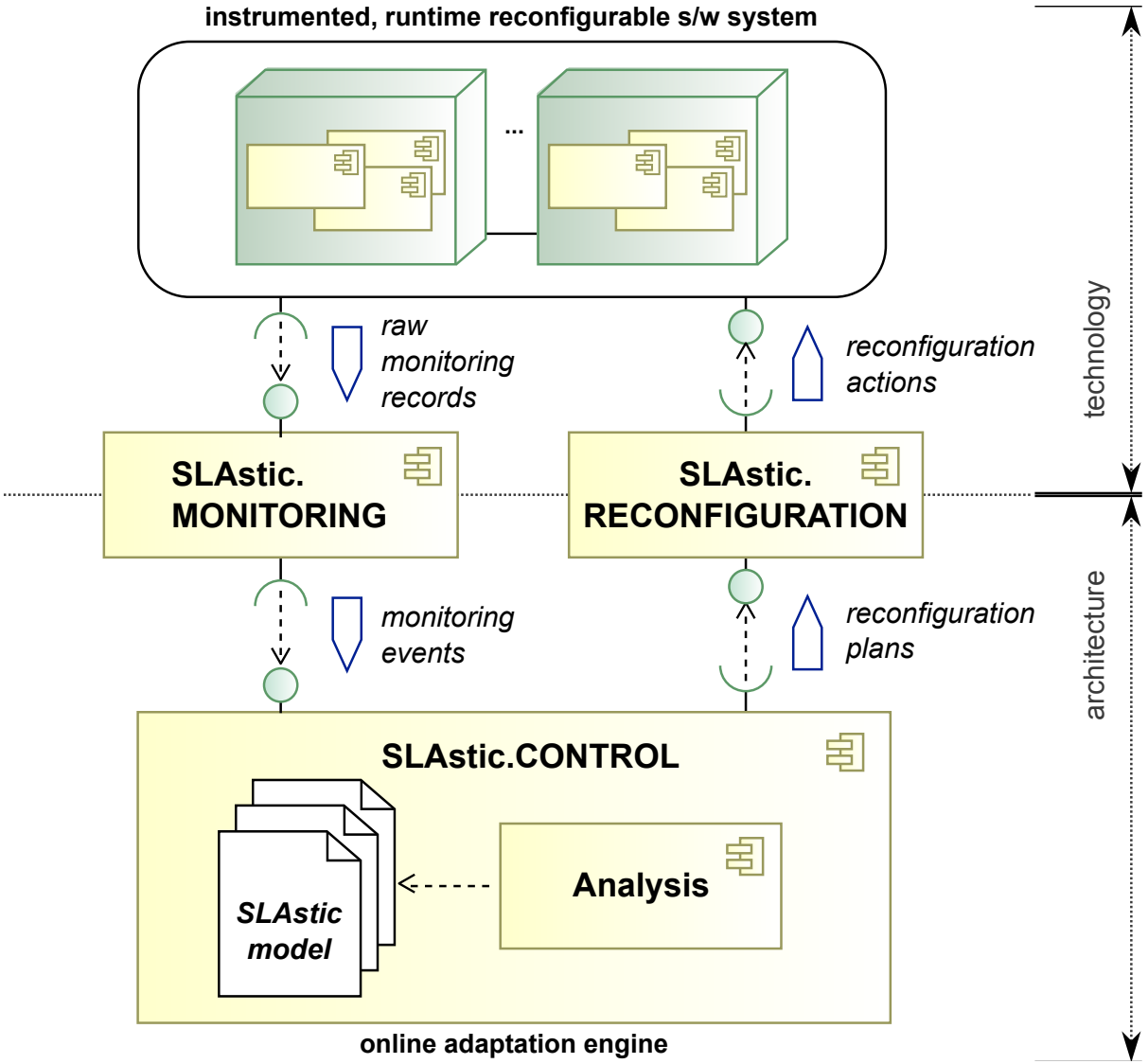
instrumented, runtime reconfigurable s/w system
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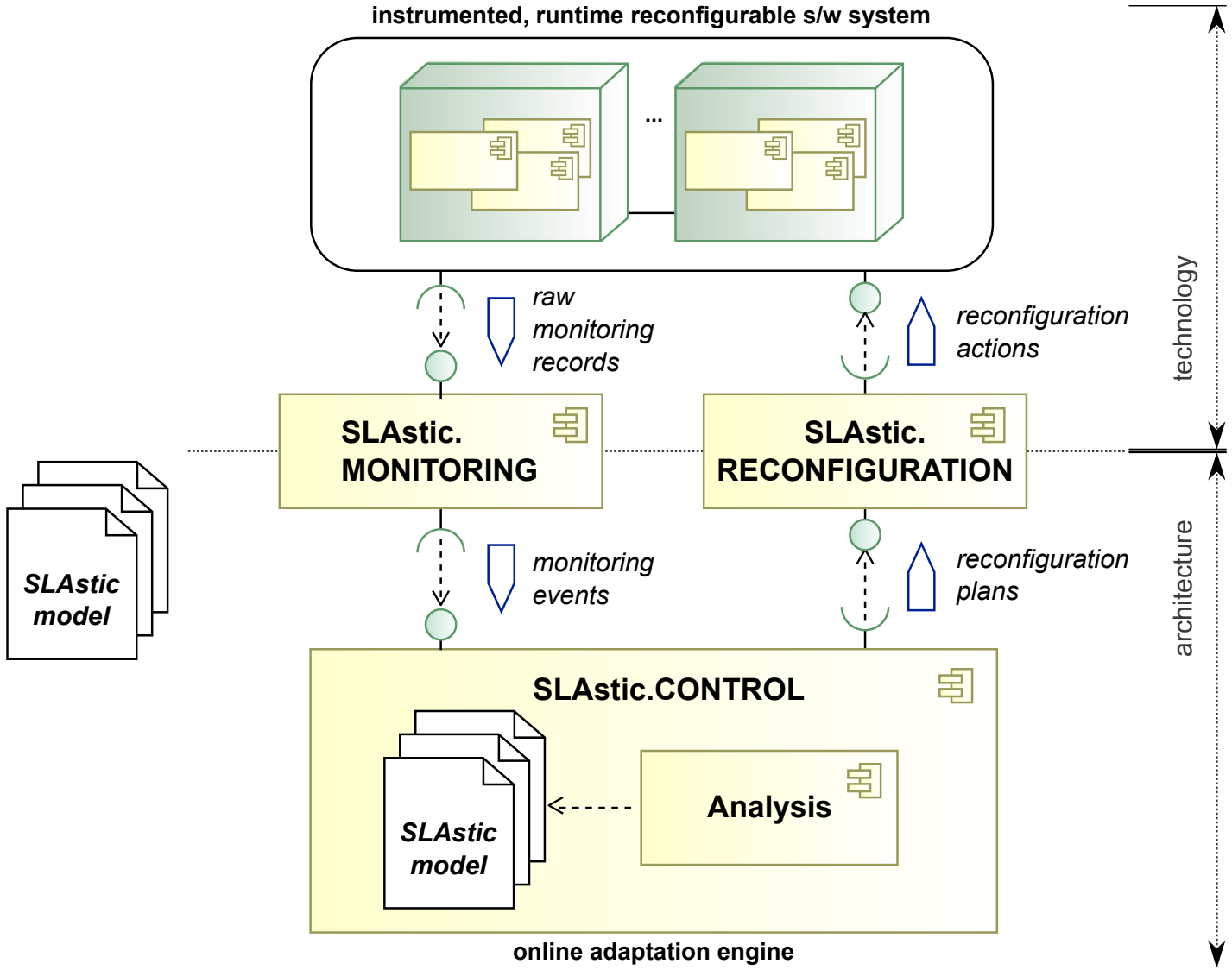
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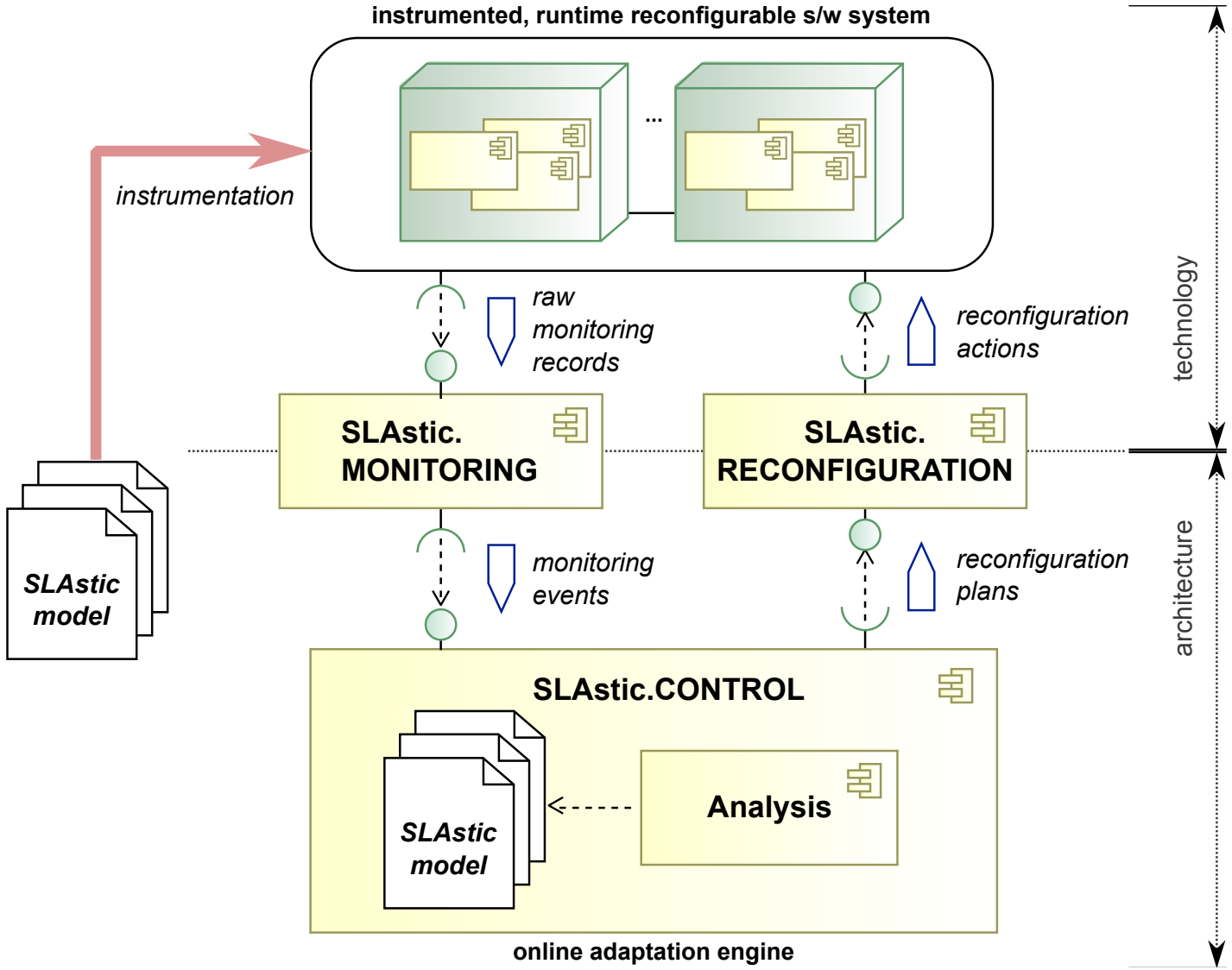
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Initialization of Framework & Runtime Models

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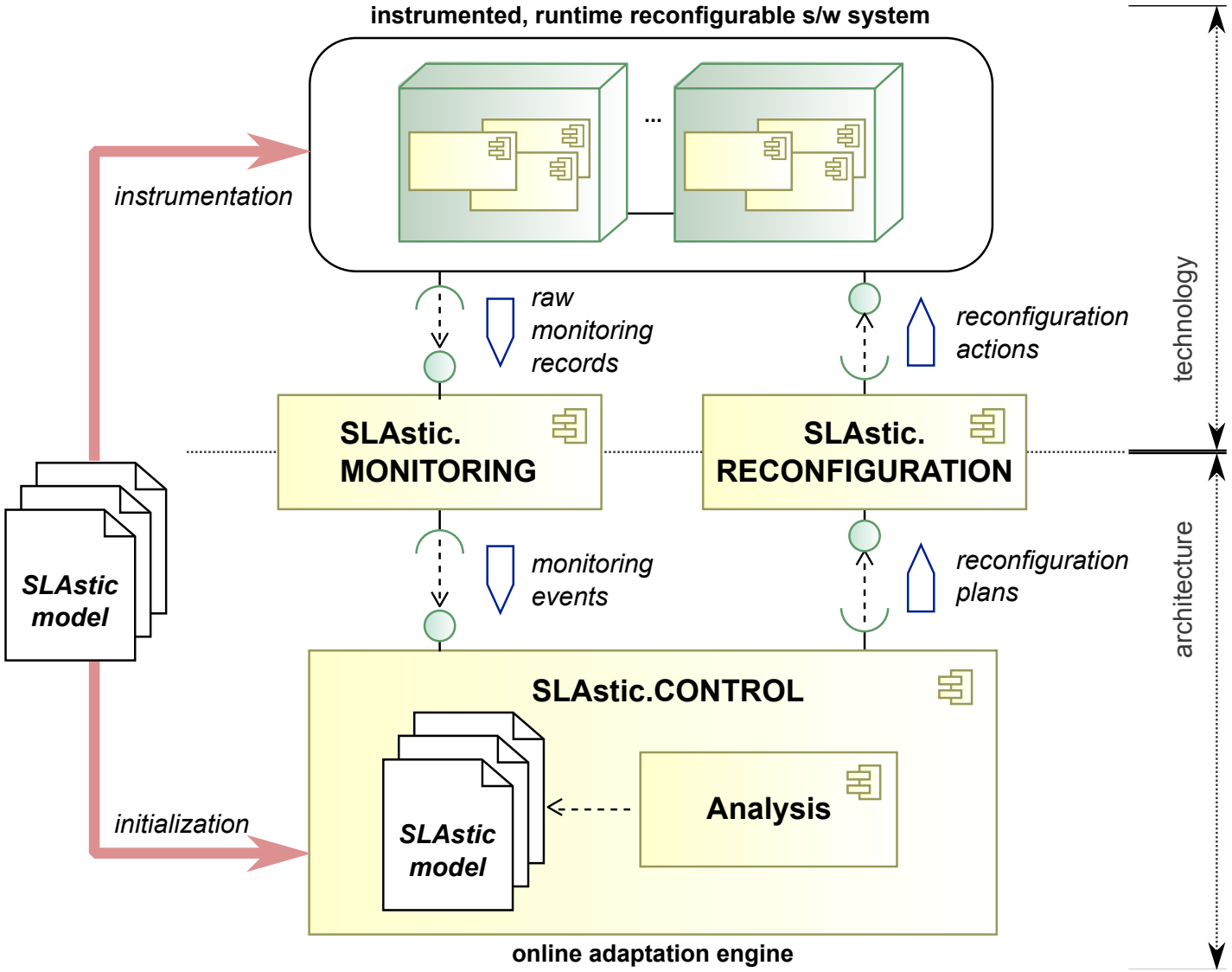
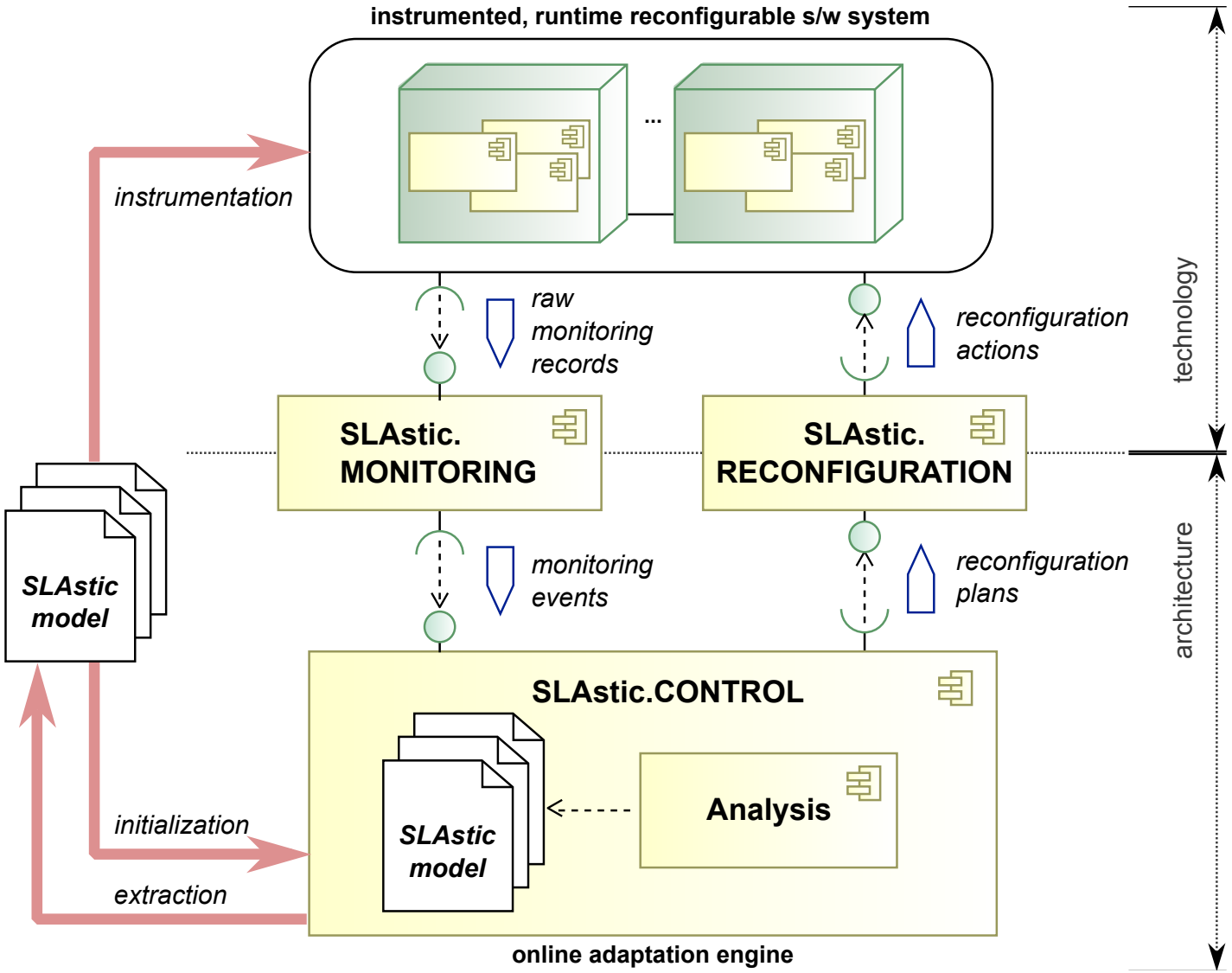
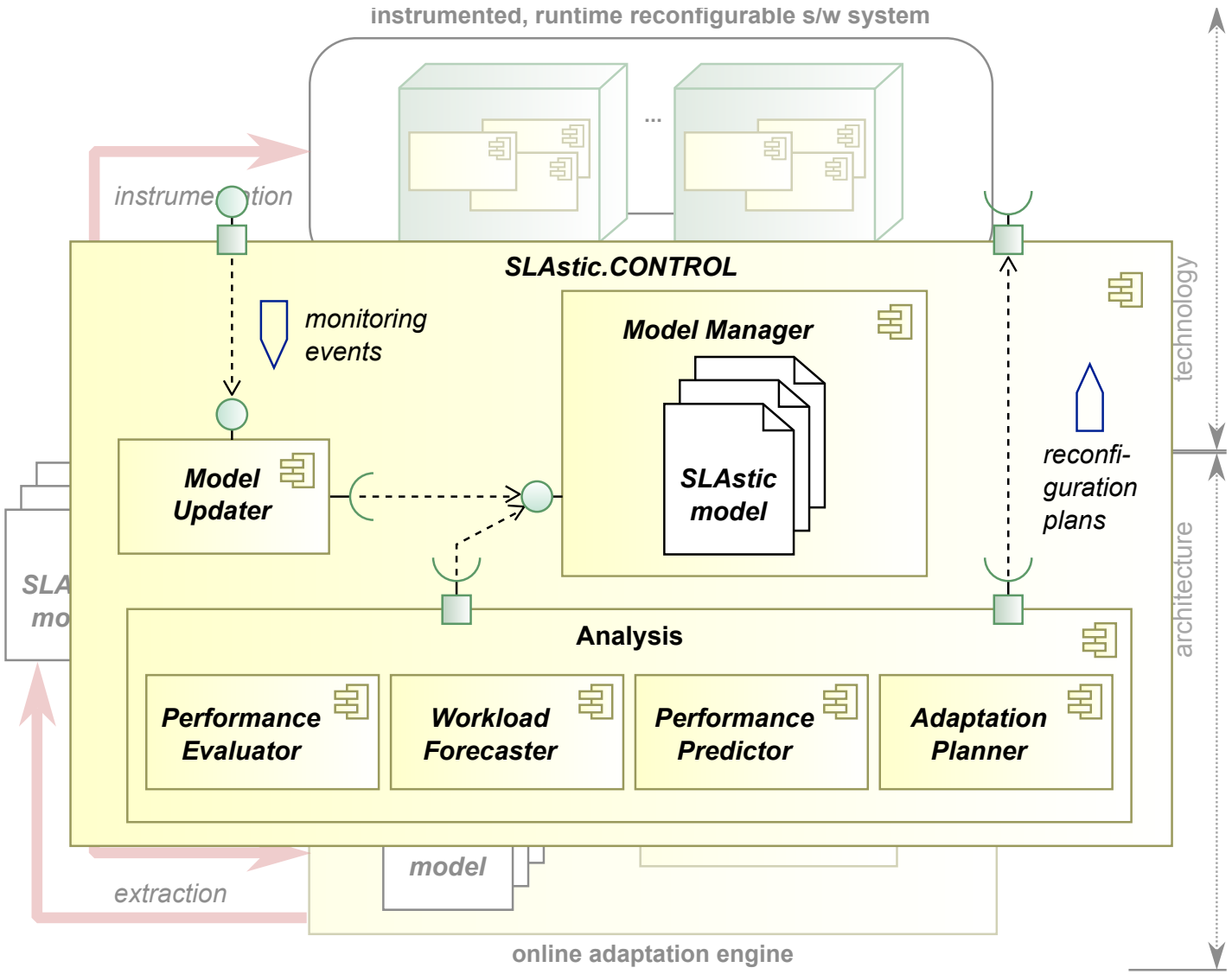


Extraction of Architectural Models (Dyn. Analysis)



SLAstic.CONTROL (zoom-in)



System Partition (also used as runtime model)

1. Type repository (e.g., component types, interfaces, connector types, execution container types)
2. Component assembly (e.g., assembly of components via connectors)
3. Execution environment (e.g., execution containers and interconnection via links)
4. Component deployment (mapping: assembly components $\rightarrow$ containers)

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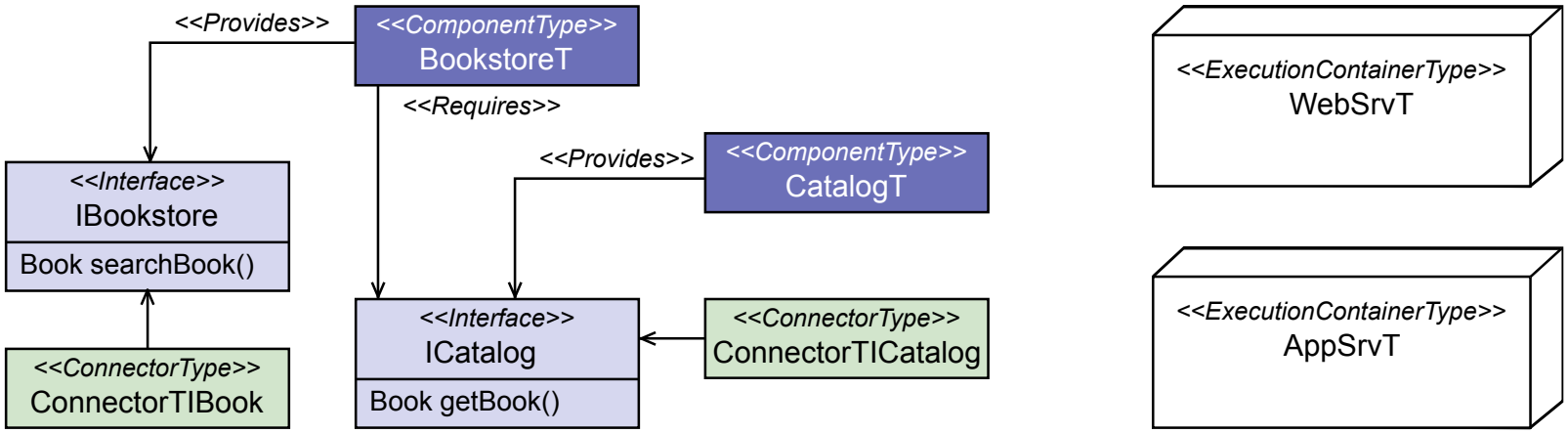

Example type repository

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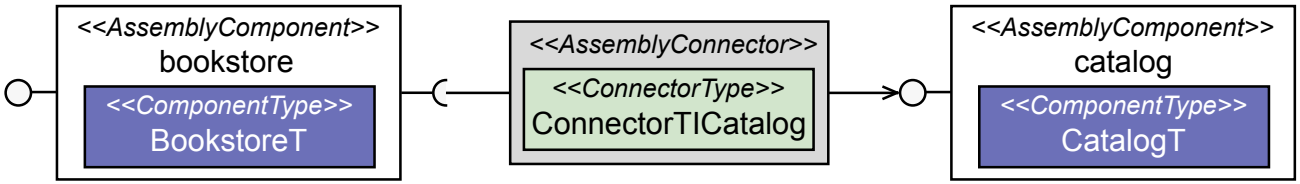

Example component assembly

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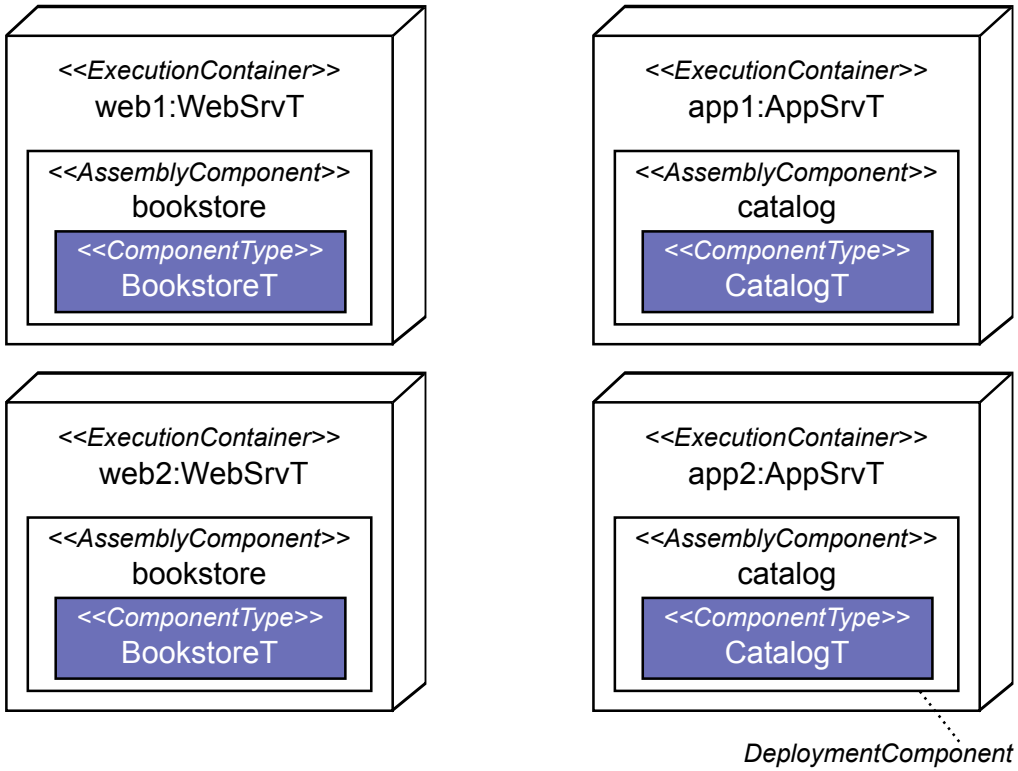
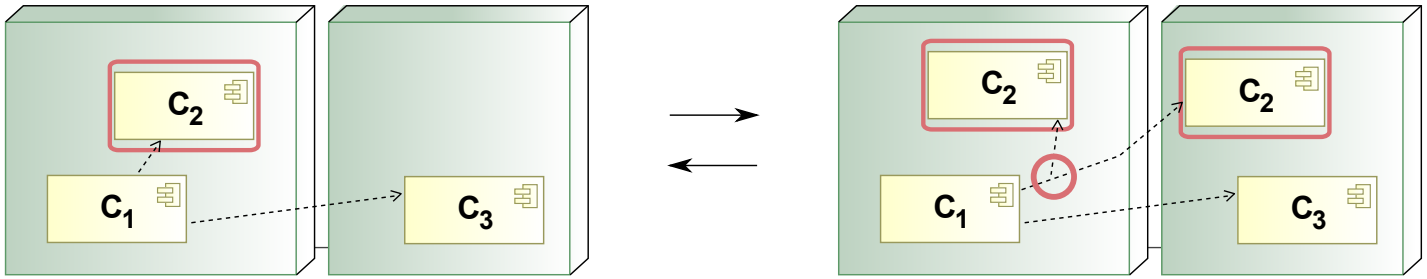


Example component deployment

1 (De-)Replication of Software Components



1 (De-)Replication of Software Components

- replicate (component: AssemblyComponent, to: ExecutionContainer)
- dereplicate (component: DeploymentComponent)

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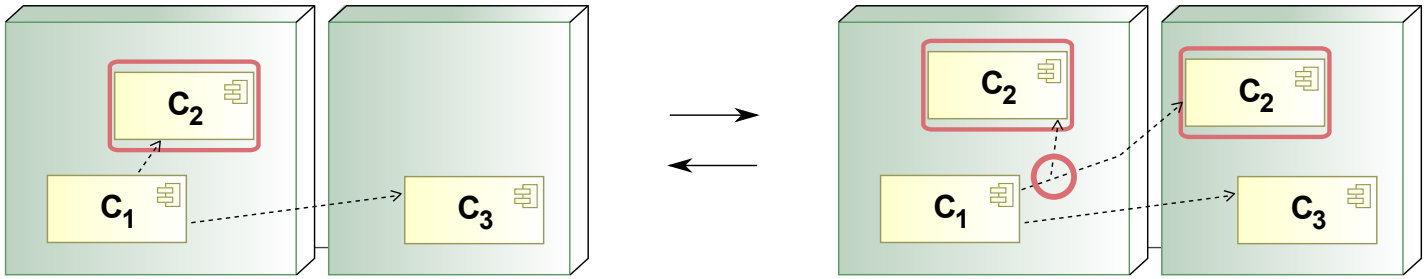

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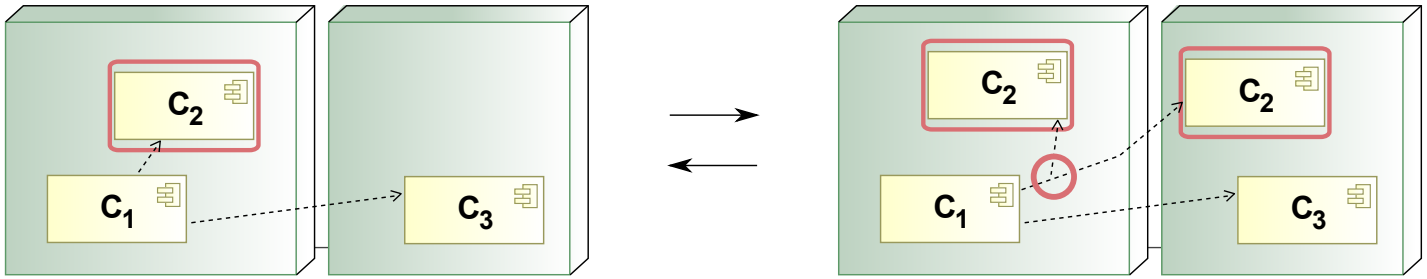
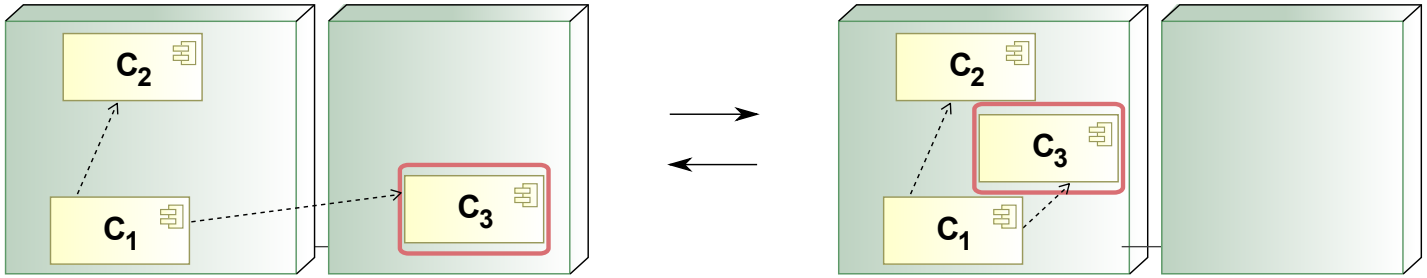


2 Migration of Software Components



SLAstic Runtime Reconfiguration Operations

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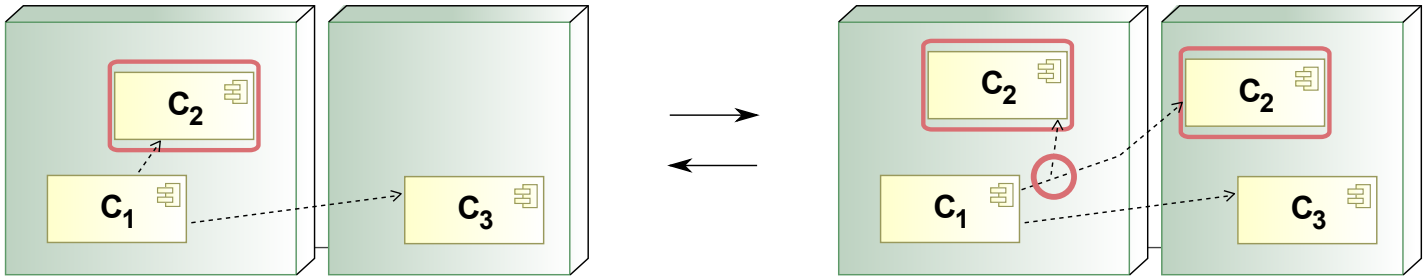

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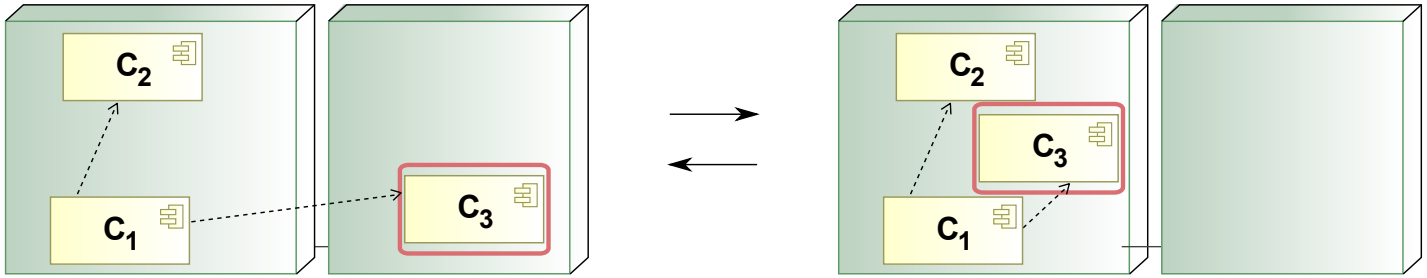
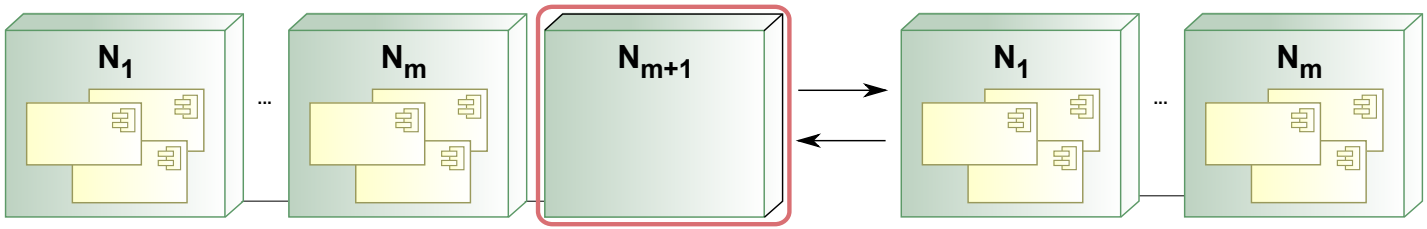


3 (De-)Allocation of Execution Containers



Completions/Decorations

- Adaptation / Reconfiguration (e.g., plans, operations, capabilities, properties)
- Measurement (e.g., workload, timing, utilization)
- Usage (e.g., operation call frequencies, calling relationships)
- . . .

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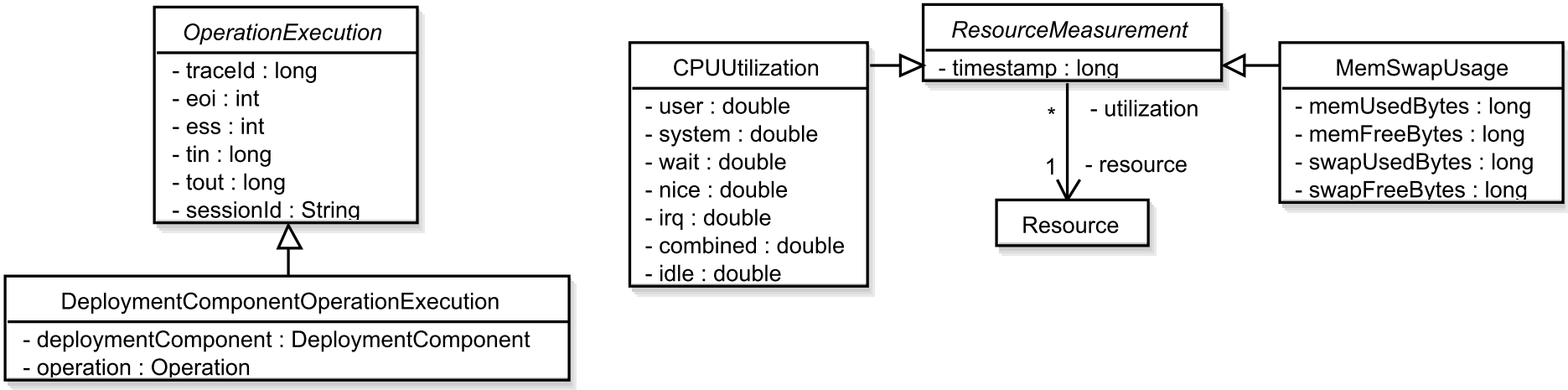
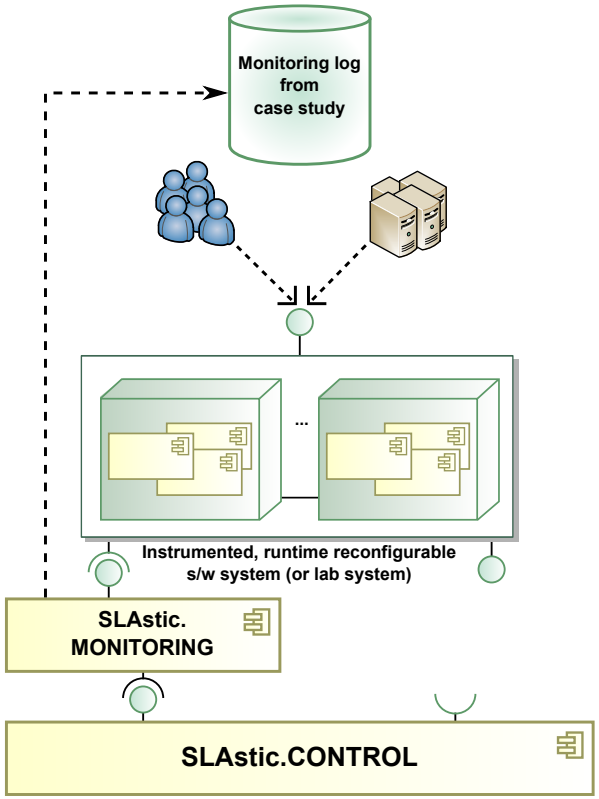


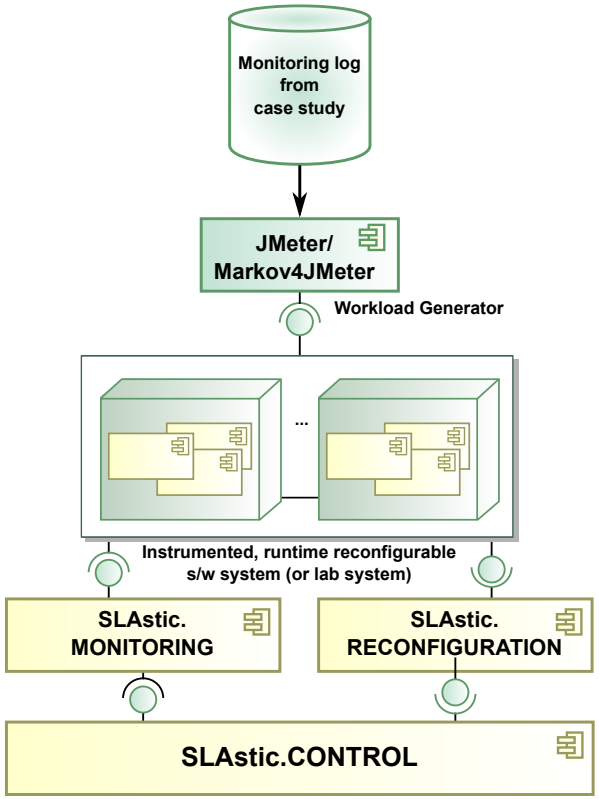
Measurement event types

Evaluation Methodology



1. Online analysis (production/lab system)

Evaluation Methodology



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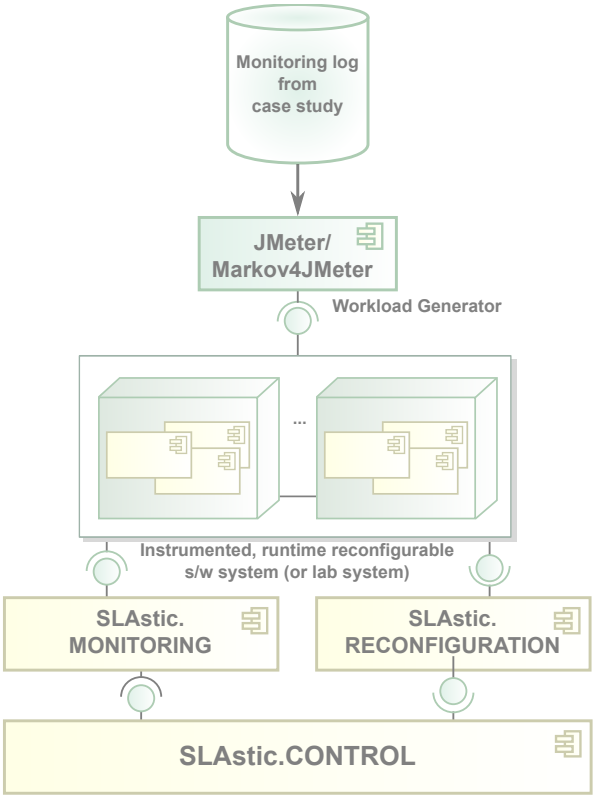

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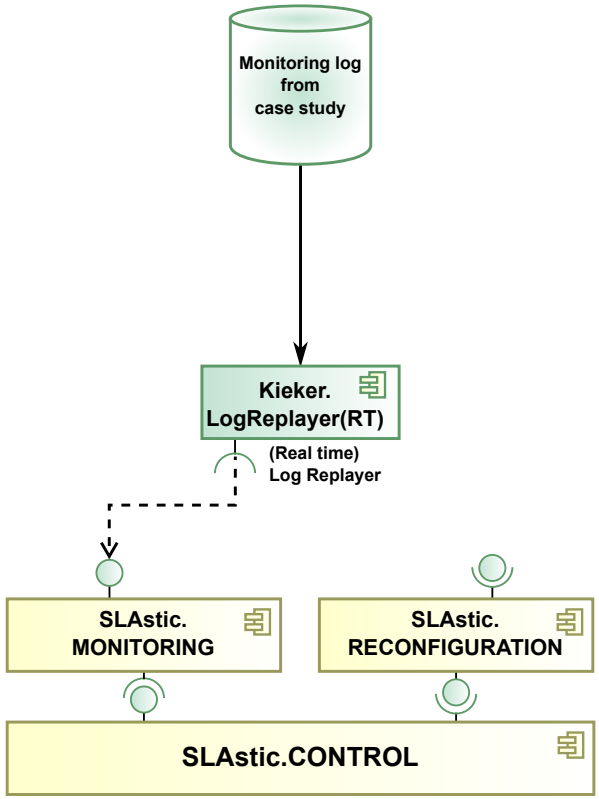

2 Offline analysis (log replay)

Evaluation Methodology

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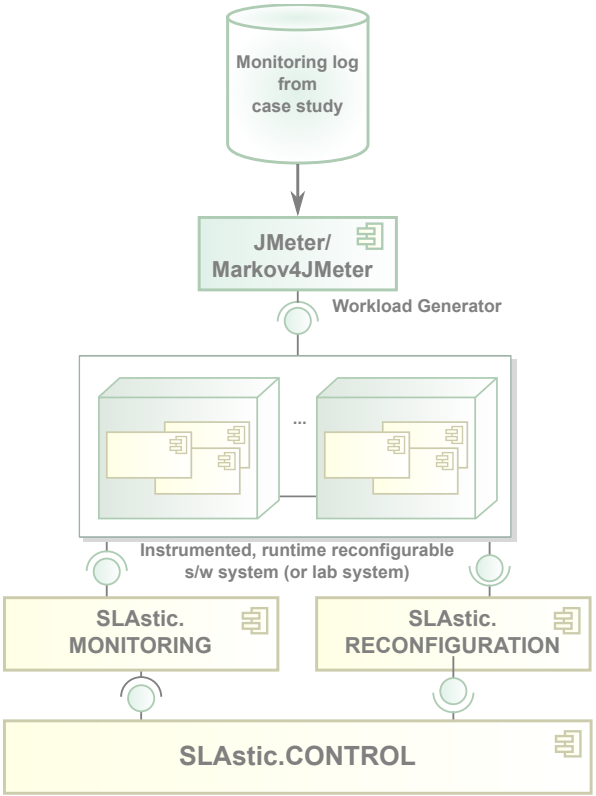

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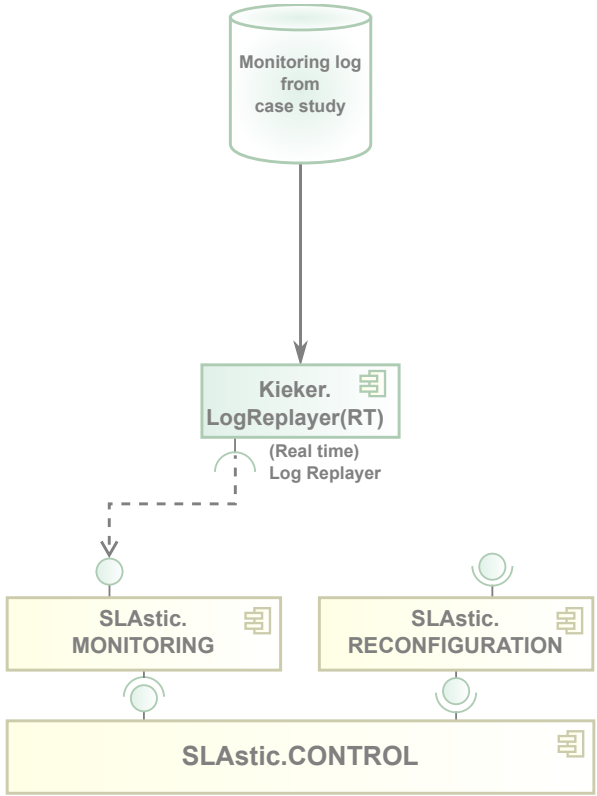

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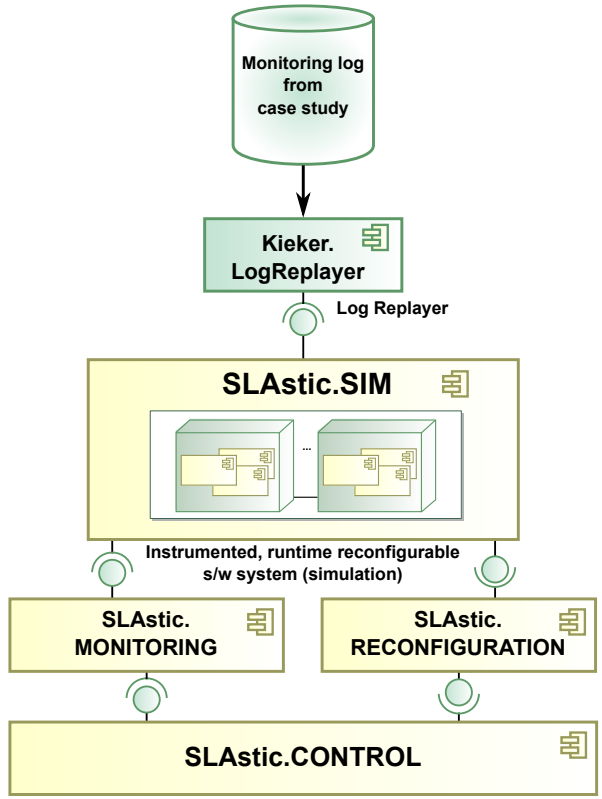

3 Simulation-based analysis

Agenda

Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

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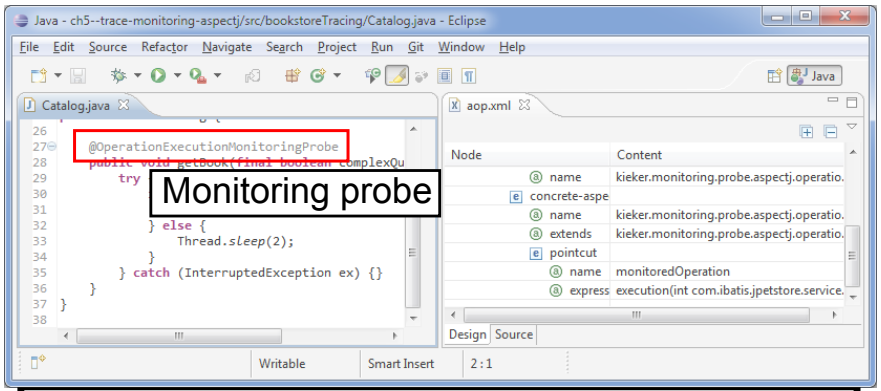

Software system with monitoring instrumentation

Kieker: Example Workflow and Use Cases

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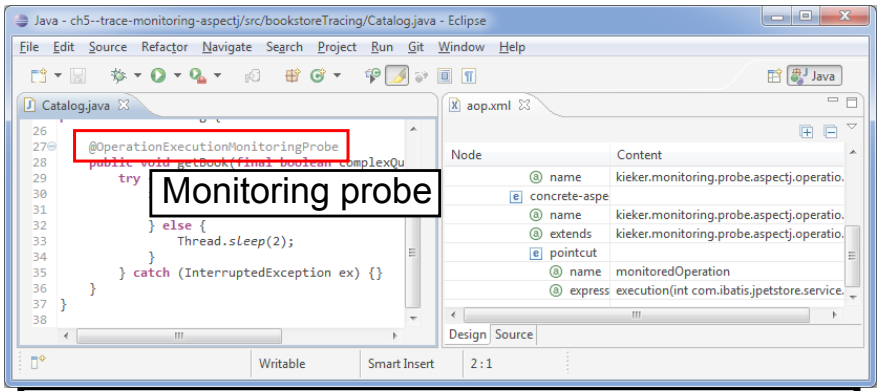

Software system with monitoring instrumentation

Java probes/samplers:

Monitoring Probes/Samplers	Control-flow tracing	Manual instrumentation	
		AspectJ	Spring
		Servlet	CXF/SOAP
		<your interception technology>	
	Resource monitoring	Servlet, Sigar	CPU utilization
			Memory usage
		<your technology>	
	<your monitoring probe>		

+ basic adapters for

- C#/.NET
- Visual Basic 6/COM
- COBOL

Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

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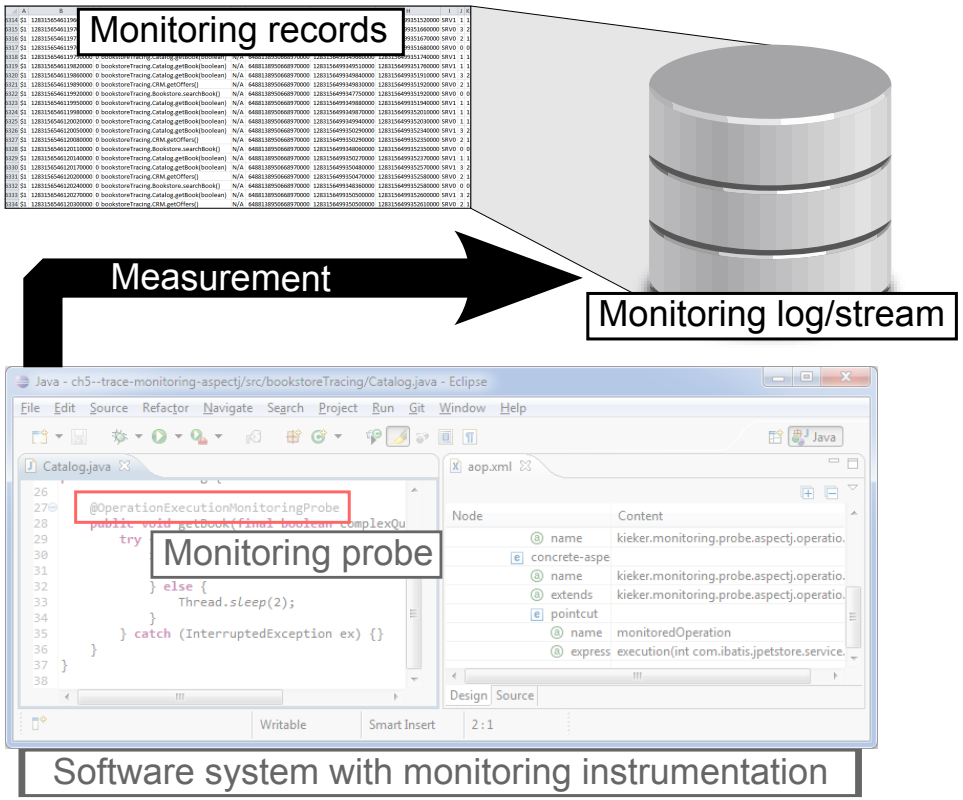

Kieker: Example Workflow and Use Cases

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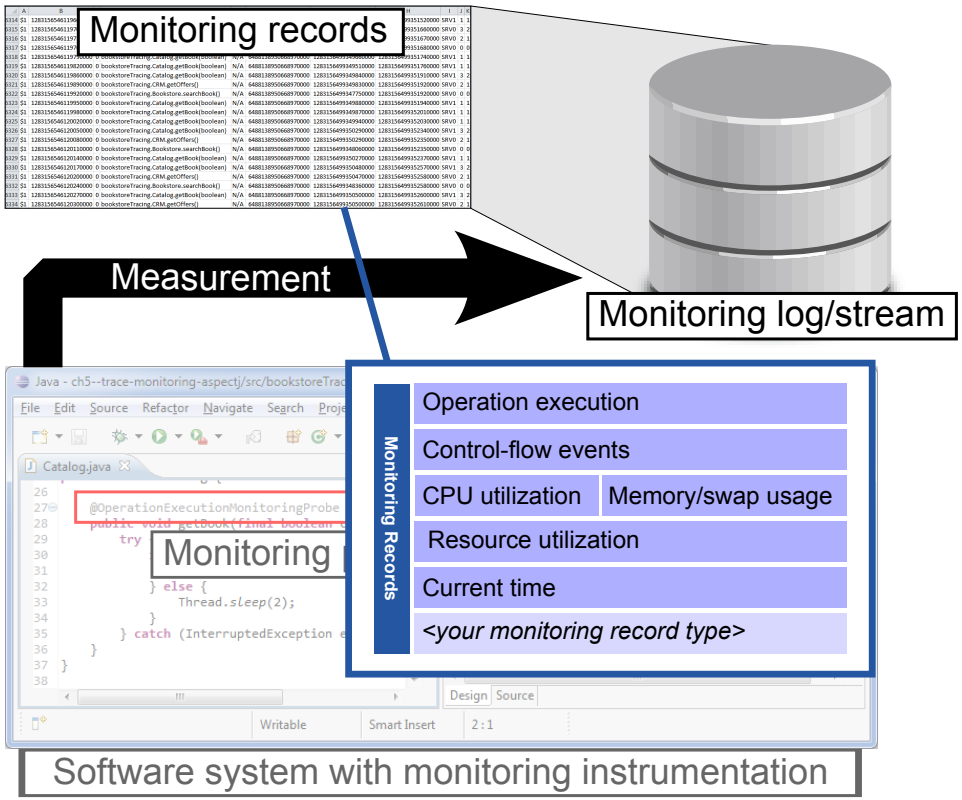

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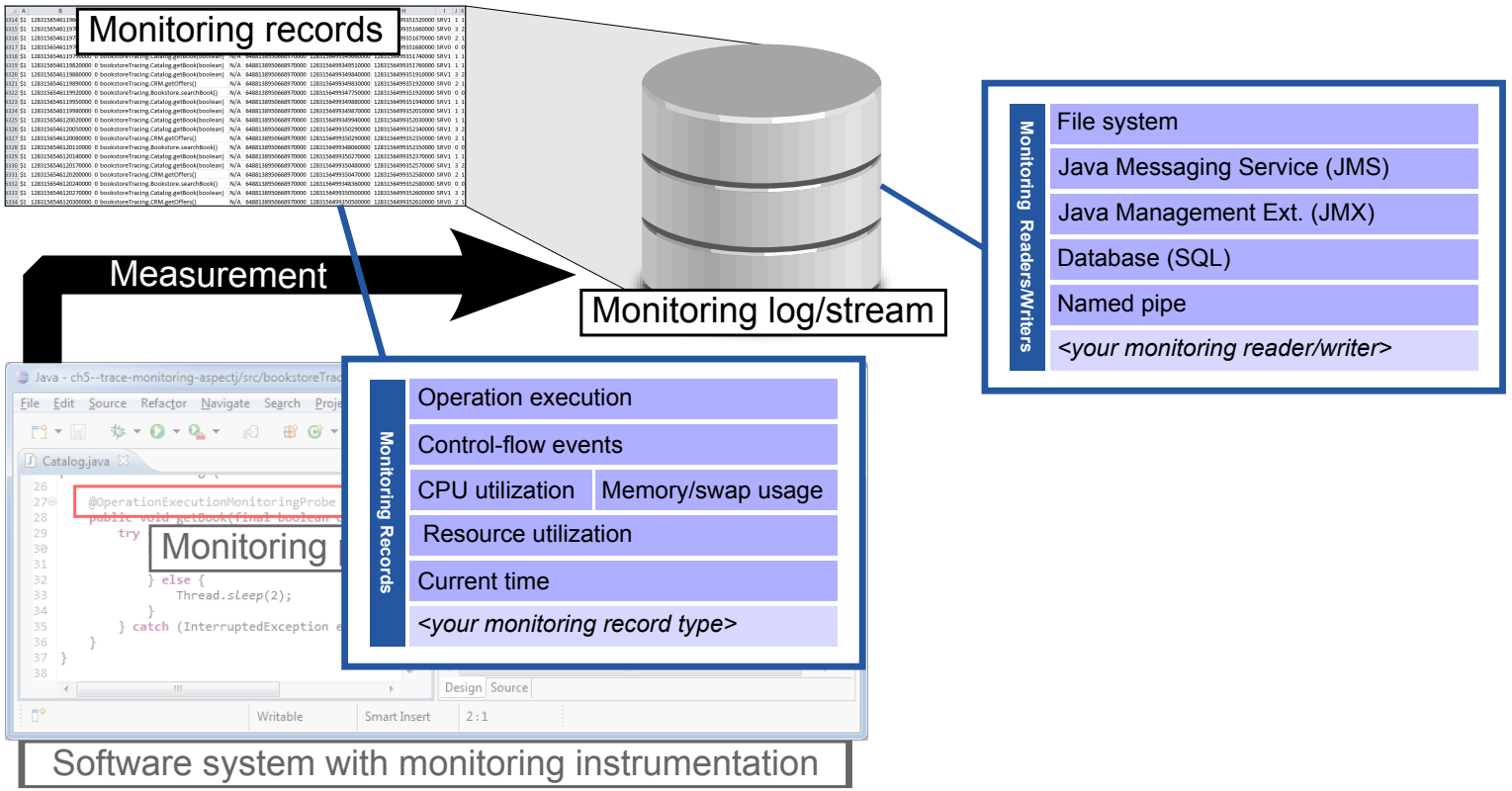

Kieker: Example Workflow and Use Cases

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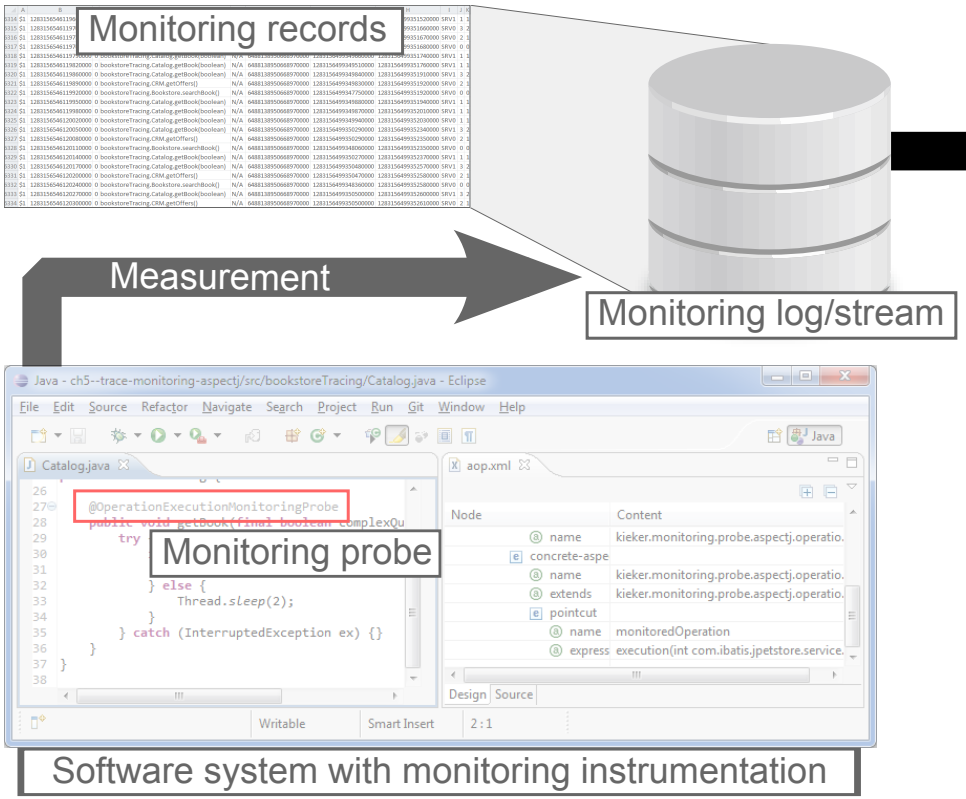

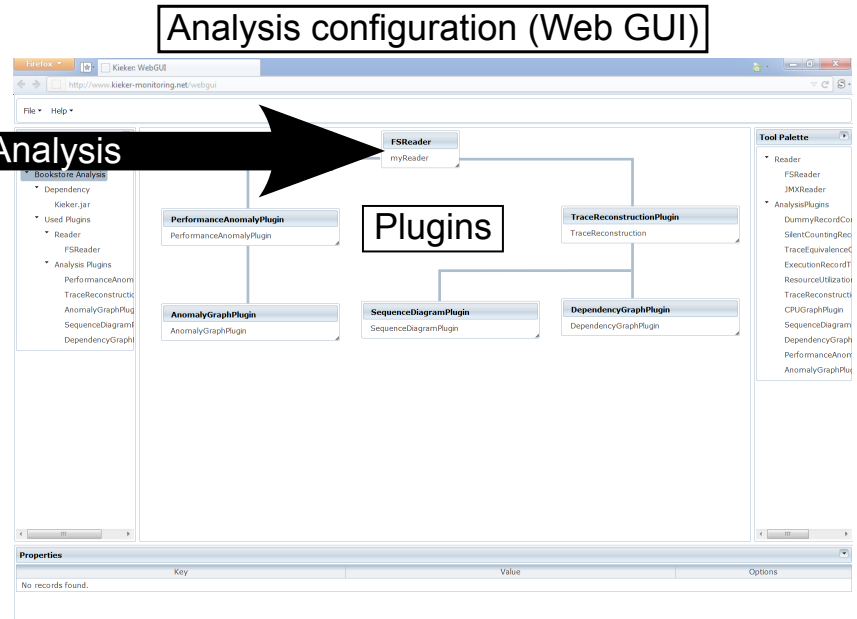

Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

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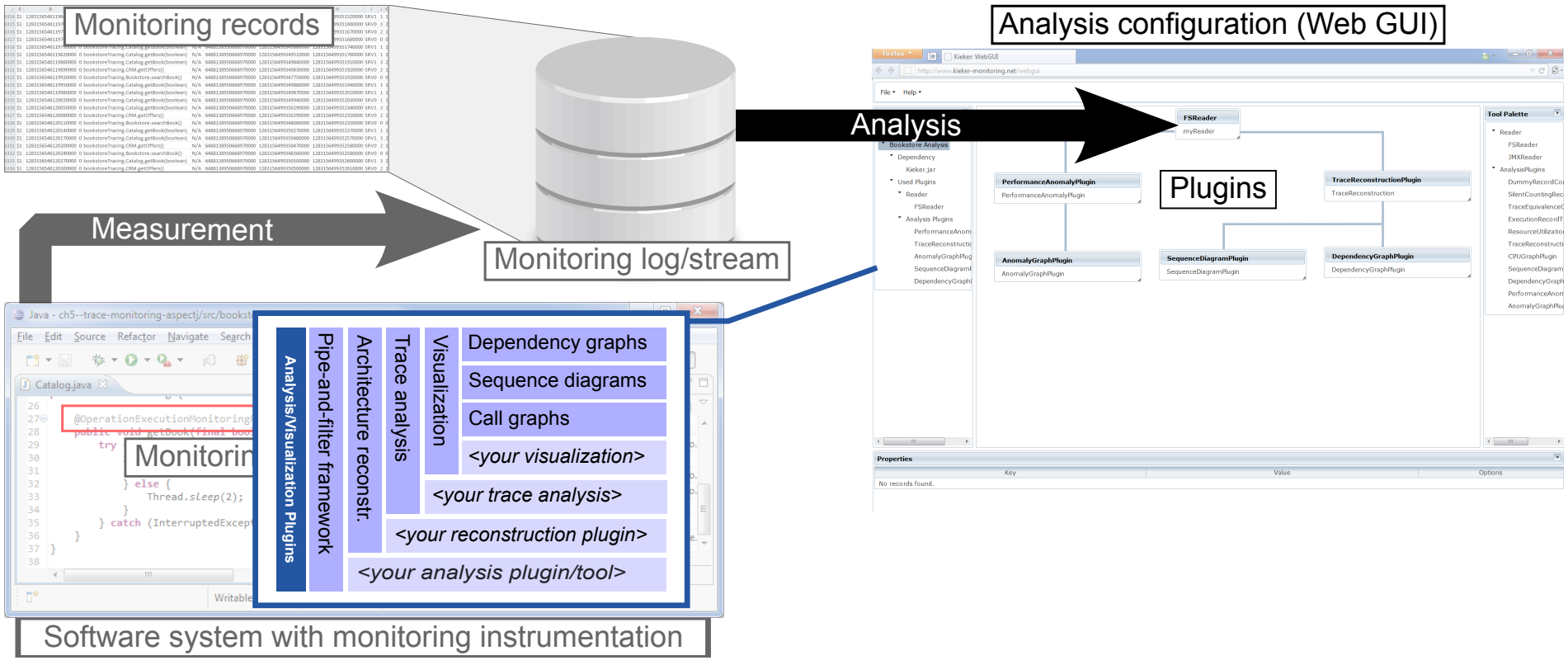

Kieker: Example Workflow and Use Cases

[van Hoorn et al. 2012]

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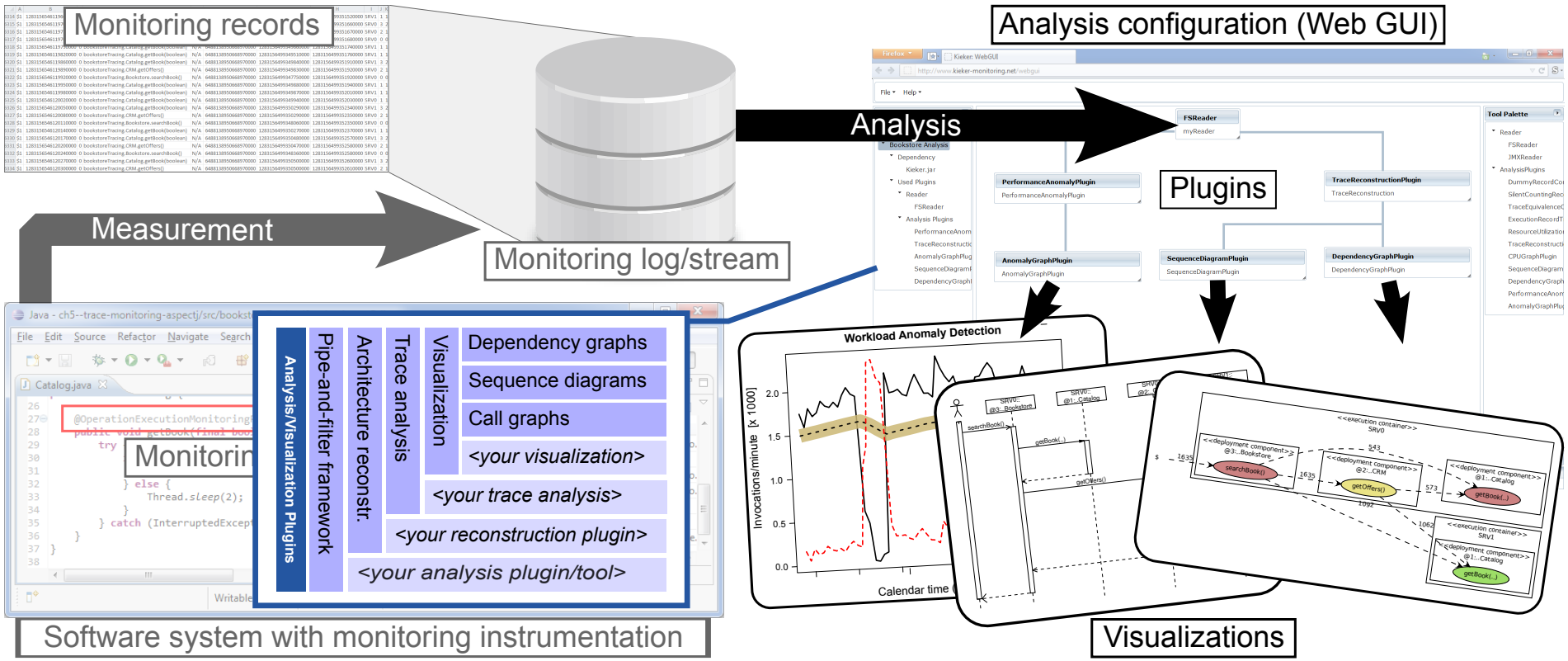
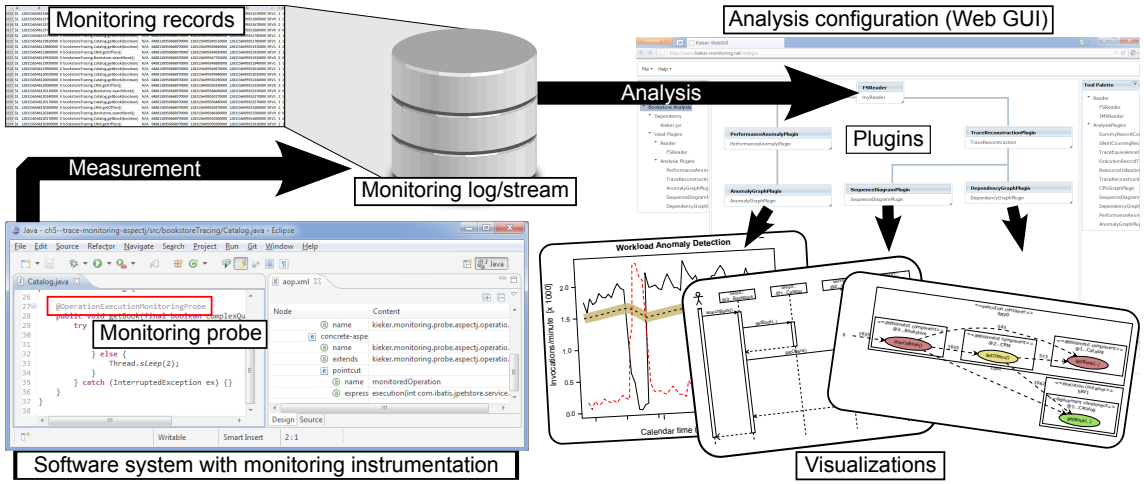
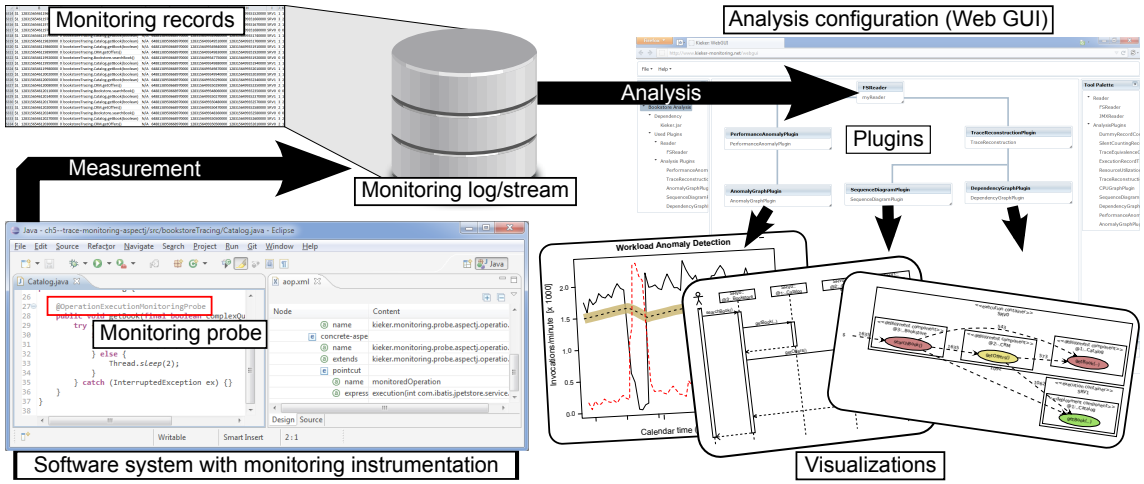




Selected use cases in research and industrial practice (+ teaching):



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- Online/offline performance evaluation and feedback, e.g.,
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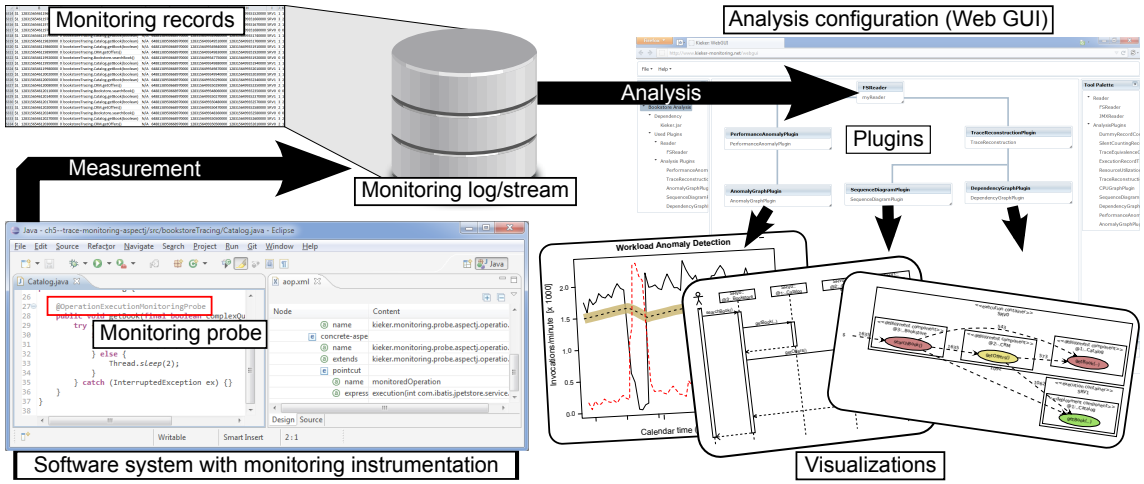

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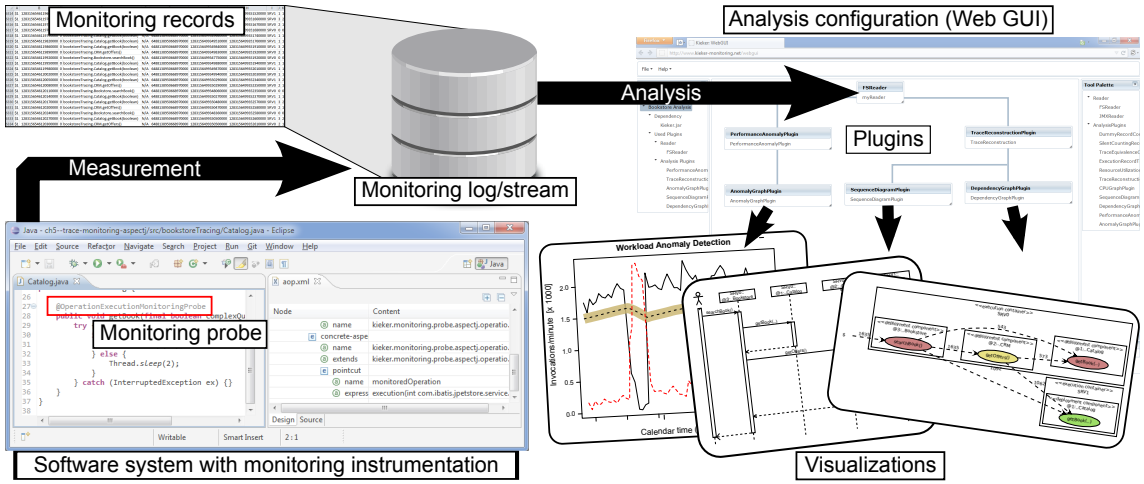

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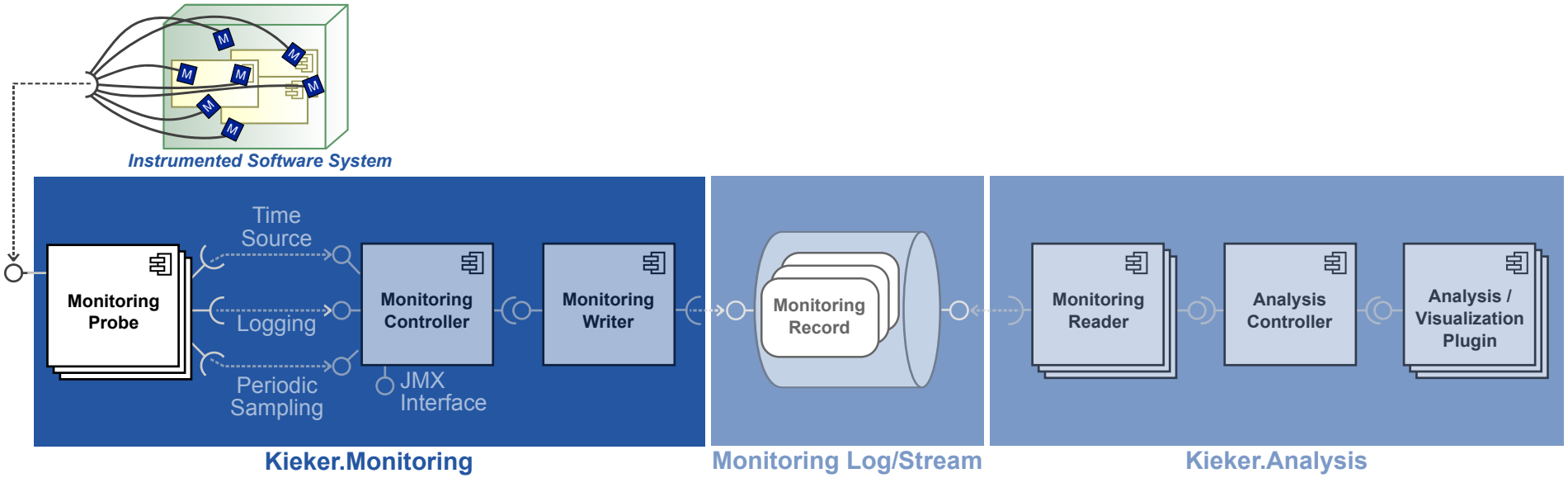
- Extraction of software architectural (performance) models and visualizations
- Simulation (replaying previously monitored stimuli; measurement, logging, and analysis)

Core Kieker Framework Components



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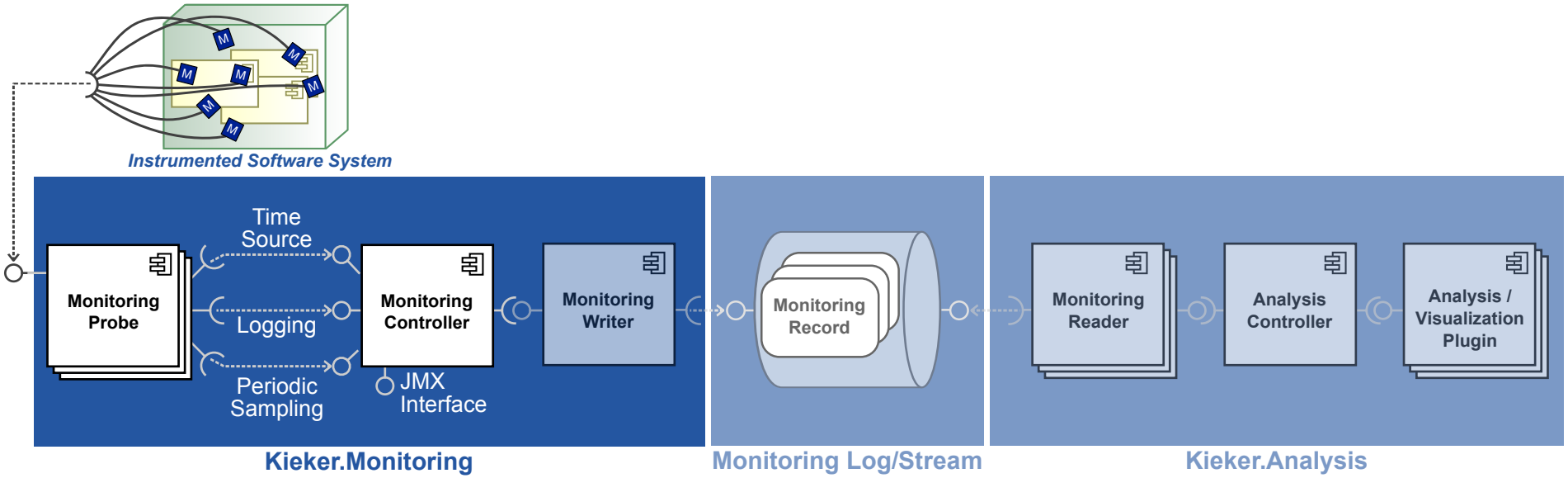

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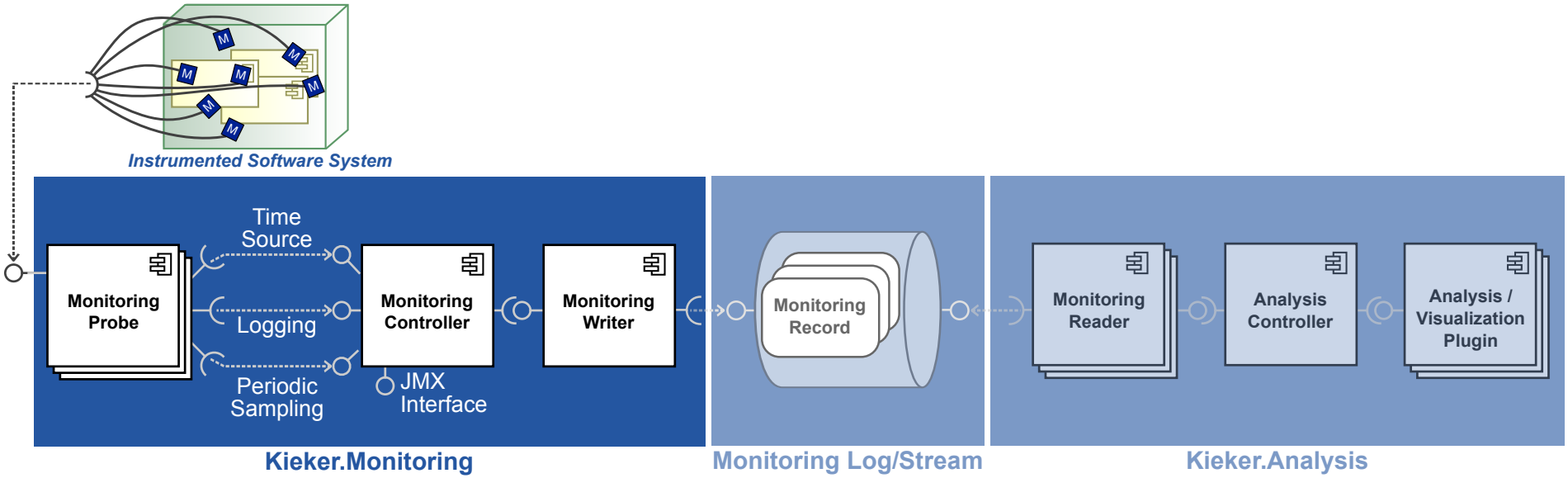

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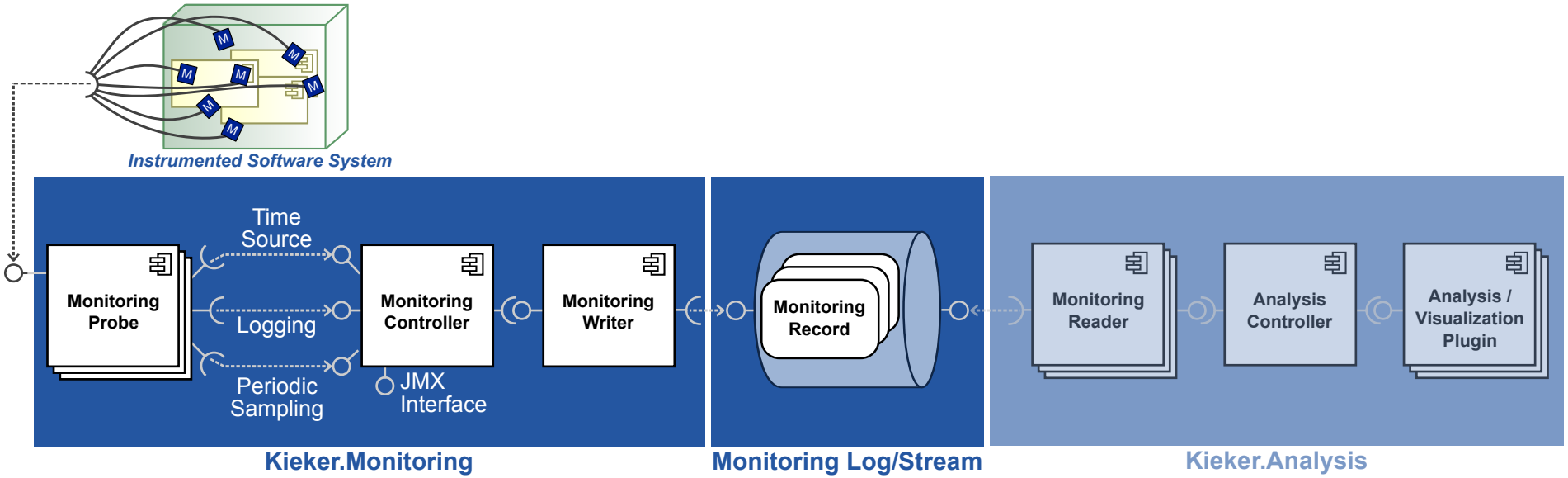

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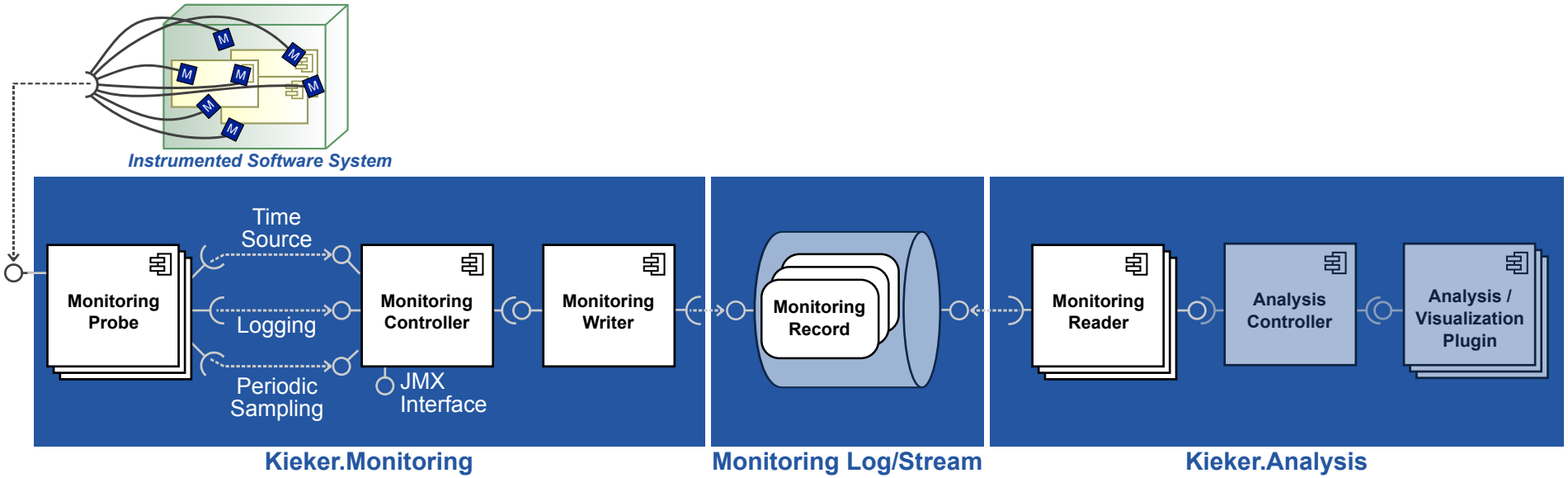

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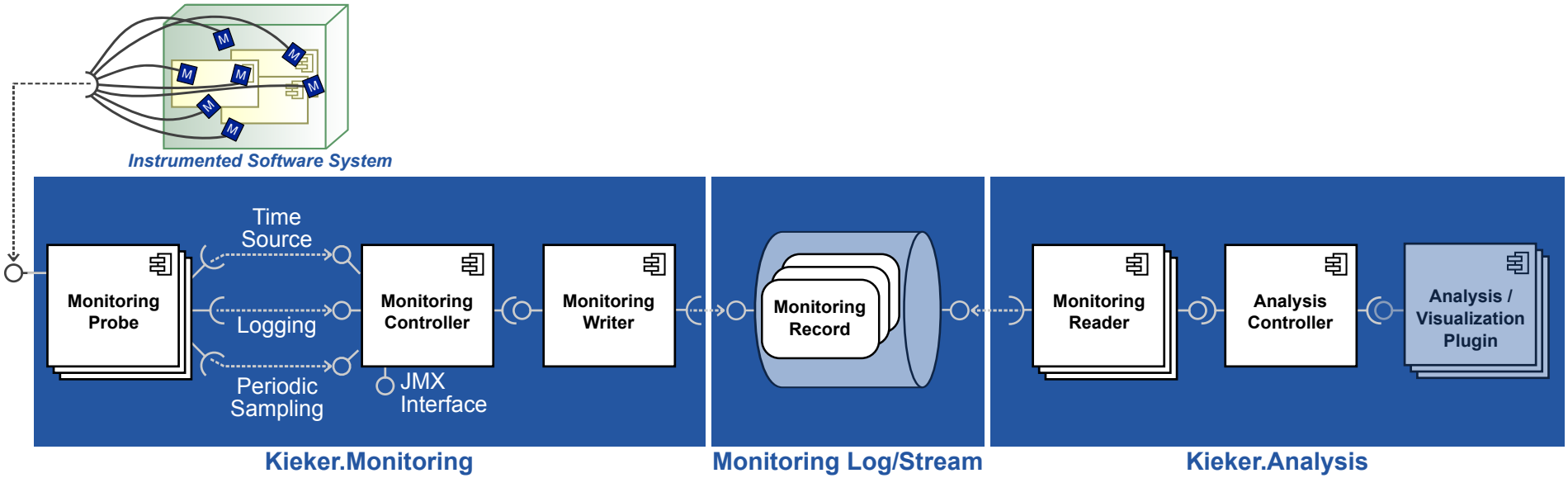

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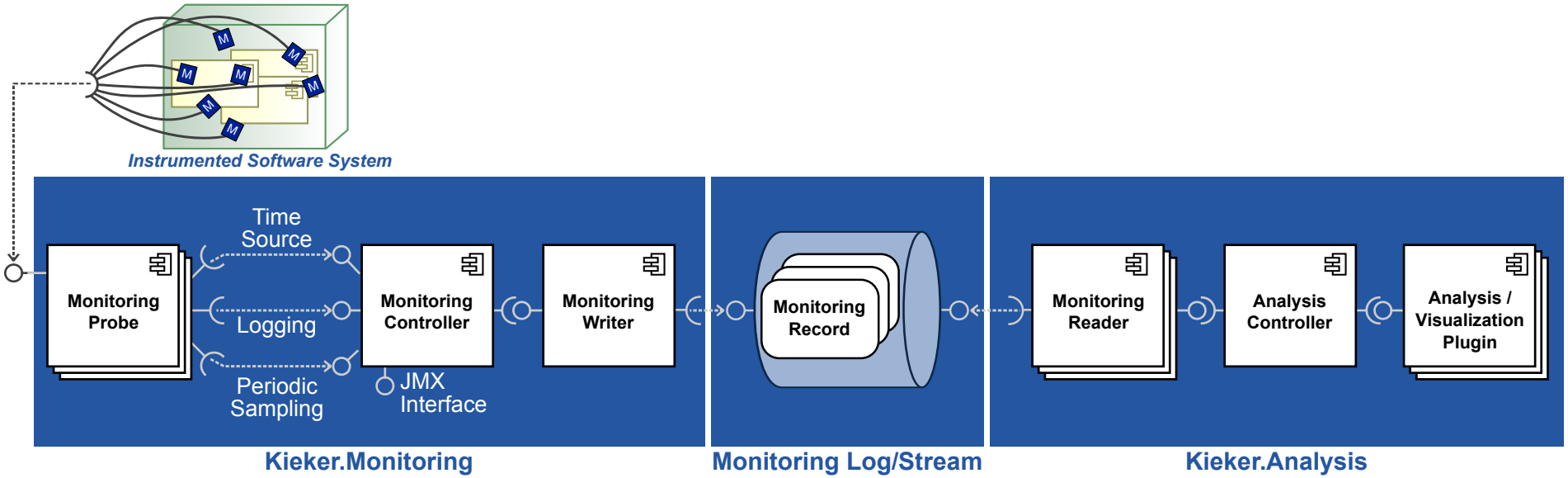
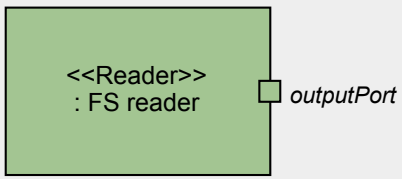


Example Pipe-and-Filter Configuration



Kieker.Analysis example pipes-and-filters configuration

- *Performance anomaly detection and visualization*
- *Architecture and trace reconstruction/visualization*

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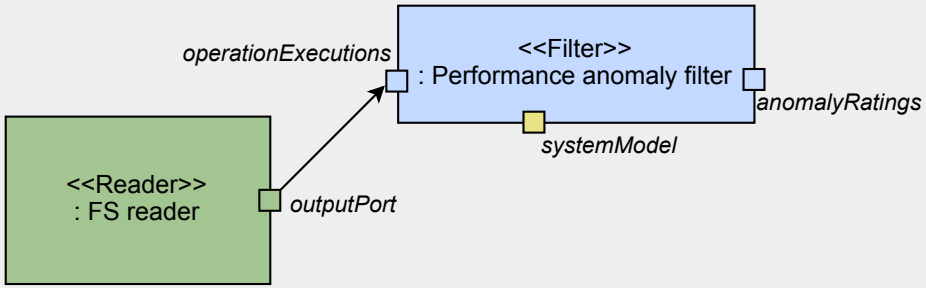

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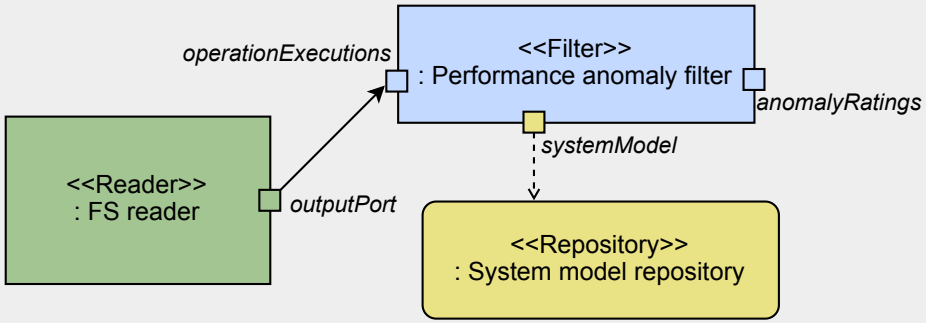

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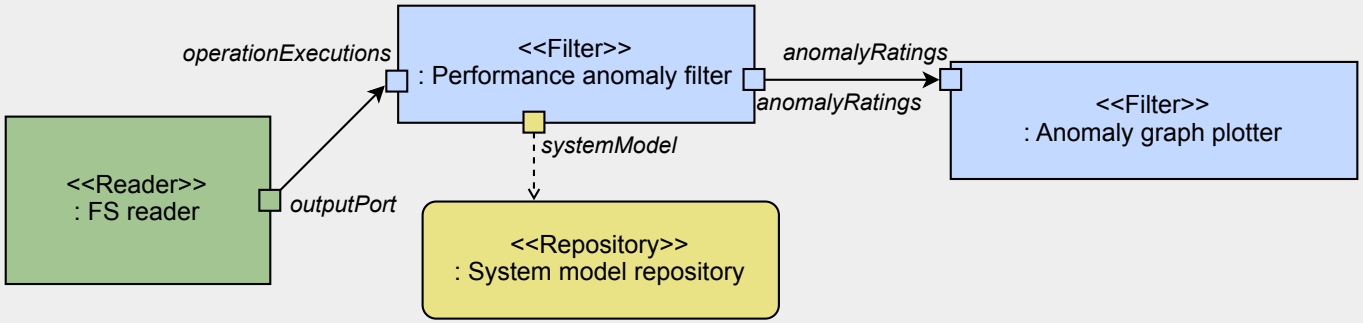

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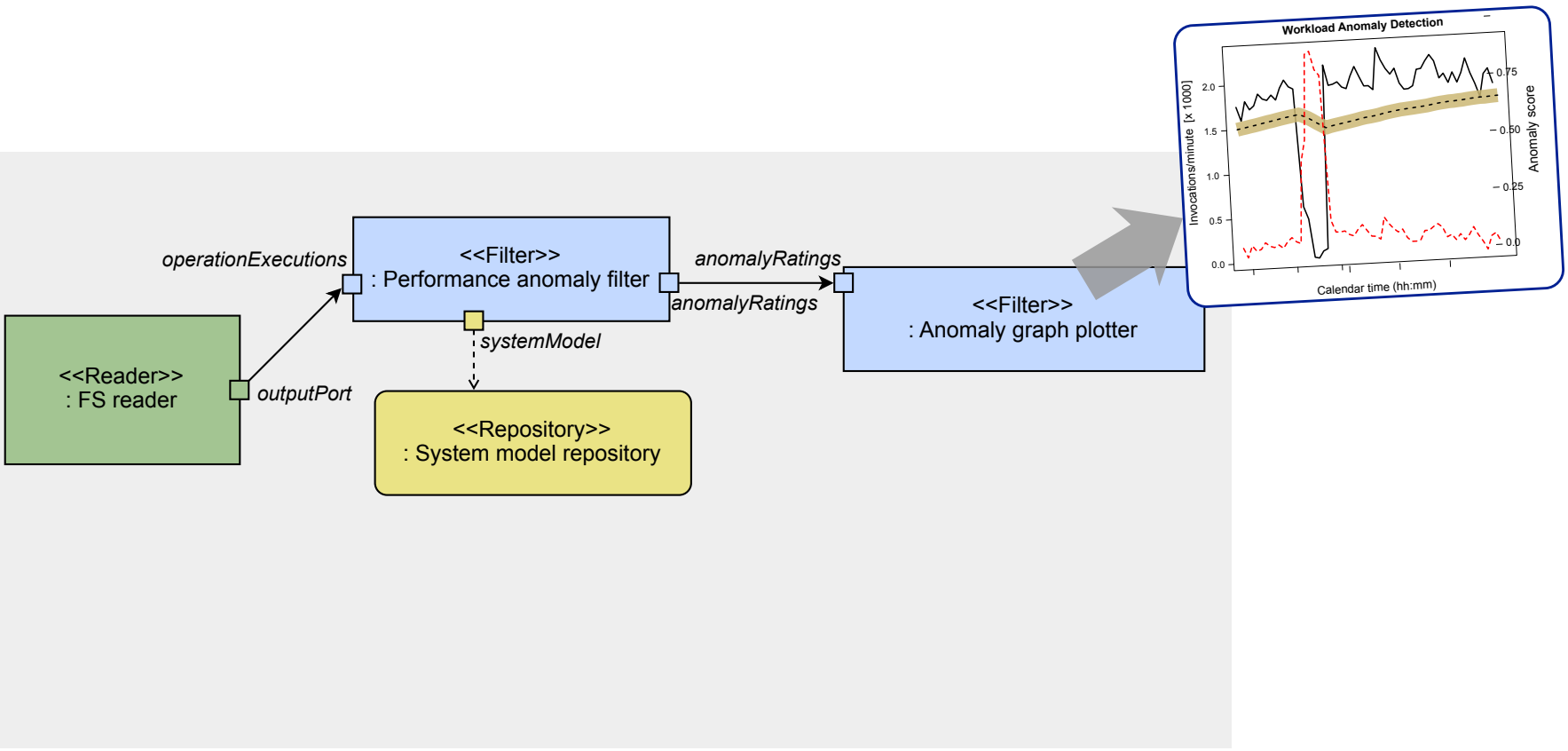

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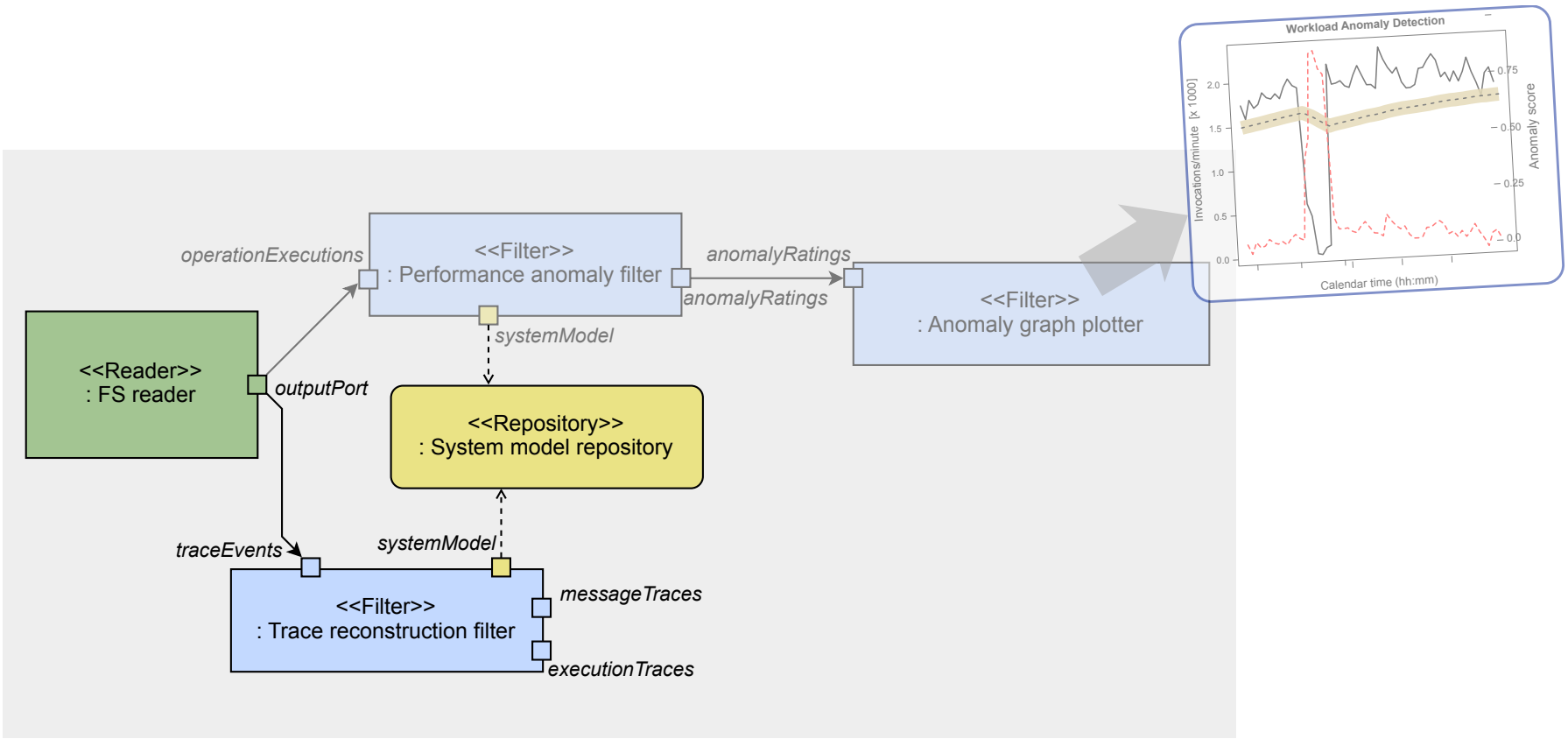

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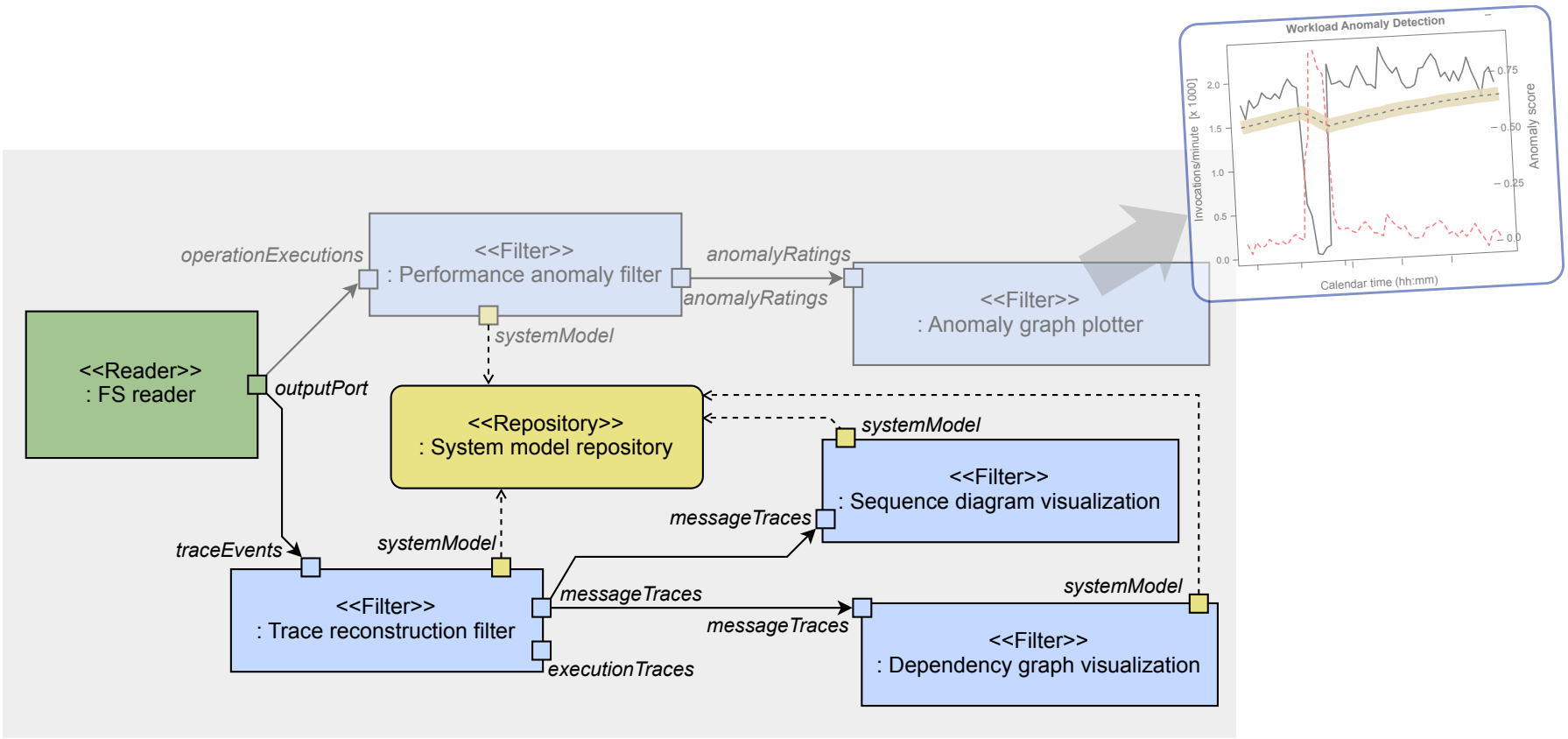

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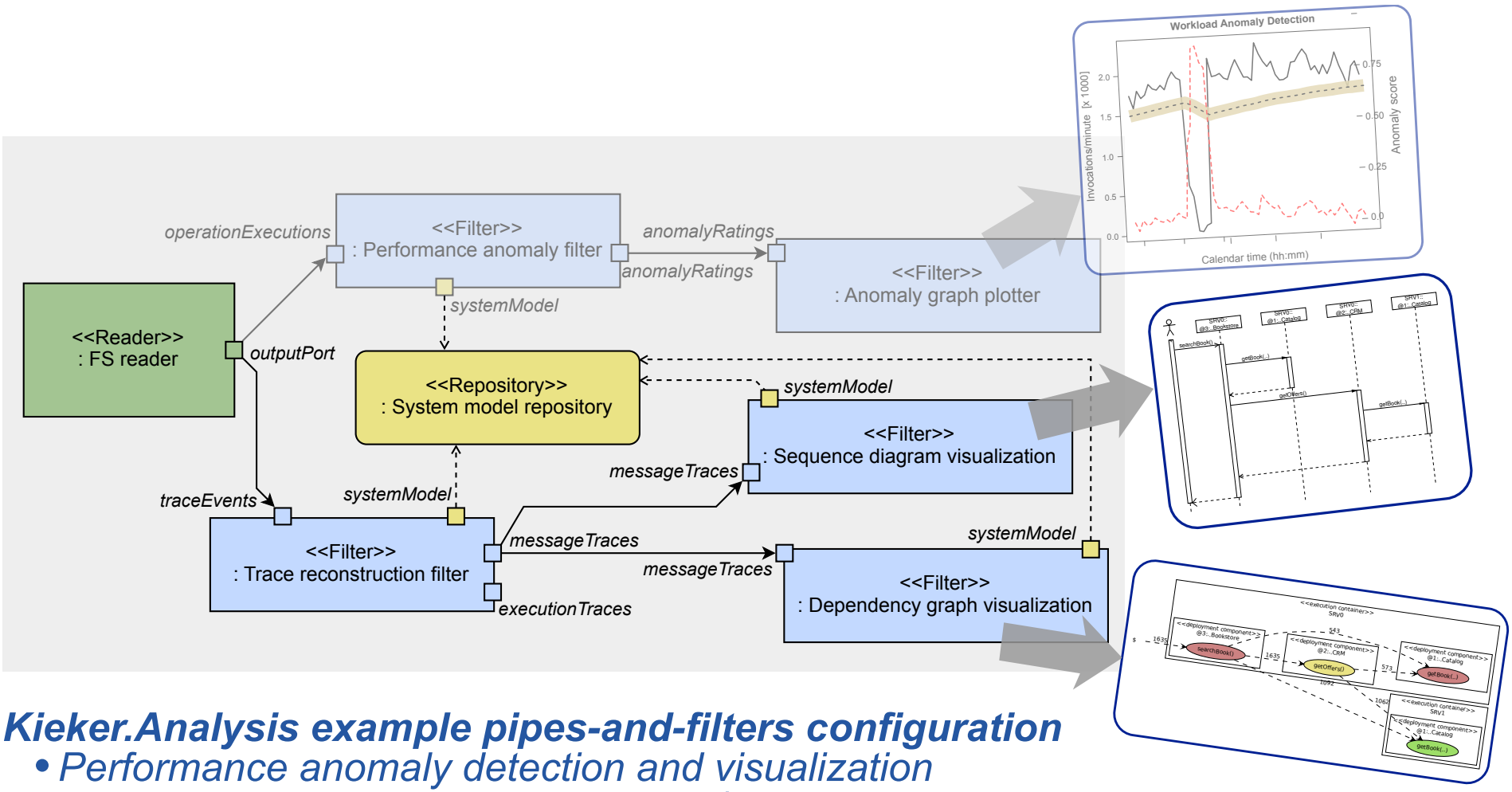

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Kieker

- Modular, flexible, and extensible architecture (Probes, records, readers, writers, filters etc.)
- Pipes-and-filters framework for analysis configuration
- Distributed tracing (logging, reconstruction, visualization)
- Low overhead (designed for continuous operation)
- Evaluated in lab and industrial case studies

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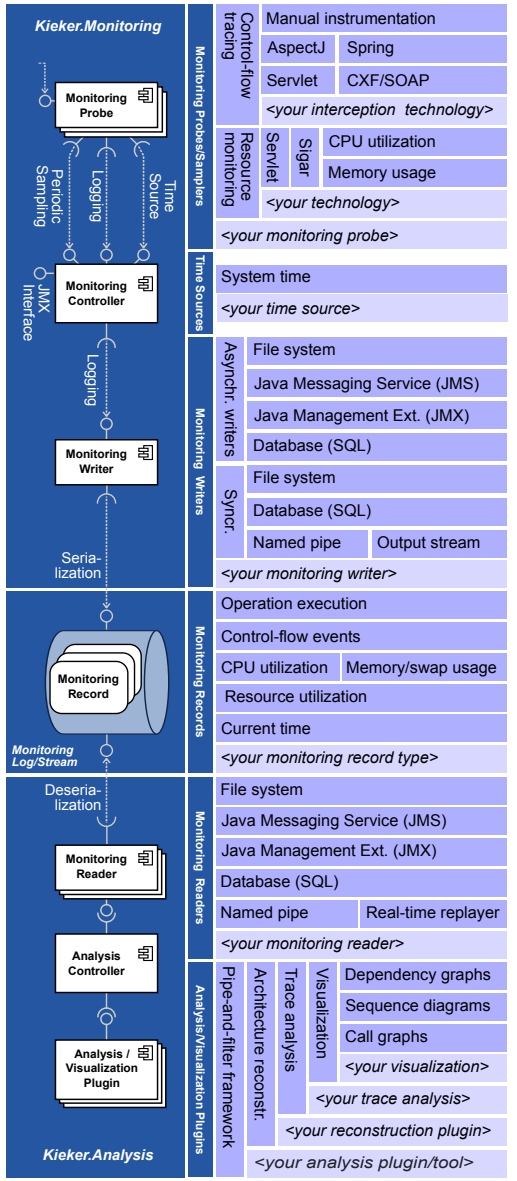

Framework Features & Extension Points

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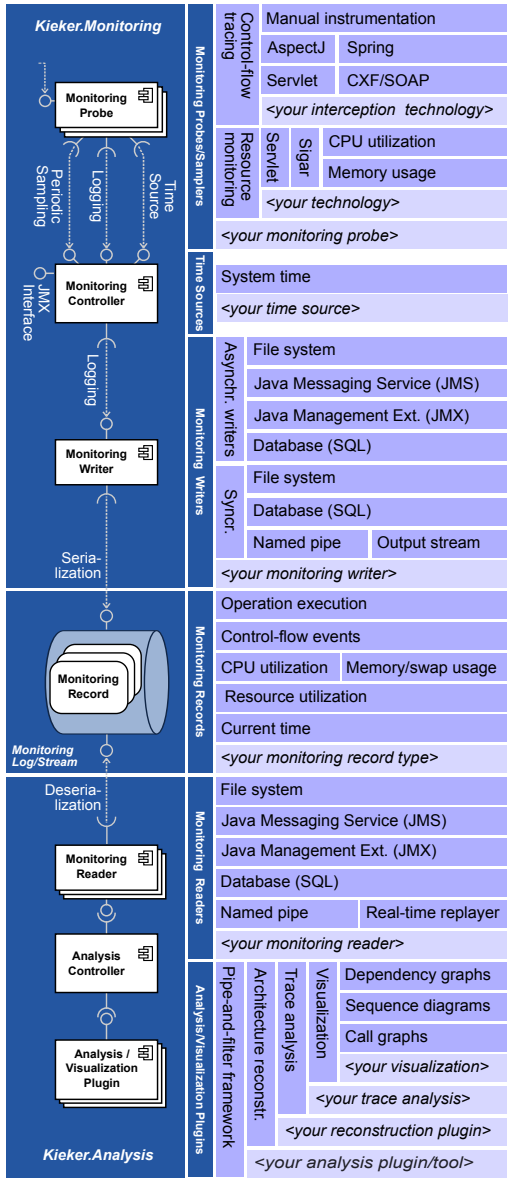
Kieker is open-source software (Apache License, V. 2.0)

`http://kieker-monitoring.net`

Kieker is distributed as part of SPEC® RG's repository of peer-reviewed tools for quantitative system evaluation and analysis

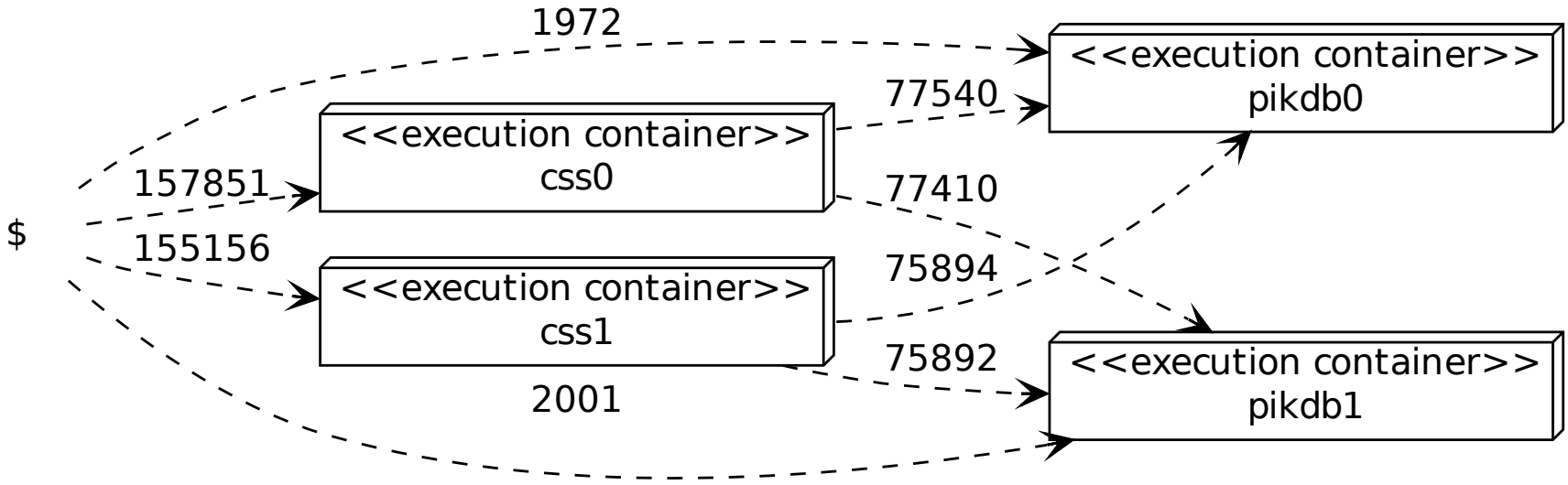
`http://research.spec.org/projects/tools.html`

spec Research



Telecommunication provider, distributed setting

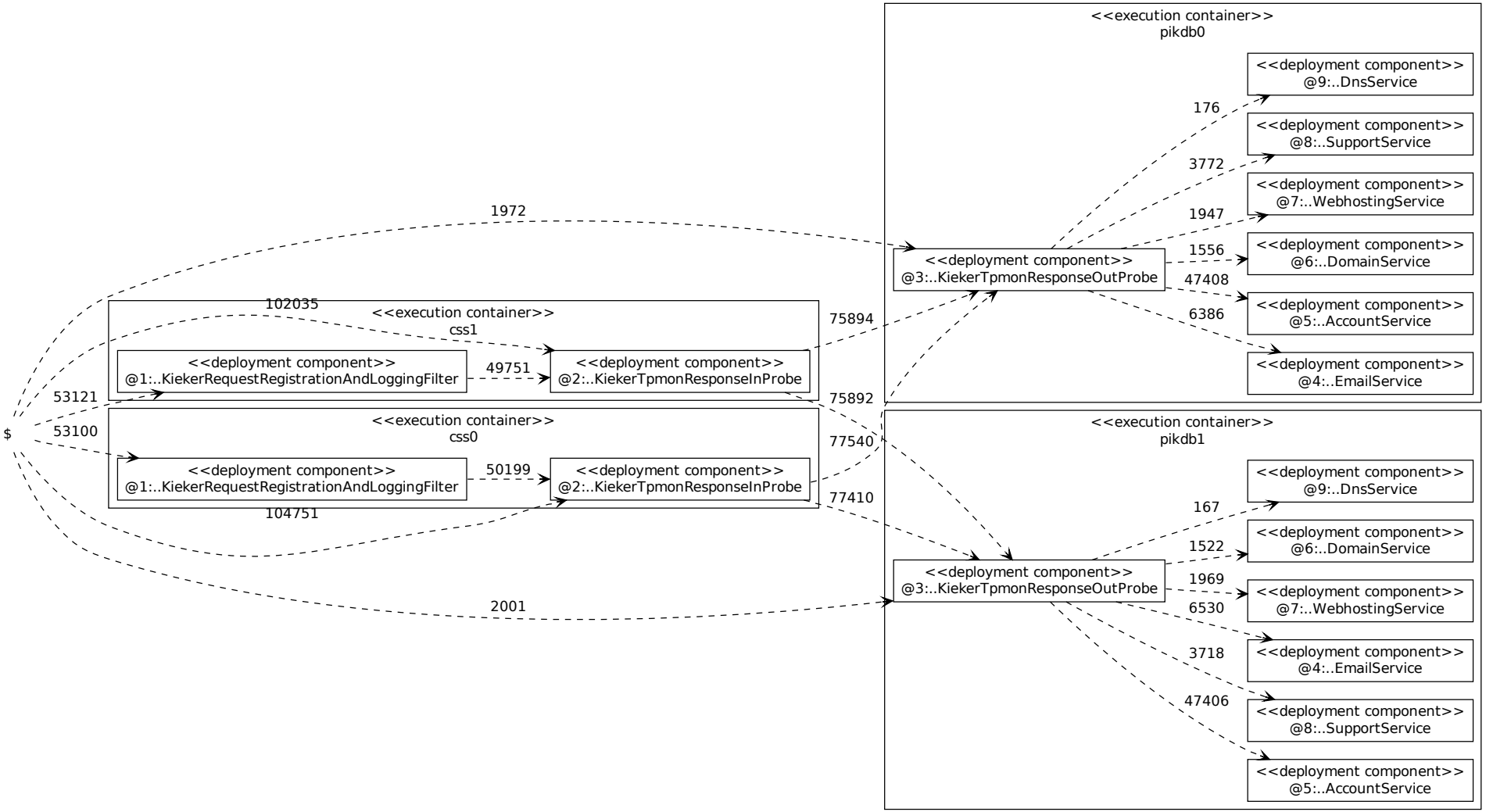
- Goal: Workload characterization and performance evaluation
- Java-based technology: Servlet, Spring, and CXF/SOAP
- Continuous Monitoring (utilizing Kieker):
  - Probes for collecting distributed application-level trace and performance data
  - Continuous monitoring in production use since 12/2009
- Model extraction examples (316,980 traces):



Container dependency graph (with calling frequencies)

Case Study: Model Extraction Examples (cont'd)

Deployment-level component dependency graph (with calling frequencies):



What I've Talked About

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SLAstic

- Self-adaptive capacity management based on application-level workload
- Adaptation goal: Increased resource efficiency while meeting SLAs
- Means for adaptation: Architectural runtime reconfiguration
- Use of architectural (performance) models at development & runtime
- Domain: Business-critical distributed component-based software systems

Kieker

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- Pipes-and-filters framework for analysis configuration
- Distributed tracing (logging, reconstruction, visualization)
- Low overhead (designed for continuous operation)
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Feel free to contact me: `avh@informatik.uni-kiel.de`

N. Günther. Modellbasierte Laufzeit-Performance-Vorhersage für komponentenbasierte Softwarearchitekturen (“Model-based online performance prediction for component-based software architectures”, in german), Nov. 2011. Diploma Thesis, University of Kiel.

A. van Hoorn. *Model-Driven Online Capacity Management for Resource Efficient Component-Based Software Systems*. PhD thesis, Department of Computer Science, University of Kiel, Kiel, Germany, 2012. work in progress.

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A. van Hoorn, J. Waller, and W. Hasselbring. Kieker: A framework for application performance monitoring and dynamic software analysis. In *Proceedings of the 3rd ACM/SPEC International Conference on Performance Engineering (ICPE 2012)*, pages 247–248. ACM, Apr. 2012.

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