How to Harvest Reusable Components in Existing Software

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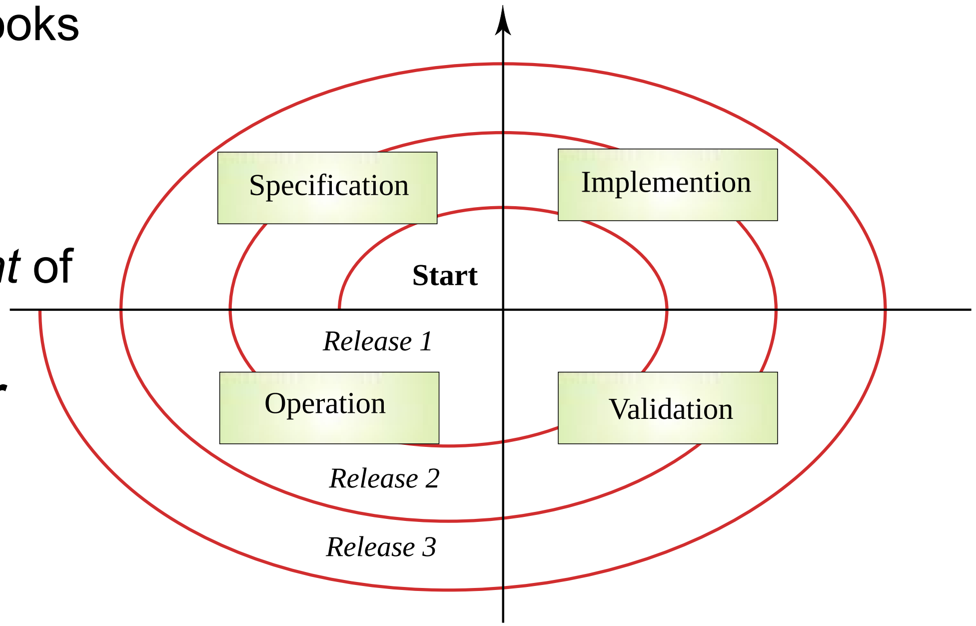
Overview

- **Introduction**
- **Reuse, Architecture and MDA**
- **Option Analysis for Reengineering (OAR)**
- **Architecture Excavation and Refactoring**
- **Harvesting as architectural refactoring**
  - First, you need to excavate your architecture, as a precise model
  - Harvesting requires the following steps:
    - Identify/localize/collect
    - Isolate component
    - Introduce a boundary
    - Implement refactoring
  - Particular challenges
    - Challenges of component identification (need to understand)
    - Challenges of component isolation
    - Challenges of soft boundaries
    - Reusable components and architecture erosion
    - Reusable components and cyclic dependencies
- **Examples**
- **Conclusions/Key points**

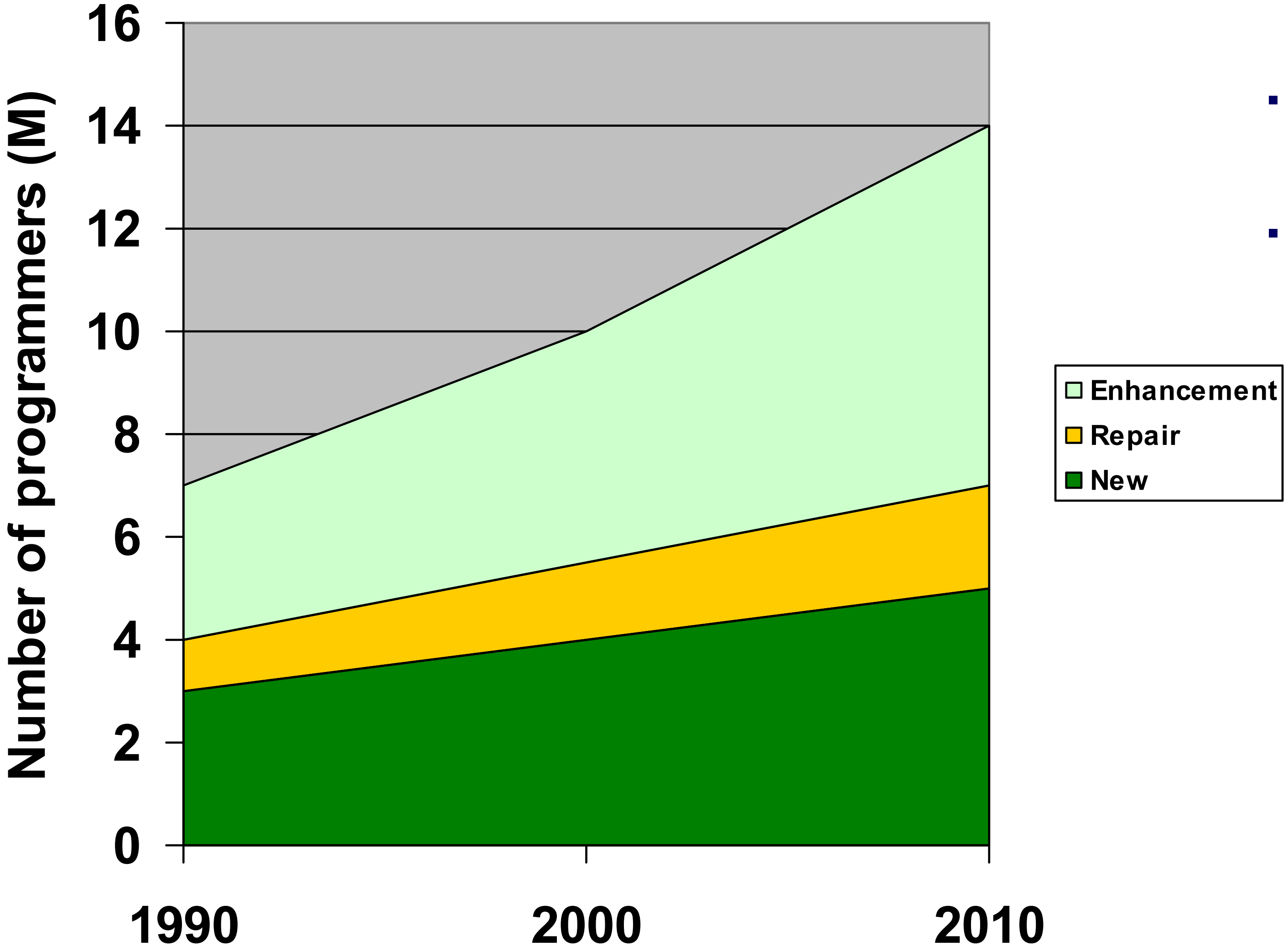
Production of software is evolutionary

- **Production of software involves *multiple* releases**
  - …despite the fact that many textbooks emphasize only the *initial* release, when *the system is built*
  - Software production after the initial release has an additional *constraint* of dealing with *existing code*
- **Changes are made to software after the initial release in order to:**
  - Develop new functionality
  - Fix bugs
  - Adapt to new operating environments
  - Improve quality



From Ian Sommerville, Software Engineering, 2000

Evolution of existing code has significant economic impact

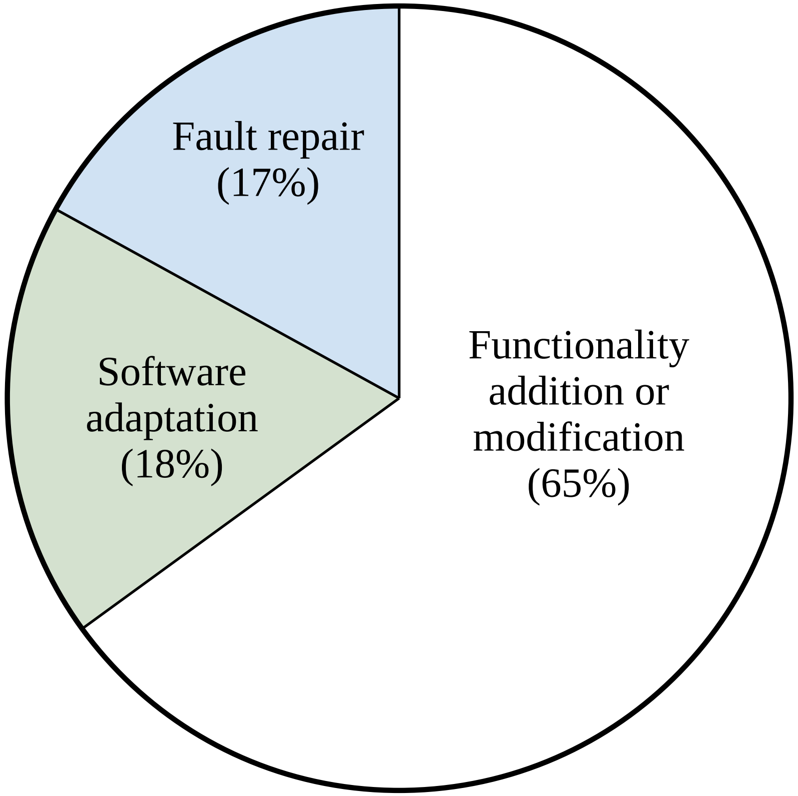


From Deursen,Klint,Verhoef,1999

- **More than one half of all programmers are *already* working with existing code (repair + enhancement)**
- **The cost of post-initial evolution has grown from 40% to 90% of the total production cost**
- **The number of programmers working with existing code *grows faster* than the number of programmers developing new software**
  - Larger amounts of software already developed
  - Large business value accumulates in existing code over time
  - Increasing cost of new development
  - The useful lifespan is increasing
  - Bigger churn of platforms and technologies
  - More defects

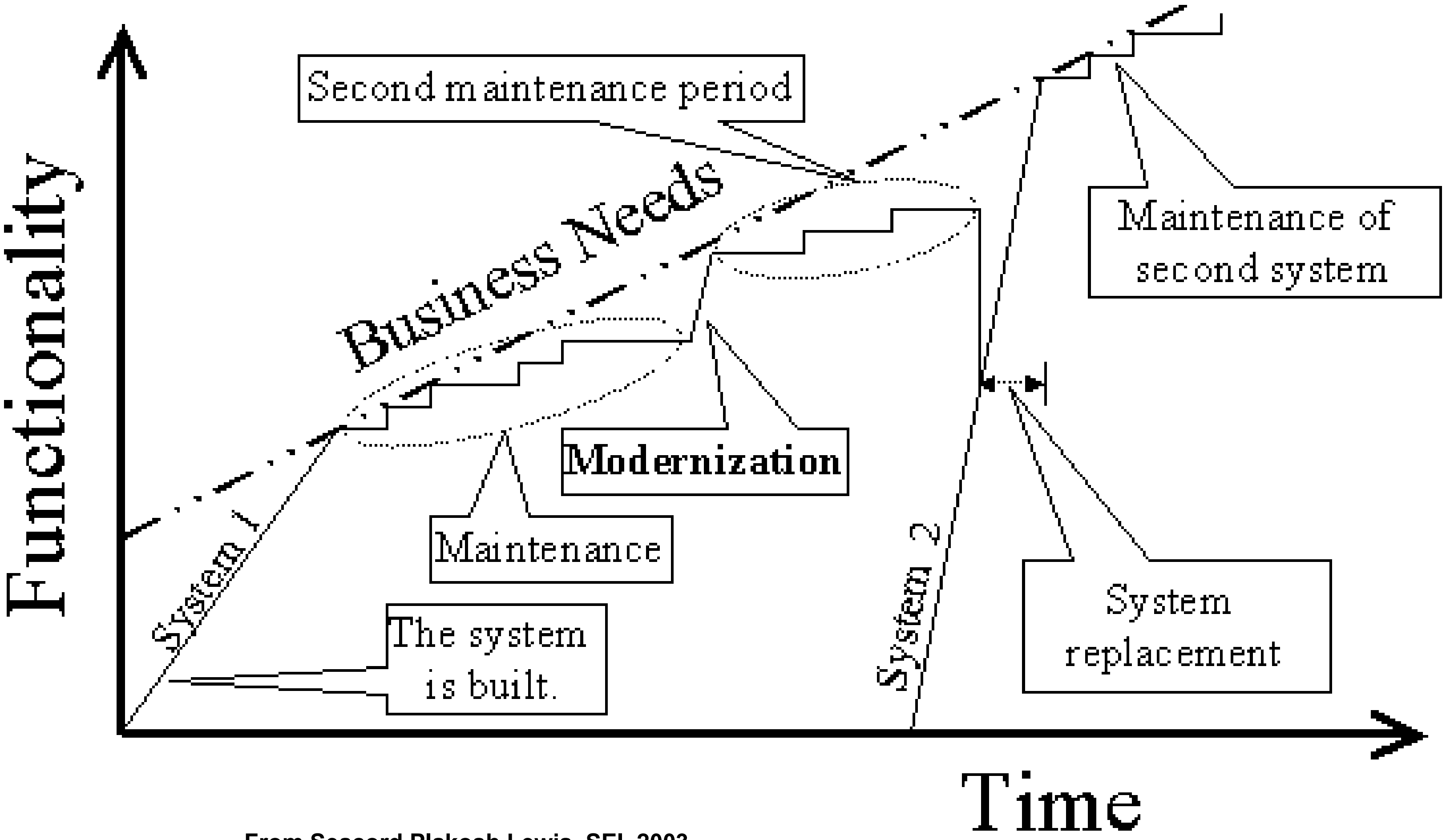
Software production with existing code

- **Changes to existing code may have different *magnitude:***
  - Traditional maintenance (repair)
    - Perfective maintenance
    - Adaptive maintenance
    - Corrective maintenance
    - Preventive maintenance
  - Major new features to existing software
    - Major modifications
    - Scaling
  - Modernization (beyond maintenance)
    - Porting to a new platform
    - Migration to a new technology
    - Migration to COTS components
    - Modularization and refactoring
  - Redevelopment



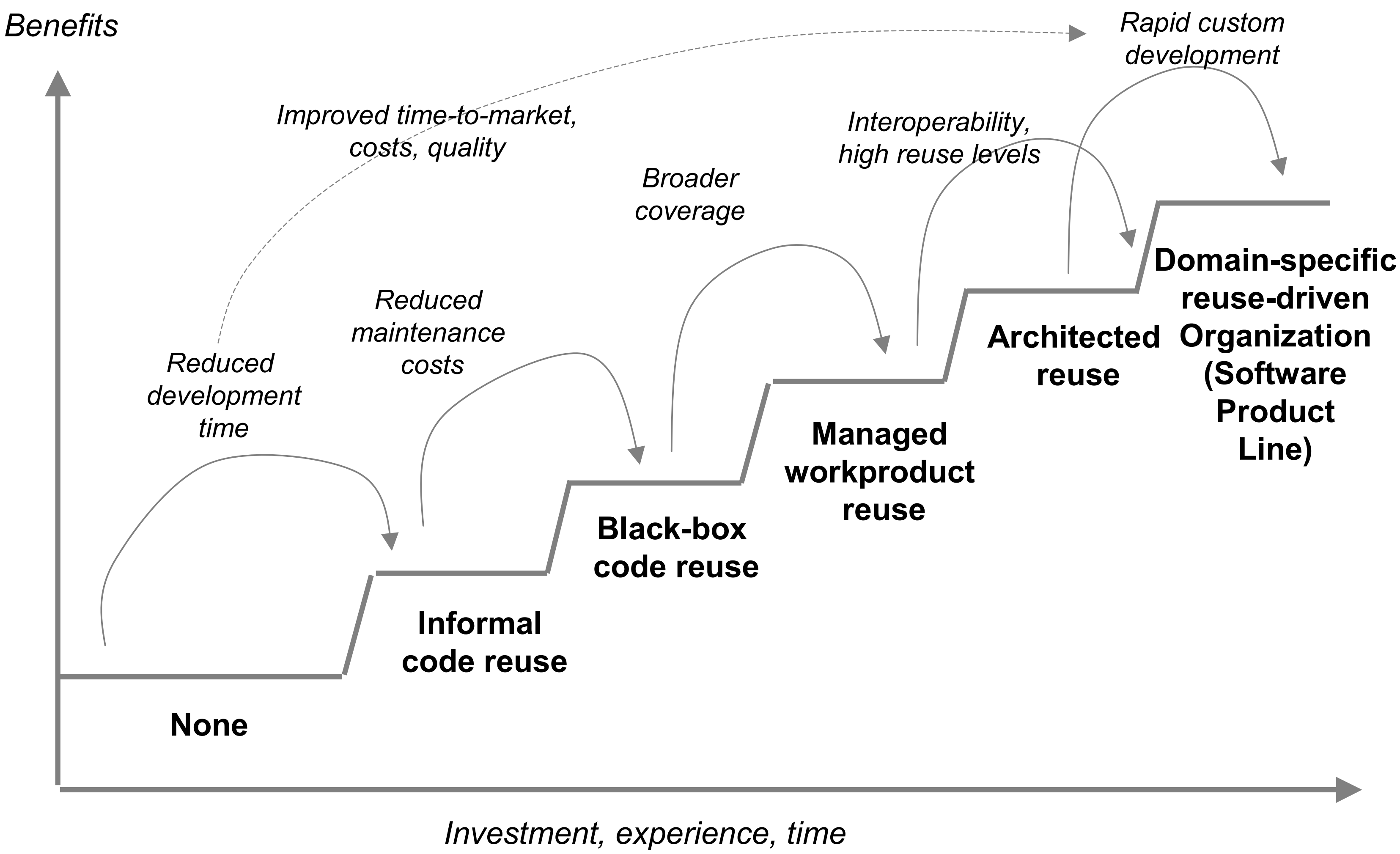
From Ian Sommerville, Software Engineering, 2000

Changes to existing software involve *reuse*



From Seacord,Plakosh,Lewis, SEI, 2003

The levels of reuse

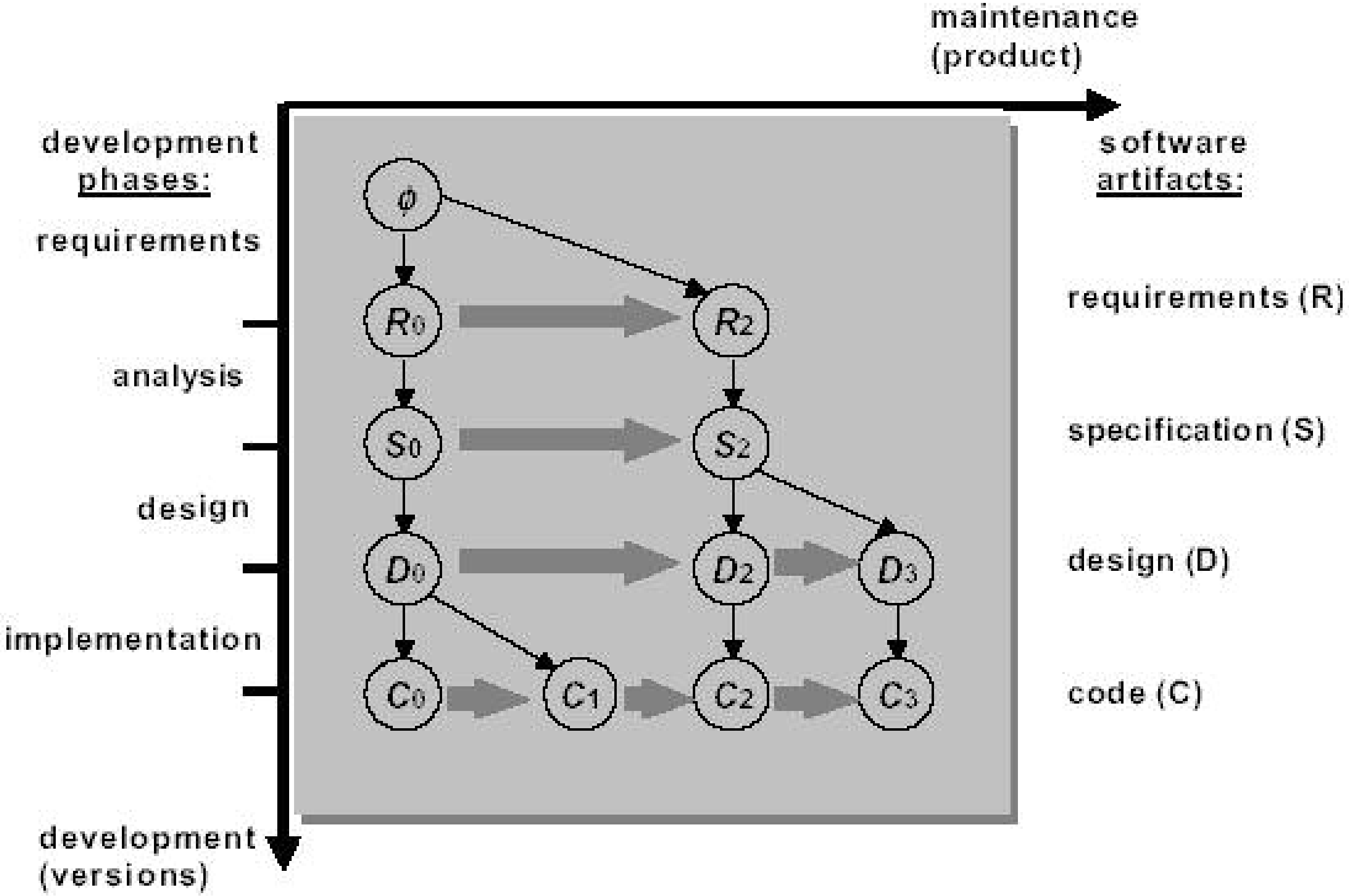


Adapted from Jacobson, et.al., 1997

Kinds of reuse

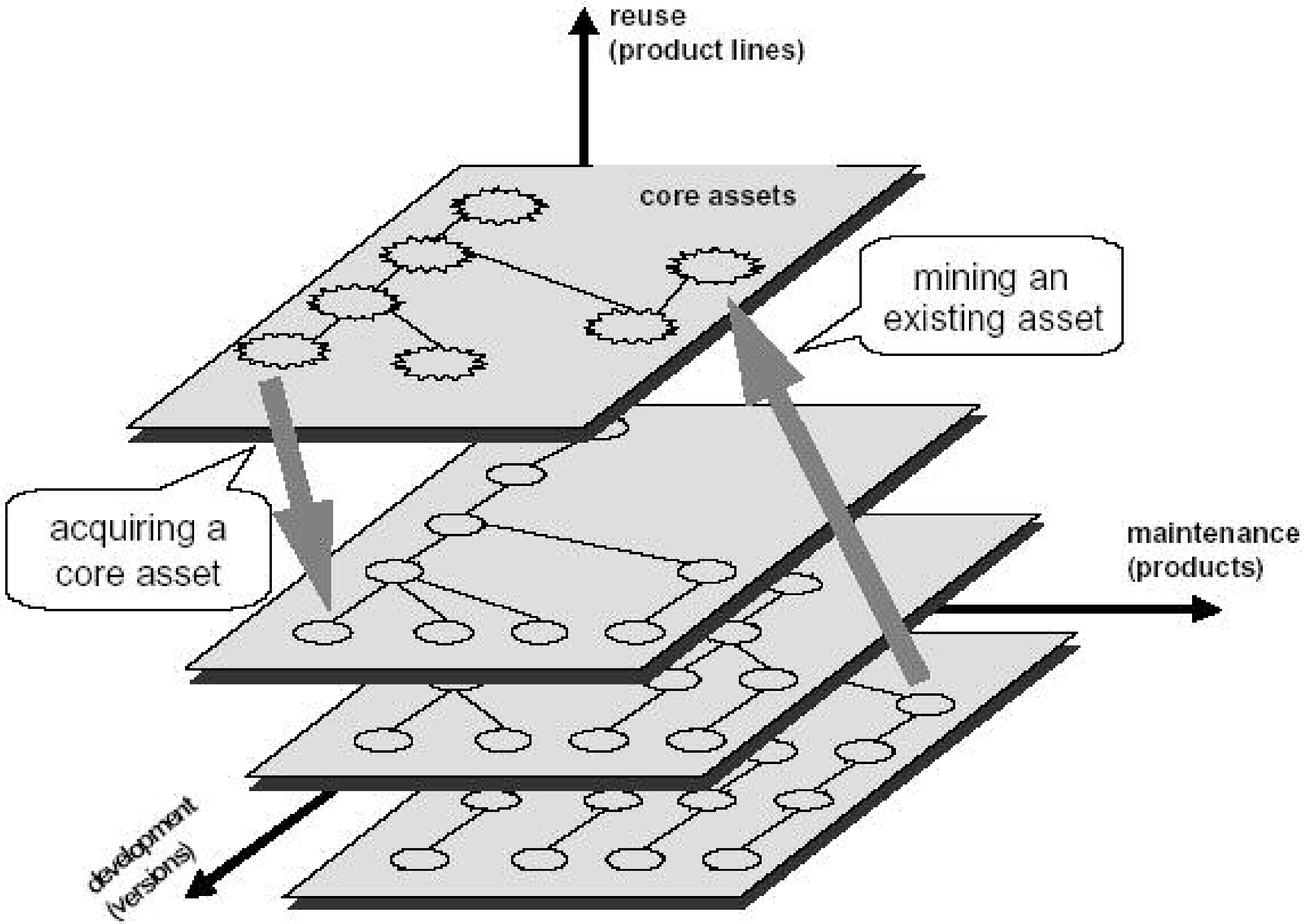
- "As is" reuse
- "Black-box" reuse
- "White box" reuse
- Workproduct reuse

Reuse in multi-release production



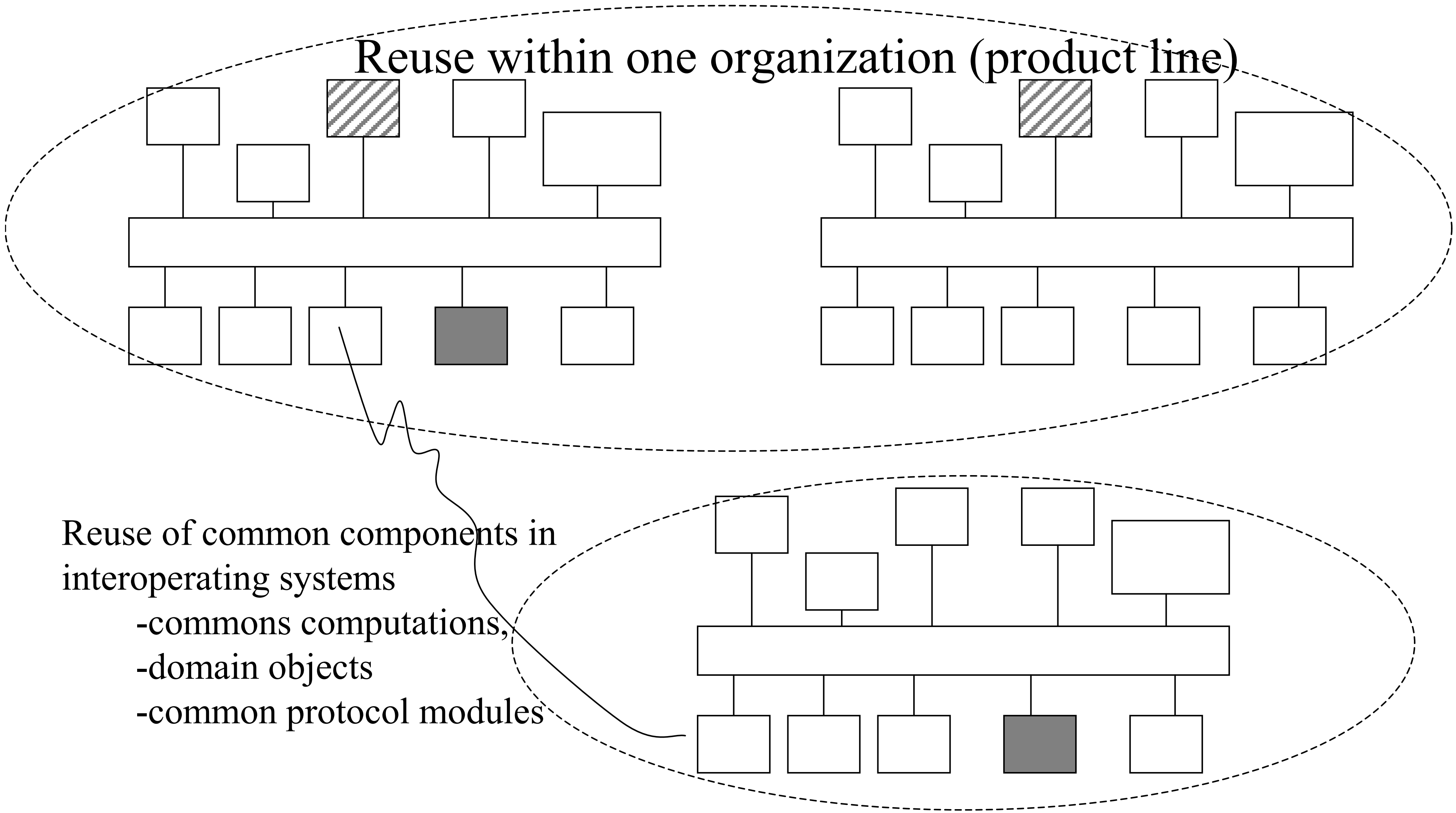
From Schach,Tomer, 2001

Product Lines add another dimension to production



From Schach,Tomer, 2001

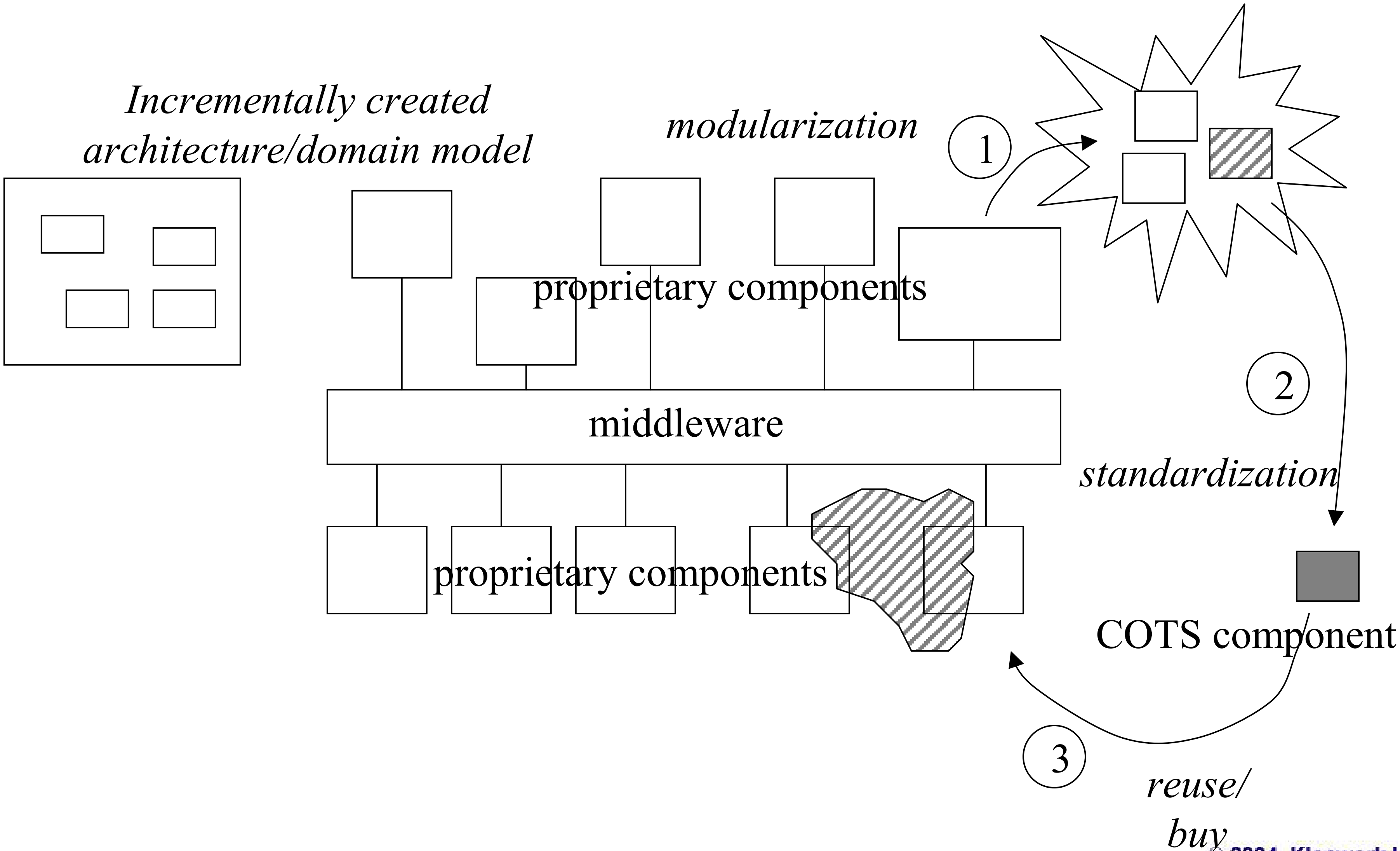
Internal and External reuse



Reuse of common components in interoperating systems

- -commons computations,
- -domain objects
- -common protocol modules

Reuse and COTS components



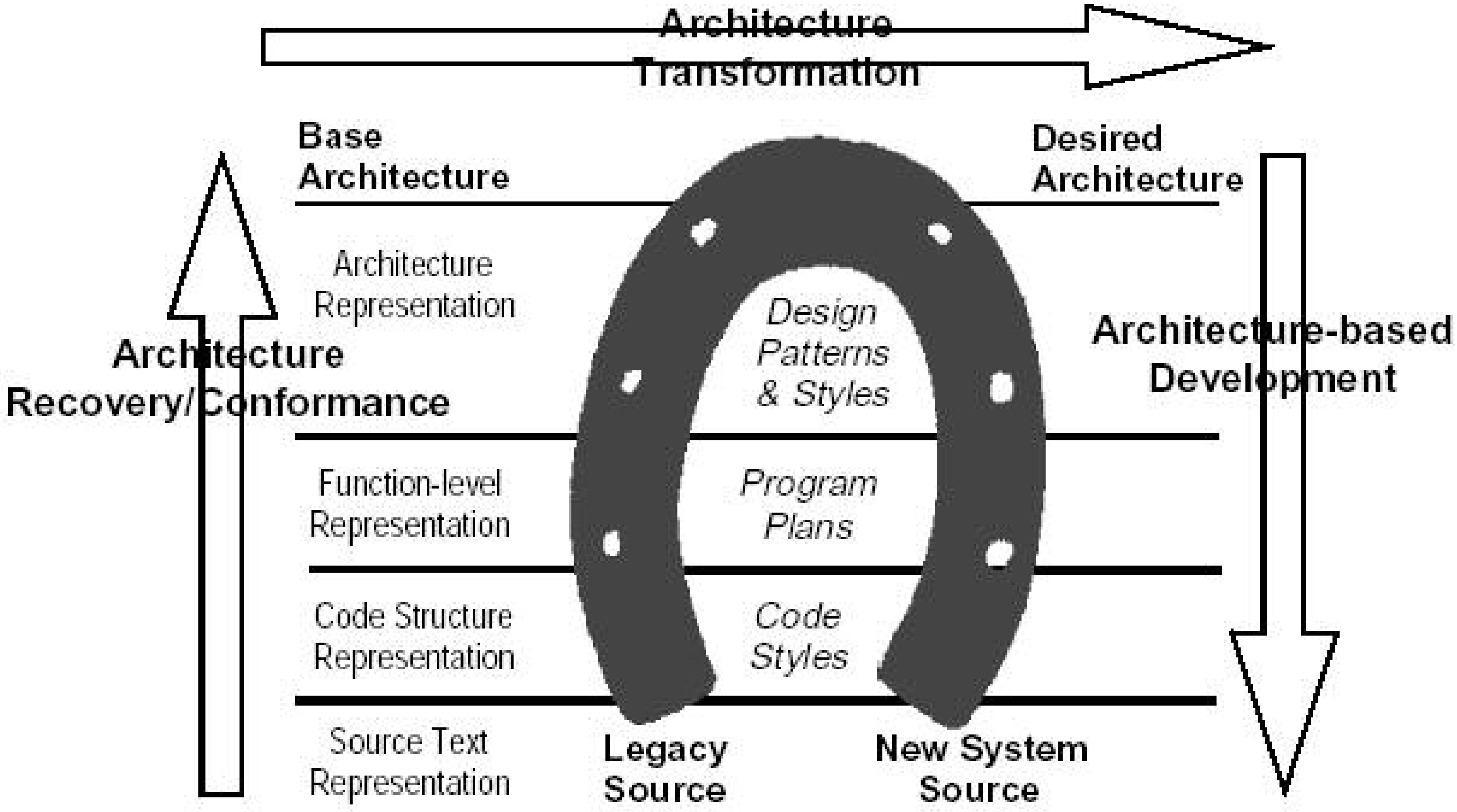
Harvesting, standardization, reuse

- (Porting to standard COTS middleware)
- Modularization
- Harvesting of reusable components
- Standardization of components
- Reuse/buy
- Emergent architecture/domain model

Overview

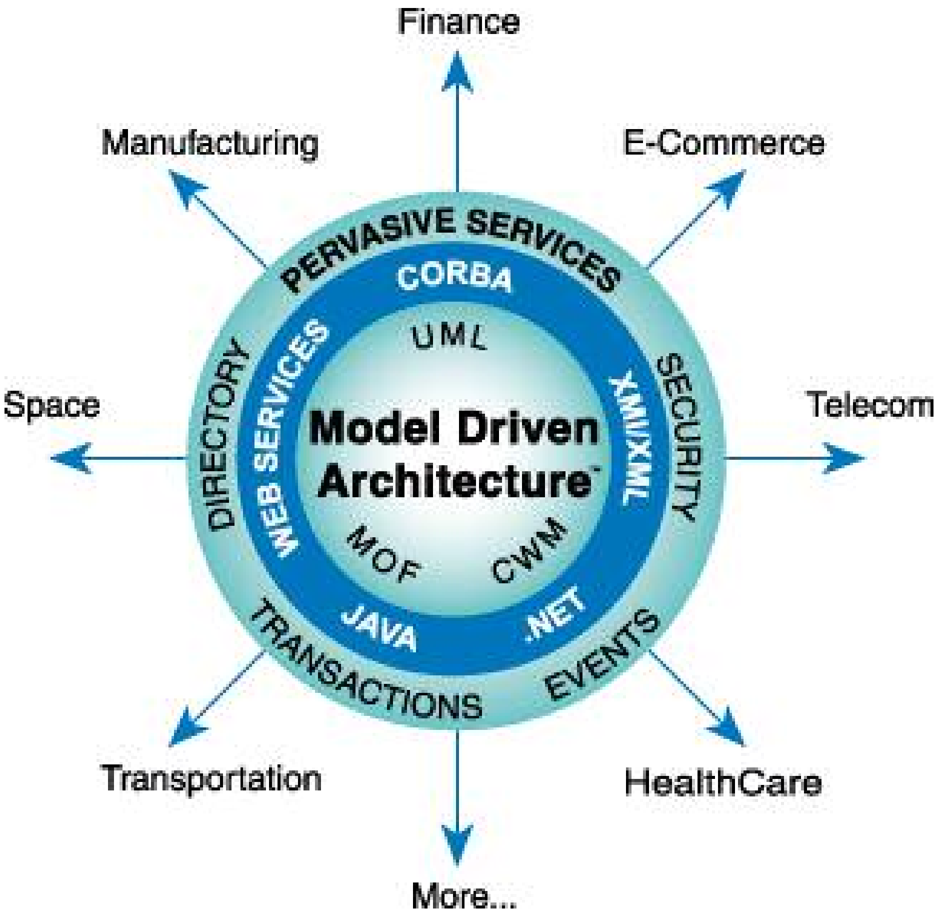
- **Reuse, Architecture and MDA**
  - Reuse does not involve any translation
  - What can be reused as opposed to what can be translated
    - reuse at low levels and at higher levels

The SEI HorseShoe model



From Smith, et.al., SEI, 1999

Model Driven Architecture



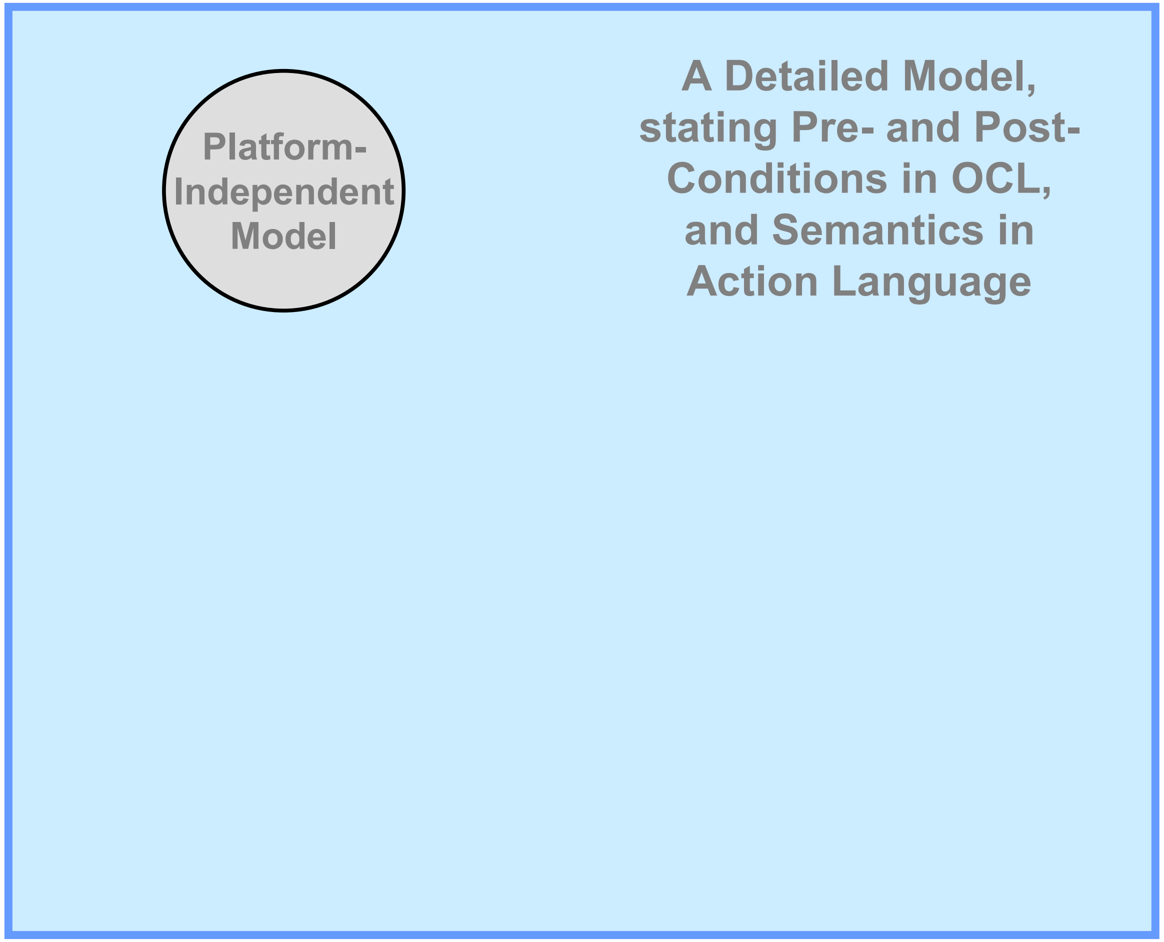
From R.Soley, OMG, 2003

What is Model Driven Architecture?

- **A New Way to Specify and Build Systems**
  - ***Based on modeling with UML***
  - Supports full lifecycle: analysis, design, implementation, deployment, maintenance, evolution & integration with later systems
  - Builds in Interoperability and Portability
  - Lowers initial cost and maximizes ROI
  - Applies directly to the mix you face:
    - Programming language
    - Operating system
    - Network
    - Middleware

From R.Soley, OMG, 2003

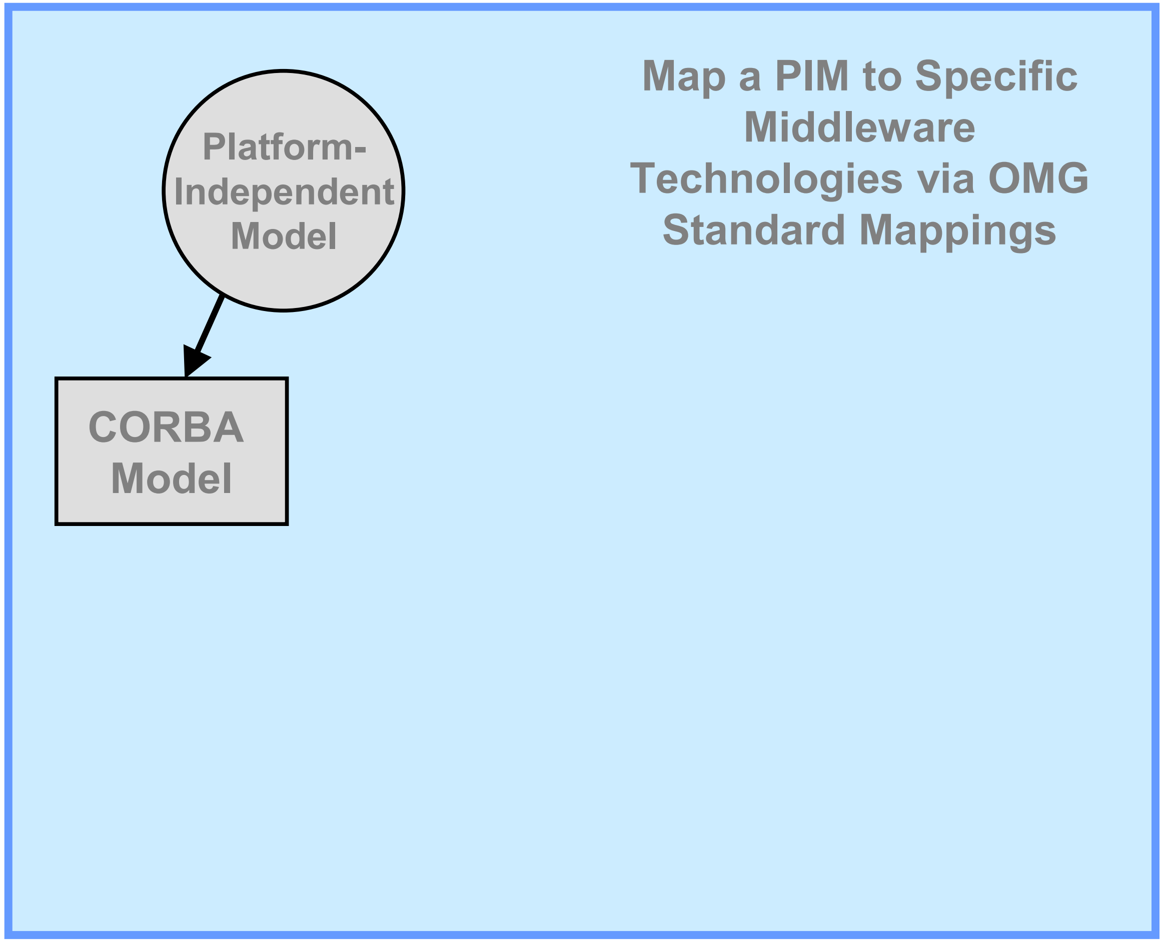
Building an MDA Application



Start with a *Platform-Independent Model* (PIM) representing business functionality and behavior, undistorted by technology details.

From R.Soley, OMG, 2003

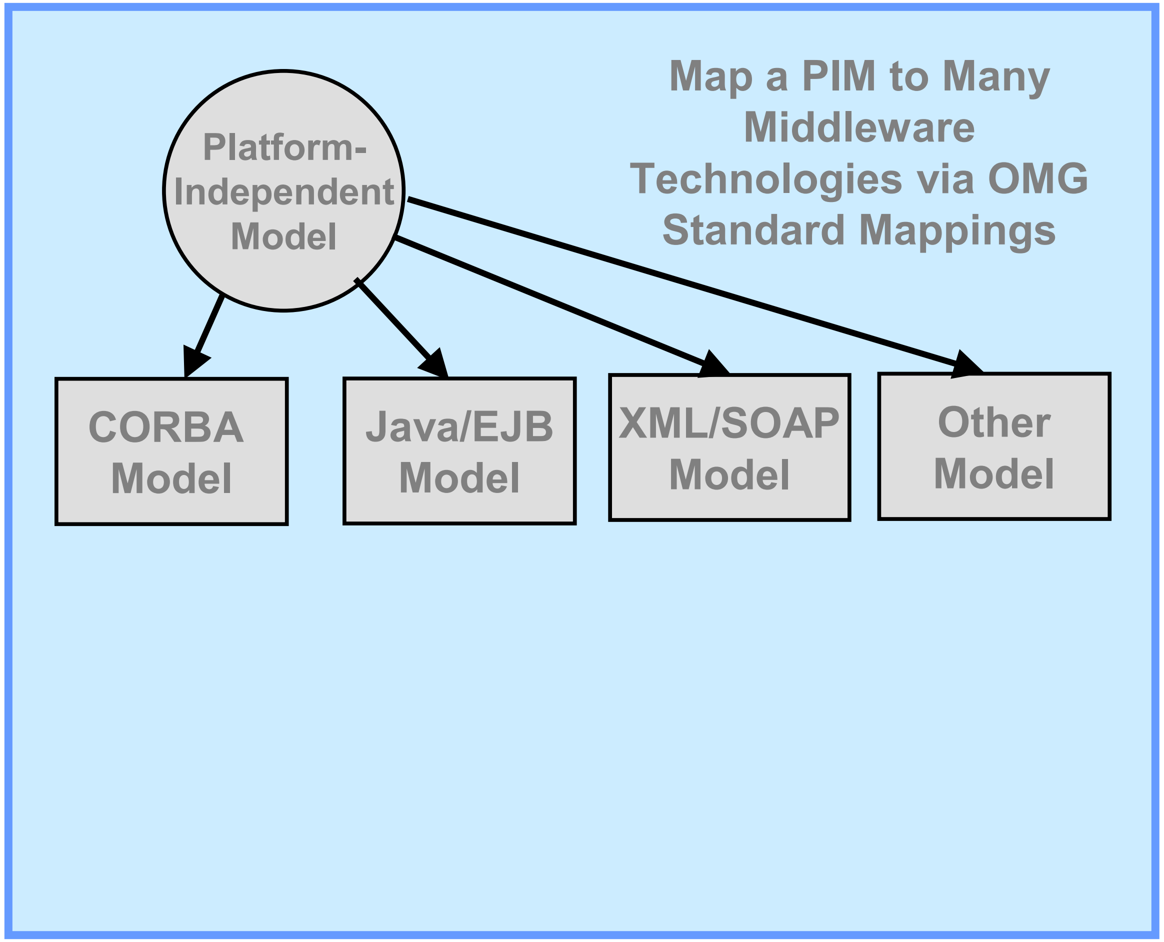
Generating Platform-Specific Model



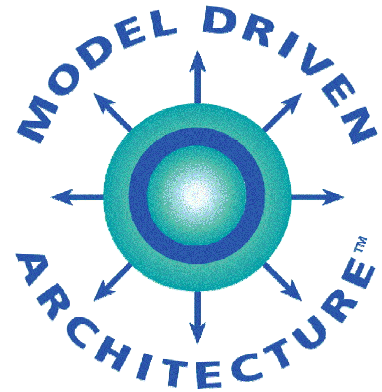
MDA tool applies a standard mapping to generate *Platform-Specific Model* (PSM) from the PIM. Code is partially automatic, partially hand-written.

From R.Soley, OMG, 2003

Mapping to Multiple Deployment Technologies

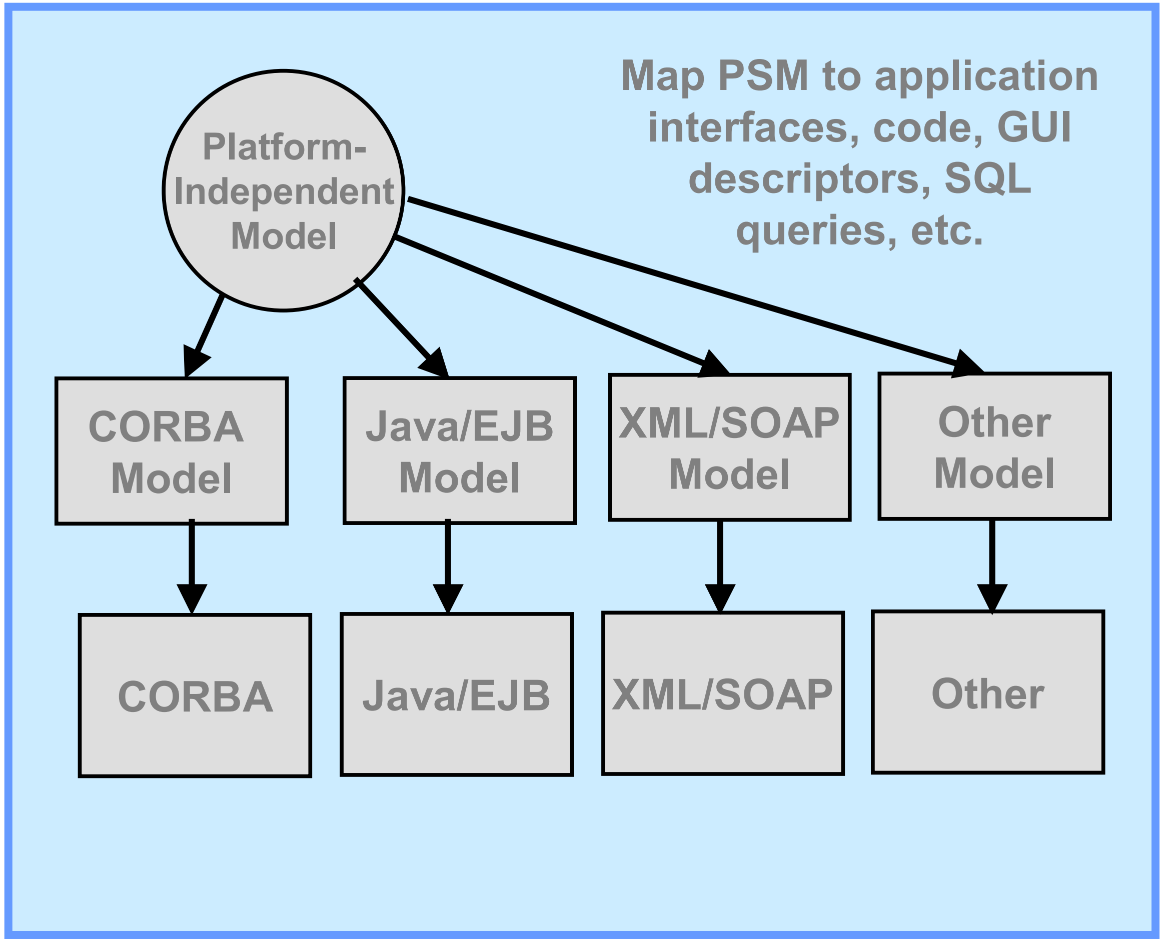


MDA tool applies an standard mapping to generate *Platform-Specific Model* (PSM) from the PIM. Code is partially automatic, partially hand-written.



From R.Soley, OMG, 2003

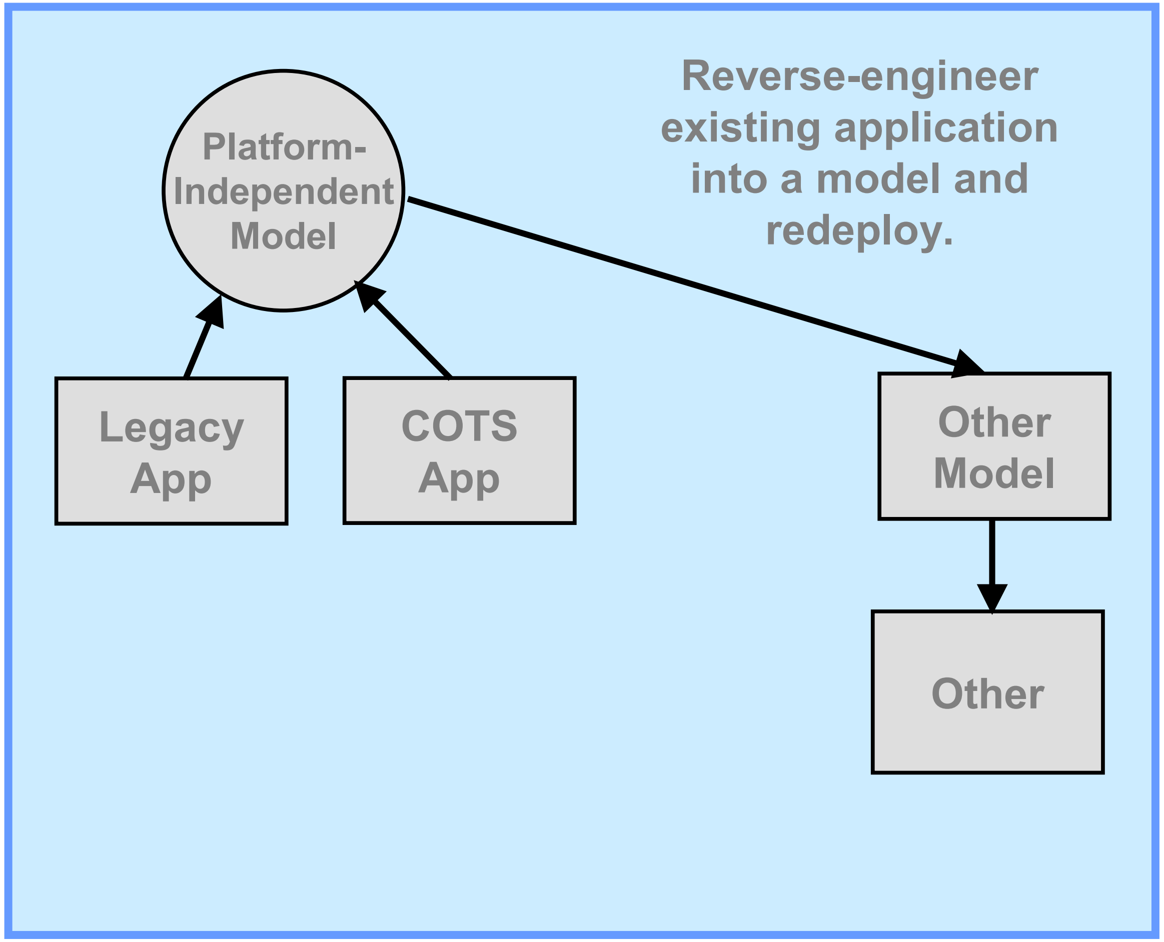
Generating Implementations



MDA Tool generates all or most of the implementation code for deployment technology selected by the developer.

From R.Soley, OMG, 2003

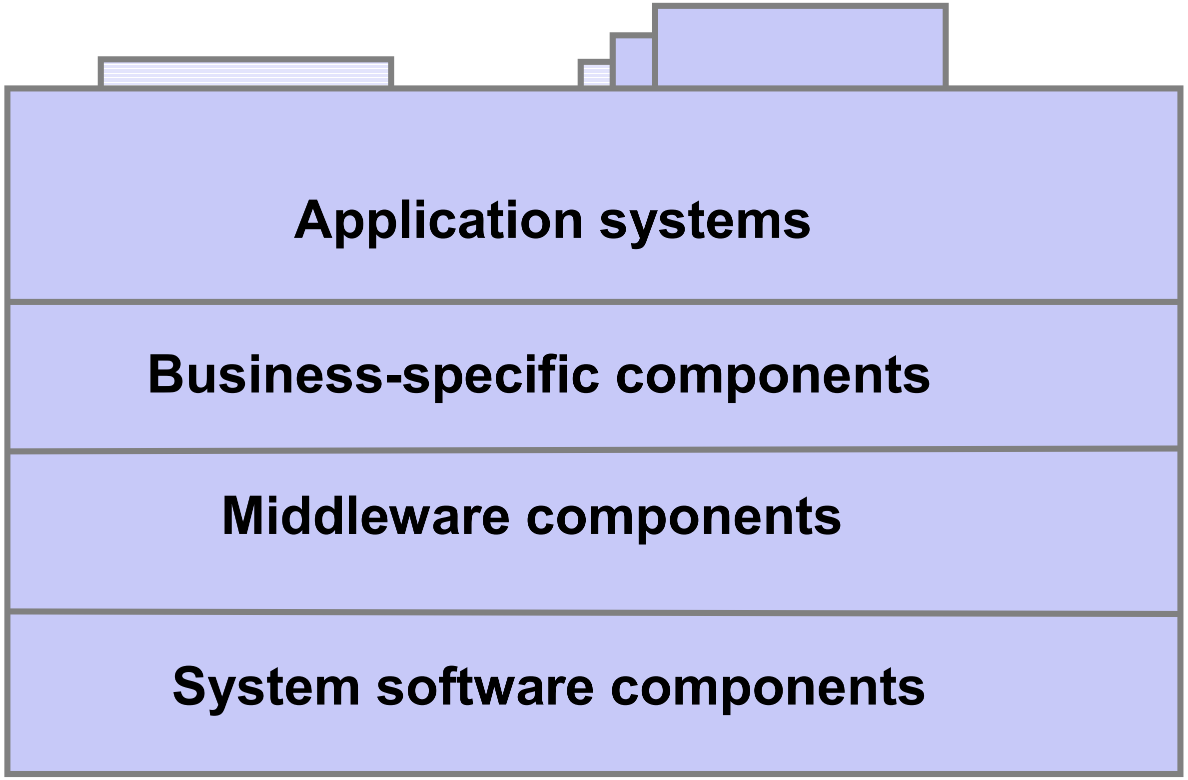
Integrating Legacy & COTS



MDA Tools for reverse engineering automate discovery of models for re-integration on new platforms.

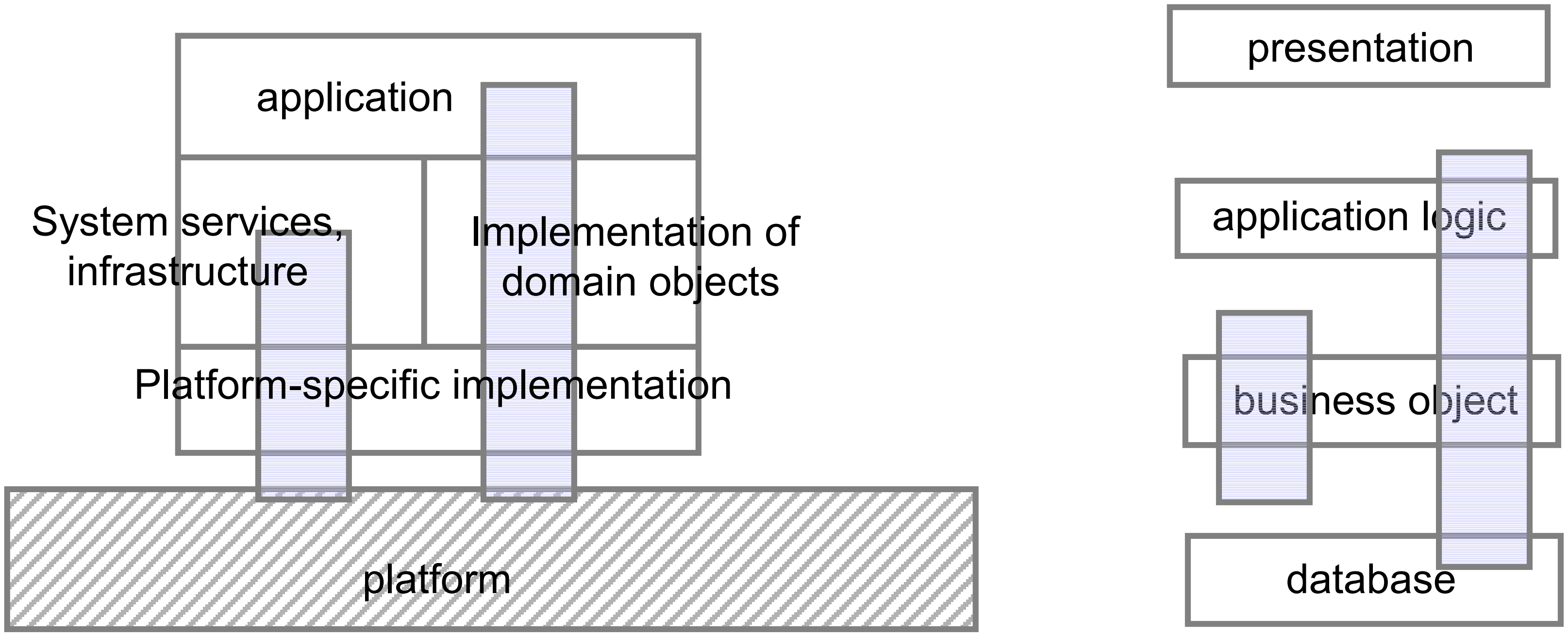
From R.Soley, OMG, 2003

A typical architecture for Business Reuse

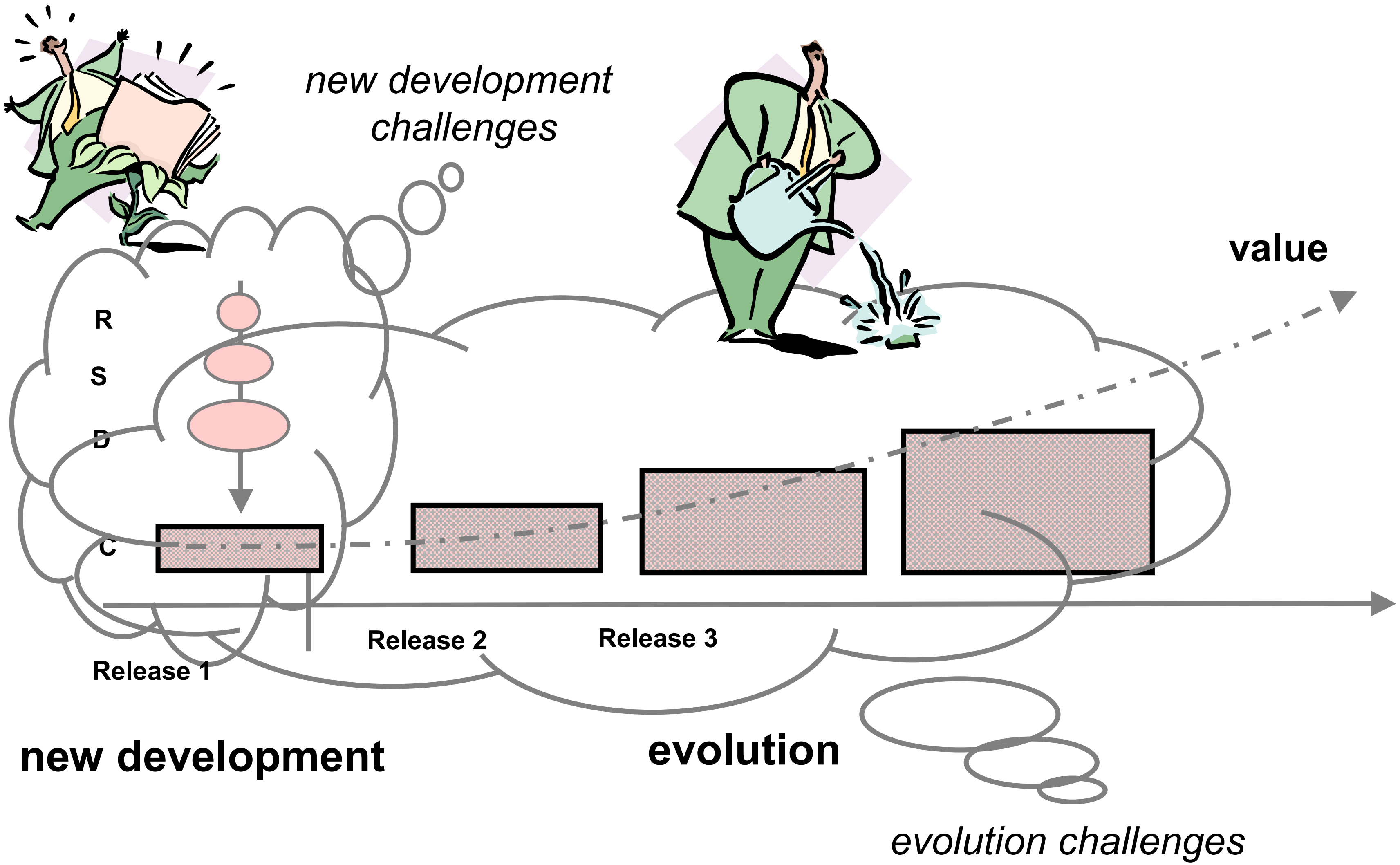


Adapted from Jacobson, et.al., 1997

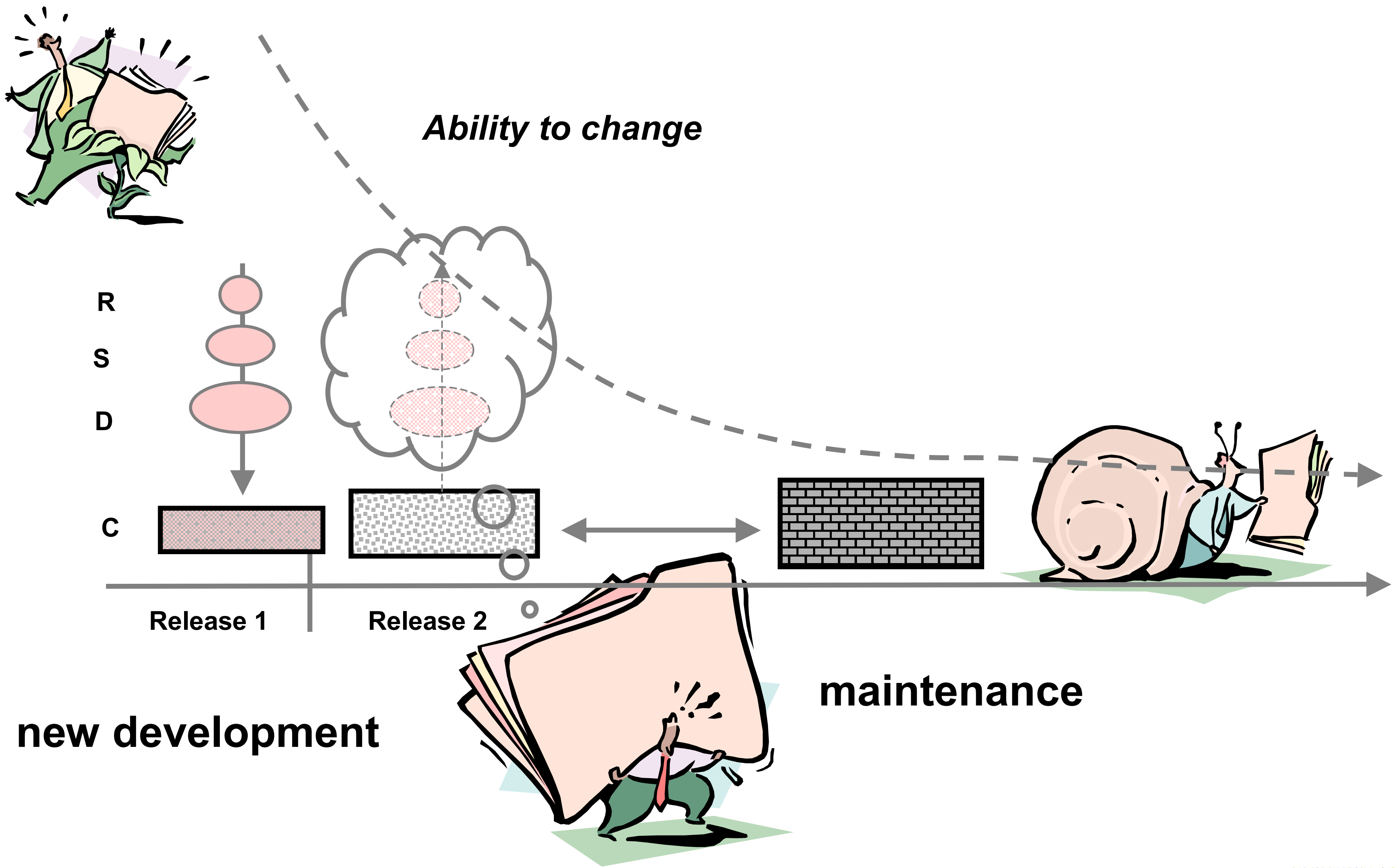
Reuse at different layers



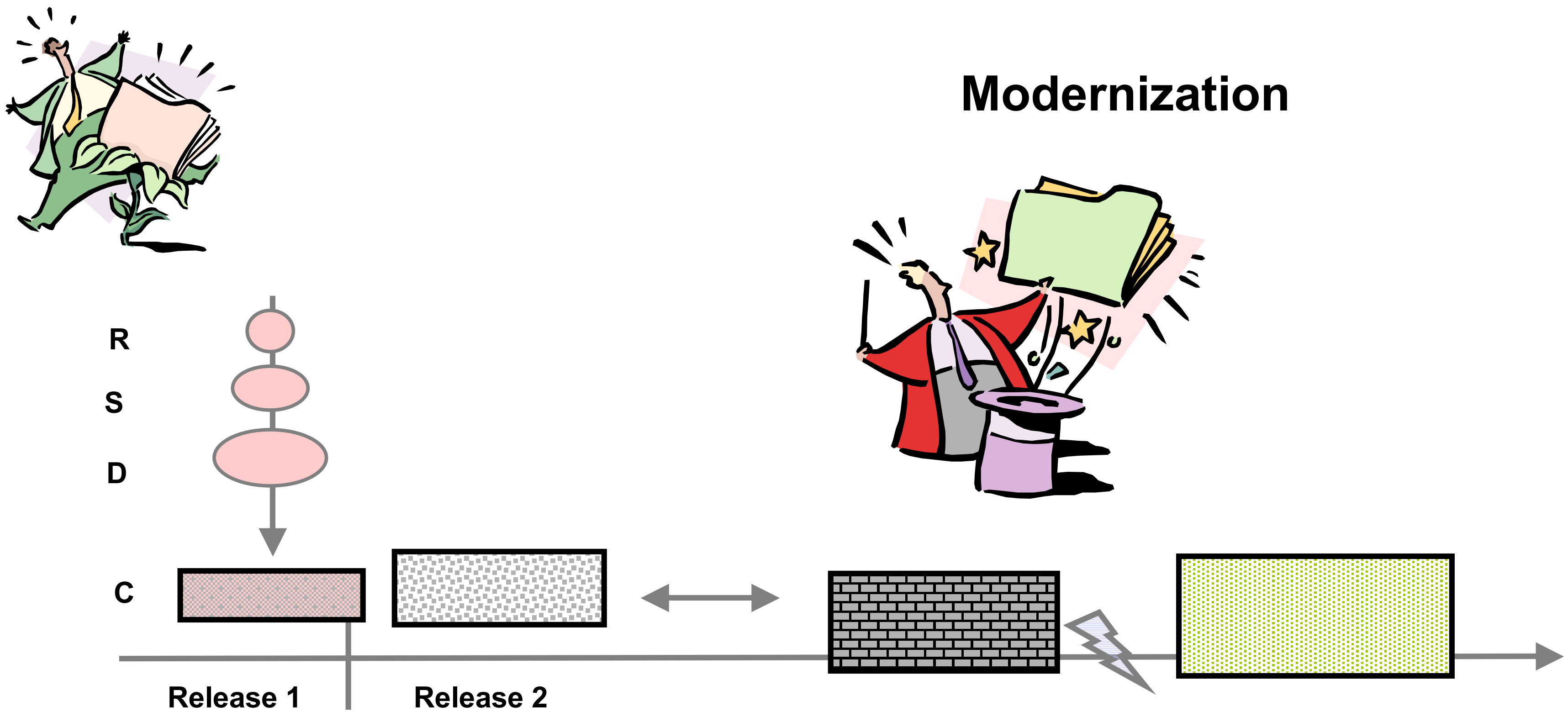
Complete life-cycle: initial release and post-build evolution



Maintenance in a complete life-cycle



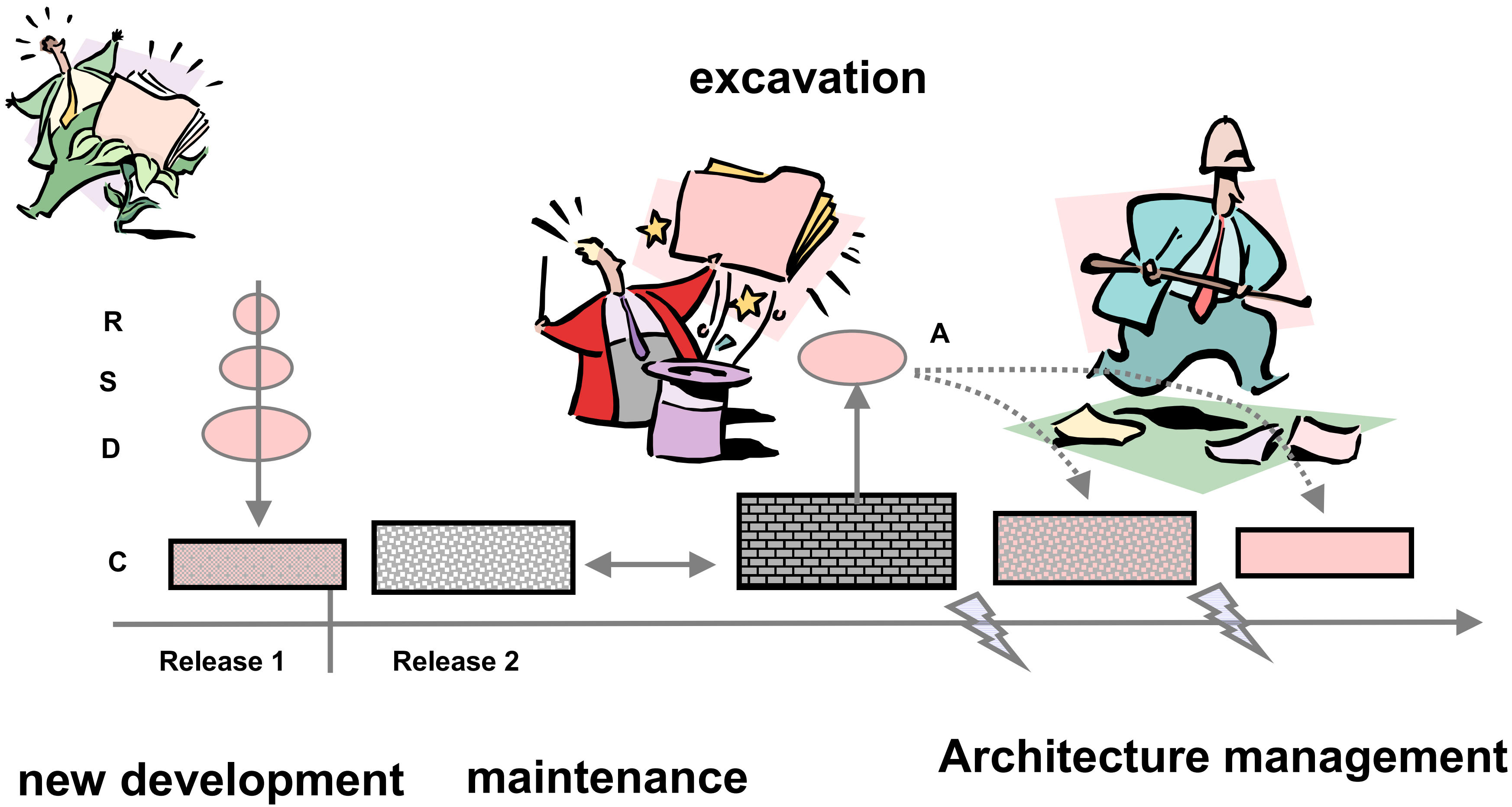
Modernization in a complete life-cycle



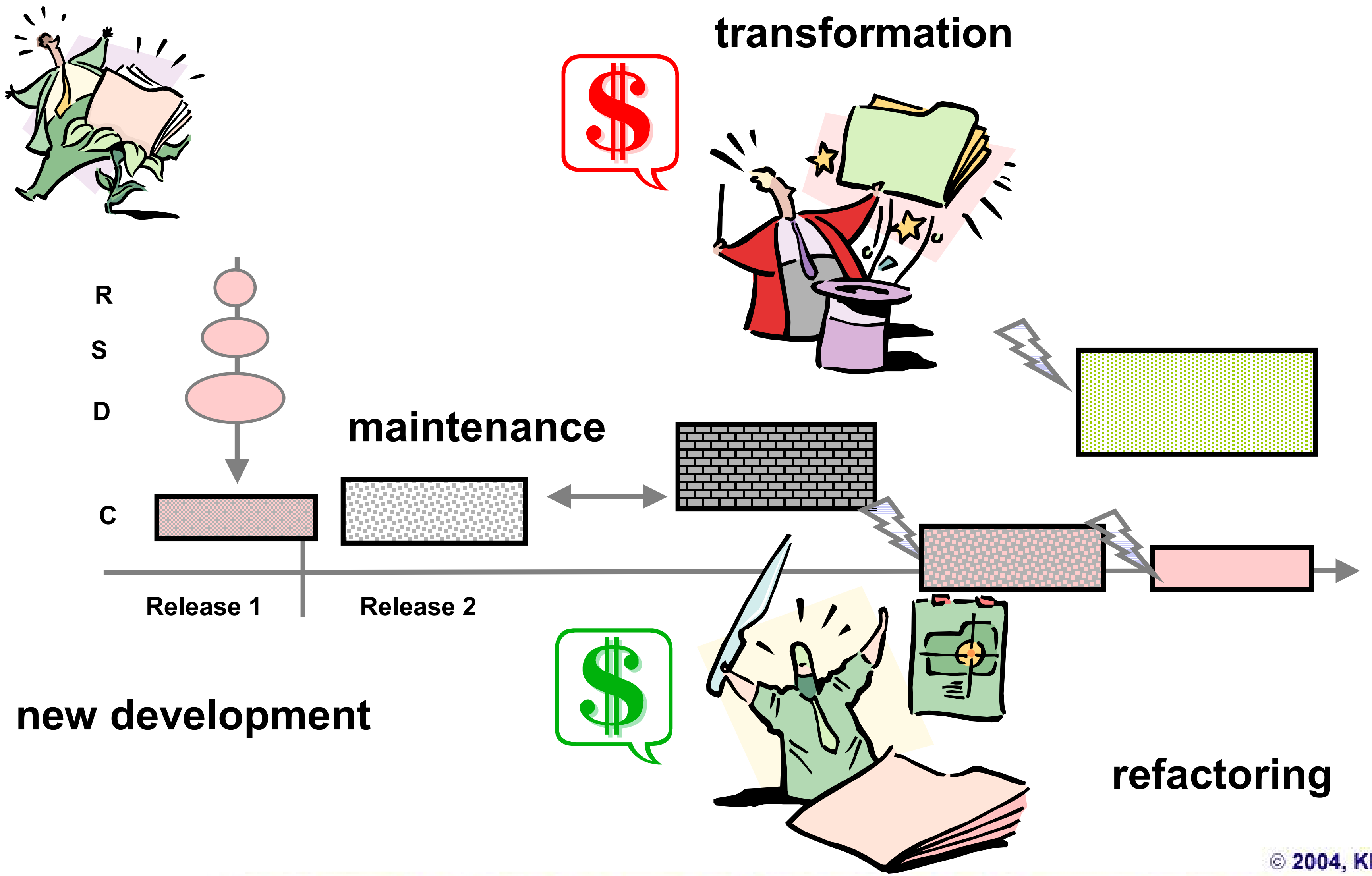
new development **maintenance**

… this includes redevelopment

Managed Architecture in complete life cycle



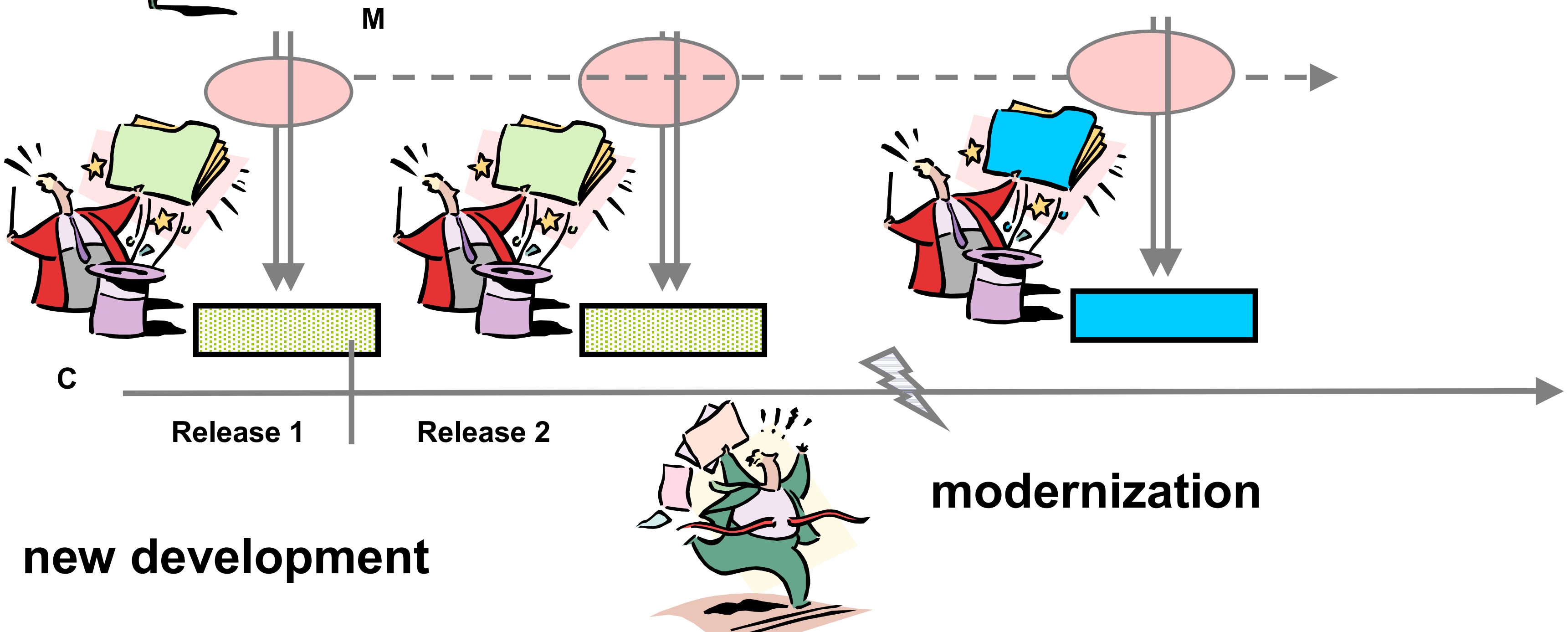
Modernization: Big-bang transformation vs Refactoring



MDA addresses the challenges of a complete life-cycle

…by addressing program comprehension challenge…

…and modernization challenges…

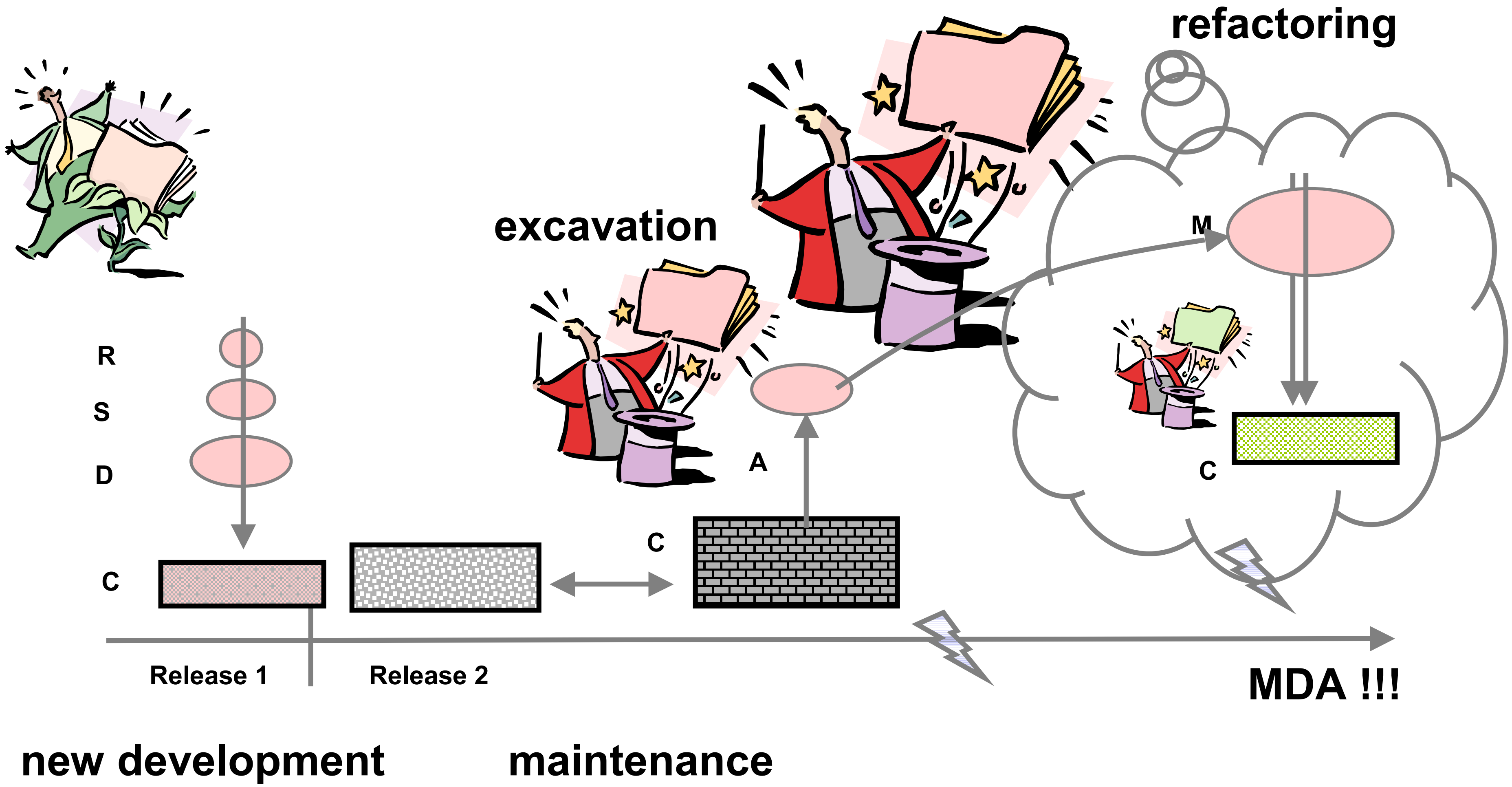


modernization

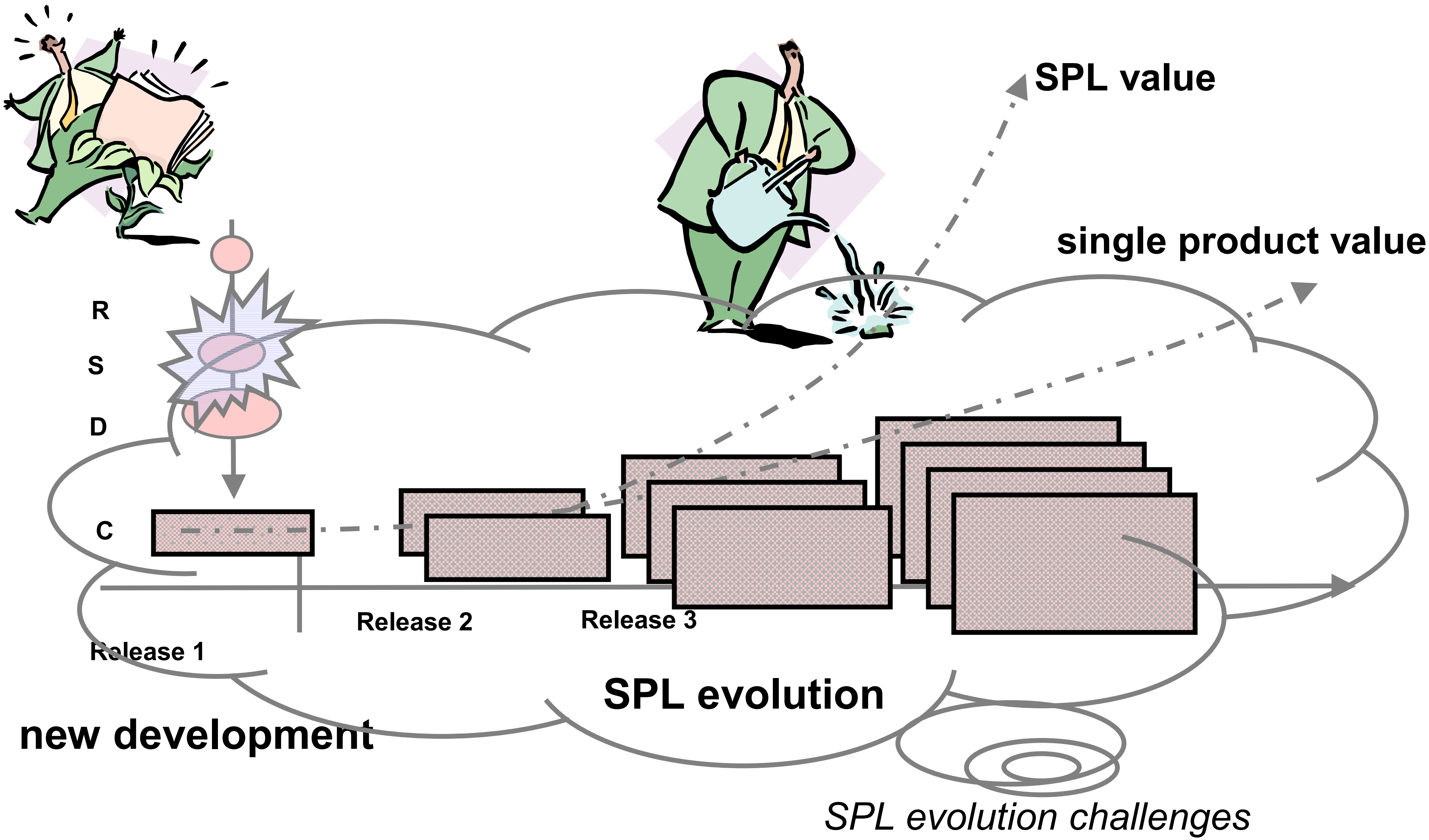
new development

maintenance=continued development

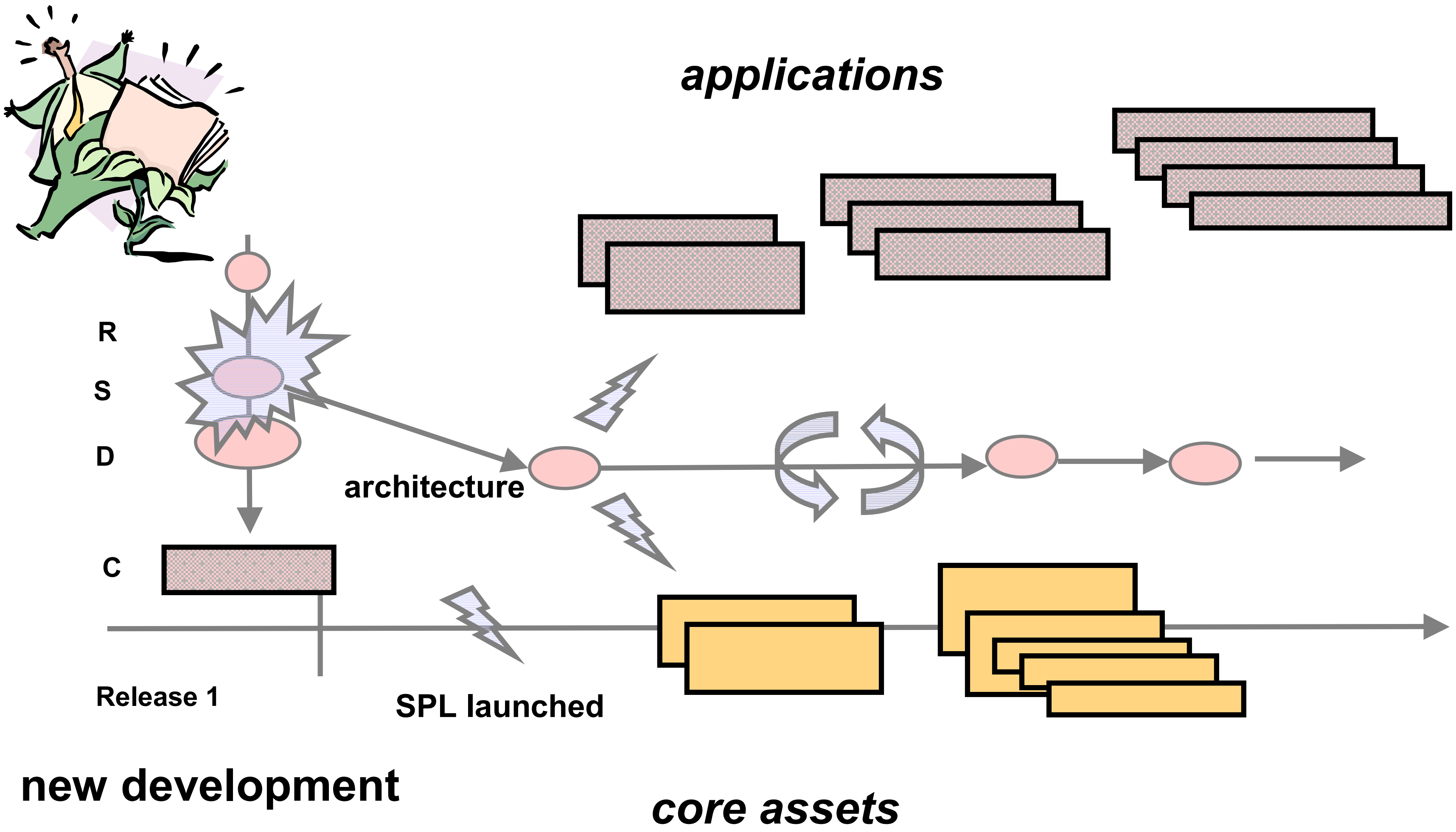
Managed Architecture can kick-start MDA



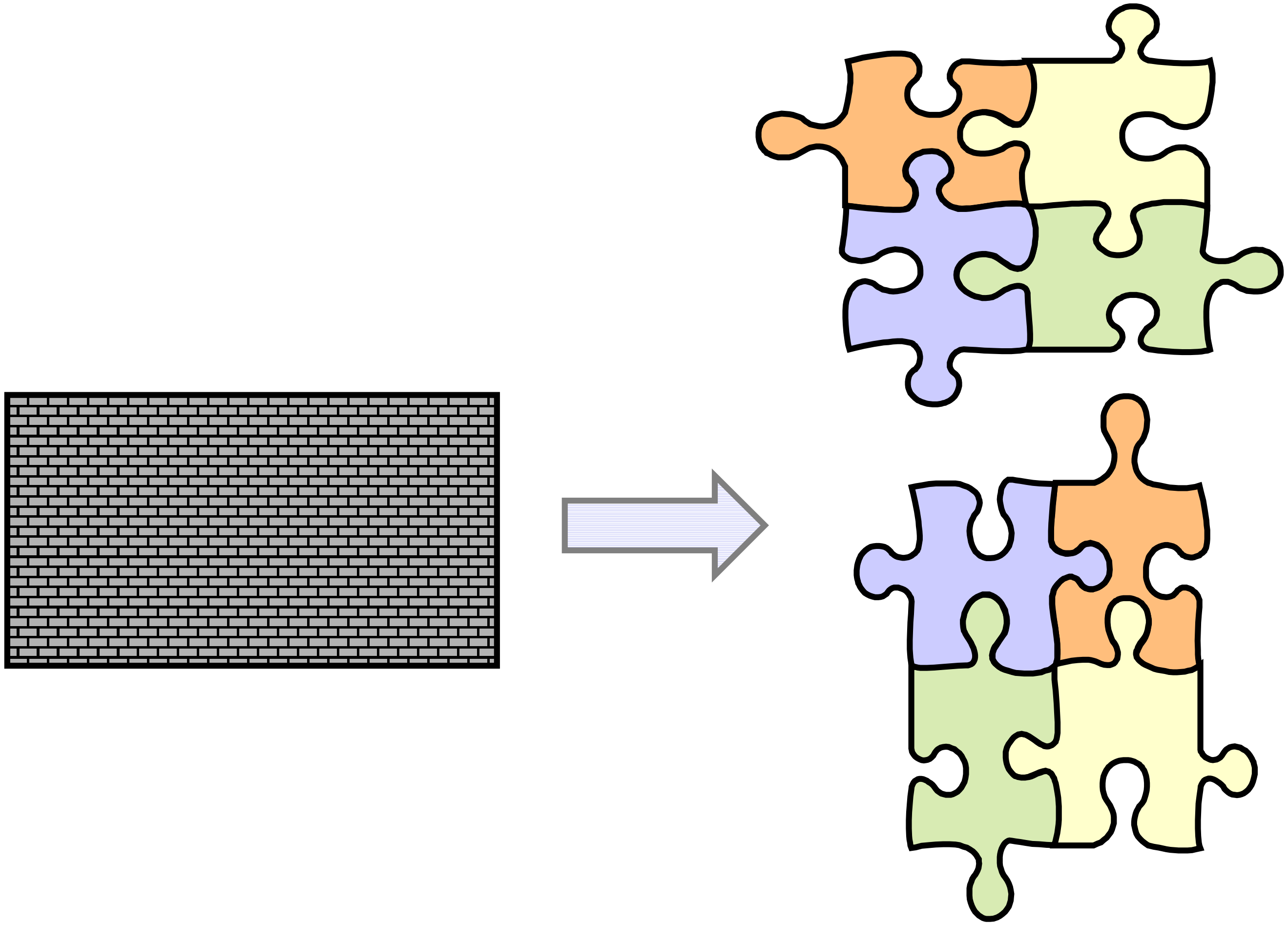
Mega life-cycle: Software Product Lines



Software Product Lines are architecture-centric



SPL require tight architecture management



Architecture Capability Maturity

- **Single aspect of SEI-CMM – refers to the capability of an organization to manage architecture in the complete life-cycle**
- **Level 1:** *Initial architecture*
- **Level 2:** *Repeatable architecture*
  - Some packaging rules, some use of libraries, some code reuse
- **Level 3:** *Defined architecture*
  - Components and their interfaces are formally defined and maintained together with the rest of the code,
  - modelling tools like Rational Rose are used
  - middleware or component environment is used,
- **Level 4:** *Managed architecture*
  - Visualization of existing software is available, feedback between the “as designed” architecture and the “as built” architecture is available, metrics of existing architecture are used, architecture integrity is enforced
- **Level 5:** *Optimizing architecture*
  - On-going architecture improvement is part of the overall development process

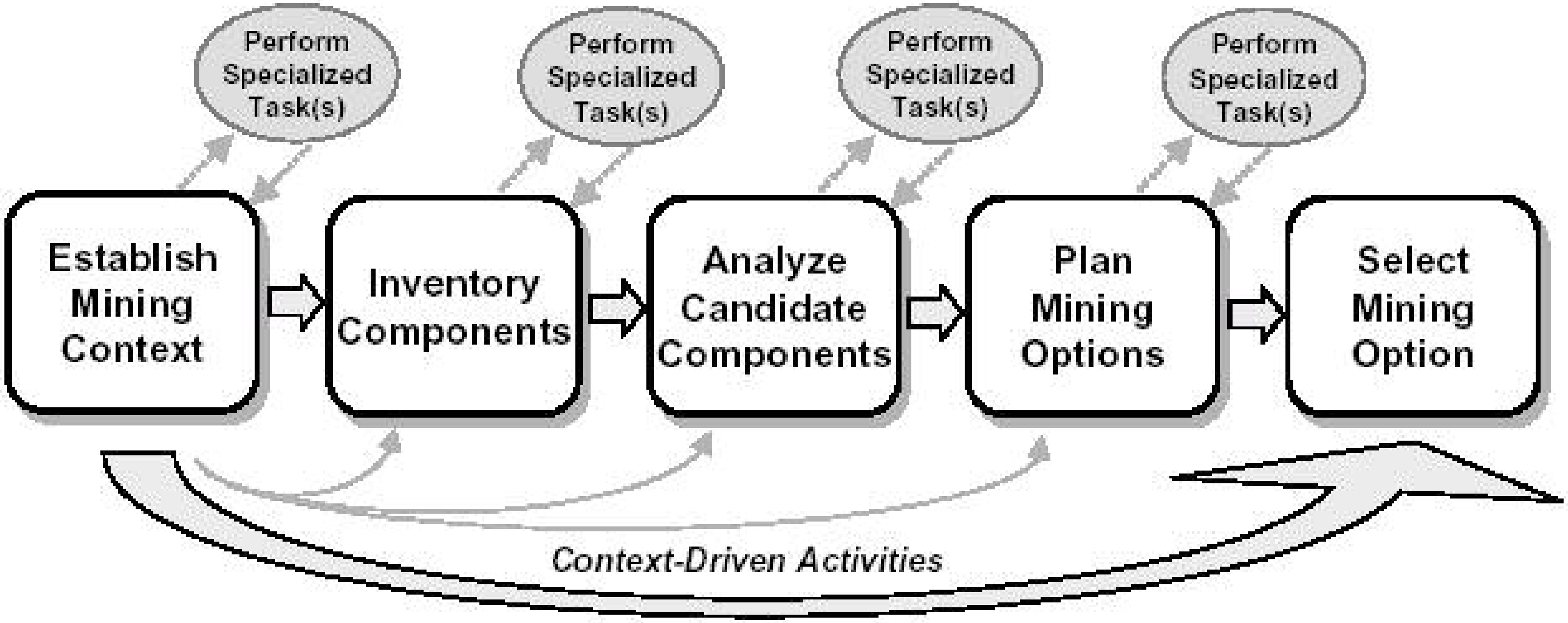
Overview

- **Decision-making process related to reuse**

- **Option Analysis for Reuse**
  - Overview of OAR
  - OAR tasks
  - Example artifacts

- **OAR is a systematic, architecture-centric, decision-making method for mining existing components. OAR is used for modernization or redevelopment of existing system.**
- **OAR is developed in SEI, by Dennis Smith, Liam O'Brien, et.al.**

Overview of OAR



From Smith, et.al., SEI, 1999

OAR: Establish Mining context

- **What:**
  - Interview stakeholders
  - Study existing product line or new system requirements
  - Study existing software assets
  - Understand expectations for mining legacy components
- **This establishes**
  - A baseline set of goals
  - Expectations
  - Component needs
- **This uncovers the program and technical drivers for making decisions**

Adapted from Smith, et.al., SEI, 1999

OAR: Inventory Components

- **What:**
  - Identify product line needs
  - Evaluate legacy components according to screening criteria
  - This results in an inventory of candidate components
- **Tasks:**
  - Identify characteristics of component needs
  - Identify components satisfying criteria
    - Create component table of the legacy components with details of these characteristics
    - Screen components that do not satisfy the required characteristics
  - Match components to product line needs
  - Update the Inventory with more details on candidate components
  - Elicit mining issues and concerns
  - Review OAR schedule

Adapted from Smith, et.al., SEI, 1999

OAR: Analyze Candidate Components

- **What:**
  - Analyze the set of legacy components for the types of changes that are required to mine
- **Tasks:**
  - Select desirable components
    - Determine desirability criteria
    - Screen out components that do not satisfy desirability criteria
  - Identify “As Is” and “Black-Box” (wrapped) components
  - Identify “White-box” components (need to be modified)
  - Determine required changes
    - Types of changes each component needs, cost and effort involved, the level of difficulty and risk, and the comparative cost and effort of developing components from scratch
  - Elicit mining options
  - Review OAR schedule

Adapted from Smith, et.al., SEI, 1999

OAR: Plan Mining Options

- **What:**
  - Develop alternatives to mining based on schedule, cost, effort, risk and resource considerations
  - Screen candidate components one more time
  - Analyze the impact of different component aggregations
- **Tasks:**
  - Select favorable components
    - Determine criteria, such as cost or effort
    - Screen out components that do not satisfy criteria
  - Perform component trade-offs
    - Identify one component or combination per product line need
  - Form component options
    - Develop criteria for aggregation
    - Aggregate components
  - Determine comparative cost and effort
  - Analyze difficulty and risk
  - Elicit mining options
  - Update OAR schedule

Adapted from Smith, et.al., SEI, 1999

OAR: Select Mining Option

- **What:**
  - Select the best mining option or combination of options by balancing program and technical considerations
  - Prepare report
- **Tasks:**
  - Choose best option
    - Determine drivers for selecting among options
    - Select an option or a combination of them
  - Verify option
  - Identify component needs satisfied
    - Complete the final list of component needs satisfied and not satisfied through options selected
  - Present findings
  - Produce summary

Adapted from Smith, et.al., SEI, 1999

Example of Component Table

Part 1 of 3 — **Legacy System Software**

COMPONENT NEEDS	Legacy System Software Components	Program Language	Characteristics Directory Name	Number of Modules	Characteristics Compilable on SGI Machine	Size[1] Lines of Code (LOC)	Complexity
1. Simulation Gateways							
	Sim1 Gateway	C	cag	17	Yes	2,297	Low
	Sim2 Gateway	C	dwg	57	Yes	4,877	Low
2. Message Gateways							
	C-Source	C	csg	45	Yes	4,186	High
3. Truth Model							
	Objects	Fortran	ojo	65	Yes	9,202	Med
	Event	Fortran	tho	39	Yes	4,412	Med
4. ETS & Message Generation							
	Event Track	C	tsd	89	Yes	5,417	Med / High
5. Man Machine Interface						30,391	
	TBD					Total	
6. Executive							
	TBD						

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From Smith, et.al., SEI, 1999

Example of Component Table

Part 2 of 3

Legacy System Software

	Characteristics			Characteristics				
Legacy System Software Components	Coupling	Cohesiveness	Black Box / White Box Suitability	Level of Changes	Level of Granularity	Support Software Required	Level of Difficulty[3]	Level of Risk
Sim1 Gateway	Low	High	BB	None	OK	S&D Files[2]	1	Low
Sim2 Gateway	Low	High	BB	None	OK	S&D Files	1	Low
C-Source	Low	High	BB	None	OK	S&D Files	1	Low
Objects	High	High	WB (minor)	Minor (10%)	Adjust	S&D Files	2	High[4]
Event	High	High	WB (minor)	Minor (10%)	Adjust	S&D Files	2	High[4]
Event Track	Low	Low	WB (major)	Major (50%)	Adjust	S&D Files	4	Low[5]
TBD								
TBD								

From Smith, et.al., SEI, 1999

Example of Component Table

Part 3 of 3

Legacy System Software

Software Components	Mining Effort[6] (mm)	Mining Cost[7]	New Development Effort (mm)	New Development Cost[8]	Comparative Cost[7] of Mining	Comparative Effort[6] of Mining
Sim1 Gateway	0.1	$1,000	7.7	$76,567	1%	1%
Sim2 Gateway	0.1	$1,000	16.3	$162,567	1%	1%
C-Source	0.1	$1,000	14.0	$139,533	1%	1%
Objects	2.2	$22,000	30.7	$306,733	7%	7%
Event	1.3	$13,000	14.7	$147,067	9%	9%
Event Track	8	$80,000	18.1	$180,567	44%	44%
TOTALs	12	$118,000	101	$1,013,033	12%	12%
TBD						
TBD						

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From Smith, et.al., SEI, 1999

Example of Options Table

Option No.	Legacy System Software Components	Support Software Required	Level of Risk	Level of Difficulty	Mining Effort[1] (mm)	Mining Cost[1]	New Development Effort (mm)	New Development Cost	Comparative Cost of Mining	Comparative Effort of Mining
1	Event Track	S&D Files	Low	4	8	$80,000	18.1	$180,567	44%	44%
	Option Summation		**Low**	**4**	**8**	**$80,000**	**18.1**	**$180,567**	**44%**	**44%**
2	Objects	S&D Files	High	2	2.2	$22,000	30.7	$306,733	7%	7%
	Event	S&D Files	High	2	1.3	$13,000	14.7	$147,067	9%	9%
	Option Summation		**High**	**2**	**3.5**	**$35,000**	**45.4**	**$453,800**	**8%**	**8%**
3	Sim1 Gateway	S&D Files	Low	1	0.1	$1,000	7.7	$76,567	1%	1%
	Sim2 Gateway	S&D Files	Low	1	0.1	$1,000	16.3	$162,567	1%	1%
	C-Source	S&D Files	Low	1	0.1	$1,000	14	$139,533	1%	1%
	Option Summation		**Low**	**1**	**0.3**	**$3,000**	**38**	**$378,667**	**1%**	**1%**

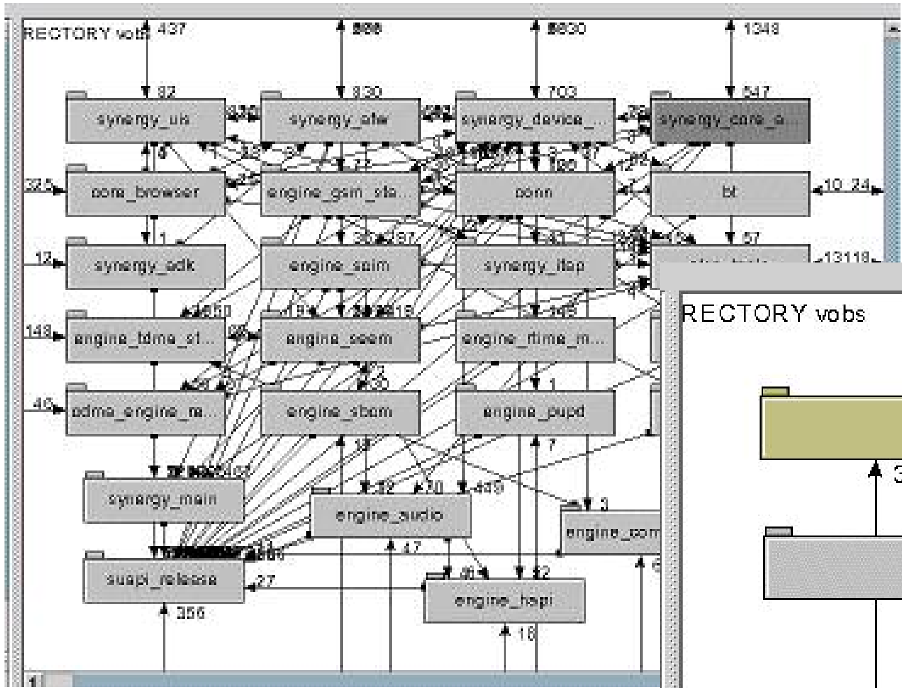
[1] Note: Mining Effort and Cost do not include effort and cost to convert scripts and data files that are part of the support software

From Smith, et.al., SEI, 1999

Overview

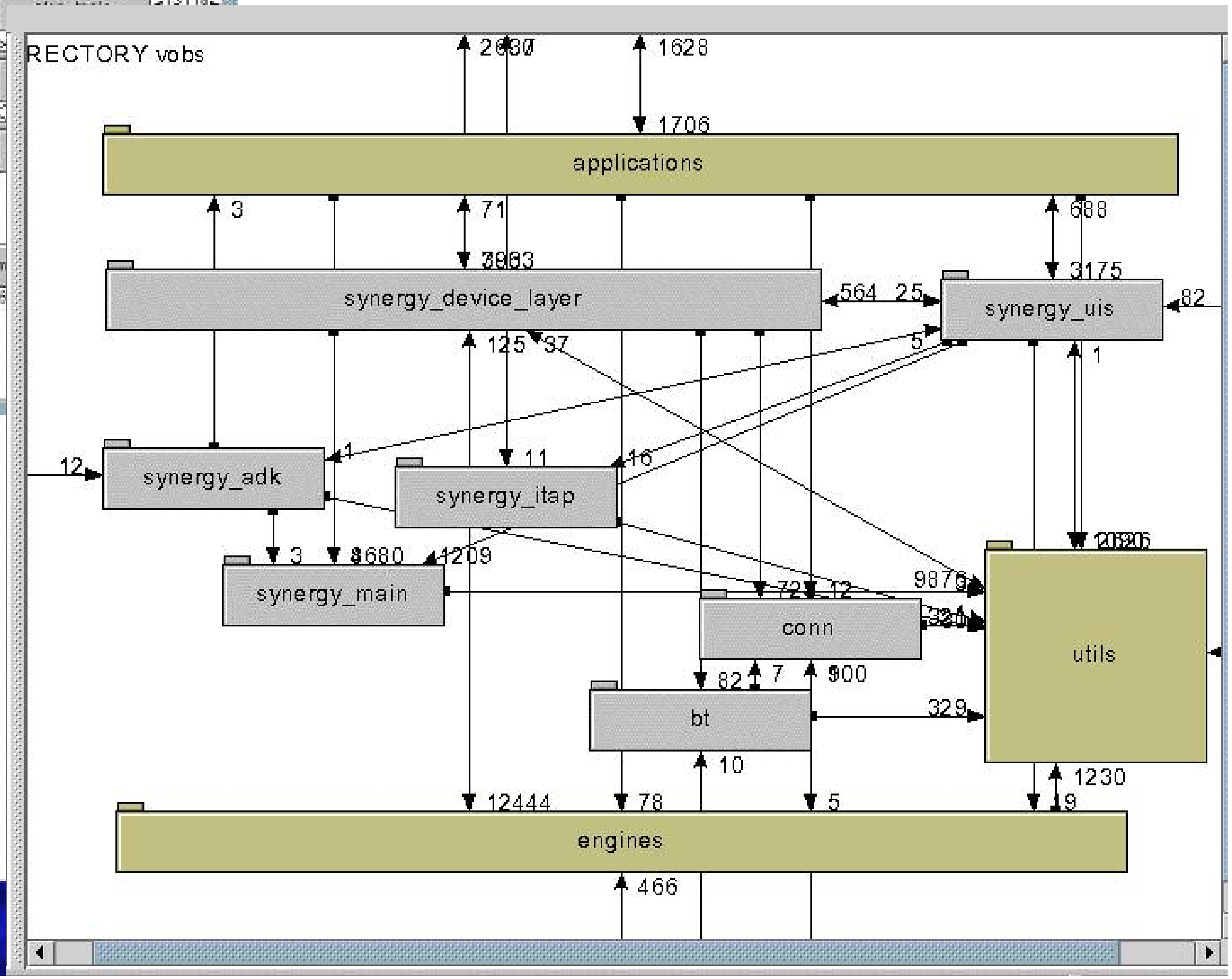
- **Architecture Excavation and Refactoring**

Excavated high-level architecture



before

after



Klocwork

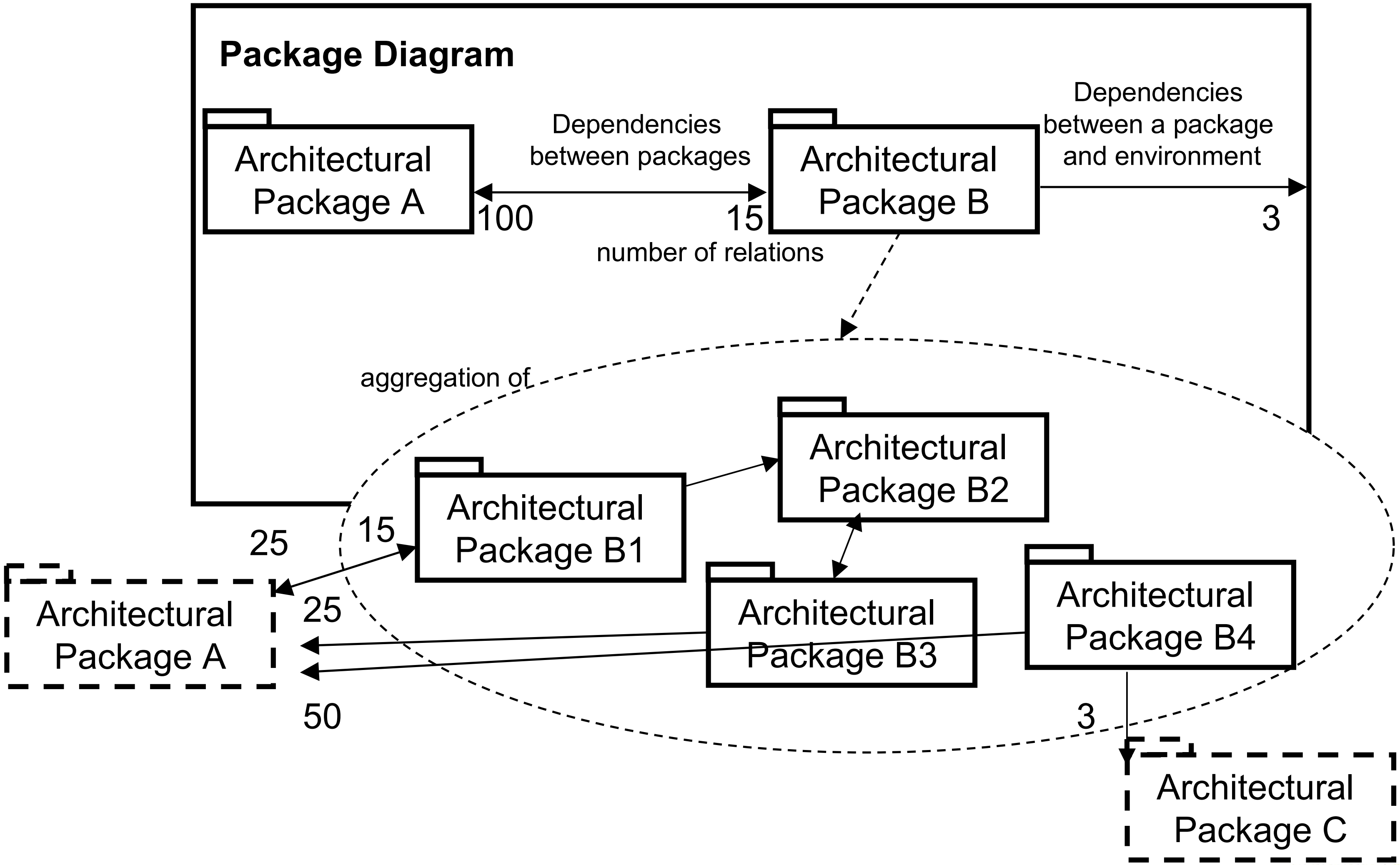
Klocwork Architecture Excavation Methodology

- **Focus:**
  - Containers, interfaces, dependencies on top of entities and relationships
- **Container Models**
  - Are scalable and precise; can be used for both abstraction and refactoring
  - Not UML, because of scalability, the need to evolve with the code, and specific “existing code” understanding concerns, like links to the code, navigation, etc.
  - Transition to UML is straightforward
- **Strategy**
  - Top-down
  - As deep as necessary, as shallow as possible
  - incremental
- **Operations:**
  - Aggregation of entities into bigger containers
  - Refactoring (moving entities between containers)

Container models

- **Represent "containers" and relations between "containers":**
  - each "container" has dependencies on other "containers"
  - each "container" provides an API to other "containers"
- **This model is scalable:**
  - aggregation of "containers" is another "container"
  - The aggregation depends on everything that individual parts depended on
  - The aggregation provides the union of APIs, provided by individual parts
- **Model can be refactored**
  - subcontainers can be moved from one container to another, model shows how dependencies and APIs change
- **This model is precise**
  - With respect to the contents of aggregations
  - With respect to APIs
- **This model is meaningful and useful**
  - Leaf "containers" can be procedures, variables, files, etc.
  - Leaf relations (APIs) are e.g. procedure-calls-procedure, etc.
- **Model can be preserved and automatically updated as changes are made to software**
  - Leaf containers and their relations are automatically extracted from source; the model stores only the hierarchy of containers; relations are recalculated on-the-fly

Container models

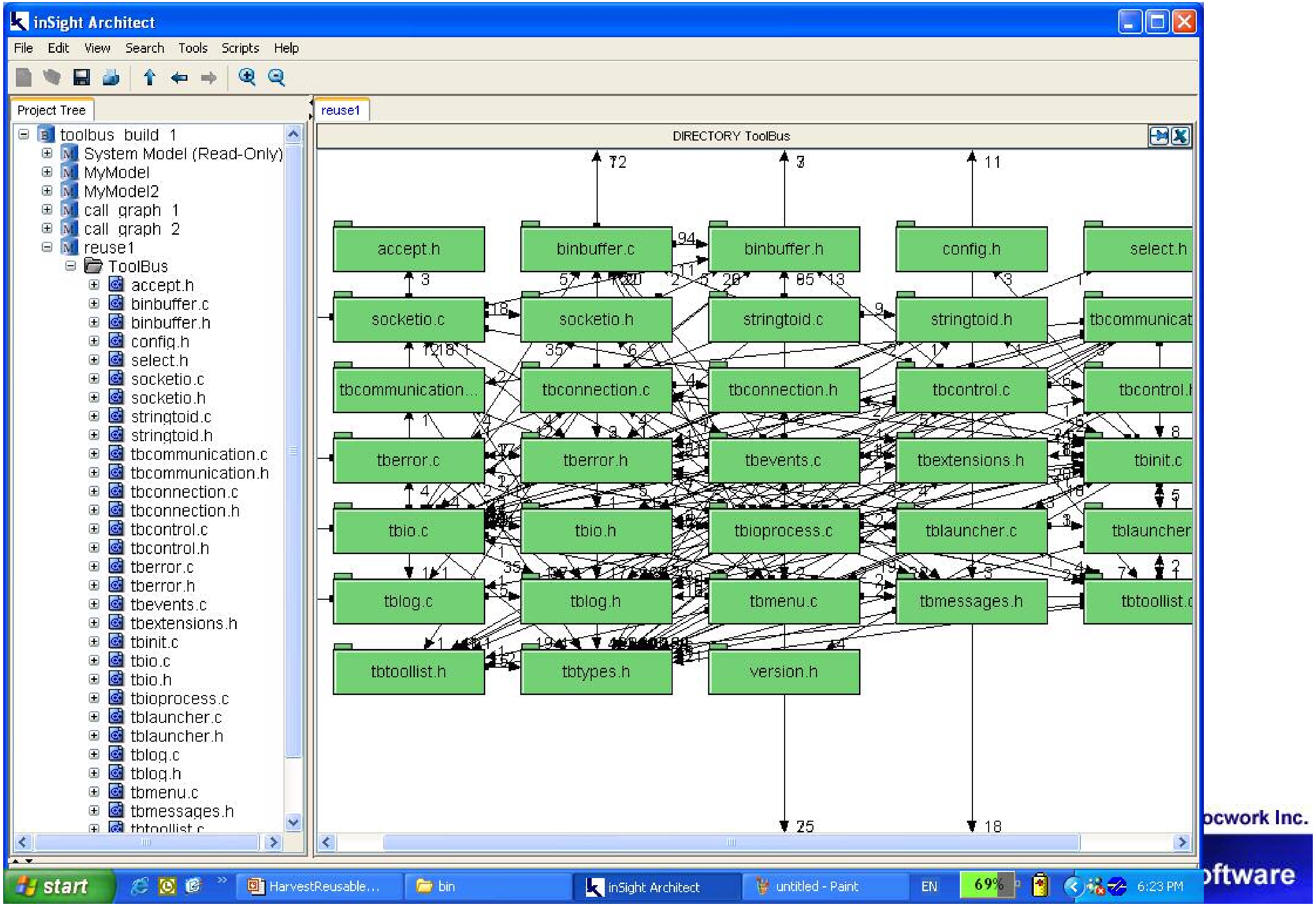


Overview

- **Harvesting as architectural refactoring**
  - First, you need to excavate your architecture, as a precise model
  - Reuse requires the following steps:
    - Identify/localize/collect
    - Isolate component
    - Introduce a boundary
    - Implement refactoring
  - Particular challenges
    - Challenges of component identification (need to understand)
    - Challenges of component isolation
    - Challenges of soft boundaries
    - Reusable components and architecture erosion
    - Reusable components and cyclic dependencies

Overview

- **Examples of Isolating Components via Refactoring**



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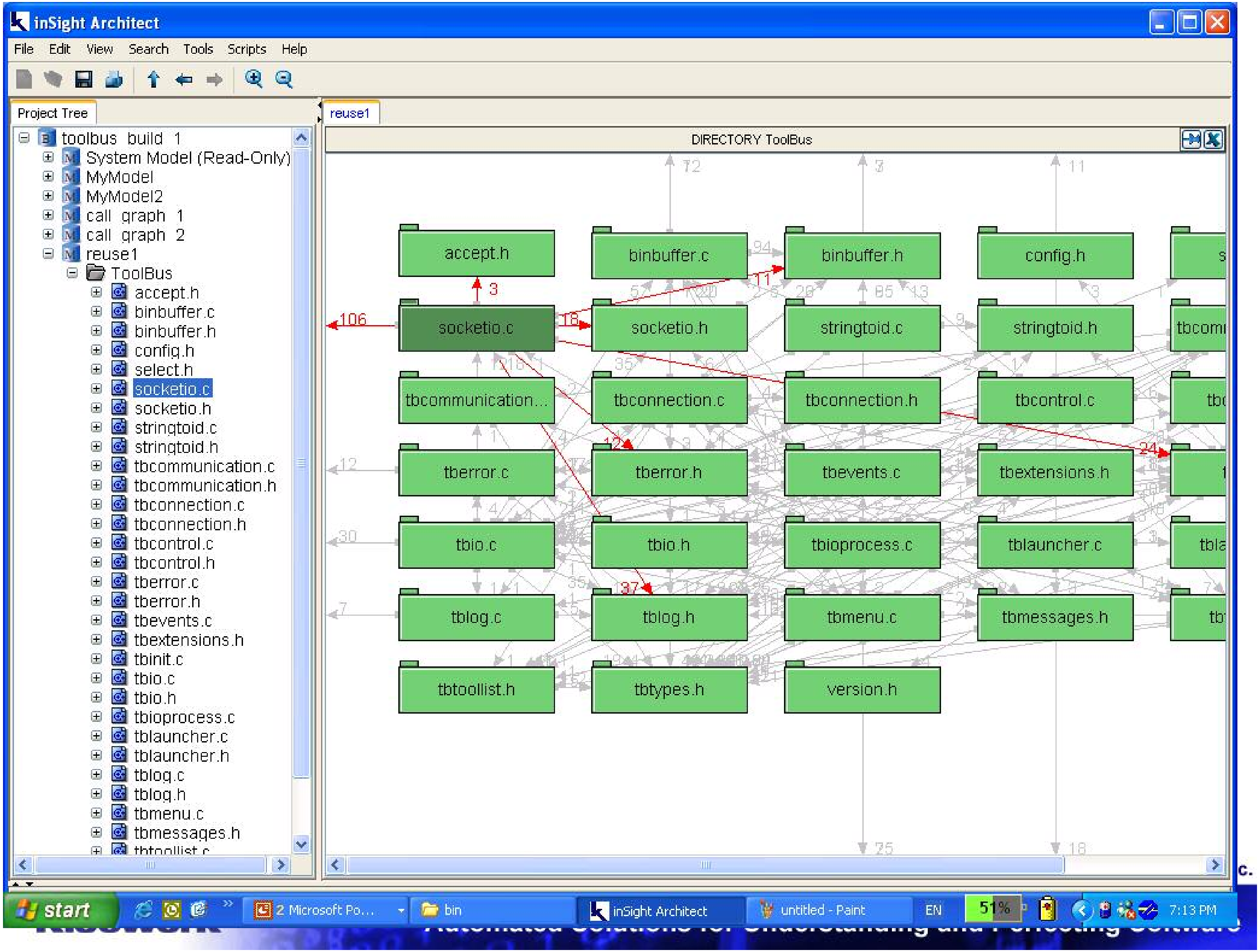
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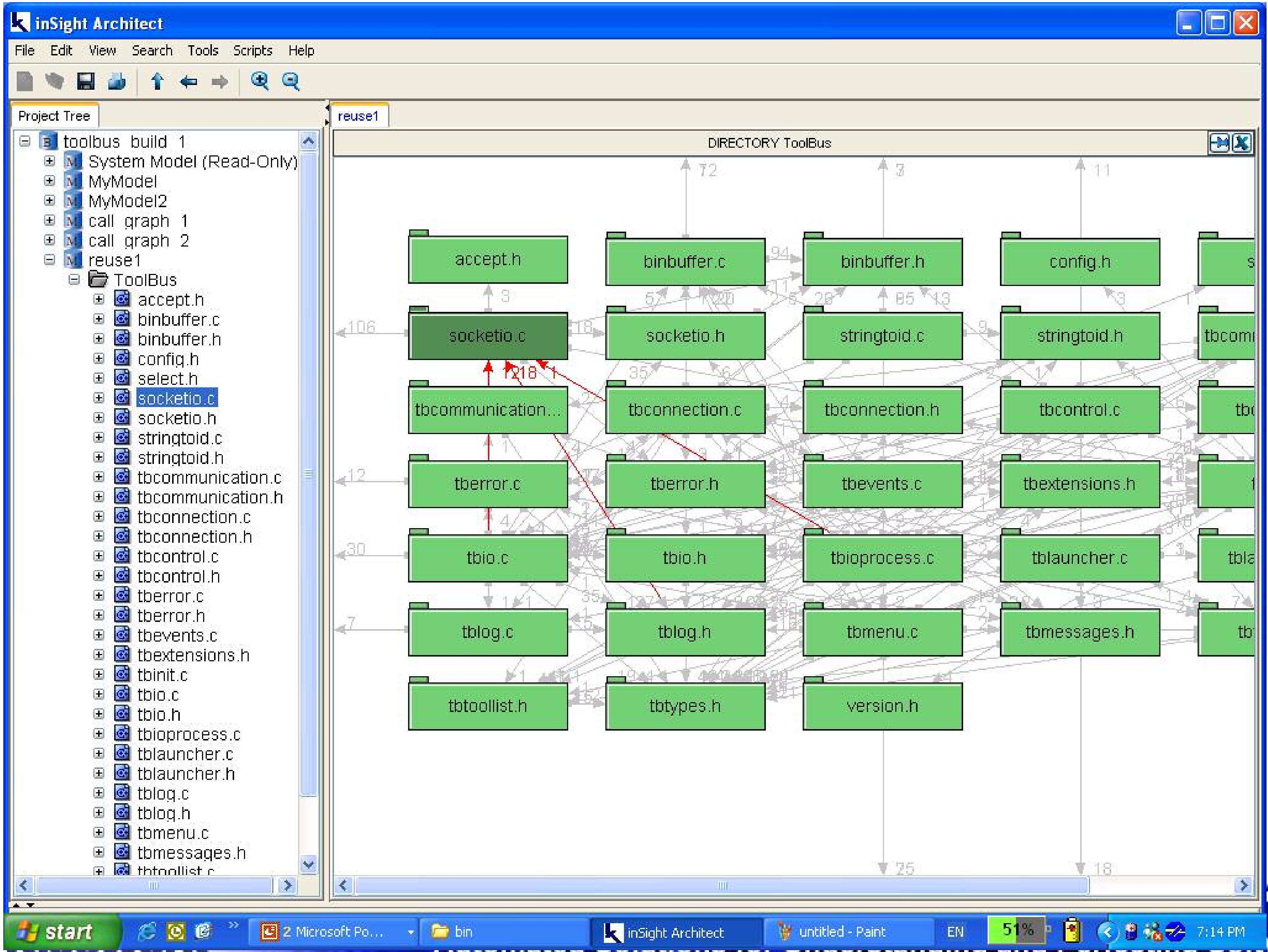

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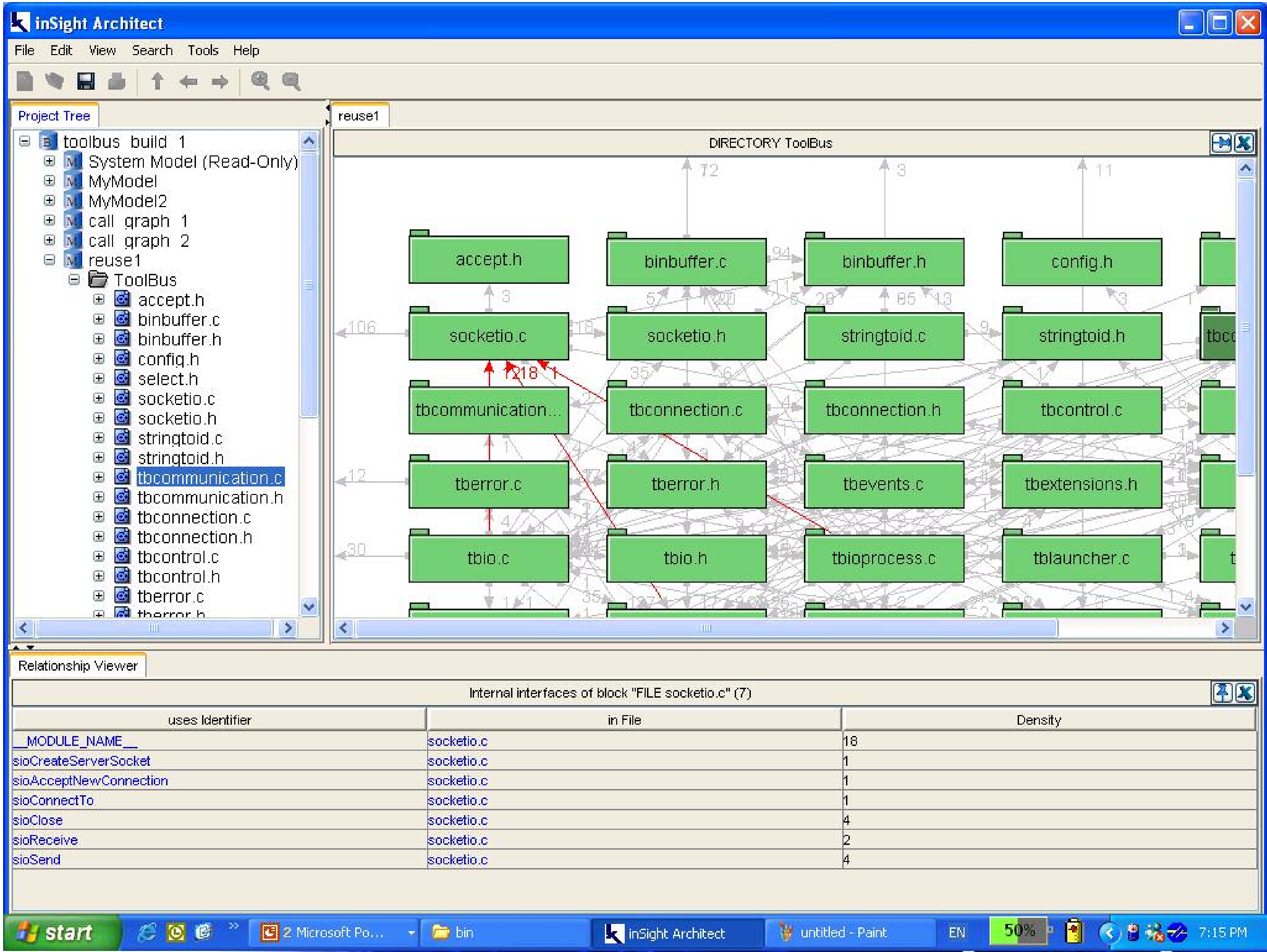
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sioConnectTo socketio.c 1
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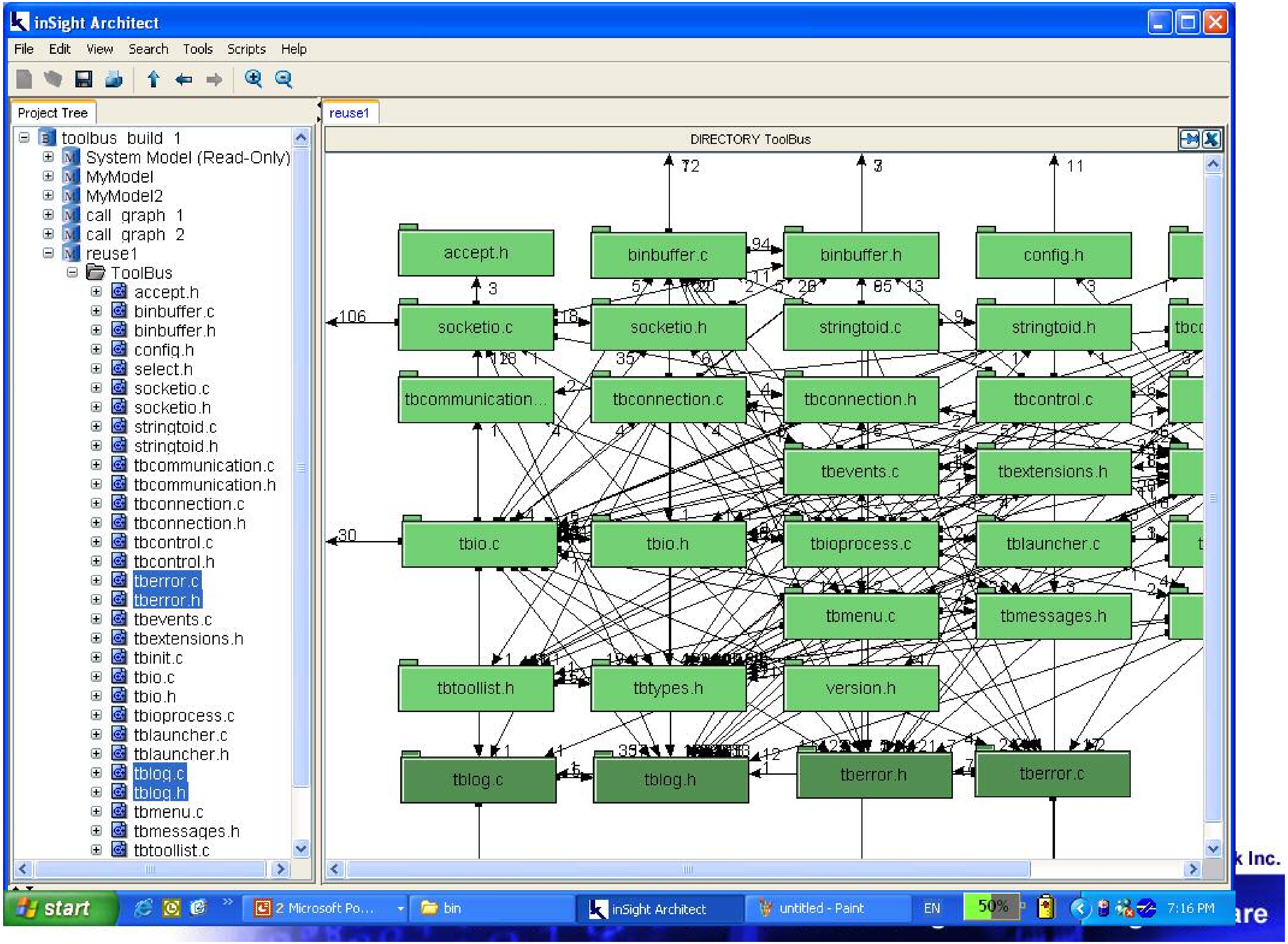

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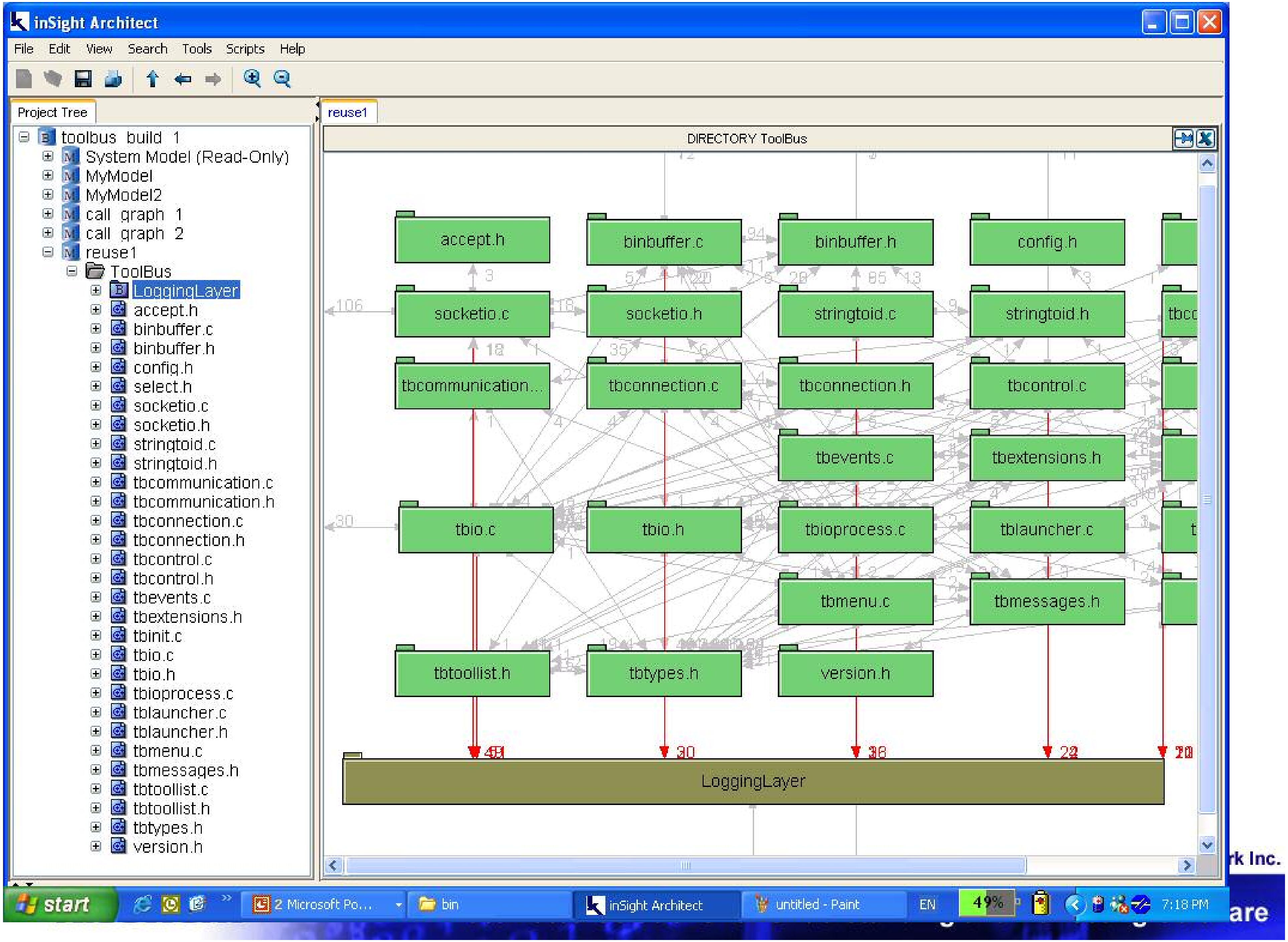

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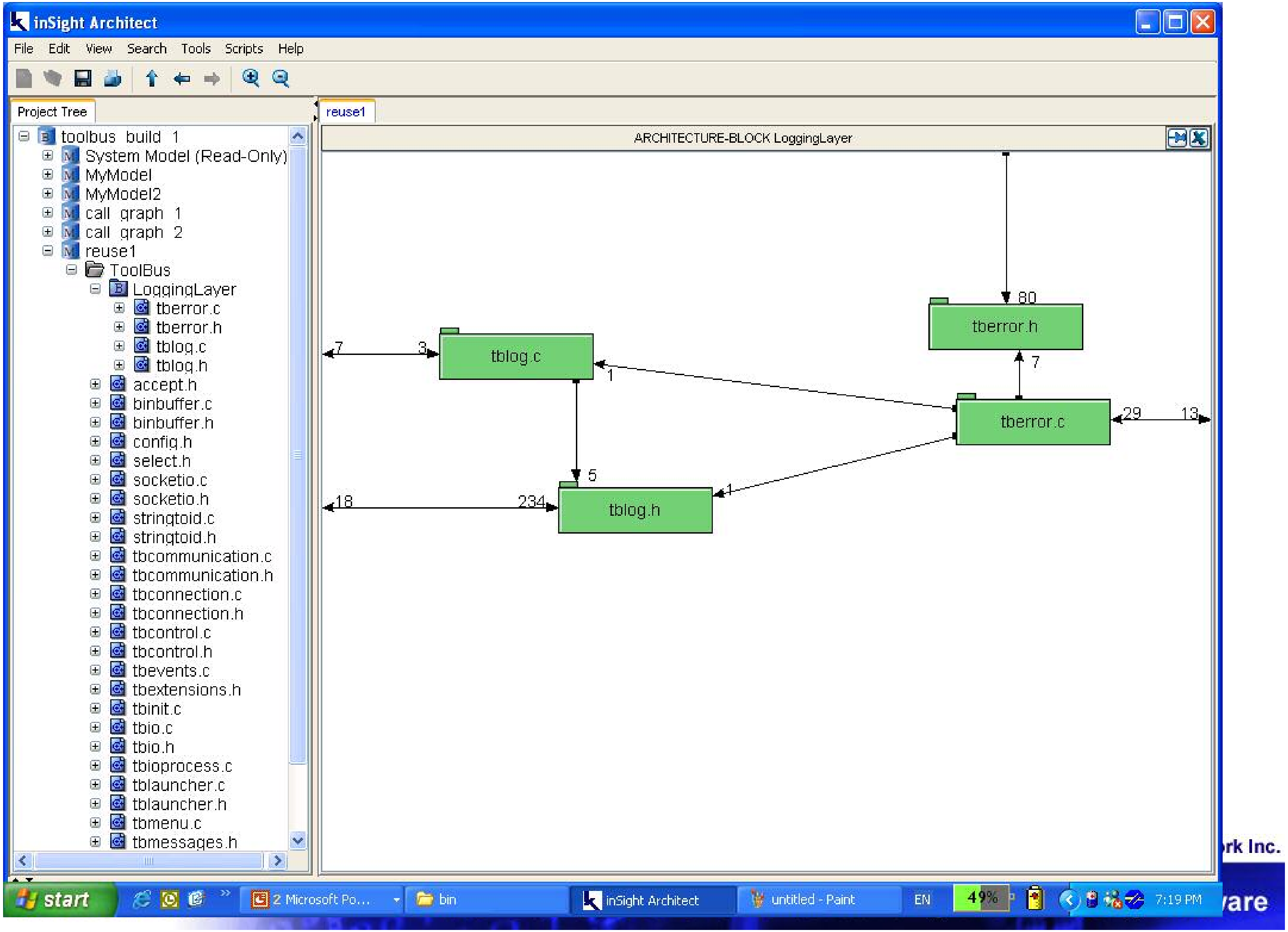
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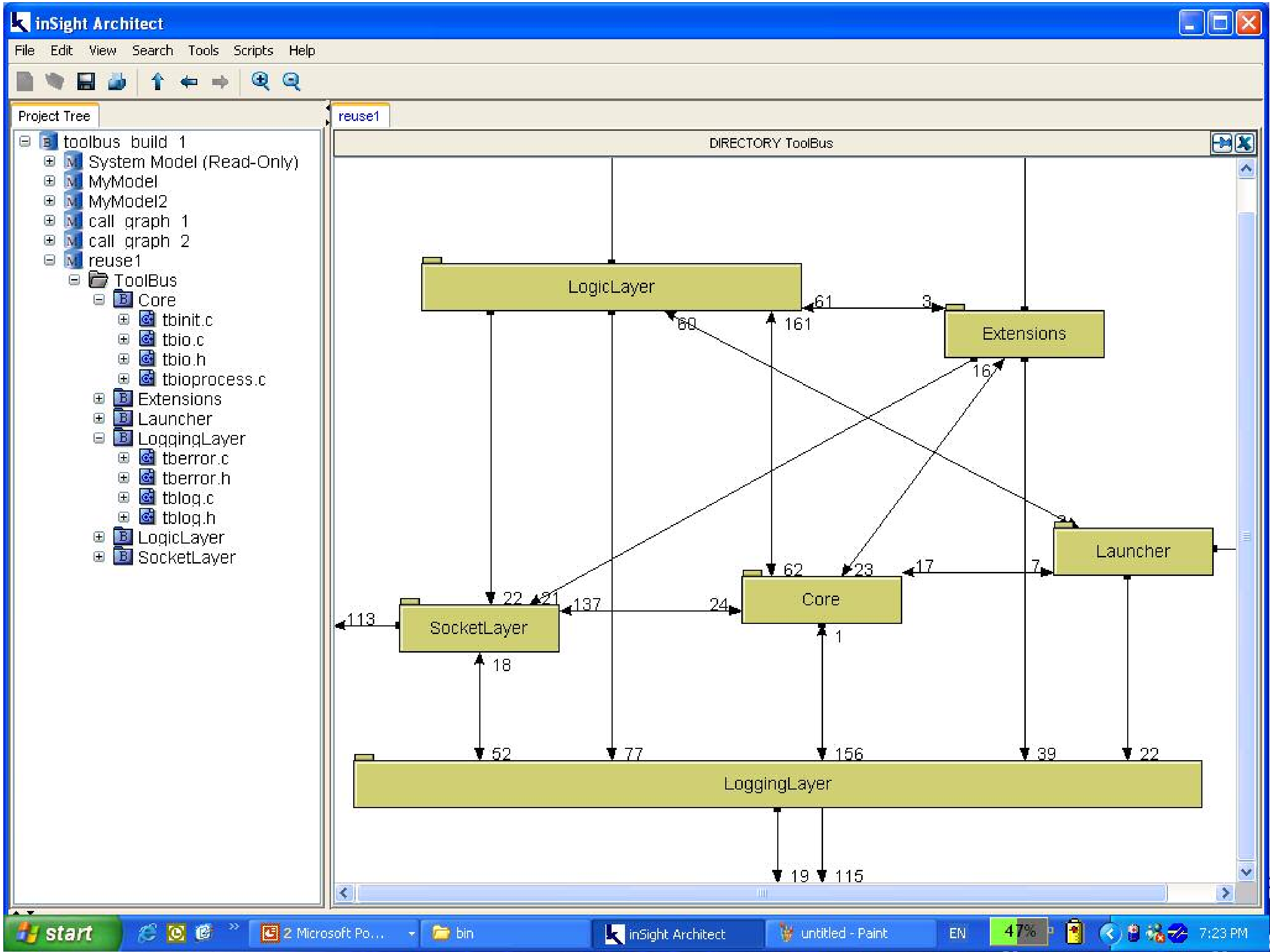

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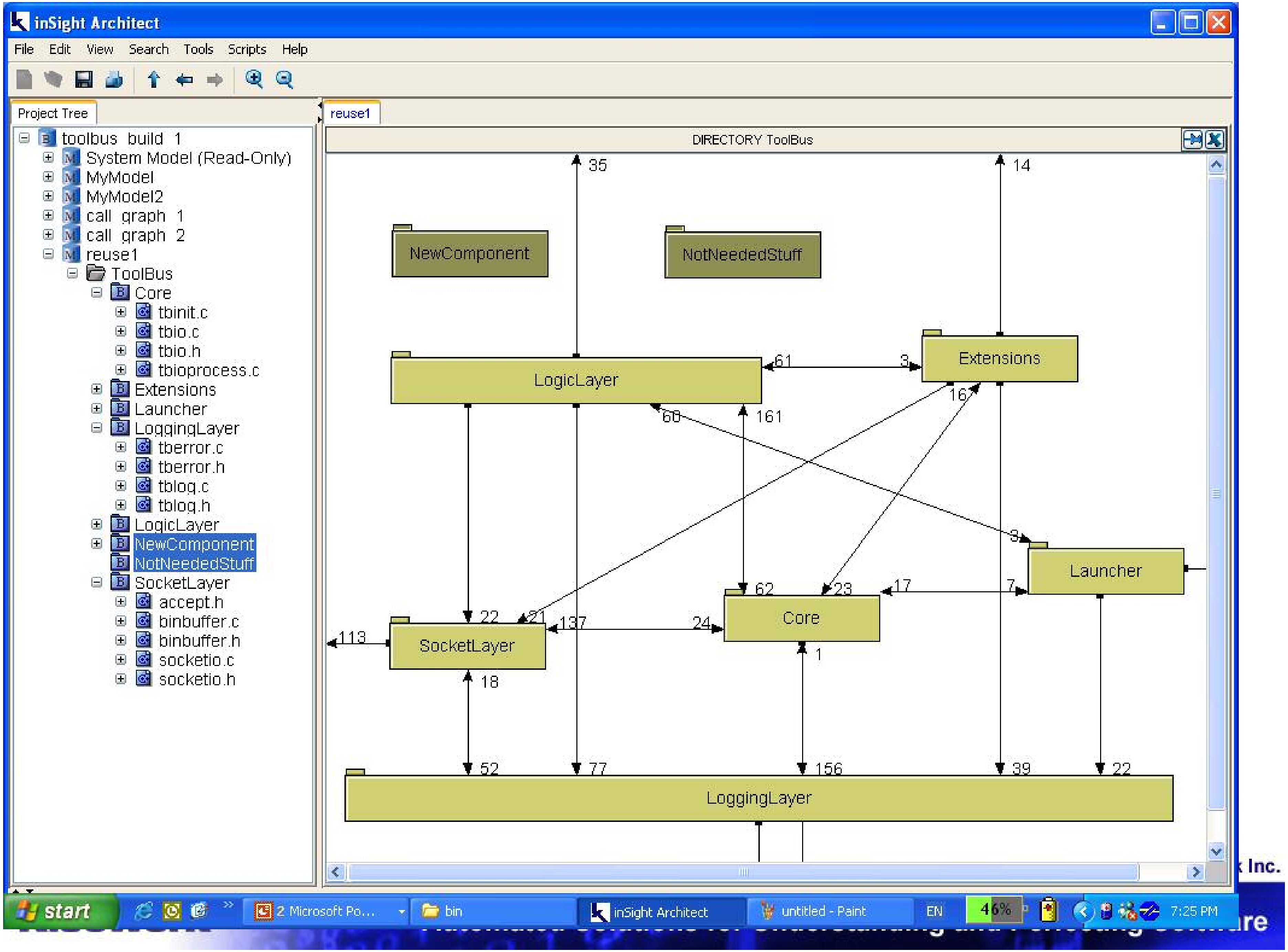

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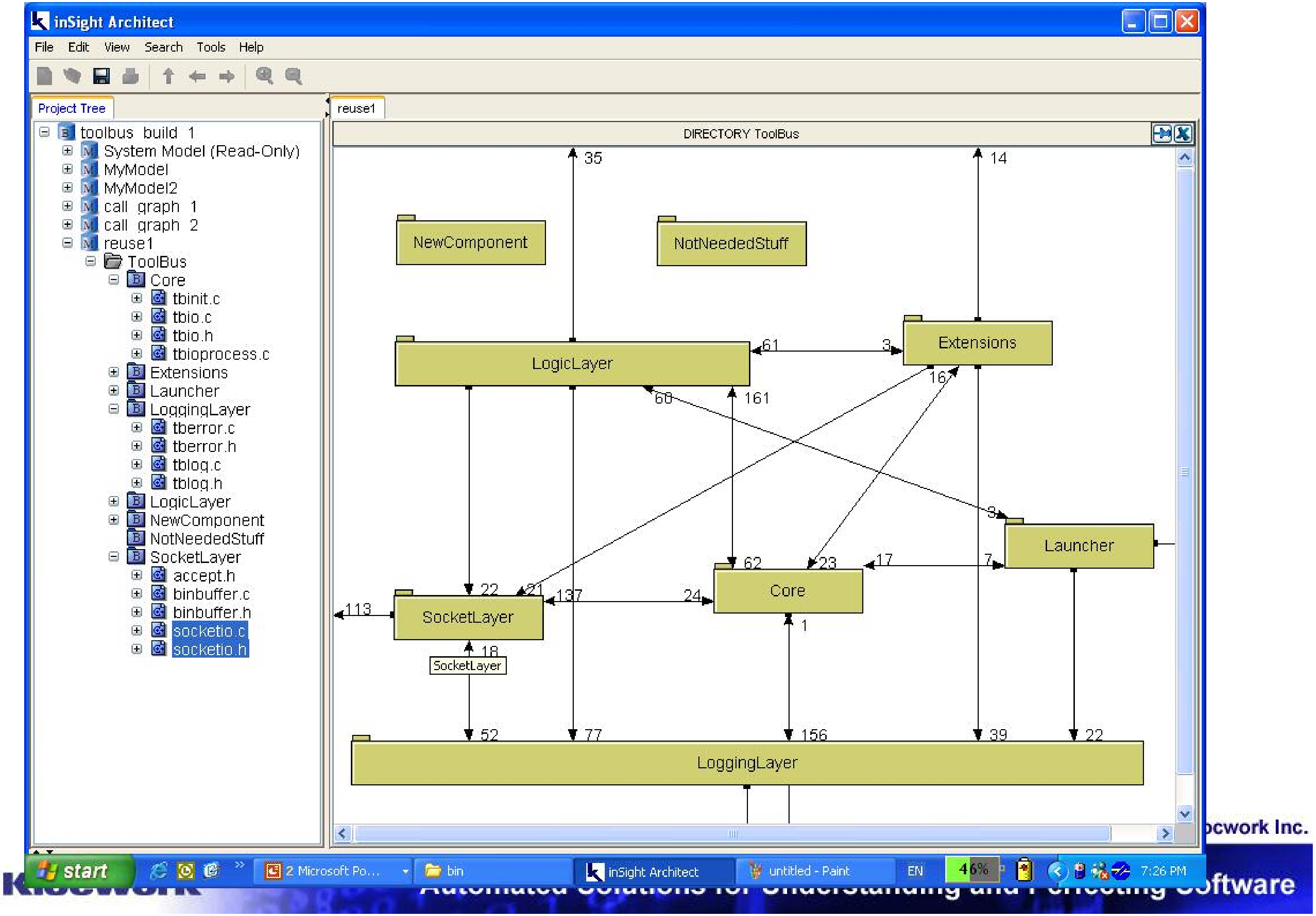
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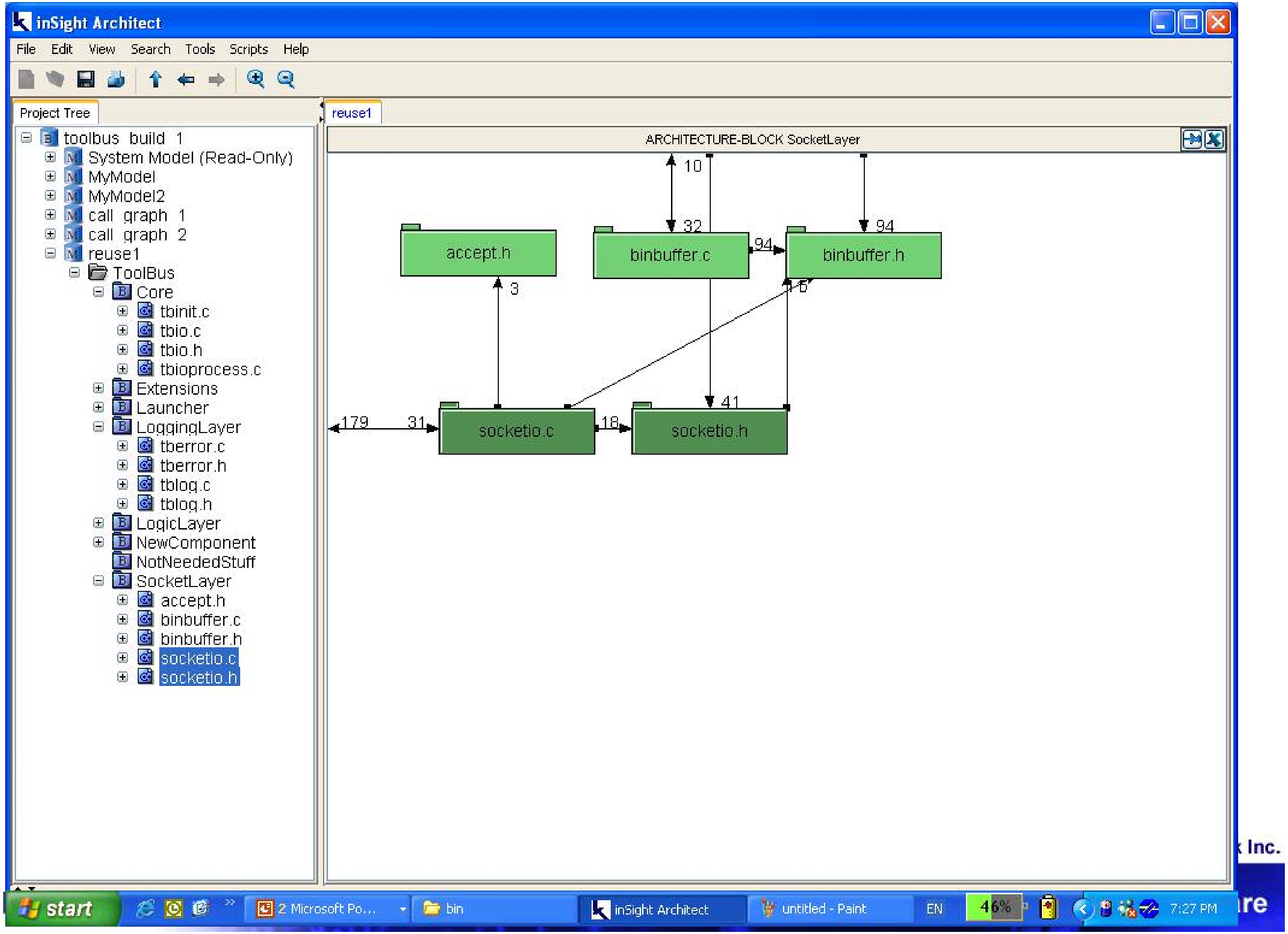
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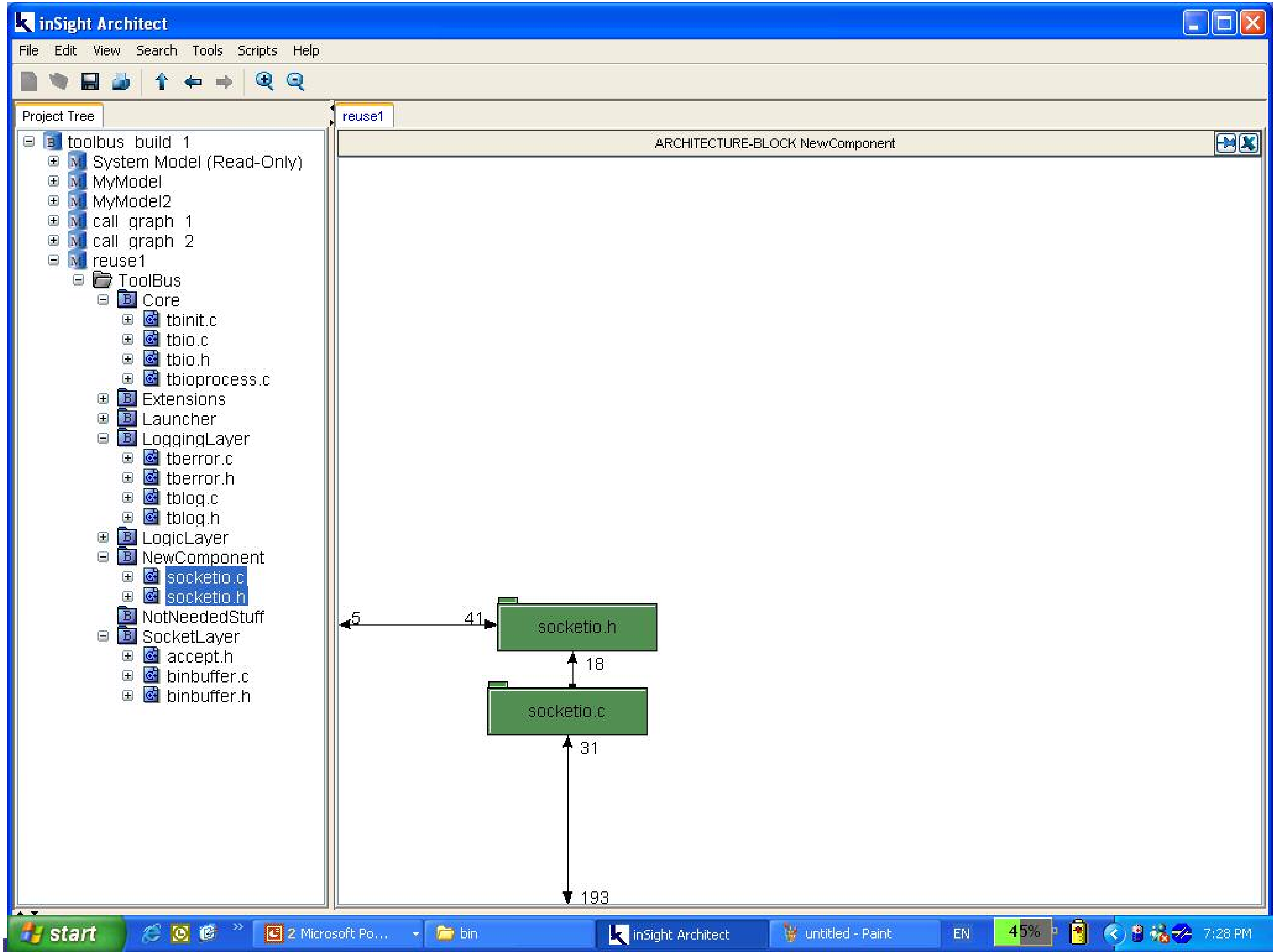
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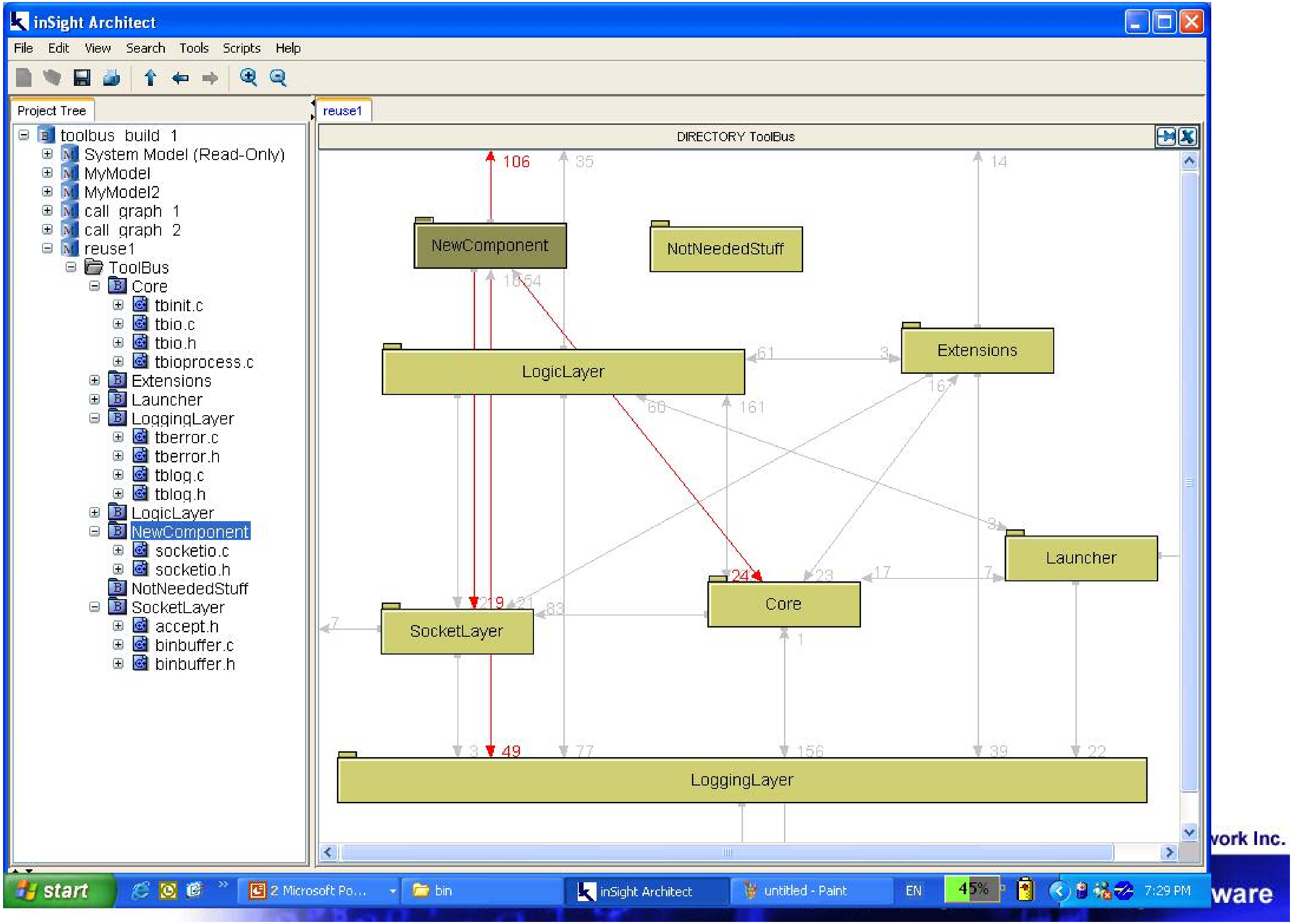
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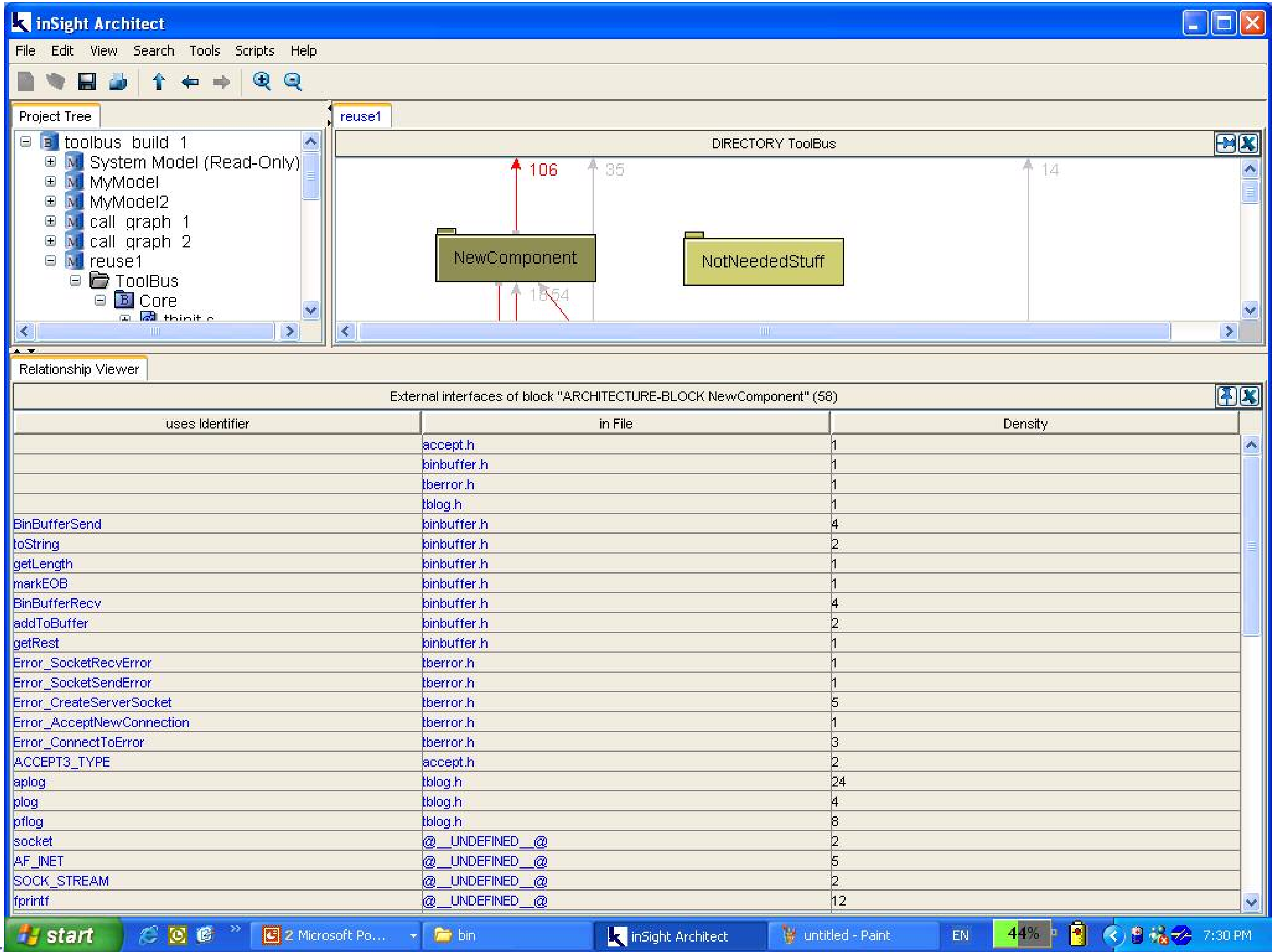

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	accept.h	1
	binbuffer.h	1
	tberror.h	1
	tblog.h	1
BinBufferSend	binbuffer.h	4
toString	binbuffer.h	2
getLength	binbuffer.h	1
markEOB	binbuffer.h	1
BinBufferRecv	binbuffer.h	4
addToBuffer	binbuffer.h	2
getRest	binbuffer.h	1
Error_SocketRecvError	tberror.h	1
Error_SocketSendError	tberror.h	1
Error_CreateServerSocket	tberror.h	5
Error_AcceptNewConnection	tberror.h	1
Error_ConnectToError	tberror.h	3
ACCEPT3_TYPE	accept.h	2
aplog	tblog.h	24
plog	tblog.h	4
pflog	tblog.h	8
socket	@__UNDEFINED__@	2
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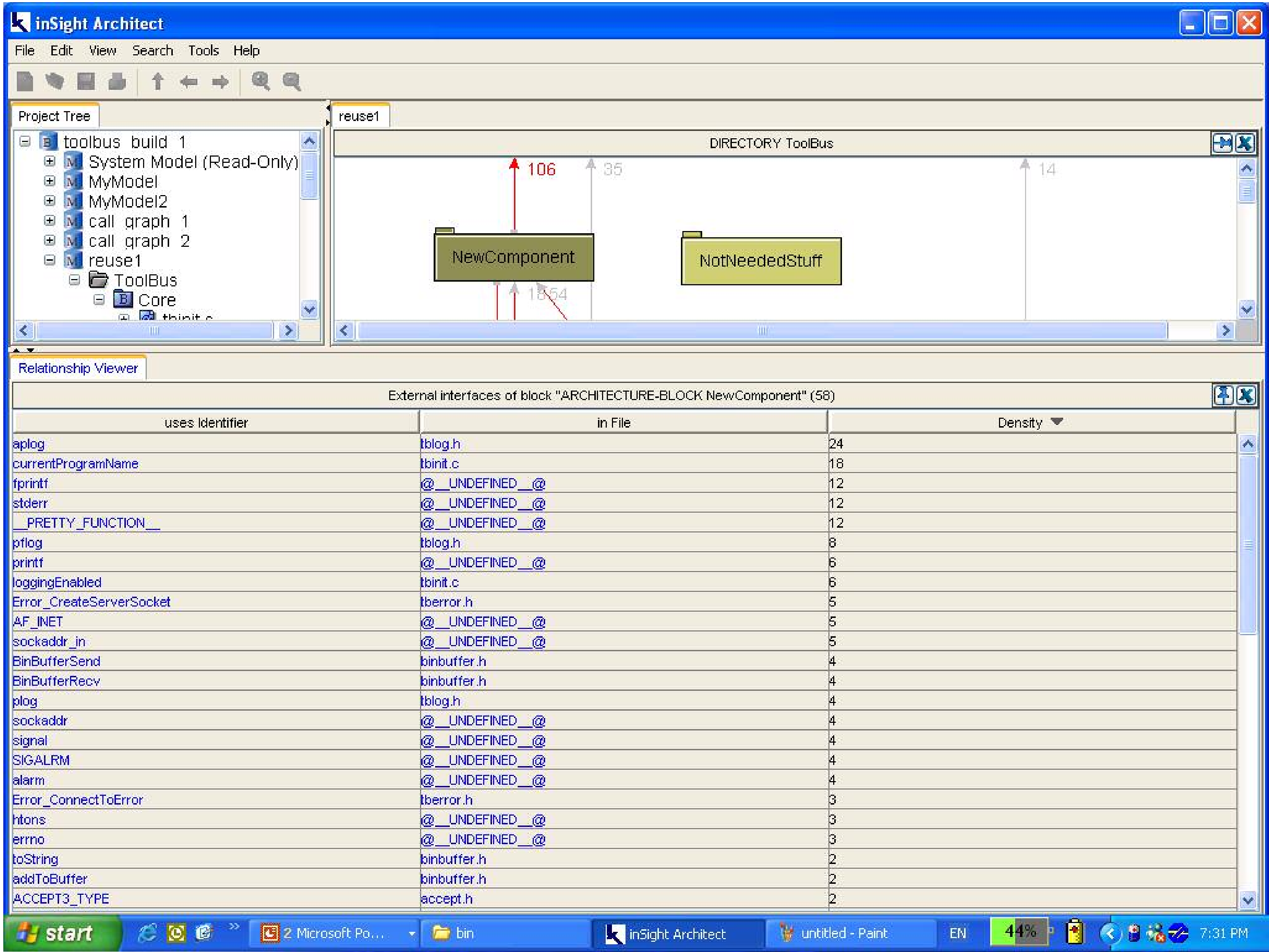
SOCK_STREAM	@__UNDEFINED__@	2
fprintf	@__UNDEFINED__@	12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Relationship Viewer
External interfaces of block "ARCHITECTURE-BLOCK NewComponent" (58)
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aplog | tblog.h | 24
currentProgramName | tbinit.c | 18
fprintf | @__UNDEFINED__@ | 12
stderr | @__UNDEFINED__@ | 12
__PRETTY_FUNCTION__ | @__UNDEFINED__@ | 12
pflog | tblog.h | 8
printf | @__UNDEFINED__@ | 6
loggingEnabled | tbinit.c | 6
Error_CreateServerSocket | tberror.h | 5
AF_INET | @__UNDEFINED__@ | 5
sockaddr_in | @__UNDEFINED__@ | 5
BinBufferSend | binbuffer.h | 4
BinBufferRecv | binbuffer.h | 4
plog | tblog.h | 4
sockaddr | @__UNDEFINED__@ | 4
signal | @__UNDEFINED__@ | 4
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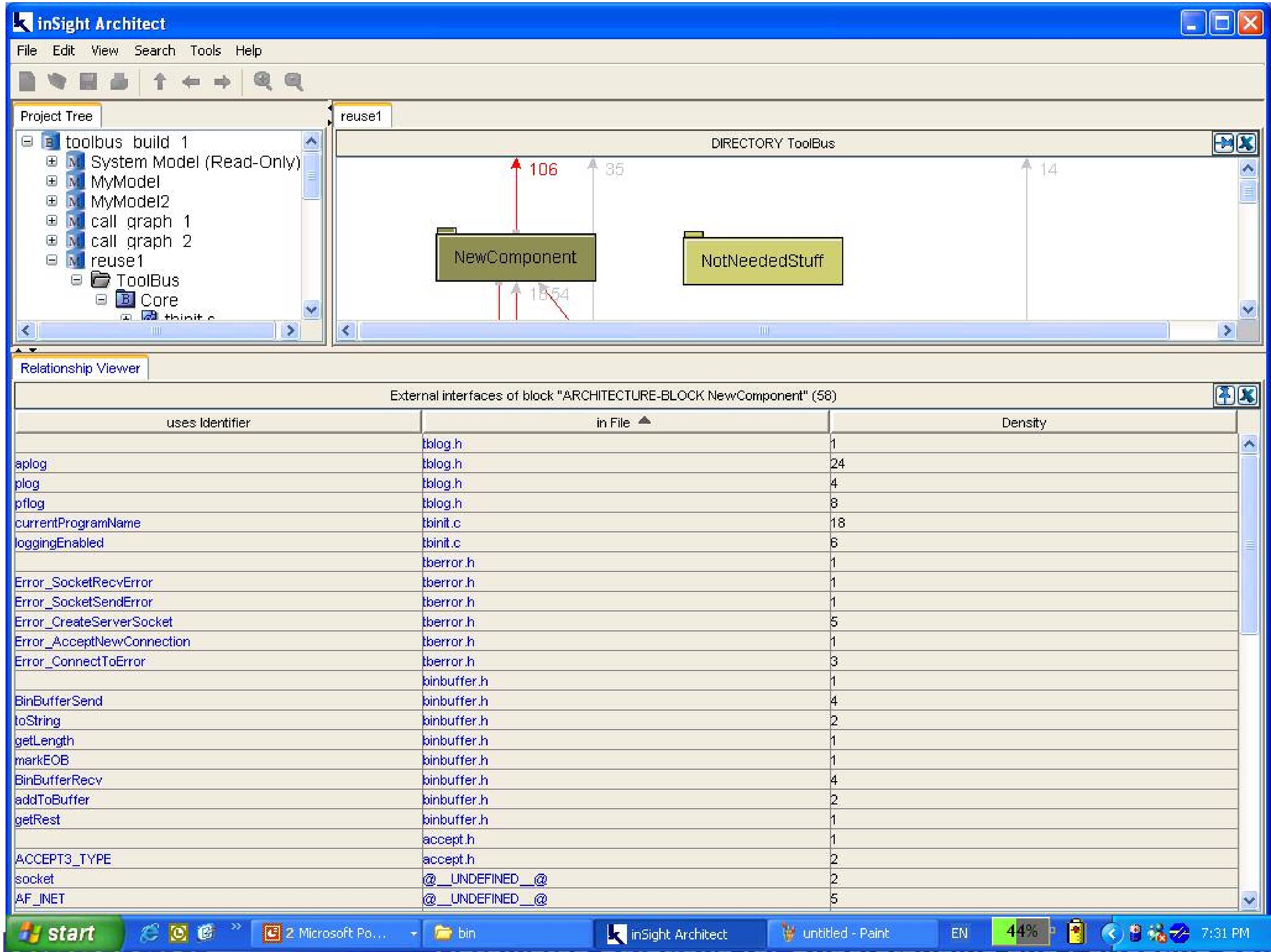

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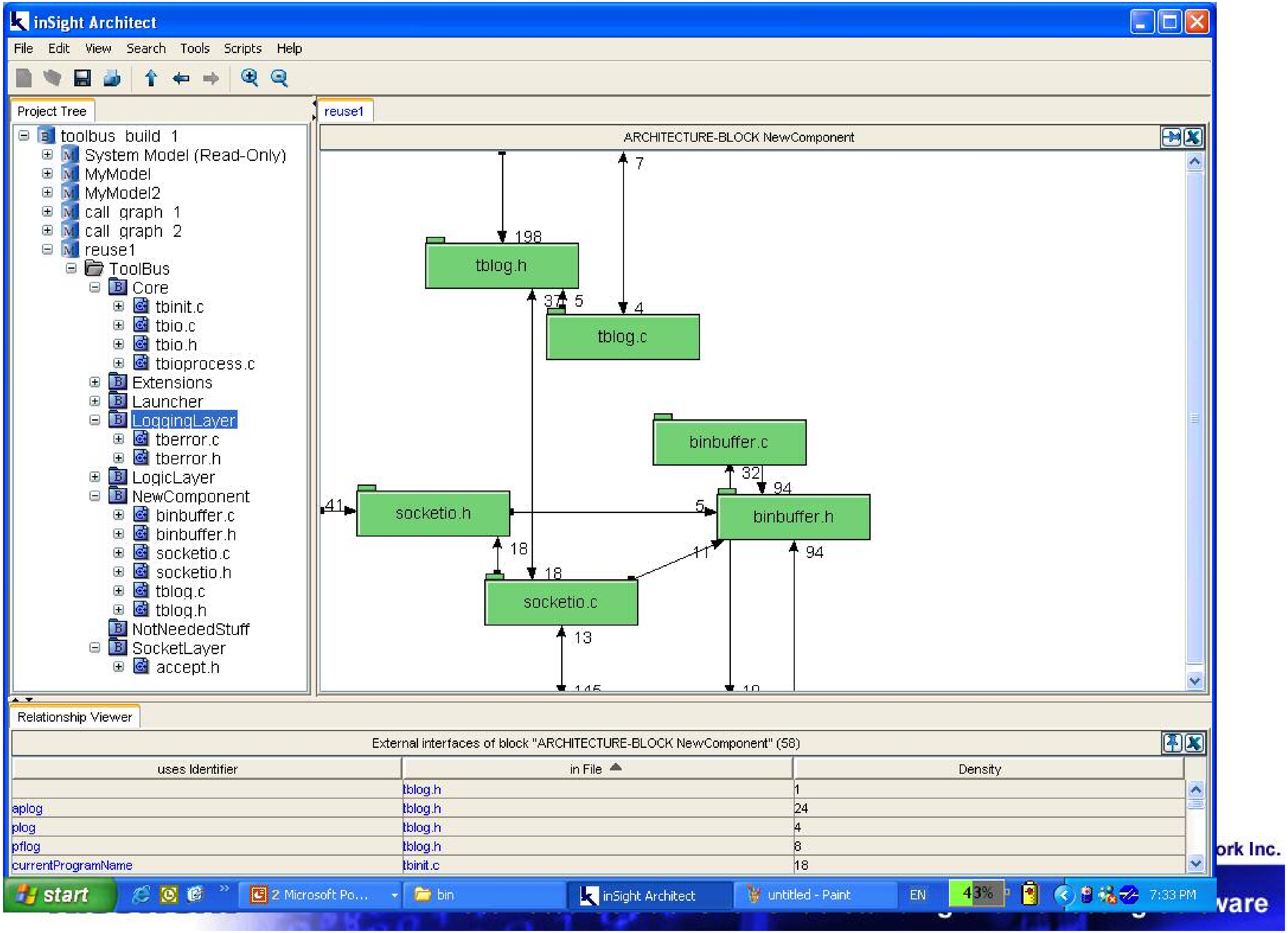
plog	tblog.h	4
pflog	tblog.h	8
currentProgramName	tbinit.c	18
loggingEnabled	tbinit.c	6
	tberror.h	1
Error_SocketRecvError	tberror.h	1
Error_SocketSendError	tberror.h	1
Error_CreateServerSocket	tberror.h	5
Error_AcceptNewConnection	tberror.h	1
Error_ConnectToError	tberror.h	3
	binbuffer.h	1
BinBufferSend	binbuffer.h	4
toString	binbuffer.h	2
getLength	binbuffer.h	1
markEOB	binbuffer.h	1
BinBufferRecv	binbuffer.h	4
addToBuffer	binbuffer.h	2
getRest	binbuffer.h	1
	accept.h	1
ACCEPT3_TYPE	accept.h	2
socket	@__UNDEFINED__@	2
AF_INET	@__UNDEFINED__@	5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Relationship Viewer
External interfaces of block "ARCHITECTURE-BLOCK NewComponent" (58)
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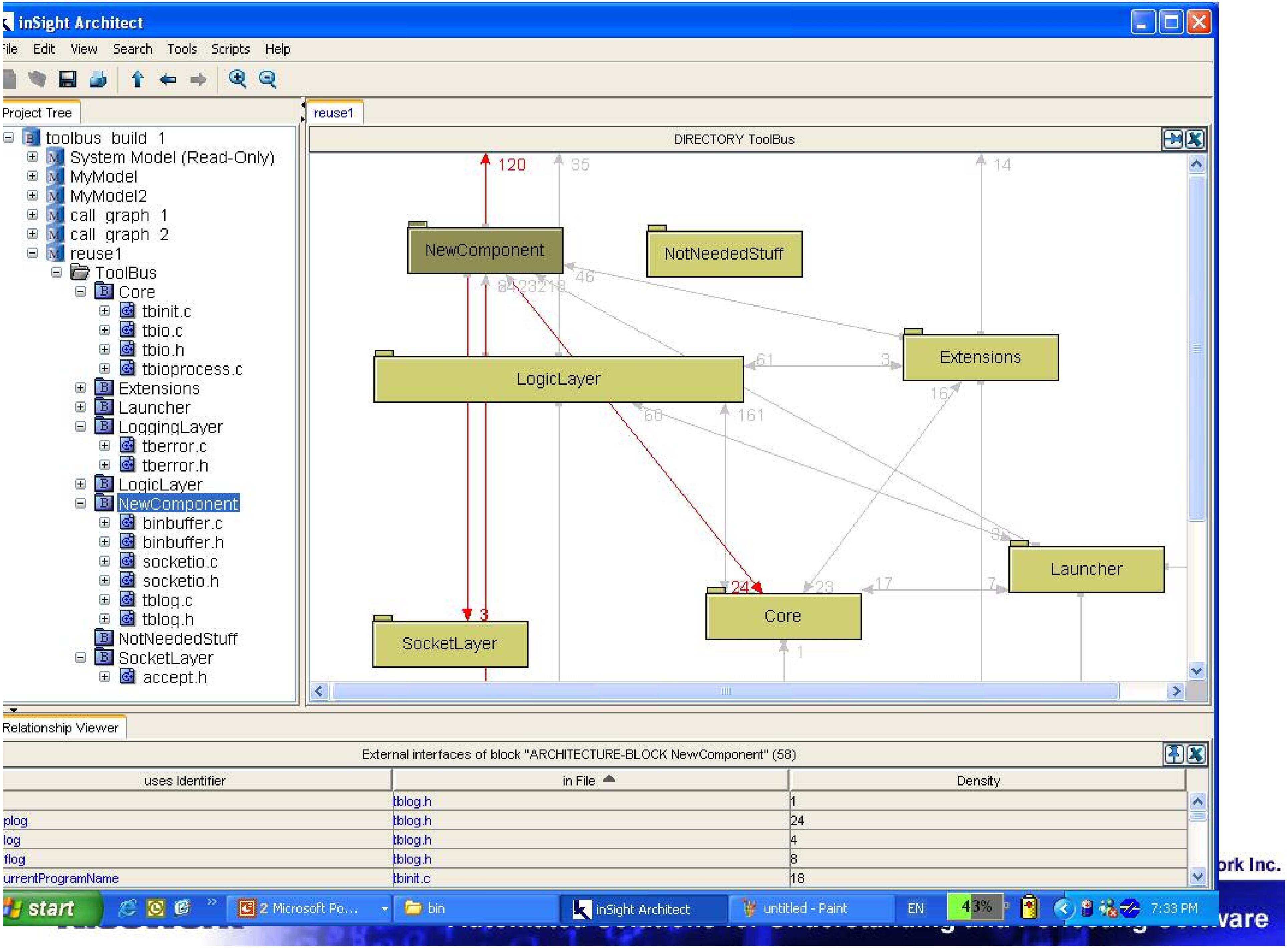

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LoggingLayer
tberror.c
tberror.h
LogicLayer
NewComponent
binbuffer.c
binbuffer.h
socketio.c
socketio.h
tblog.c
tblog.h
NotNeededStuff
SocketLayer
accept.h
reuse1
DIRECTORY ToolBus
NewComponent
NotNeededStuff
LogicLayer
Extensions
Launcher
Core
SocketLayer
120
35
14
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61
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1
Relationship Viewer
External interfaces of block "ARCHITECTURE-BLOCK NewComponent" (58)
uses Identifier
in File
Density
tblog.h 1
plog tblog.h 24
log tblog.h 4
flog tblog.h 8
urrentProgramName tbinit.c 18
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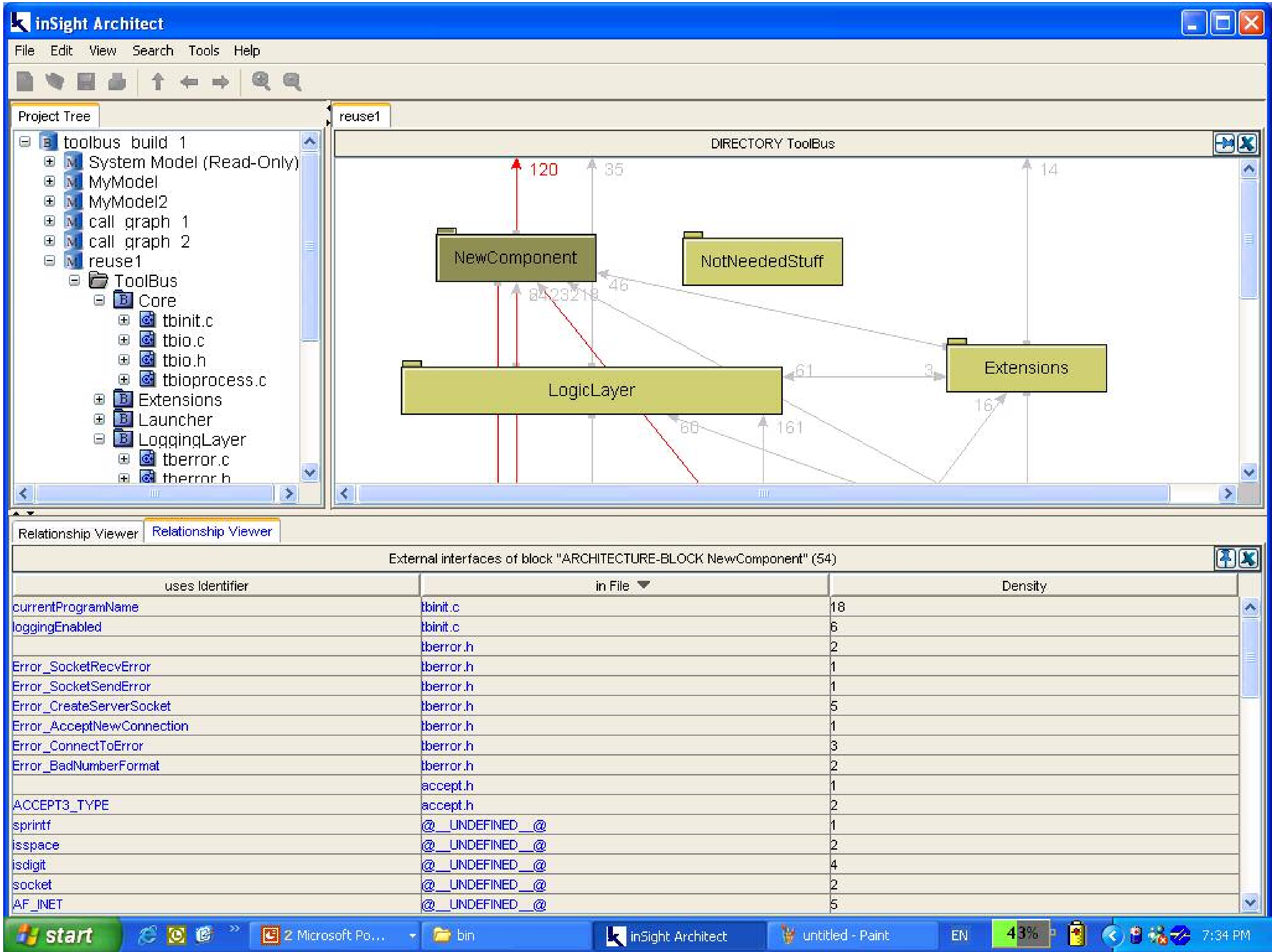
inSight Architect
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Project Tree
toolbus build 1
System Model (Read-Only)
MyModel
MyModel2
call graph 1
call graph 2
reuse1
ToolBus
Core
tbinit.c
tbio.c
tbio.h
tbioprocess.c
Extensions
Launcher
LoggingLayer
tberror.c
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Relationship Viewer
Relationship Viewer
External interfaces of block "ARCHITECTURE-BLOCK NewComponent" (54)
uses Identifier | in File | Density
currentProgramName | tbinit.c | 18
loggingEnabled | tbinit.c | 6
| tberror.h | 2
Error_SocketRecvError | tberror.h | 1
Error_SocketSendError | tberror.h | 1
Error_CreateServerSocket | tberror.h | 5
Error_AcceptNewConnection | tberror.h | 1
Error_ConnectToError | tberror.h | 3
Error_BadNumberFormat | tberror.h | 2
| accept.h | 1
ACCEPT3_TYPE | accept.h | 2
sprintf | @__UNDEFINED__@ | 1
isspace | @__UNDEFINED__@ | 2
isdigit | @__UNDEFINED__@ | 4
socket | @__UNDEFINED__@ | 2
AF_INET | @__UNDEFINED__@ | 5
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Conclusions/Key points

- **Reuse activities add another dimension to multi-release software production**
  - Reuse for maintenance (cloning)
  - Reuse for modernization
  - Reuse for redevelopment
  - Reuse for product line (across products)
- **Reuse is an architecture-centric activity**
- **Suitable Architecture Models are required to manage reuse**
- **Harvesting is an architecture refactoring**
  - First, you need to excavate your architecture, as a precise model
  - Harvesting requires the following steps:
    - Identify/localize/collect
    - Isolate component
    - Introduce a boundary
    - Implement refactoring