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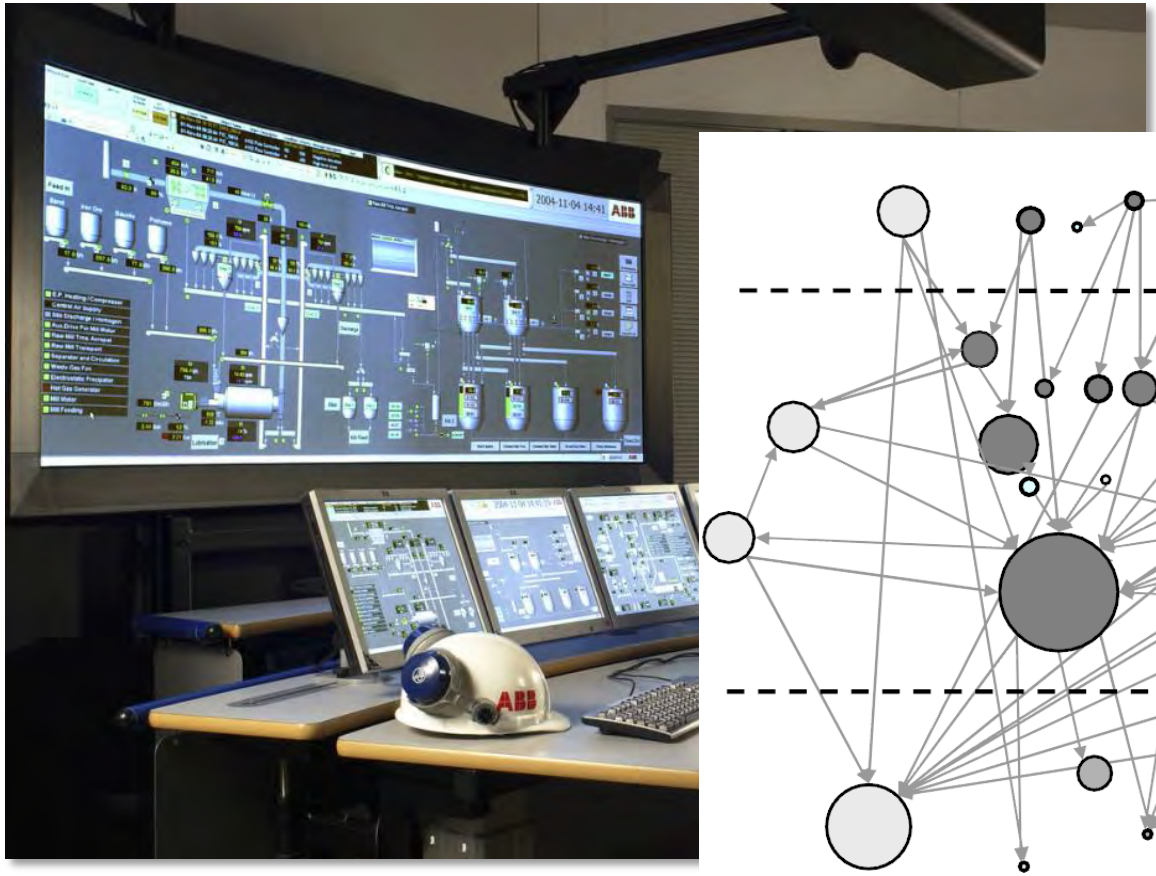
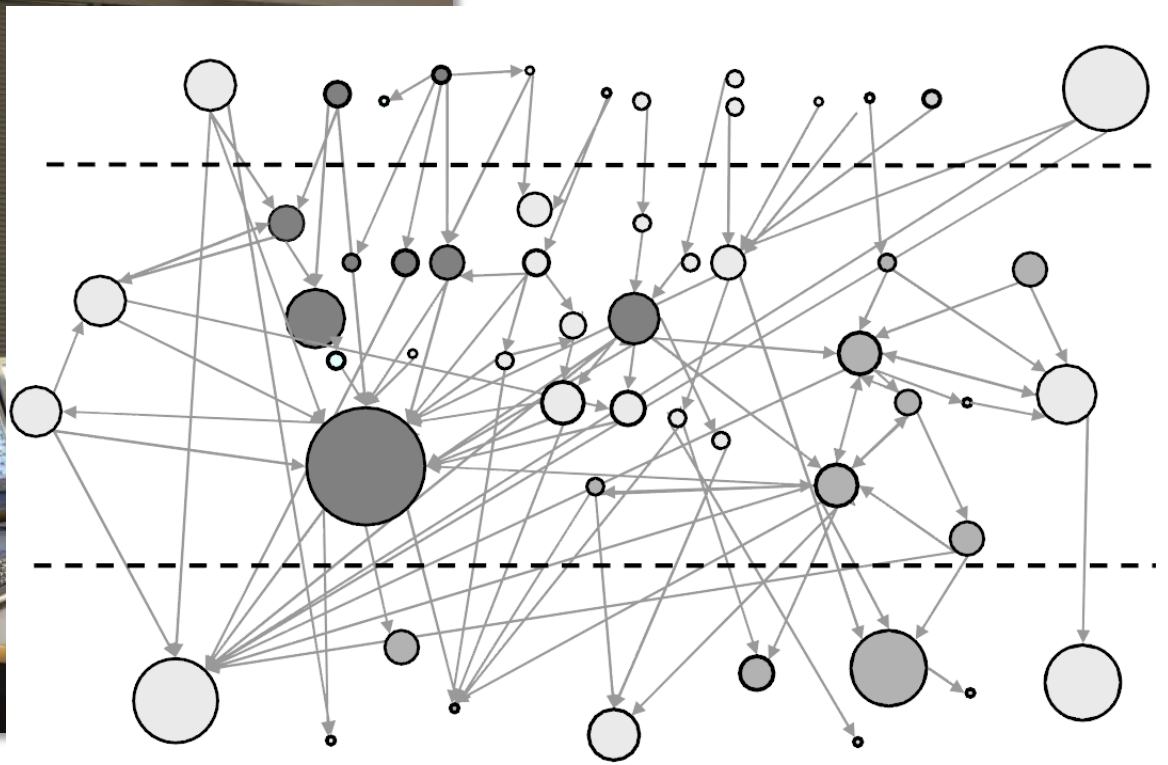
MORPHOSIS

A Case Study on Lightweight Architecture Sustainability Analysis

Large-scale Industrial Control Systems
Challenge: Software Architecture Erosion





Circles = components, Colors = subsystems,
Size = lines of code, Arrows = dependencies

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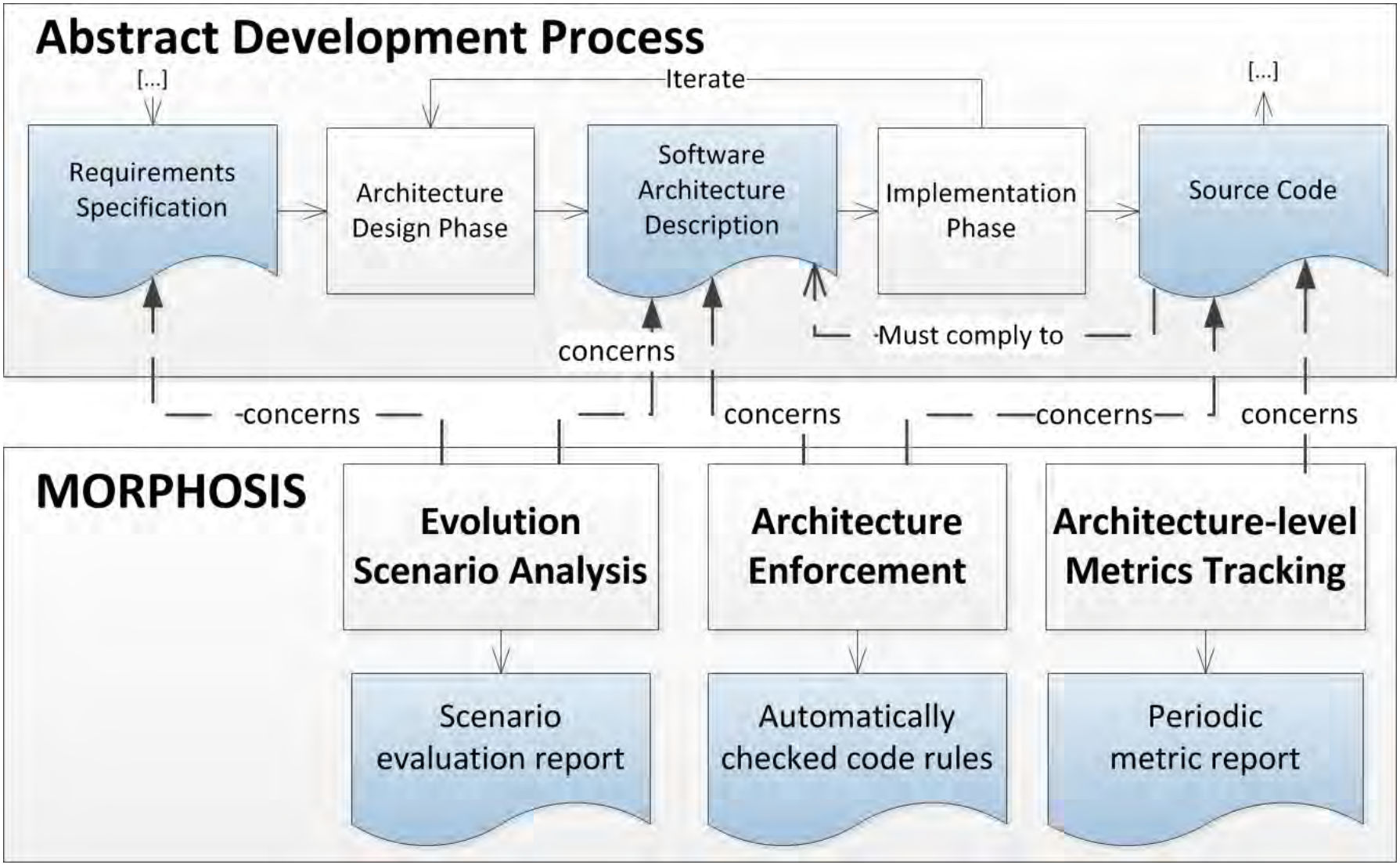
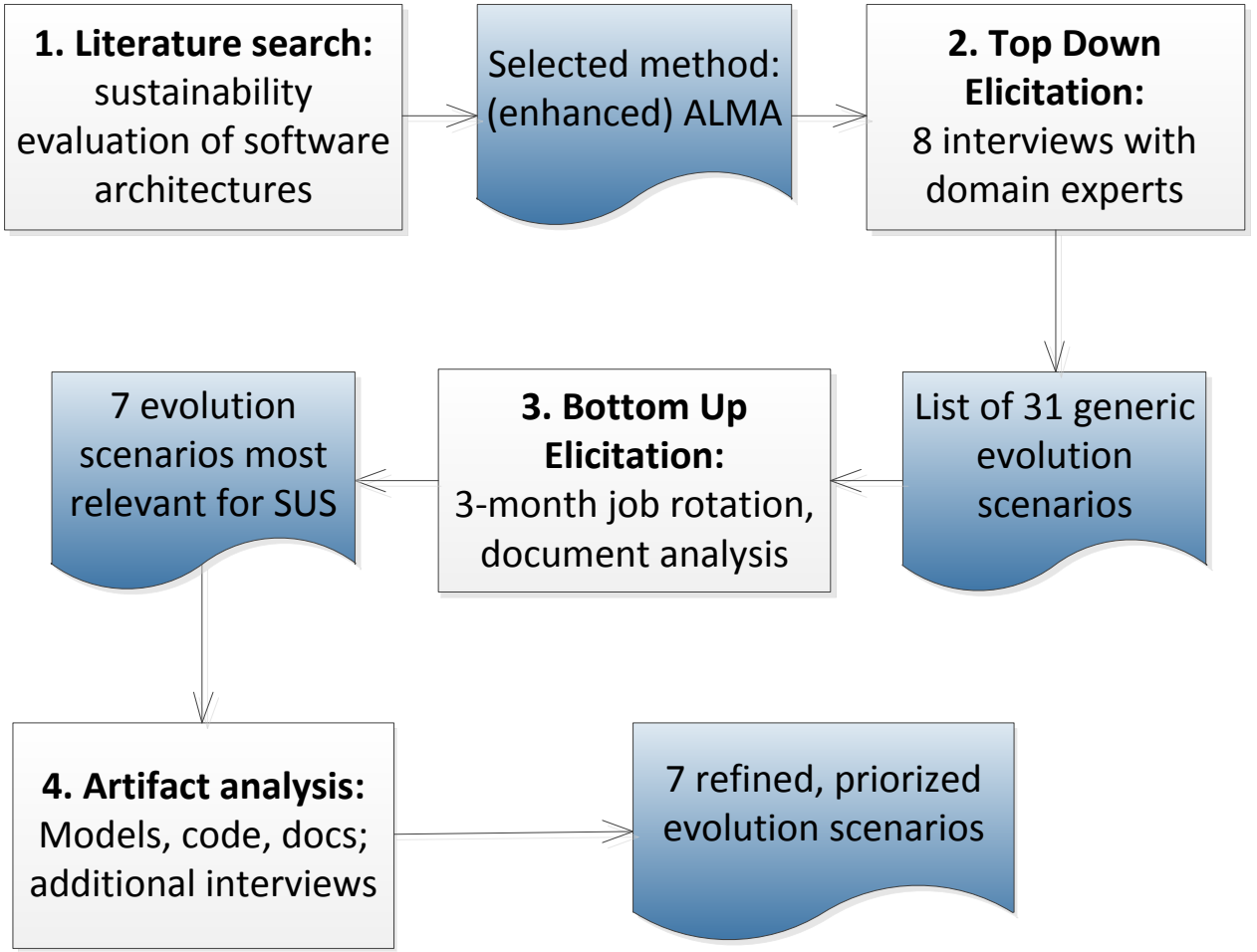
Multi-perspective SW Architecture Analysis Method



Evolution Scenario Analysis
Method



P. Clements, R. Kazman, and M. Klein, ***Evaluating software architectures: methods and case studies***. Addison-Wesley, Reading, MA, 2002.

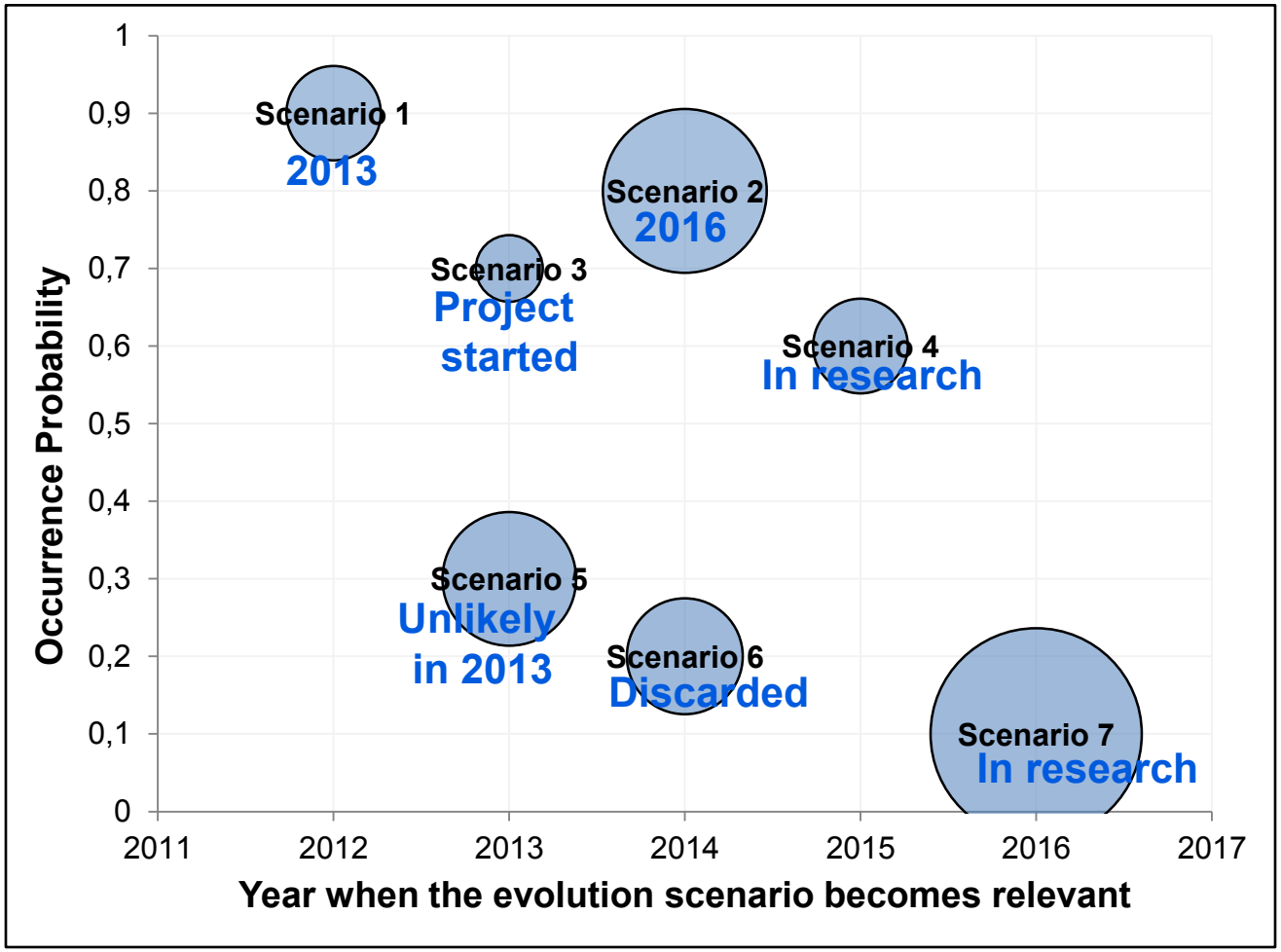
H. Koziolek ***Sustainability evaluation of software architectures: A systematic review.*** Proc. QoSA'11, *p. 3-12,* ACM, June 2011.

P. Bengtsson, N. Lassing, J. Bosch, and H. van Vliet, ***Architecture-level modifiability analysis (ALMA)*** Journal of Systems and Software, vol. 69, no. 1-2, pp. 129–147, 2004

Evolution Scenario Analysis
Results

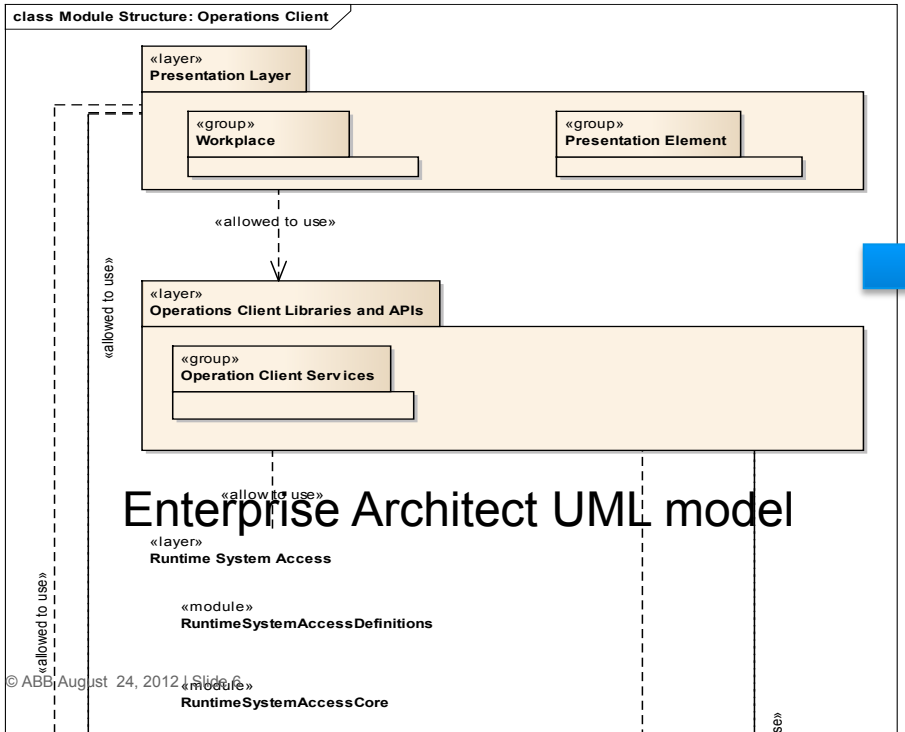
Status:

- **mid 2011**
- **mid 2012**



Architectural Enforcement
Derived Module Dependency Rules from UML Tool

- Goal: Automatic checking of allowed dependencies
  - Derived dependency rules from UML layer diagrams
  - Created name mapping from modules in UML to code
  - Constructed CQL rule for each module



Enterprise Architect UML model

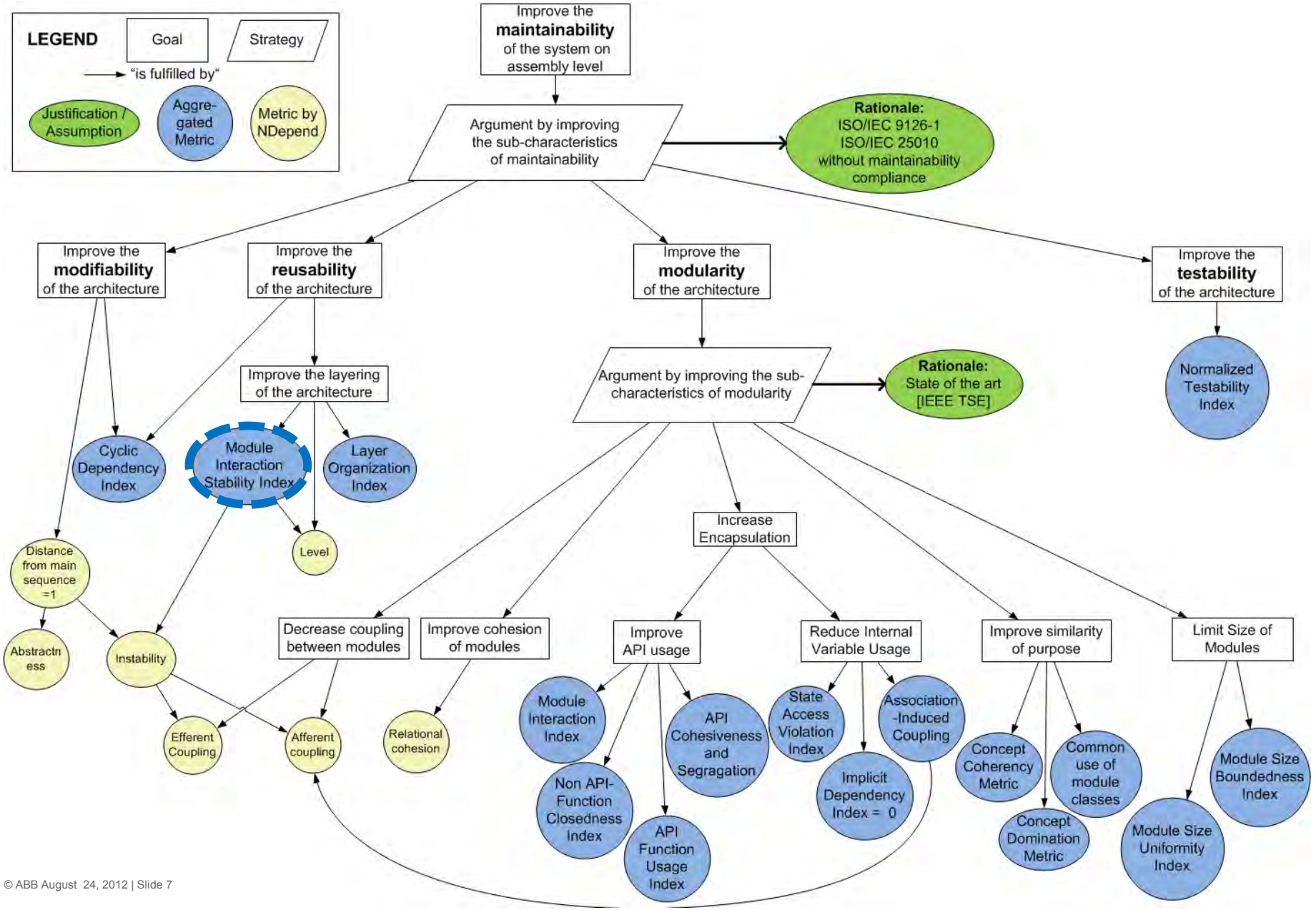
```
// <Name>Presentation Layer Dependencies</Name>
WARN IF Count > 0 IN
SELECT ASSEMBLIES  WHERE  IsDirectlyUsedBy  "ASSEMBLY=      OperationsClient.Workplace"
AND !(
  (
  ( NameIs          perationsClient.Workplace" OR
    NameIs          OperationsClient.WorkplaceApplication" OR
    NameIs          perationsClient.WorkplaceCore" OR
    NameIs          OperationsClient.WorkplaceOverlap" OR
    NameIs          OperationsClient.WorkplacePresentation" OR
    NameIs          OperationsClient.WorkplaceScreen" OR
    NameIs          OperationsClient.WorkplaceTools"

  OR
  (
    NameIs          OperationsClient.GraphicsViewer" OR
    NameIs          OperationsClient.ProcessGraphics.SystemAccessAdapter" OR

    NameIs "GraphicsKernel" OR
    NameIs          ProcessGraphics.SystemAccess" OR
    NameIs          ProcessGraphics.Types" OR
    NameIs          SystemAccess" OR
    //other elements
```

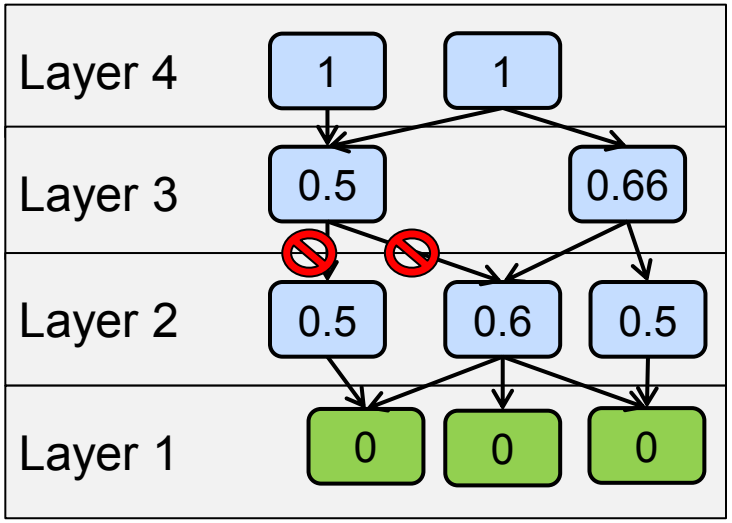
NDepend CQL rule
(Code Query Language)

Architecture-level Metric Tracking



Architecture-level Metric Tracking
Example: Module Interaction Stability

S. Sarkar, G. M. Rama, and A. C. Kak, ***"API-based and information-theoretic metrics for measuring the quality of software modularization,"*** IEEE Trans. Softw. Eng., vol. 33, pp. 14–32, January 2007.



- Characterizes software according to the principle of Maximization of Stand-Alone Extensibility
- Promotes the use of stable modules in lower layers

Instability of a module

Modules m depends on

$$\mathcal{I}(m) = \frac{|fanout(m)|}{|fanin(m)| + |fanout(m)|}$$

Modules that depend on m

$$SD(m) = \{m_i \in fanout(m) \mid \mathcal{I}(m) > \mathcal{I}(m_i) \;\&\; \mathcal{L}(m) \geq \mathcal{L}(m_i)\}$$

Set of stable dependencies to lower layers

$$MISI(m) = \frac{|SD(m)|}{|fanout(m)|}$$

$$= 1 \text{ when } fanout(m) = \emptyset,$$

$$MISI(\mathcal{S}) = \frac{1}{M}\sum_{i=1}^{M} MISI(m_i).$$

For all modules

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Lessons learned

- Perceived good cost / benefit ratio
  - Low analysis overhead, high automation
  - However: benefits are not quantified yet
- Quantifying the costs for evolution scenarios is hard
  - Impact prediction difficult if code not available
- Externalizing and prioritizing evolution scenarios provides focus to plan mitigation measures
- Architecture enforcement raises developer awareness
  - Higher regard for the architecture description
- High developer interest in metrics
  - Desire to improve quality,
    less concerned about being judged

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Conclusions

- Evolution Scenario Analysis
  - Provided detailed description template
- Architecture Enforcement
  - Integrated rules from UML model into build process
- Architecture-level Metrics Tracking
  - Automated tracking of novel architecture metrics

- Future Work
  - Re-evaluate / add evolution scenarios
  - Conduct a longitudinal study correlating metrics to actual maintenance costs

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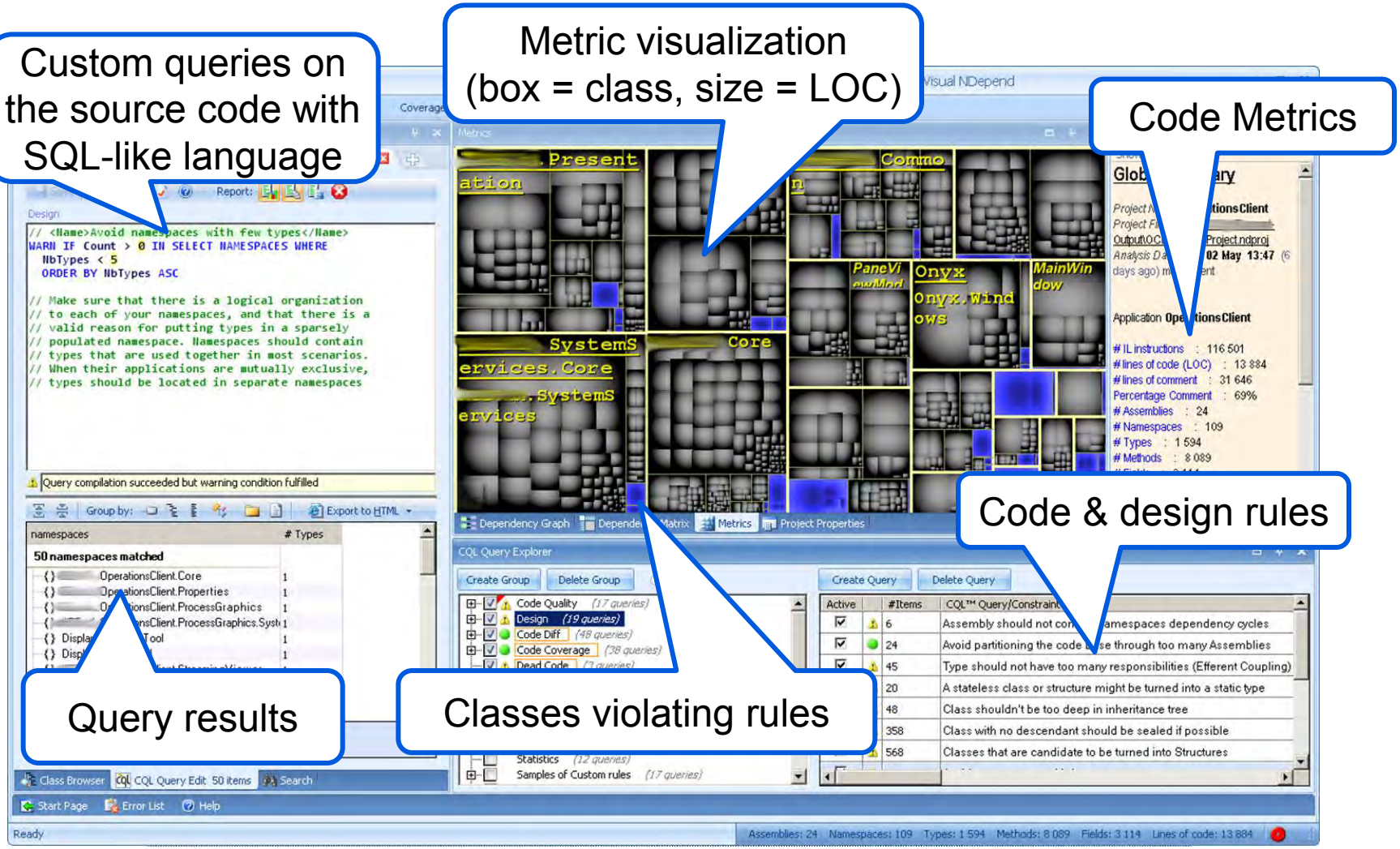
Architecture Enforcement
Tool Support: NDepend (C#), CppDepend (C++)



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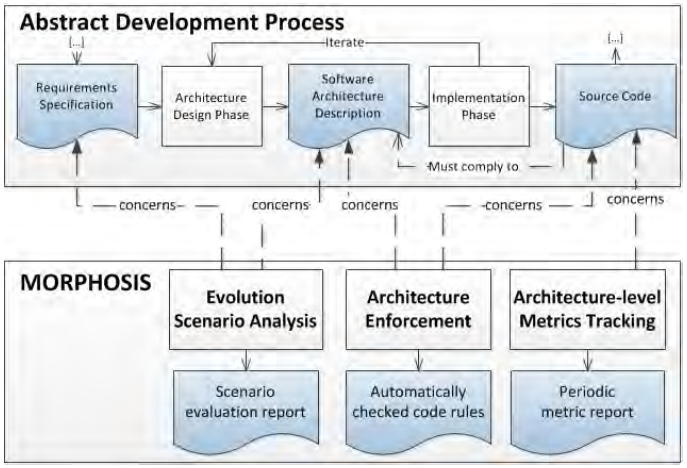
Discussion



- Lightweight method?
  - Scenario analysis w/o workshops
  - Automated metrics reporting
- In case of conflicting stakeholders: better run ATAM
- Substantial architecture redesign unlikely
  - Method aims at selective improvements
- Future Work
  - Re-evaluate evolution scenarios
  - Conduct a longitudinal study correlating metrics to actual maintenance costs