Product Line Software Engineering in Europe –

Fundamental Concepts and Case Study

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Outline

- Product Line Concepts

  - Definition

  - Approaching Reuse

  - Life cycle

- Case Study: Testo

  - Adoption

  - Quality Measurement at Architecture Level

  - Experience and Next Steps

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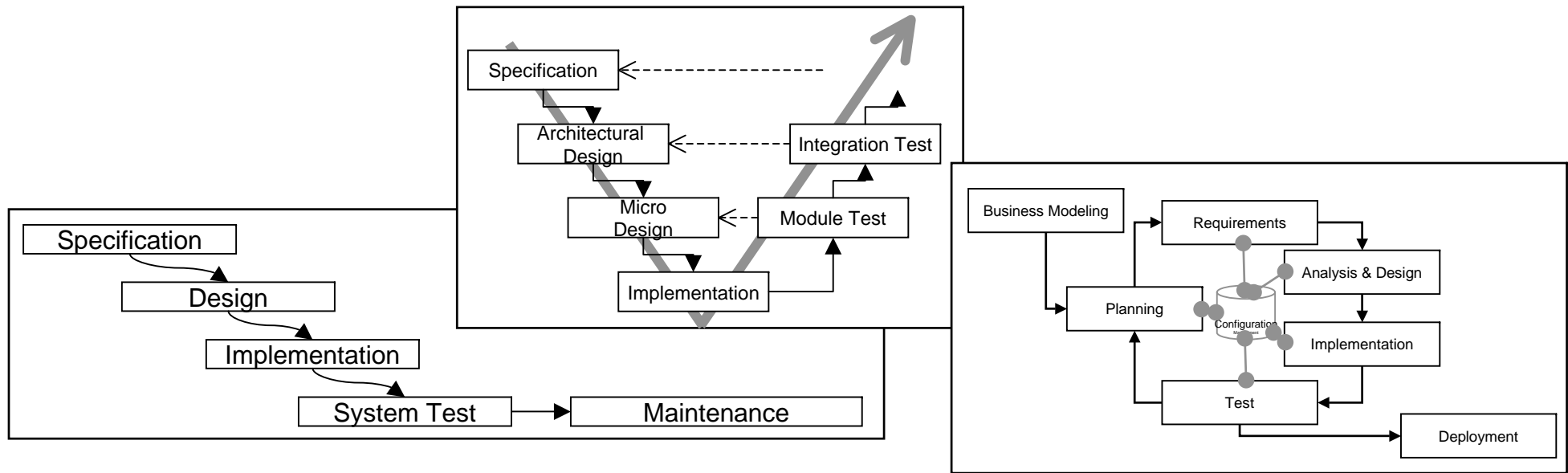
Definition: Product Line

- Definitions: Product Lines

    - A product line is "a set of systems sharing a common set of features that satisfy the specific needs of a particular market segment" [Clements, Northrop]

    - A product line is "a family of products designed to take advantage of their common aspects and predicted variabilities" [Weiss, Lai]
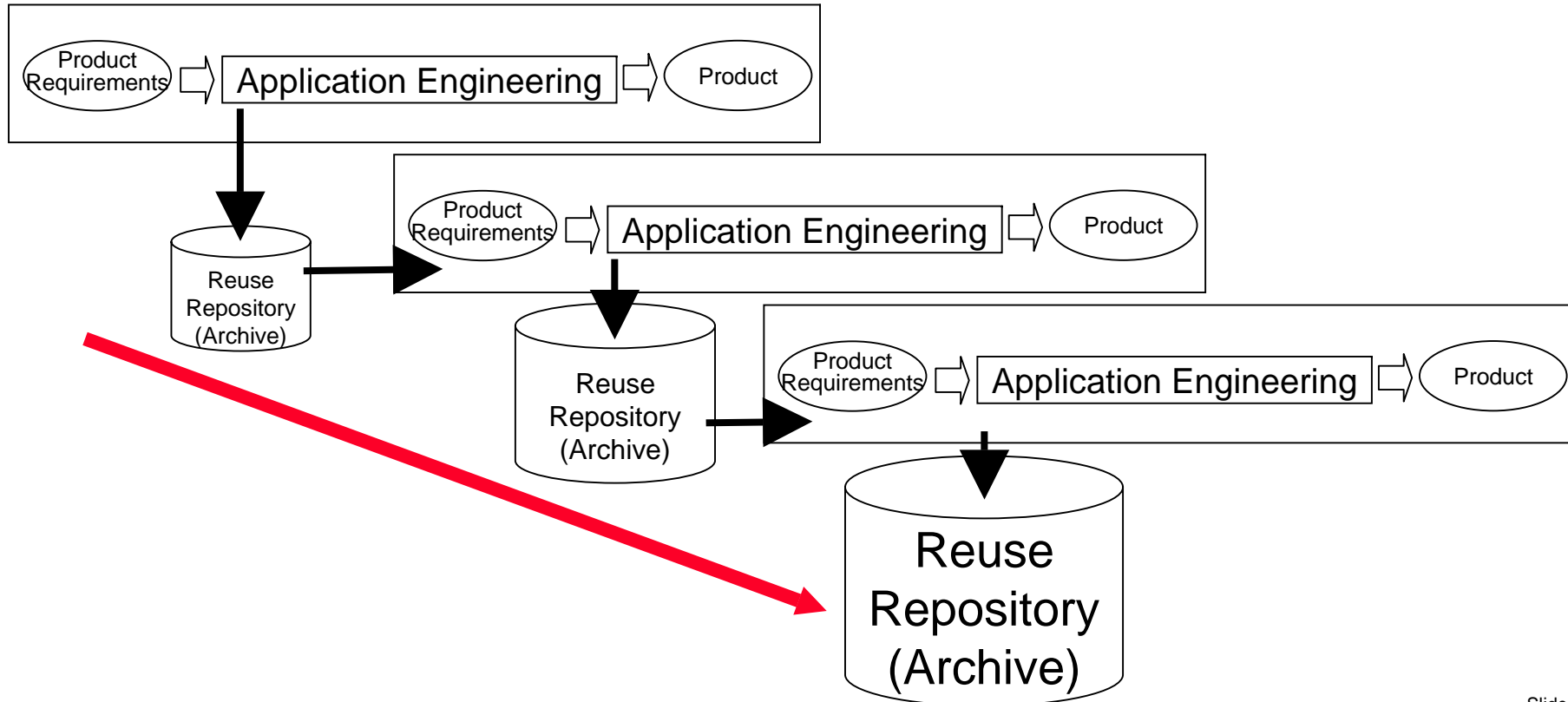
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Application Engineering

Product Requirements ⇨ Application Engineering ⇨ Product

Specification

Architectural Design ← Integration Test

Micro Design ← Module Test

Implementation

Specification

Design

Implementation

System Test → Maintenance

Business Modeling

Requirements

Analysis & Design

Planning

Configuration Management

Implementation

Test

Deployment

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Ad hoc Reuse

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Domain Engineering

Successes
- GUI Libraries
- Databases
- Middleware
- Operating Systems
- ...
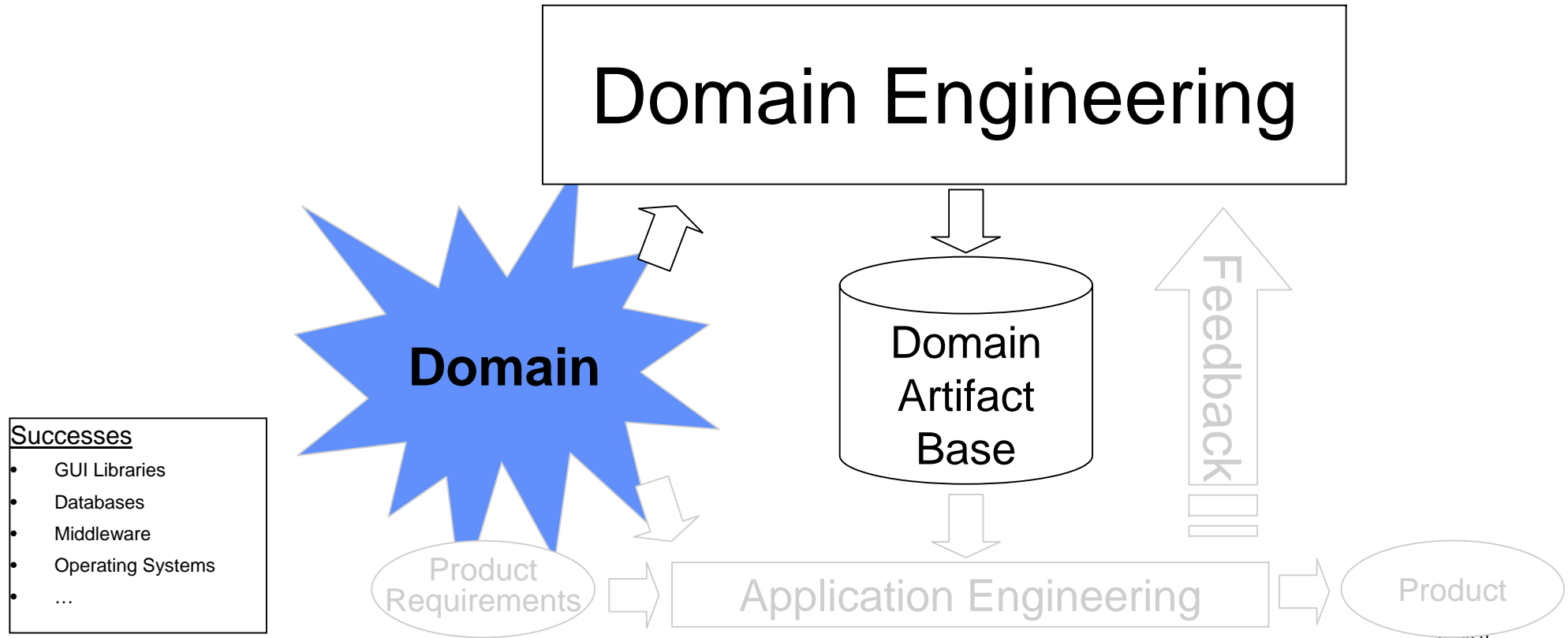
Series of Application Engineering Projects
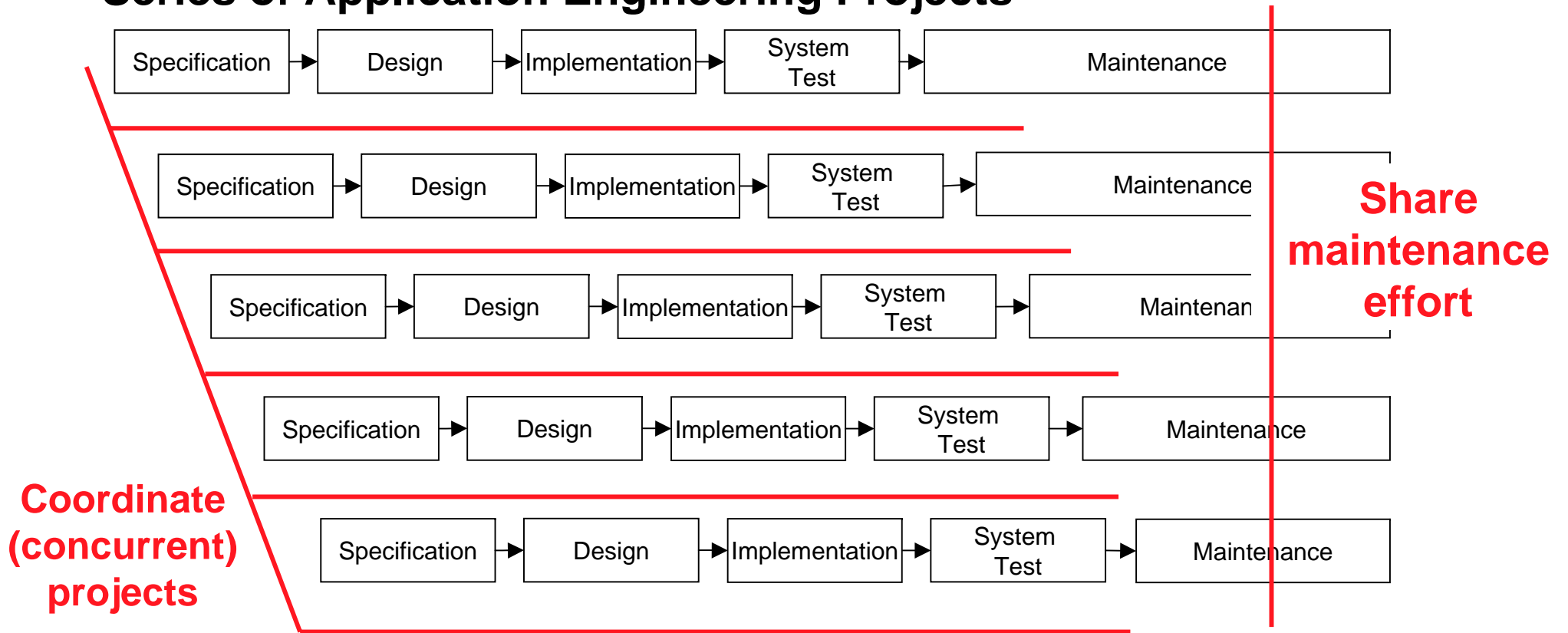
Slide 7

Organizational Life Cycle

Application Engineering

| Specification | → | Design | → | Implementation | → | System Test |

| Specification | → | Design | → | Implementation | → | System Test |

| Specification | → | Design | → | Implementation | → | System Test |

| Specification | → | Design | → | Implementation | → | System Test |

Family Engineering

?

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Product Line Life Cycle

Product Requirements

Product

Application Engineering

Evaluation   Adaptation

Identification   Integration

Domain

Product Line Artifact Base

Coordination

Feedback

Product Requirements **A**

Requirements **B**

Requirements **C**

Scoping

Classification   Evolution

Documentation

Family Engineering

Product Line Infrastructure

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Testo – Product Family

- Subject: climate and flue gas measurement devices

  - Domain: Embedded system

  - Programming Language: C

  - Product Line: ~ 100 – 600 KLOC per system

- Sample products:

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Testo – Product Line Adoption

Organizational Issues

Incremental introduction of product line concepts due to

- Limited resources

- Tight deadlines

- Learning process of engineers due to changed development paradigm

Establishment of a special team for maintenance and evolution of the framework

History – Product line adoption

2002 – Scoping

2003 – Architecture development

2004 – Development of first 3 commercial products as product line instances

2005 – Update of product line architecture based on measured feedback from product developments

2005/06 – Development of additional 7 products as product line instances

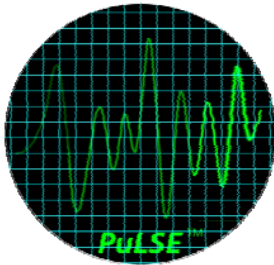**2006/07** – Monitoring and analysis of product line performance
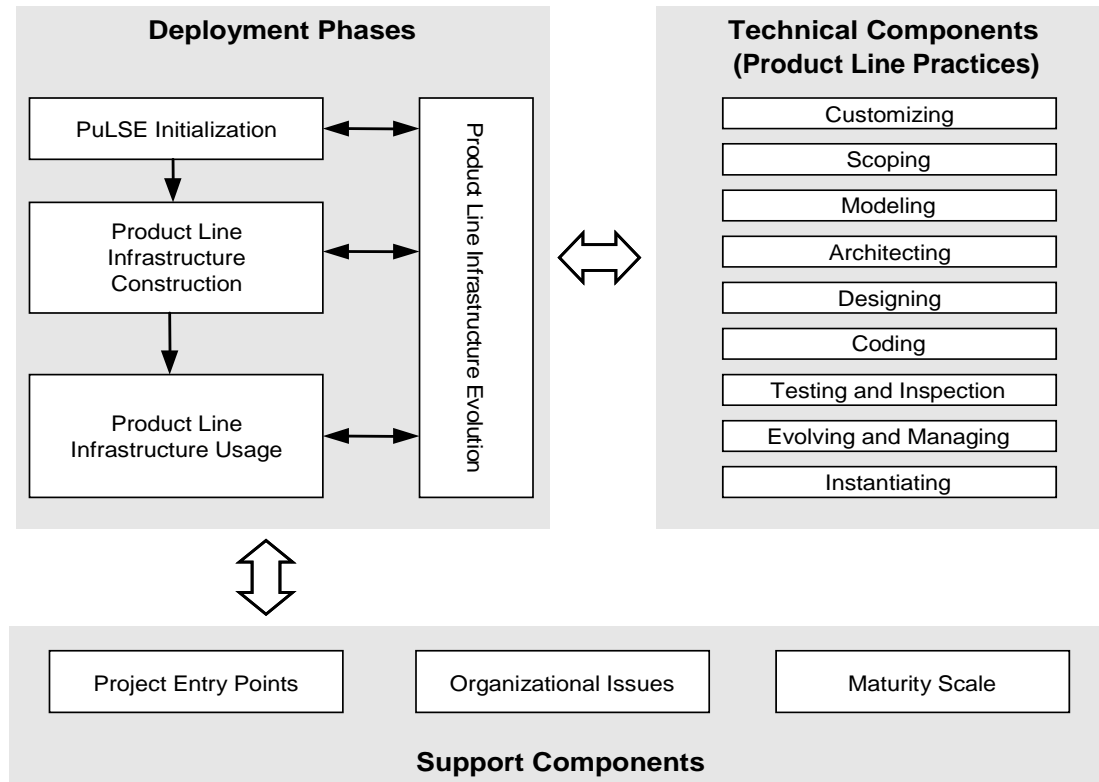
-2009 – 2nd release of PL infrastructure

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Testo – Product Line Methodology and Technology [Fraunhofer PuLSE™]

Applied research
since 1997
(= 3-4 innovation cycles)

PuLSE™

Industry Partners (**selection**)

BOSCH

HITACHI
Inspire the Next

MARKET MAKER

testo

BLAUPUNKT

Deployment Phases

PuLSE Initialization

Product Line
Infrastructure
Construction

Product Line
Infrastructure Usage

Product Line Infrastructure Evolution

**Technical Components
(Product Line Practices)**

| Customizing |
| Scoping |
| Modeling |
| Architecting |
| Designing |
| Coding |
| Testing and Inspection |
| Evolving and Managing |
| Instantiating |

Project Entry Points

Organizational Issues

Maturity Scale

Support Components

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Testo – Product Line Architecture and Framework

- All product line instances comply to a single product line architecture

- 1st Release of framework components cover ~ 40% of product implementation

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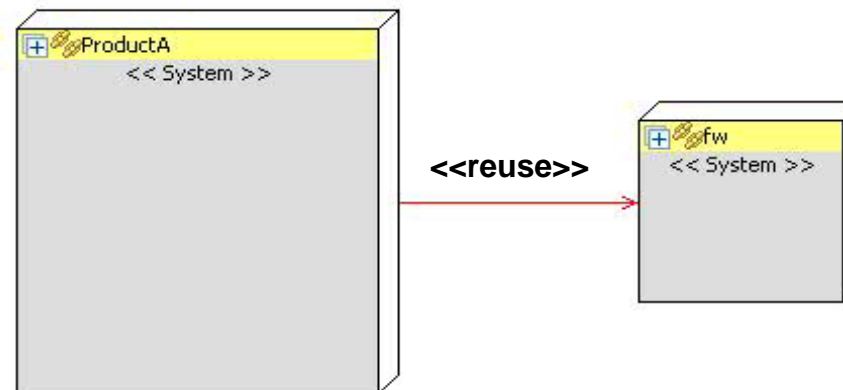
Fraunhofer SAVE – <u>S</u>oftware <u>A</u>rchitecture <u>V</u>isualization and <u>E</u>valuation
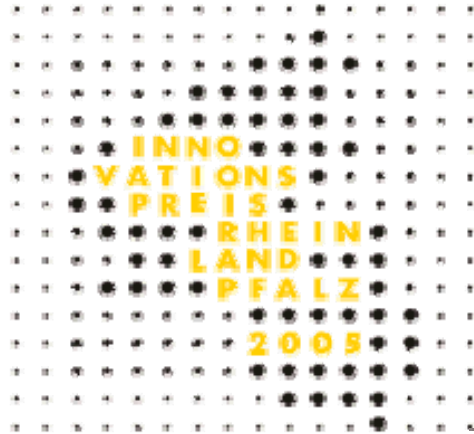
- Collection of eclipse plug-ins
    - Supported languages: Java, C/C++, Delphi
    - Computations of
        · Architectural compliance (implemented as specified)
        · Model transformations (lifting, manipulation)
    - Visualization
        · Graphical modeling of architectures
            - UML-based notation (extensible)
        · Exploration of extracted architectures

- Awarded the Innovation Price 2005 of Rhineland-Palatinate
    - Ministry of Economics, Transportation, Agriculture and Viniculture

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# Fraunhofer SAVE – Features
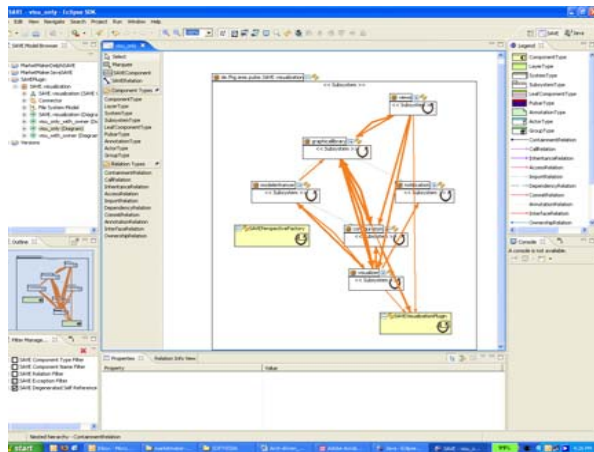
- Additional Features
    - Ownership computation
    - Rule-based evaluation
    - Visualization of deltas between two system states
    - Generic interface for multiple metrics
    - System environment analysis
- Application Purposes
    - Evolution control
    - Comprehension
    - Re-documentation
    - What-if scenarios

→ Instrument to support, control and evolve the architecture of a system or product line

→ Hard connection between architecture definition and implementation!

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Testo – Quality Measurement at Architecture Level (top level)
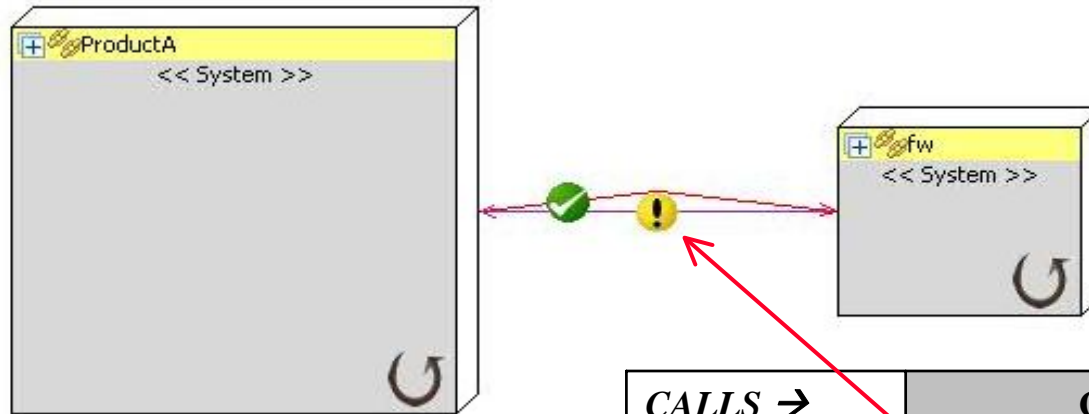
CALLS →	CALLEE		Total
CALLER	Product_A	Framework	
Product_A	9226	1021	10247
Framework	**58**	858	916
Total	9284	1879	11163

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Testo – Quality Measurement at Architecture Level (refined level)

For illustration only!

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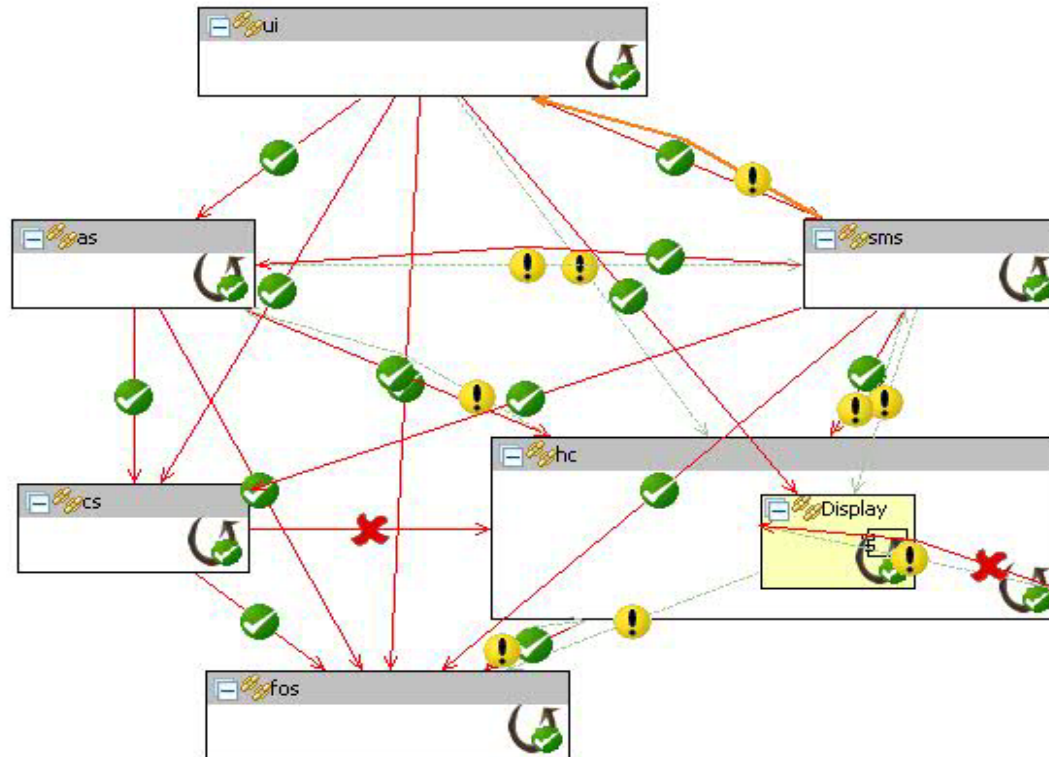
Testo – Improvement Recommendations

- Decomposition structure

  - Reference architecture in place (with exceptions)

  - Improvements to framework to support the derivation of future products

    · Adaptation of either the framework or the product implementation

    · Refactoring of obsolete dependencies (e.g., includes, but no included element is used), as well as to encapsulate global variables.

- Documentation consistency

  - Documentation has not fully reflected implemented architecture

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Testo – Currently Addressed Product Line Issues

- Maintainability in a product line context
  - Balancing of variability in components
  - Decision criteria for suitable framework component candidates
- Testability of new products reusing framework components
  - Reduction of test effort
- Monitoring the component quality for the identification of
  - inspection candidates
  - Subsystem interface refinements
- Measuring the efficiency and impact of applied actions

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Thank you for your attention!

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