Managed Architecture of Existing Software as a Practical Transition to MDA

Professional Advanced

OBJECT MANAGEMENT GROUP • UML™ CERTIFICATION PROGRAM •

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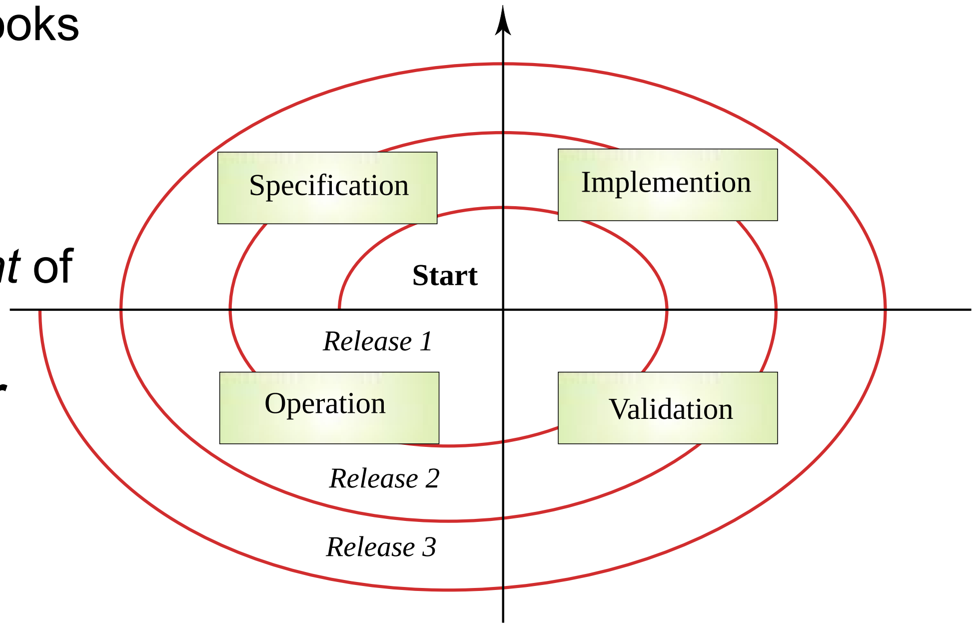
Overview

- **Introduction: The Complete Life-Cycle of software production**
- **The challenges of the complete-life cycle**
  - New Development
  - Evolution
    - Program Comprehension
    - Architecture Erosion
    - The increasing cost of production
  - Modernization
- **Model-Driven architecture (MDA)**
- **Managed Architecture**
  - Architecture Excavation
  - Architecture Management
  - Architecture Enforcement
  - Refactoring
- **Managed Architecture and MDA**
- **Remaining challenges**
- **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

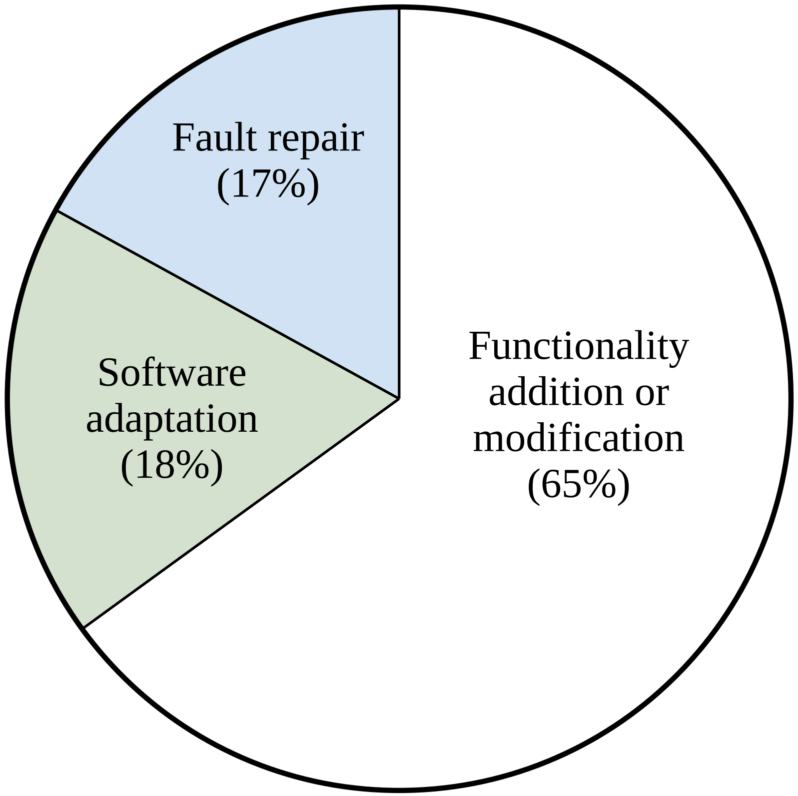
Traditional definition of maintenance

- **Software maintenance has been defined within the ANSI standard [ANSI83] as**

  "the modification of software products after delivery to correct faults, to improve performance or other attributes, or to adapt the product to a changed environment."

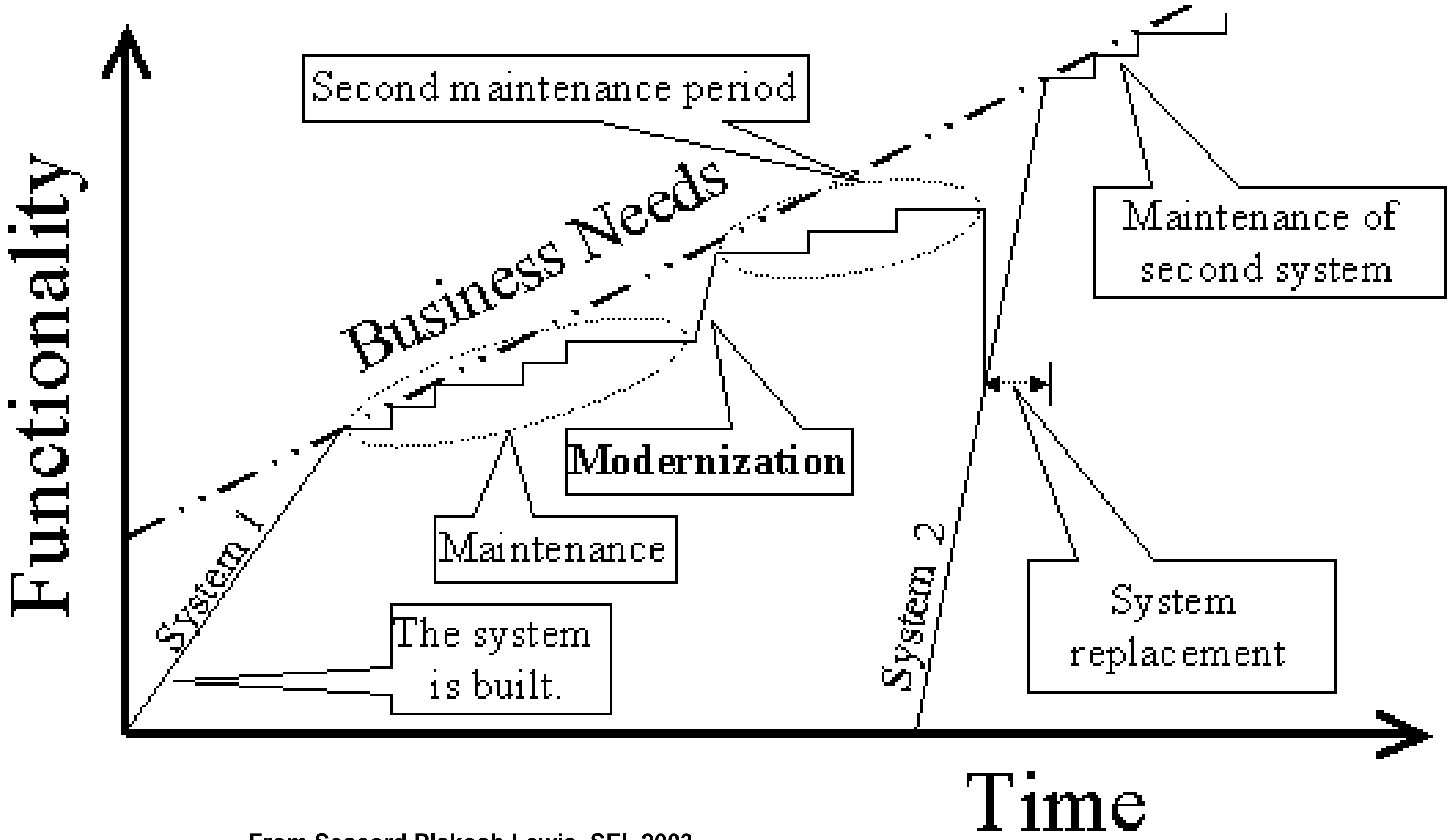
Software production with existing code

- **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



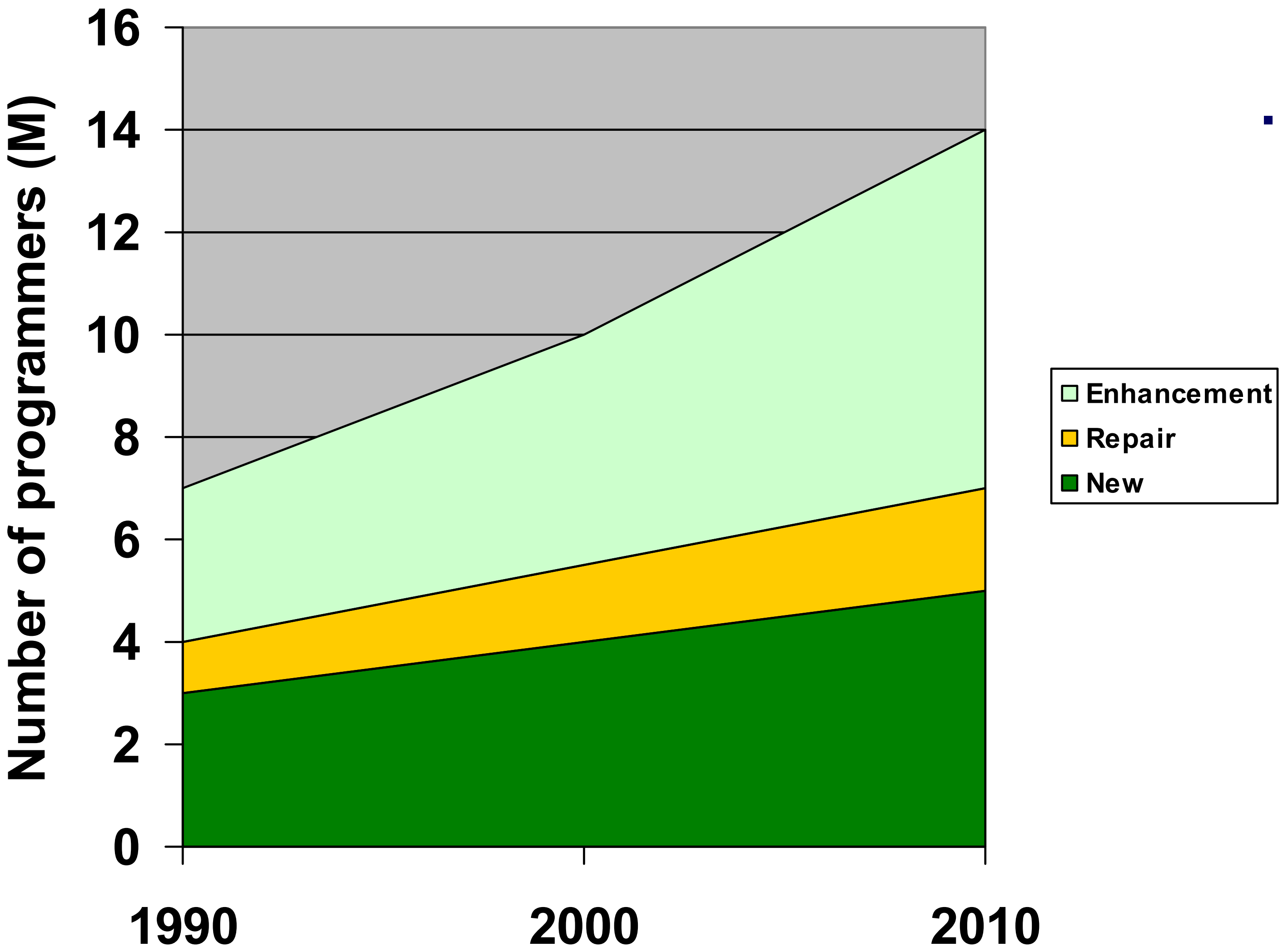
From Ian Sommerville, Software Engineering, 2000

Changes of *increasing* magnitude are required to address changing business needs



From Seacord,Plakosh,Lewis, SEI, 2003

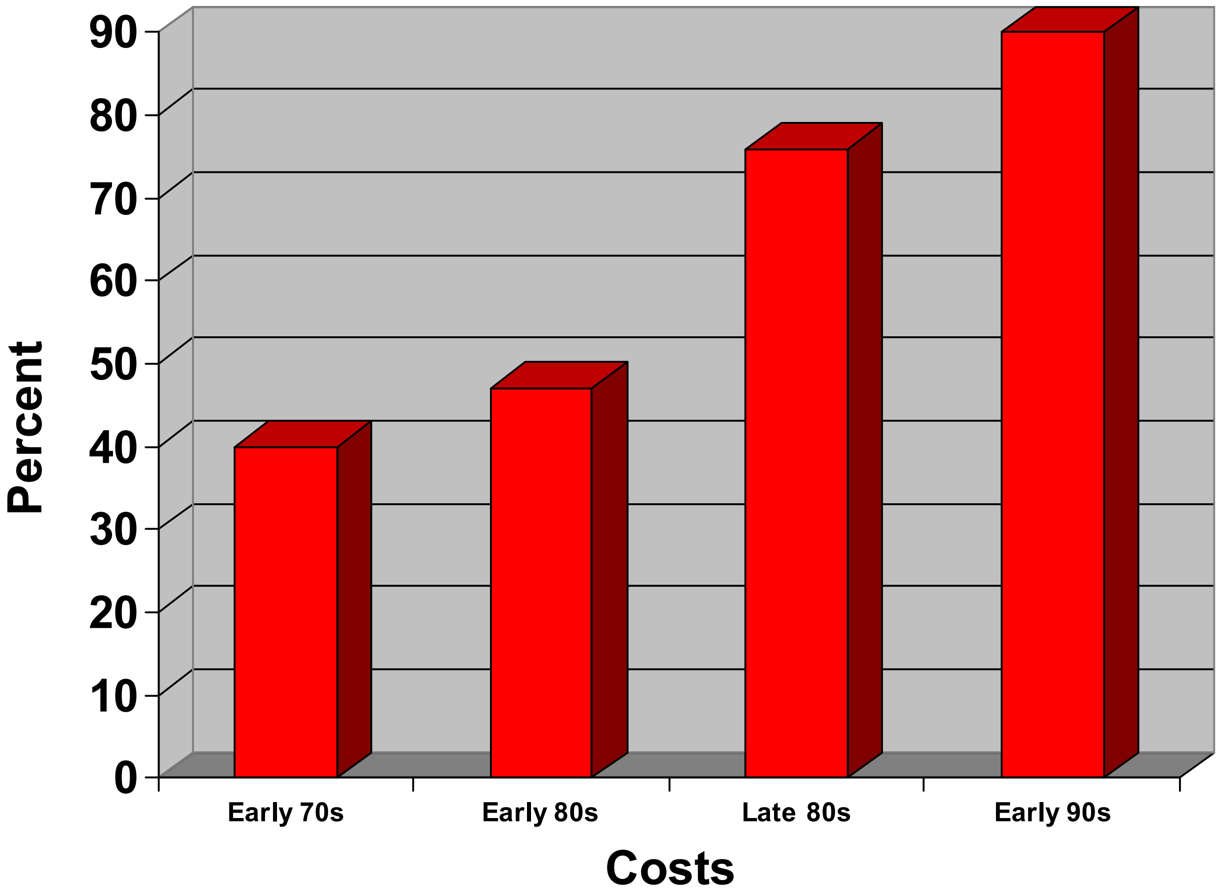
Evolution of existing code has significant economic impact



From Deursen,Klint,Verhoef,1999

- **More than one half of all programmers are *already* working with existing code (repair + enhancement)**
- **The 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

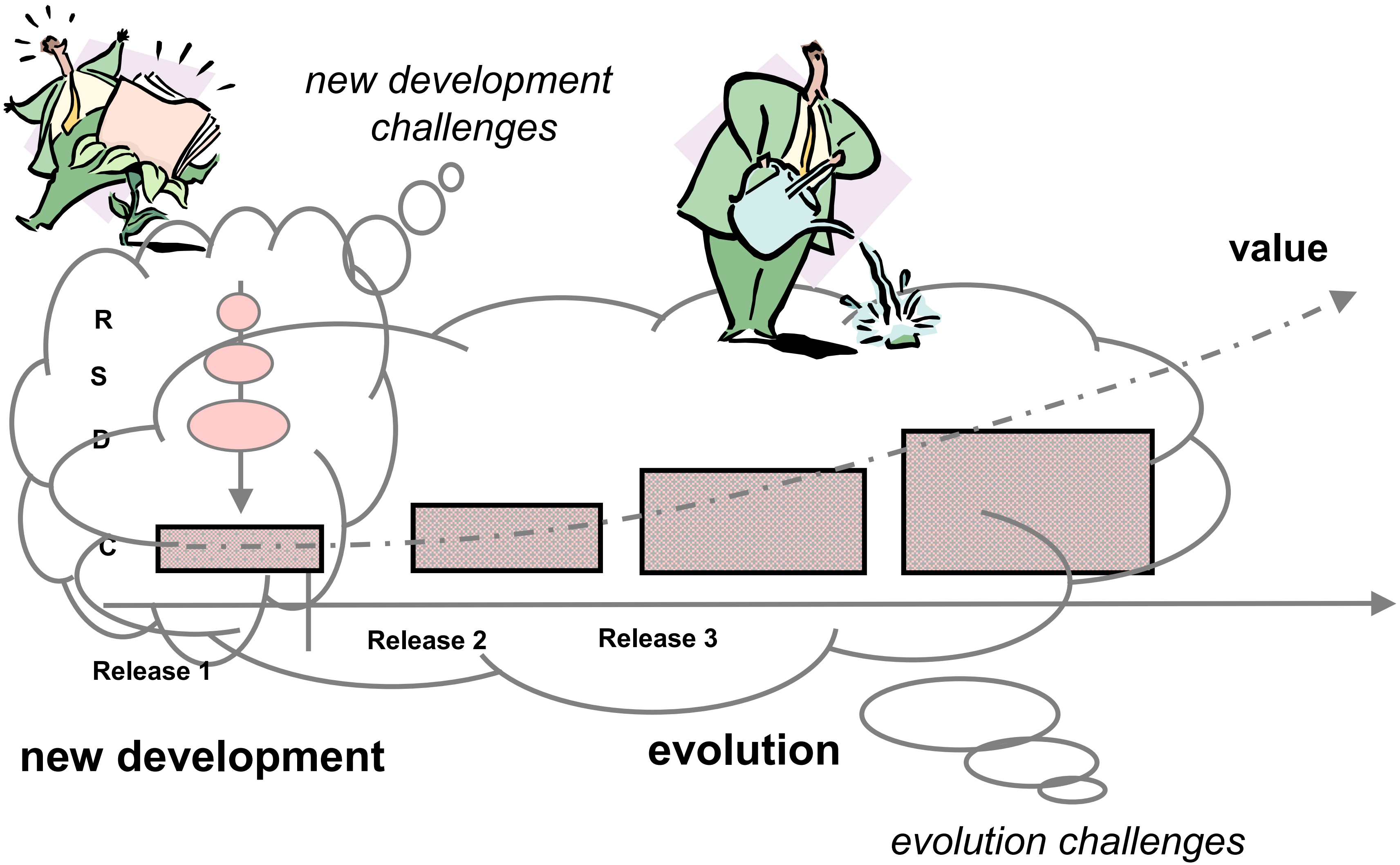
Cost of evolution overshadows the cost of the initial release



- The cost of post-initial evolution has grown from 40% to 90% of the total production cost
- The cost of the initial release is only 10% of the total production cost
- Software is getting larger, more feature-rich
- Overall cost of development is increasing
- The useful lifespan is increasing
- Production cost is increasing over time

From Lehman,1999

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

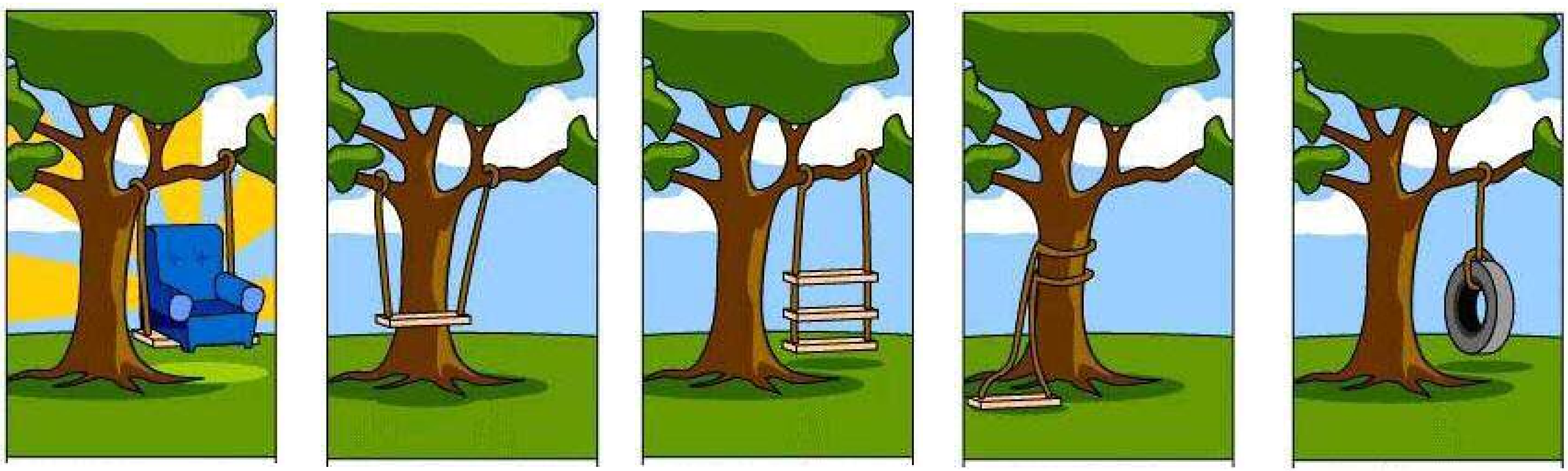


Where do we go from here ?

- **OMG's Model-Driven Architecture (MDA) is a new development approach focused at *complete life-cycle of software production*. It emphasizes**
    - Modeling using UML, MOF, etc,
    - separation of Platform-independent and Platform-dependent concerns,
    - transformation of models (eventually – into the code)
    - shifting away from maintenance of the code to maintenance of the model and the transformation specifications
  - MDA addresses *the program comprehension challenge*: once started with an upfront model the knowledge is never lost
  - MDA addresses *modernization challenges*
- **Managed Architecture is an new development approach focused at *evolution of existing software assets*. It emphasizes**
    - *excavation of an Architecture Model,*
    - proactive *enforcement* of architecture integrity
  - Addresses program comprehension challenge: re-capture preserve and accumulate the knowledge of the software,
  - Eliminates or slow down *architecture erosion* by visualization and impact analysis
  - *Refactoring* of the Architecture Model drives *modernizations*
- **Managed Architecture can also kick-start transition into MDA when the upfront model is not available**

Challenges of software production: new development

- **Developing new software is challenging:**
  - need to understand requirements
  - make decisions



How the client has explained his need

What was in the requirements specification

What was in the design specification

What was implemented

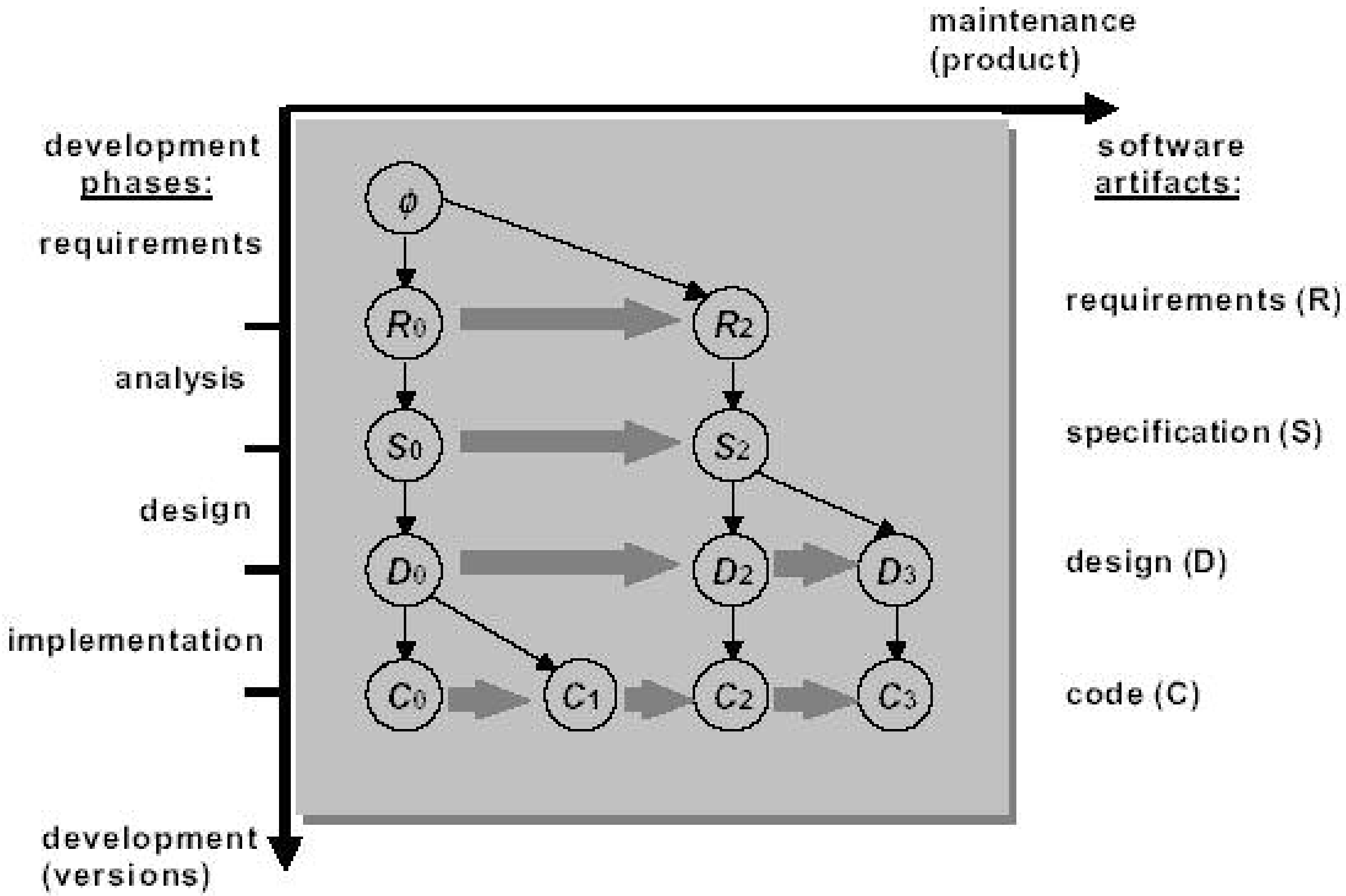
What the client needed

Adapted from www.oper.ru

Challenges of software production: evolution

- **Software production after the initial release has an additional *constraint* of dealing with *existing code***
- **Evolution of existing software *adds* new challenges:**
  - Make new decisions to change existing code and not to break existing features
  - Understanding existing decisions
  - The hierarchy of decisions requirements-architecture-design-code often not available; most information needs to be recovered from code
  - High volume and complexity of information
  - Evolution pace of documentation and code are different– there can be significant lags
  - Maintenance often assigned to junior staff
  - Loss of knowledge
  - Knowledge “walks away”

Challenges of multi-release production



From Schach,Tomer, 2001

Program comprehension challenge

- The costs of performing program comprehension have been widely cited as being between 50 and 90 percent of the overall cost of performing maintenance [Standish84]
- Program comprehension during software maintenance involves the acquisition of knowledge about programs, as well as accompanying documentation and operating procedures

From Boldyreff, 2002

High volume and complexity of information

- **Assuming 4,000,000 lines of software printed on listing paper covers 1 mile**

average data processing program is	0.06 mile
complete works of Shakespeare is	0.3 miles
BT customer support software	10 miles
Royal Bank Toronto	205 miles
total COBOL and C	**500,000,000 miles**

- **1/10 mile is baseline for person to understand**
- **Growth rate per year 2 Billion lines**
- **Estimations indicate Windows XP contains upwards of 50 million lines of code. The source code for NT doubles every 800 days.**

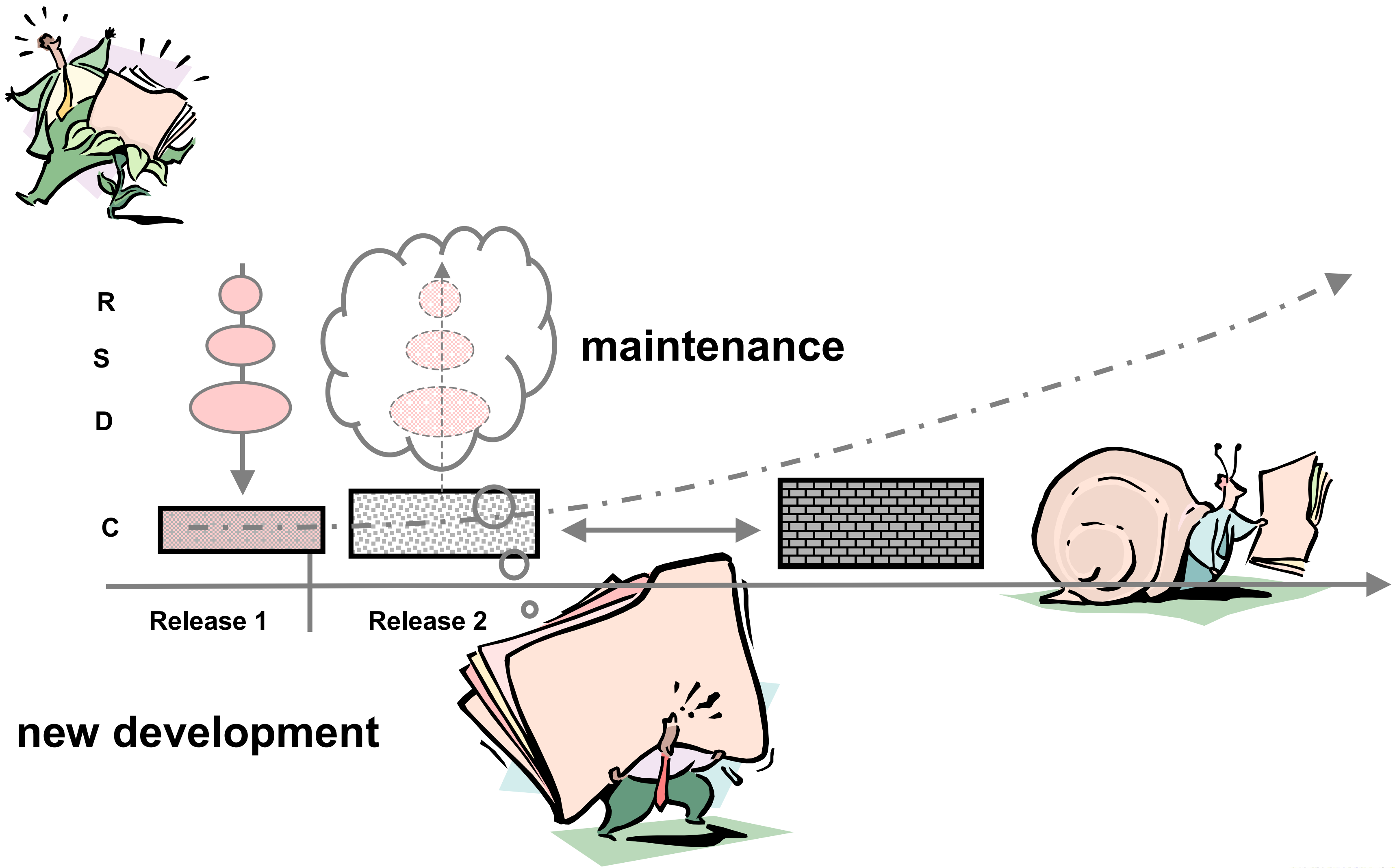
From Boldyreff, 2002

The Cost of Program Comprehension

- Program comprehension consumes a significant proportion of effort and resources
- HP estimated that reading code costs $200 million a year
- Maintenance expenditure increases as the age of the software increases since documentation becomes out of data or if it is carried out by maintainers other than the original developers
- Changes are necessary so these problems must be overcome

From Boldyreff, 2002

Program comprehension and production cost



Architecture Erosion

- ***Architecture Erosion*: Positive feedback between**
  - the loss of software architecture coherence
  - the loss of the software knowledge
    - less coherent architecture requires more extensive knowledge
    - if the knowledge is lost, the changes will lead to a faster deterioration
- **loss of key personnel = loss of knowledge**

Lehman's laws on program change dynamics

Law	Description
Continuing change	A program that is used in a real-world environment necessarily must change or become progressively less useful in that environment.
Increasing complexity	As an evolving program changes, its structure tends to become more complex. Extra resources must be devoted to preserving and simplifying the structure.
Large program evolution	Program evolution is a self-regulating process. System attributes such as size, time between releases and the number of reported errors are approximately invariant for each system release.
Organisational stability	Over a program's lifetime, its rate of development is approximately constant and independent of the resources devoted to system development.
Conservation of familiarity	Over the lifetime of a system, the incremental change in each release is approximately constant.

Program change

- **Prior to making a change it is essential to understand the software product as a whole. During maintenance this involves**
  - having a general knowledge of what the software does and how it relates to its environment
  - identifying where in the system the changes are to be effected
  - having an in-depth knowledge of how the parts to be corrected or modified work

The Impact of software change

- Productivity decreases for maintenance staff
- Cost increase for maintaining software
- Code is harder to understand
- Documentation become out of date
- The number of errors reported increases
- The original design becomes corrupted

Strategies for comprehension

- **Types of strategies applied are**
  - **systematic strategy**: using this strategy, the entire program is examined to establish the interactions between components. Maintenance begins only once the understanding process is complete i.e. when the maintainer considers the mental model to be accurate
  - **as-needed strategy**: using this strategy the maintainer only attempts to gain an understanding of part of the program. In this case, only a partial model of the software is devised before the modifications process begins

Plans

- **Much discussion by researchers in the field of program comprehension has concentrated on program plans**
- **Two levels of program plans are discussed**
  - At the lowest level we have what are termed 'rules of programming discourse'. These rules are said to be composed of the conventions of programming such as the use of meaningful variable names
  - The other types of plans are 'program plans'. These are said to be stereotypic action sequences such as a high level functional description of a loop. Programs are said to consist of a number of plans
- **If plans are well implemented, they can provide the maintainer with a high level of understanding of the program under maintenance**

Plans become de-localized over time

- Over time plans become de-localised, interleaved, merged or nested with other plans and thus their benefits for maintenance can be reduced
- The problem with the information plans provide is that the use of a as-needed strategy with de-localised plans can lead to incorrect assumptions being made about the way a program functions
- For this reason, while the as-needed strategy is a more realistic approach to tackling maintenance, it is also a risky process. Both systematic and as-needed strategies need to be applied but at different levels of detail

Results of analyzing files

- Increase in size of most applications
- Increase in the number of files
- Some files more highly maintained, others hardly ever maintained
- Plans become de-localised

Results of analyzing functions

- New functions are added to code
- Objects are created via a splitting process
- Call depth increases
- Over time the number of functions increases
- Call graphs have specific traits than can be used to spot legacy tendencies

Results of analyzing data

- Localized data items become de-localized

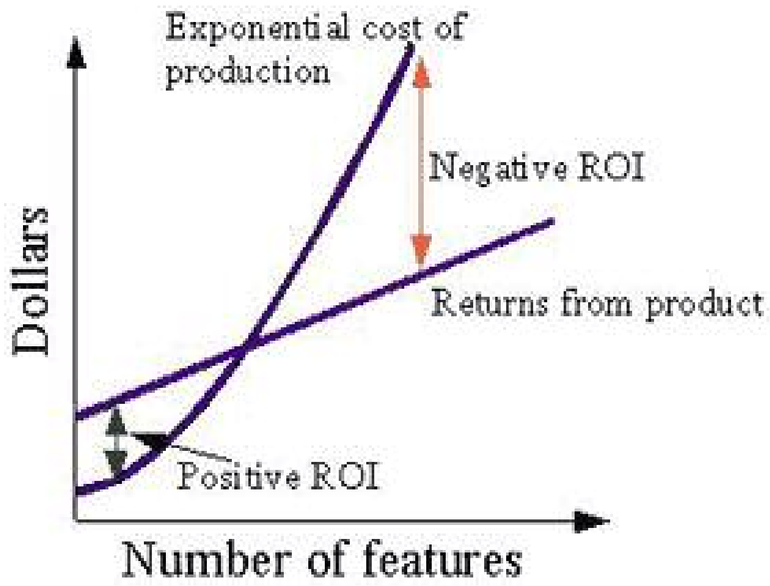
- Interfaces between modules become more complex

Implications for comprehension

- De-localised plans - modules of functionality are split
- More to comprehend as code becomes larger and more complex
- Larger impacts of change due to ‘globalization’ of data
- Documentation not kept up to date with changes

The cost of production increases over time

- **The cost of changing software increases over time, and is not linear, but exponential**
  - Brooks attributes the exponential rise in costs to the cost of communication
  - Maintenance corrupts the software structure so makes further maintenance more difficult
  - The number of error reports increases
  - Productivity of the maintenance staff decreases
  - Code becomes harder to understand
- ***Architecture Erosion*: Positive feedback between**
  - the loss of software architecture coherence
  - the loss of the software knowledge
    - less coherent architecture requires more extensive knowledge
    - if the knowledge is lost, the changes will lead to a faster deterioration
- **loss of key personnel = loss of knowledge**
- **Exponential cost of production may lead to *project failures* (Negative ROI)**

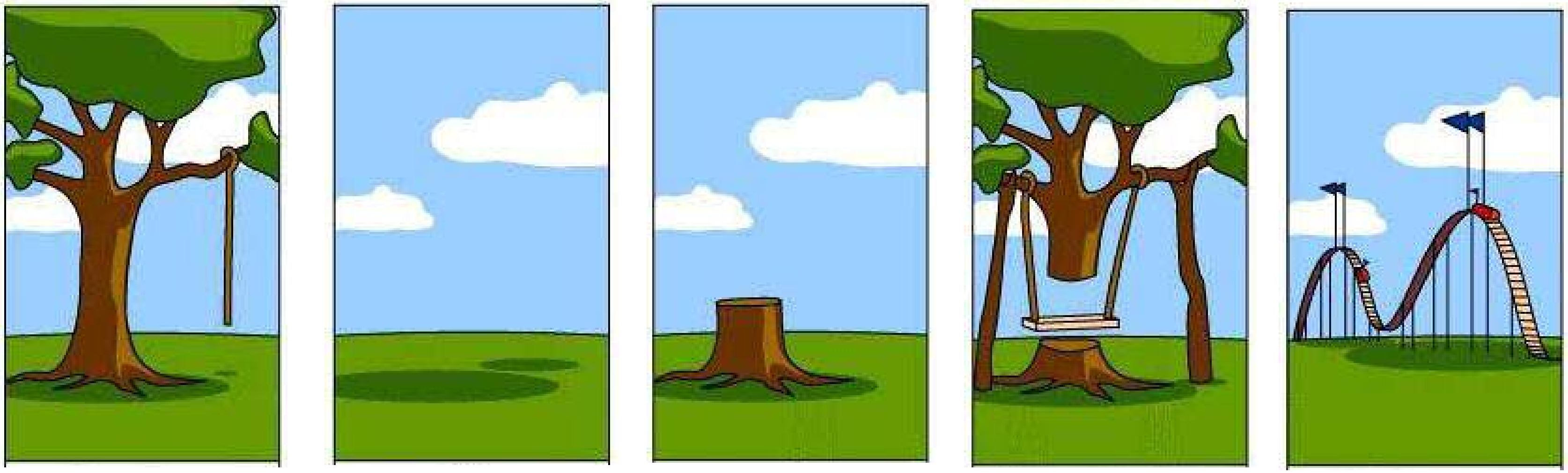


From C.Mangione, CIO Update, 2003

Need to manage the cost of production

- **Managing features vs “software infrastructure” to avoid negative ROI**
  - Manage new functionality and features
  - Improve “software infrastructure”:
    - Eliminate or slow down architecture erosion
    - Upgrade the robustness of the software infrastructure to balance the addition of the new features
- **Measures to eliminate or slow down architecture erosion:**
  - Preserve and accumulate knowledge
  - Restore architecture coherence
  - Proactively slow down erosion by visualization of the architecture and impact analysis
  - Refactor software to introduce better firewalls (localize design plans, scope the need for understanding and change; scope the impact of changes)

Challenges of the post-build production



What was in the second release

What features were working in the first release

What is the production cost

What was in the maintenance documentation

What was understood by reading the code

Adapted from www.oper.ru

Modernization

- **Modernization (beyond maintenance)**
  - Porting to a new platform
  - Migration to a new technology
  - Migration to COTS components
  - Modularization and refactoring

When do you need to modernize ?

Modernization can be caused by several factors:

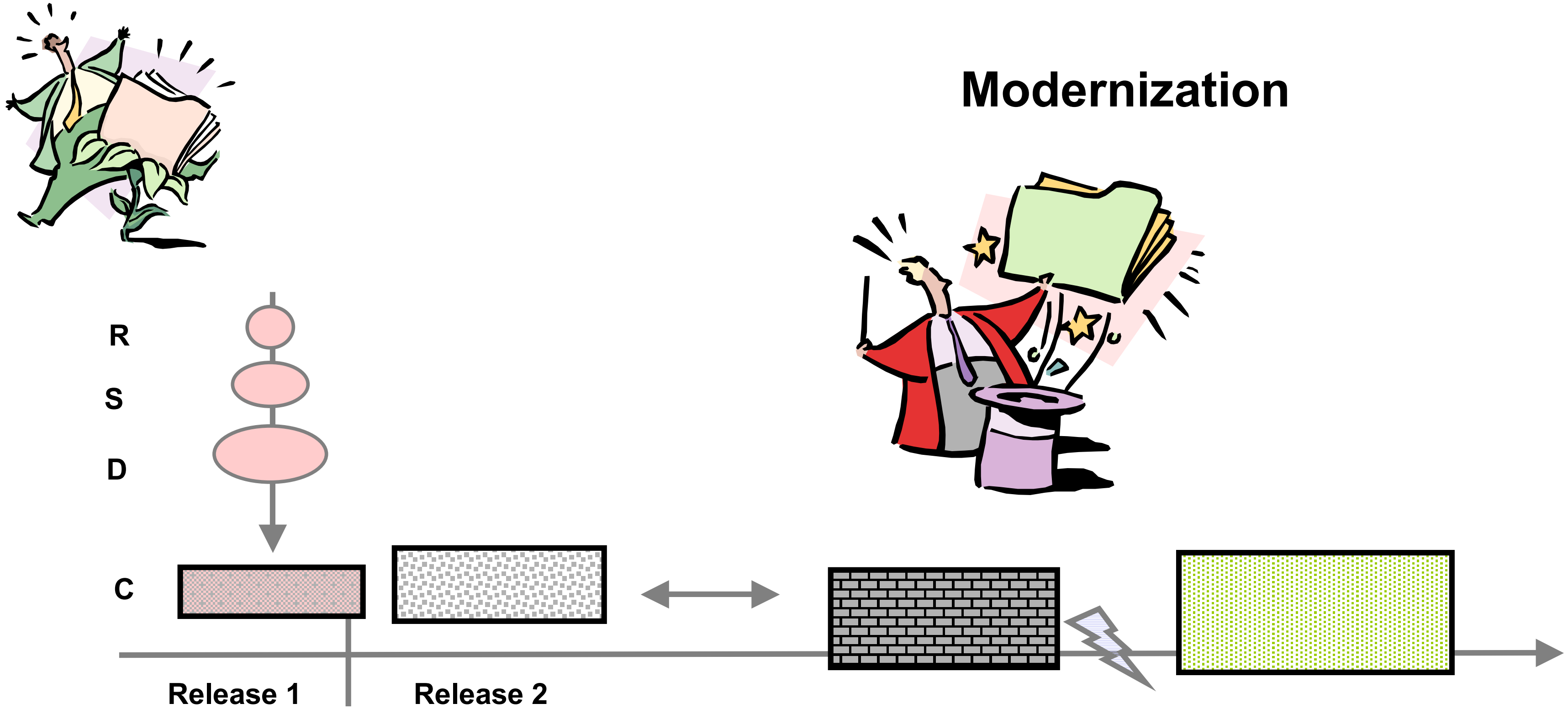
- **Major New functionality/Changes in functionality**
- **Modularization to improve reuse of the core software assets, esp. in an SPL**
- **Migration to standard COTS components**
- **Platform change or upgrade**
- **Modernization of software development technology**
- **Decision to improve robustness of software**
- **Outsourcing, reorganization of the company**

Aspects of modernization

Modernization may involve several different aspects:

- **Source code (programming language constructs)**
- **Design (algorithms, design patterns)**
- **Architecture (packages, components and their dependencies)**
- **Business rules (business processes, scenarios, requirements)**

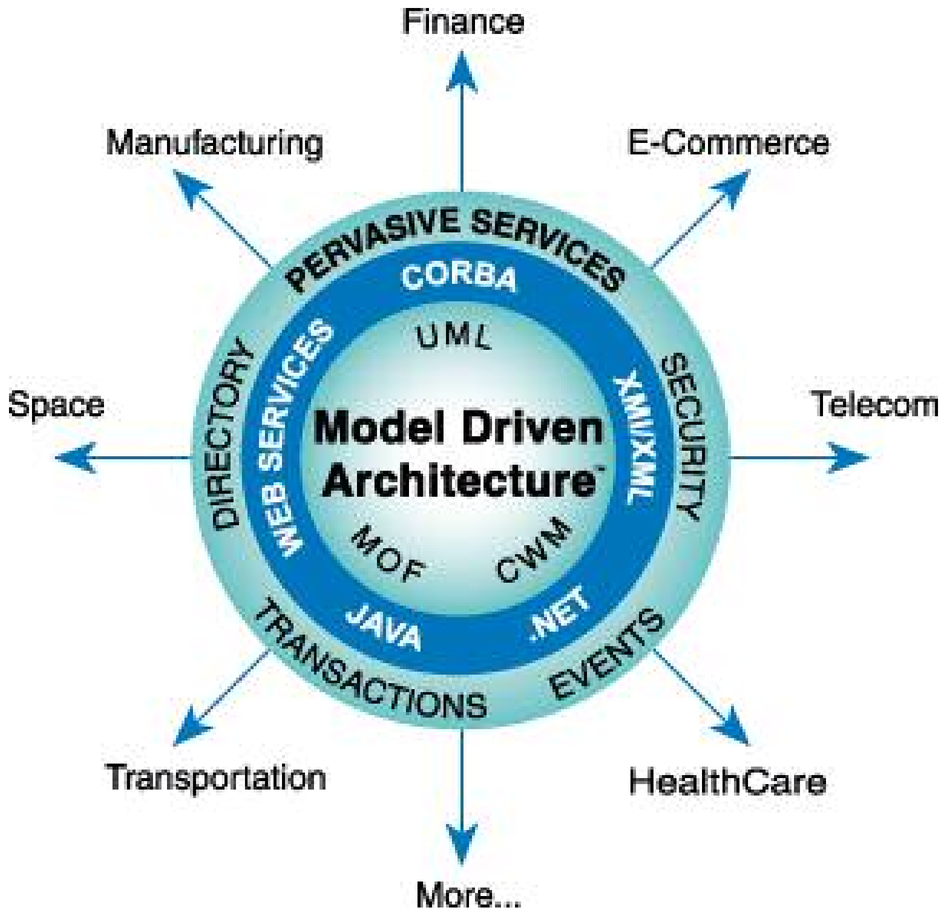
Modernization and production cost



new development

maintenance

Model Driven Architecture



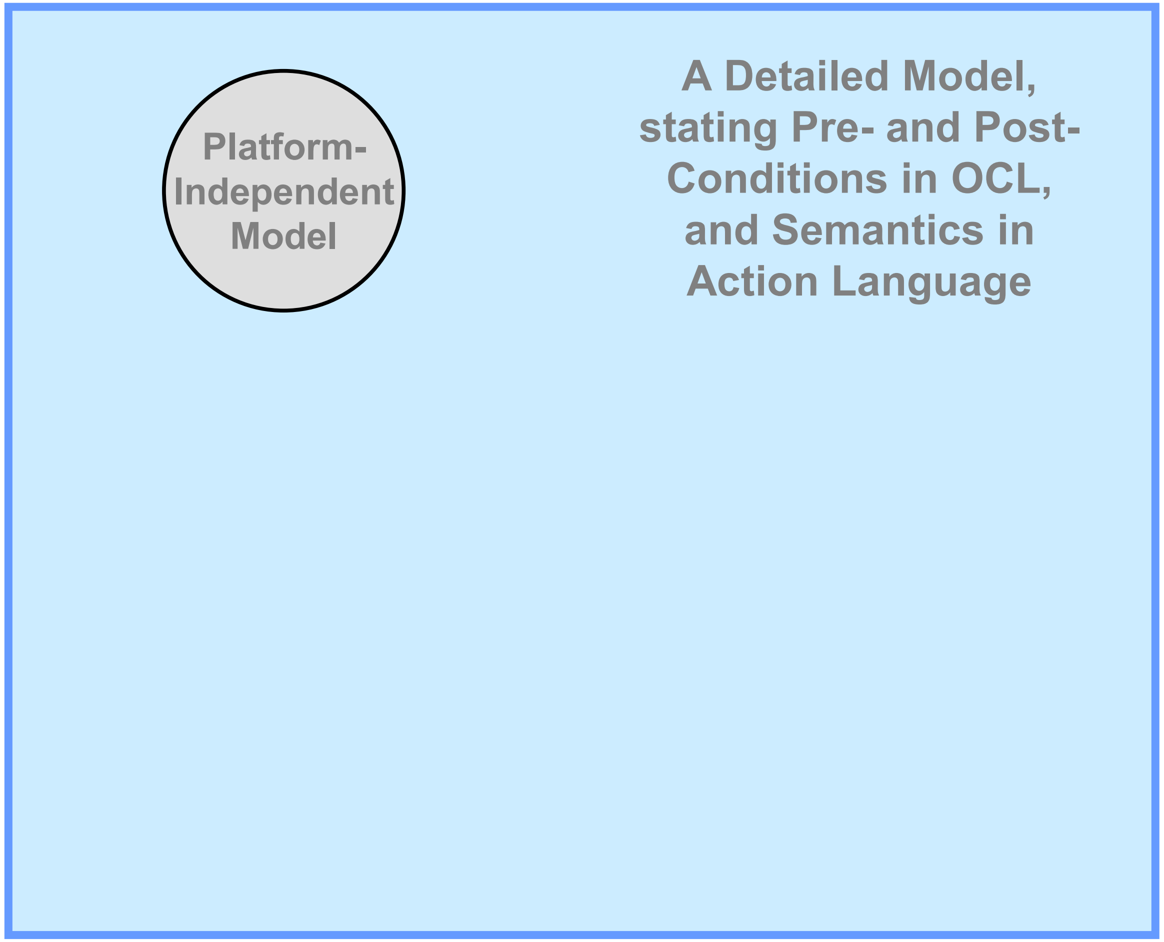
From R.Soley, OMG, 2003

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

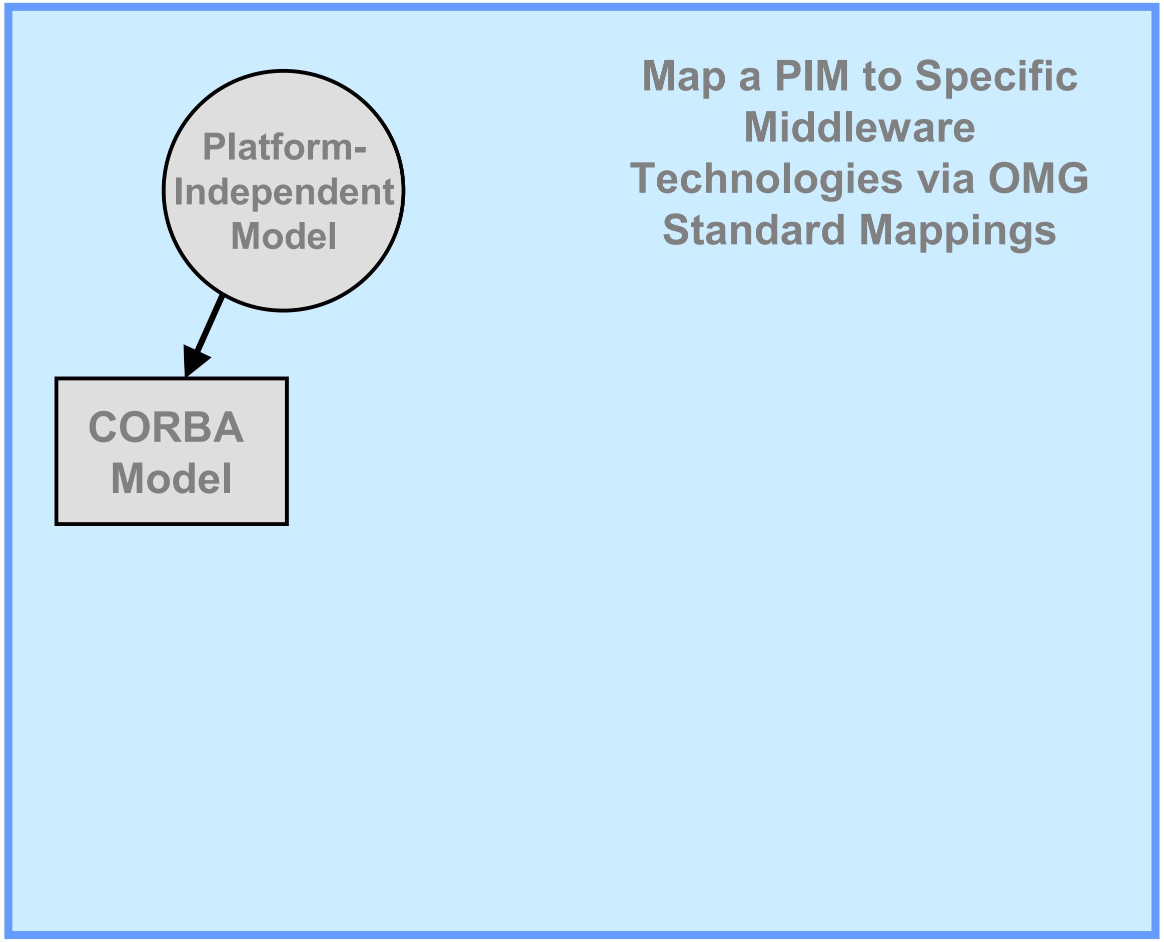
Building an MDA Application



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

From R.Soley, OMG, 2003

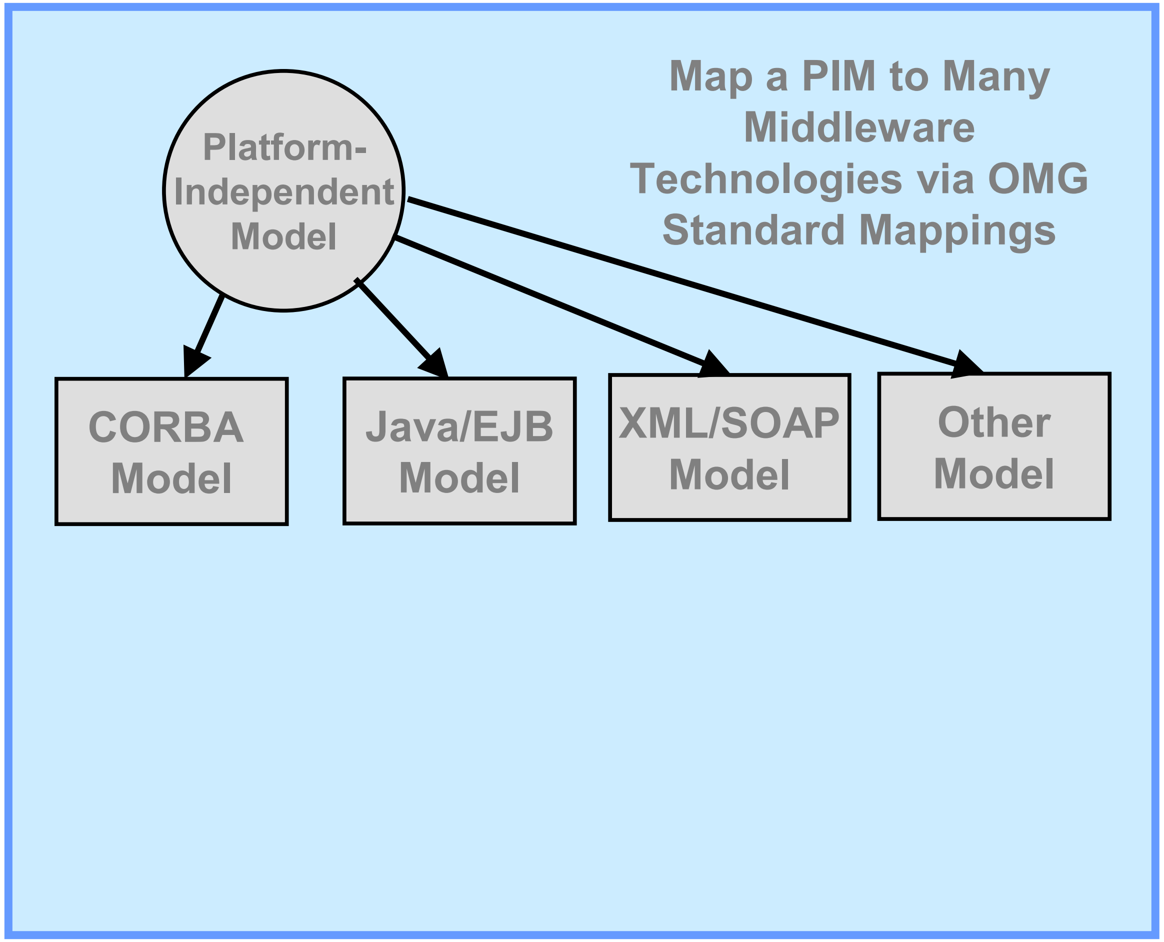
Generating Platform-Specific Model



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



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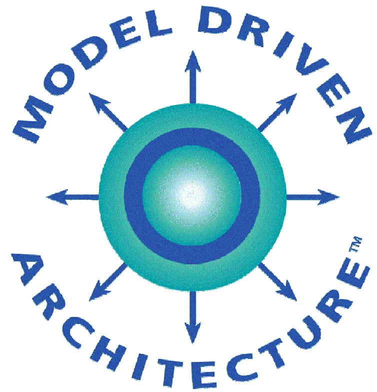
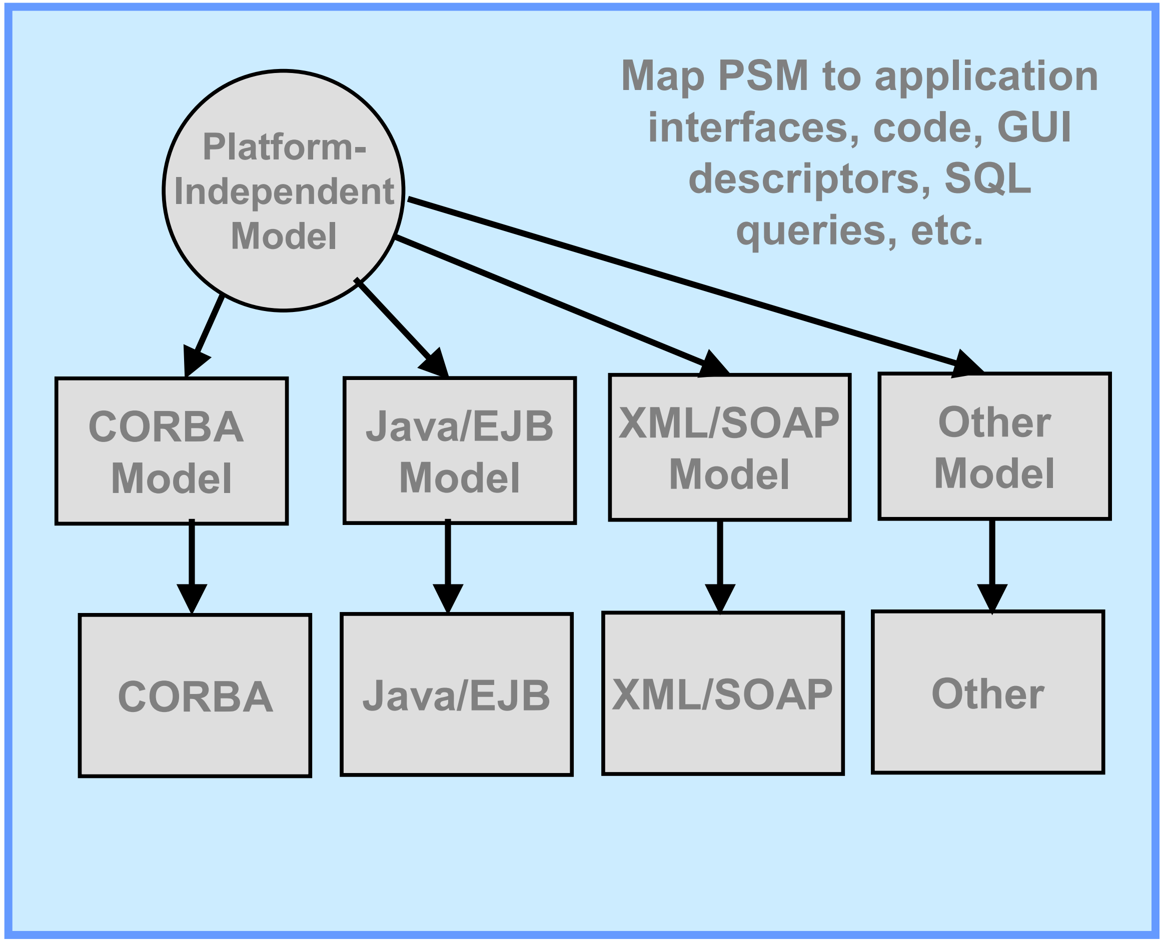


From R.Soley, OMG, 2003

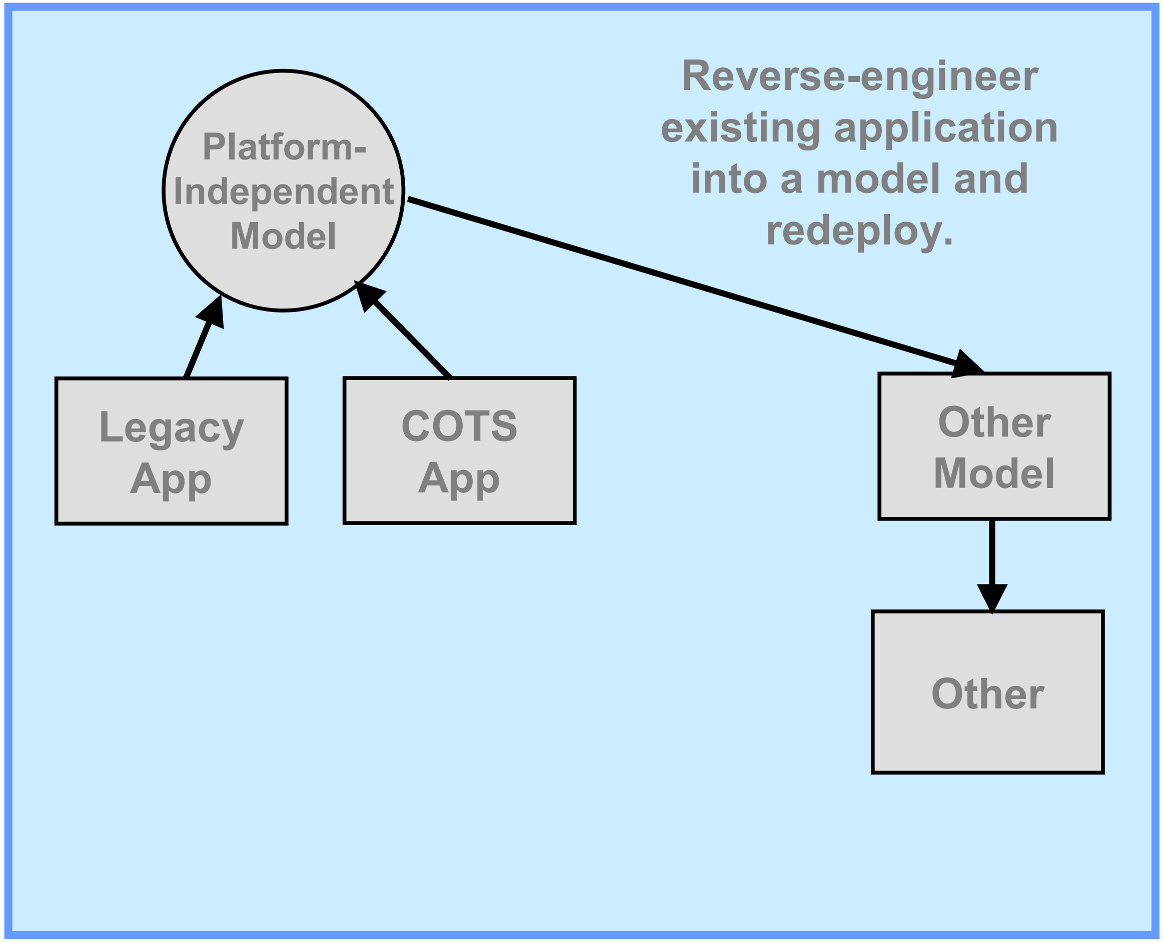
Generating Implementations



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



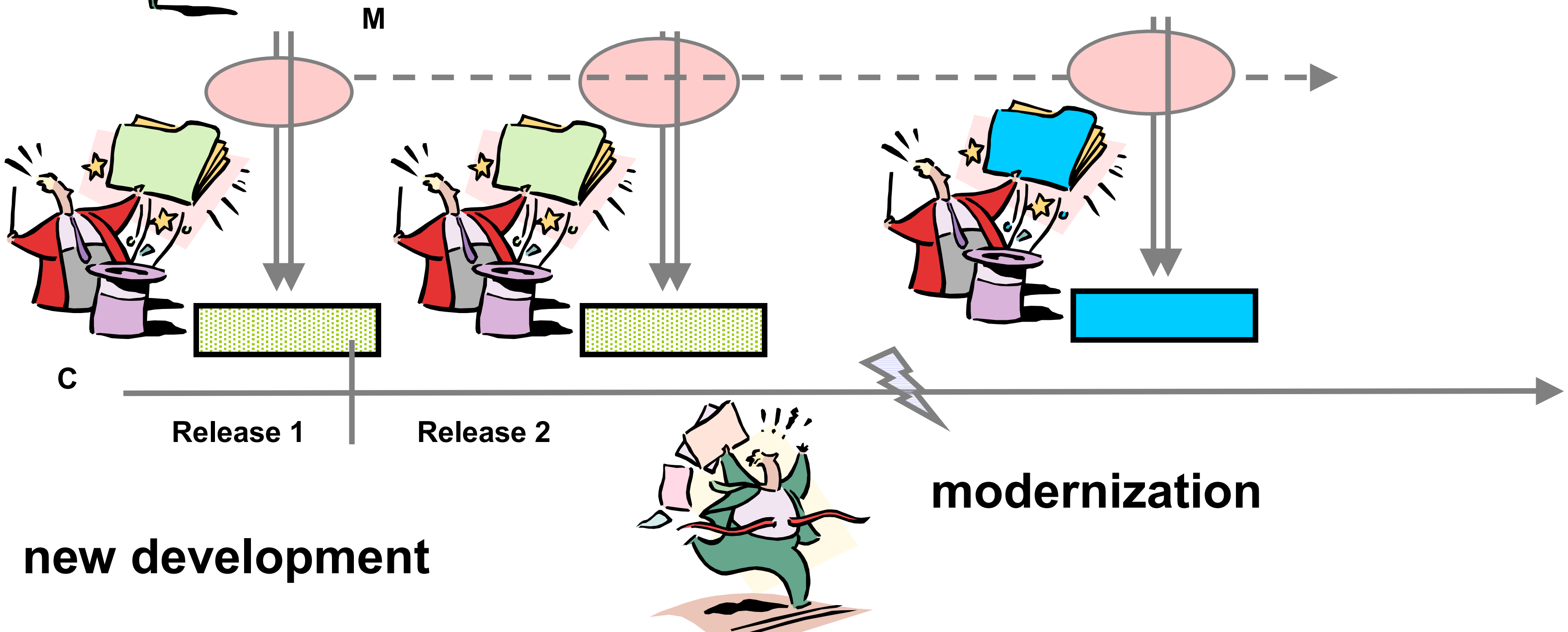
MDA Tools for reverse engineering automate discovery of models for re-integration on new platforms.

From R.Soley, OMG, 2003

MDA helps manage production cost

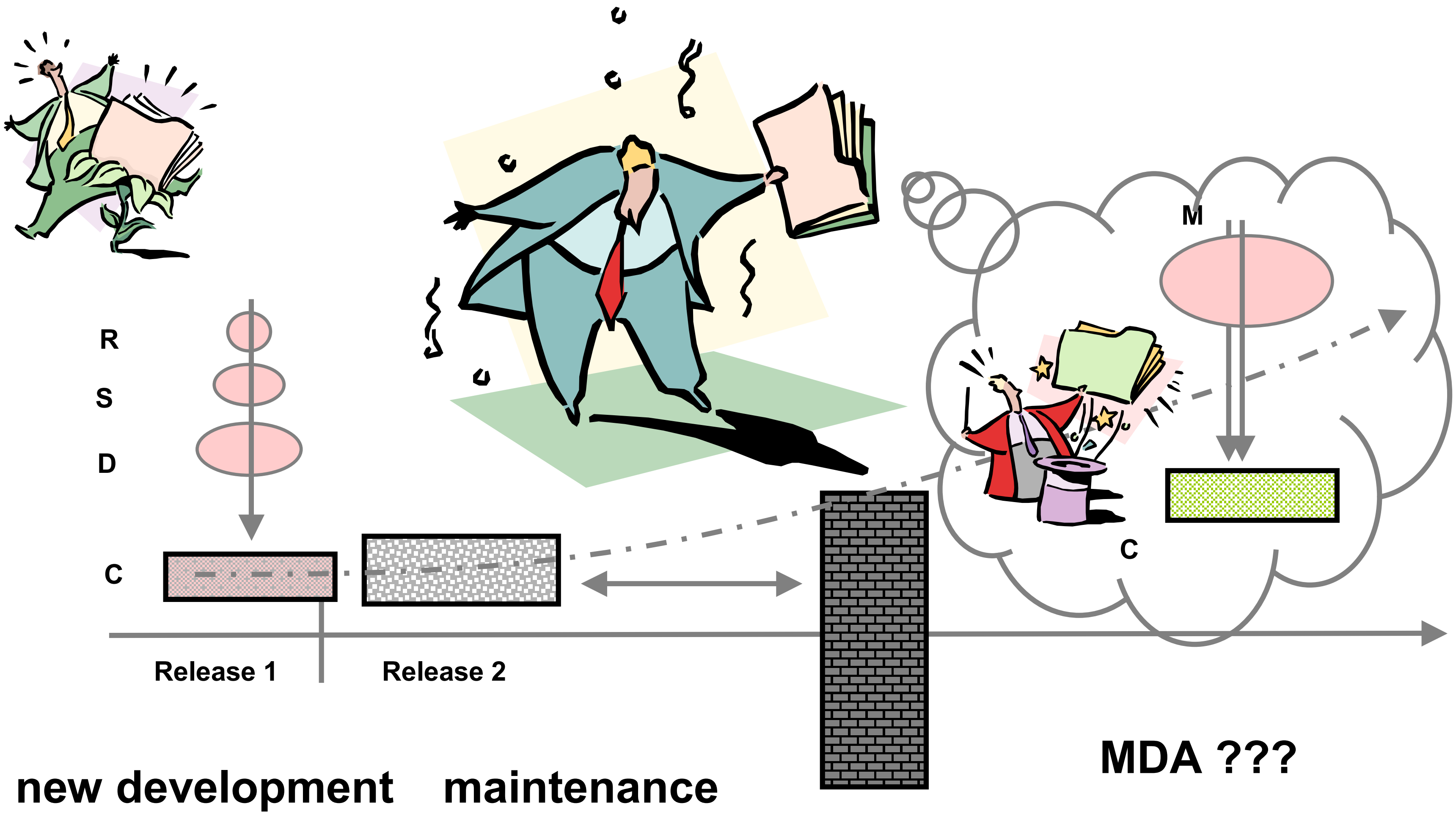
…by addressing program comprehension challenge…

…and modernization challenges…



maintenance=continued development

Existing code becomes the barrier for adopting MDA



Managed Architecture

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    - *excavation of an Architecture Model,*
    - proactive *enforcement* of architecture integrity
  - Addresses program comprehension challenge: re-capture preserve and accumulate the knowledge of the software,
  - Eliminates or slow down *architecture erosion* by visualization and impact analysis
  - *Refactoring* of the Architecture Model drives *modernizations*

Architecture Capability Maturity

- **Single aspect of SEI-CMM – refers to the architecture of the existing software**
- **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

Managed Architecture: overview

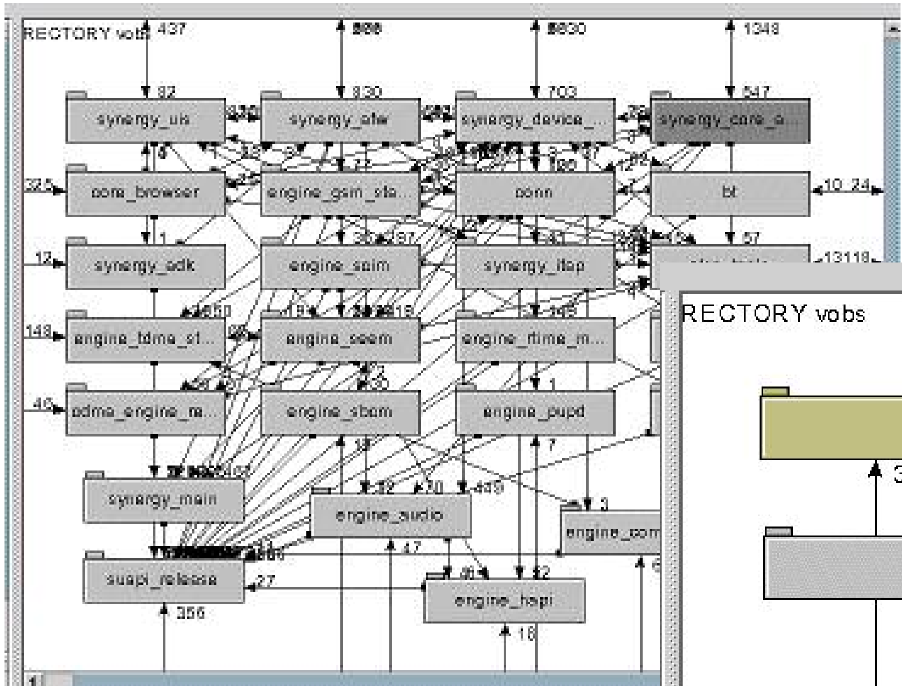
- **Visualize *Architecture* of the "as built" software as a *model***
  - "*Excavation*", because the model is likely to be created manually by abstracting from existing code
  - Abstraction level is *sufficient*, when the architect can
    - Explain the model to the team
    - Use the architecture model to detect anomalies
    - Plan refactorings through the model
    - Enforce integrity of the model

- **Align the "as built" model with the "as designed" description, if available**
- **Use the architecture model to detect anomalies and effects of architecture erosion**
- **Use the architecture model for impact analysis**
- **Use the architecture model for efficient program comprehension**
- **Change the architecture model to plan and implement architecture improvement**

Architecture Excavation summary

- **Build Architecture Model of existing code**
  - Scalable
  - precise
  - Can be automatically updated as changes are made to the code
  - Can be refactored
- **Model visualizes the effects of architecture erosion**
- **Model allows understanding code**
- **Eliminates or slows down erosion:**
  - Restore architecture cohesion, therefore slowing down architecture erosion
  - Proactively slow down erosion by impact analysis
  - Plan modernizations to improve the robustness of the software infrastructure as the new features are being added
- **Model preserves and accumulates the architectural knowledge about the software**
- **Architecture model is shared among the whole development team**
- **Model is changed to drive new development**

Excavated high-level architecture



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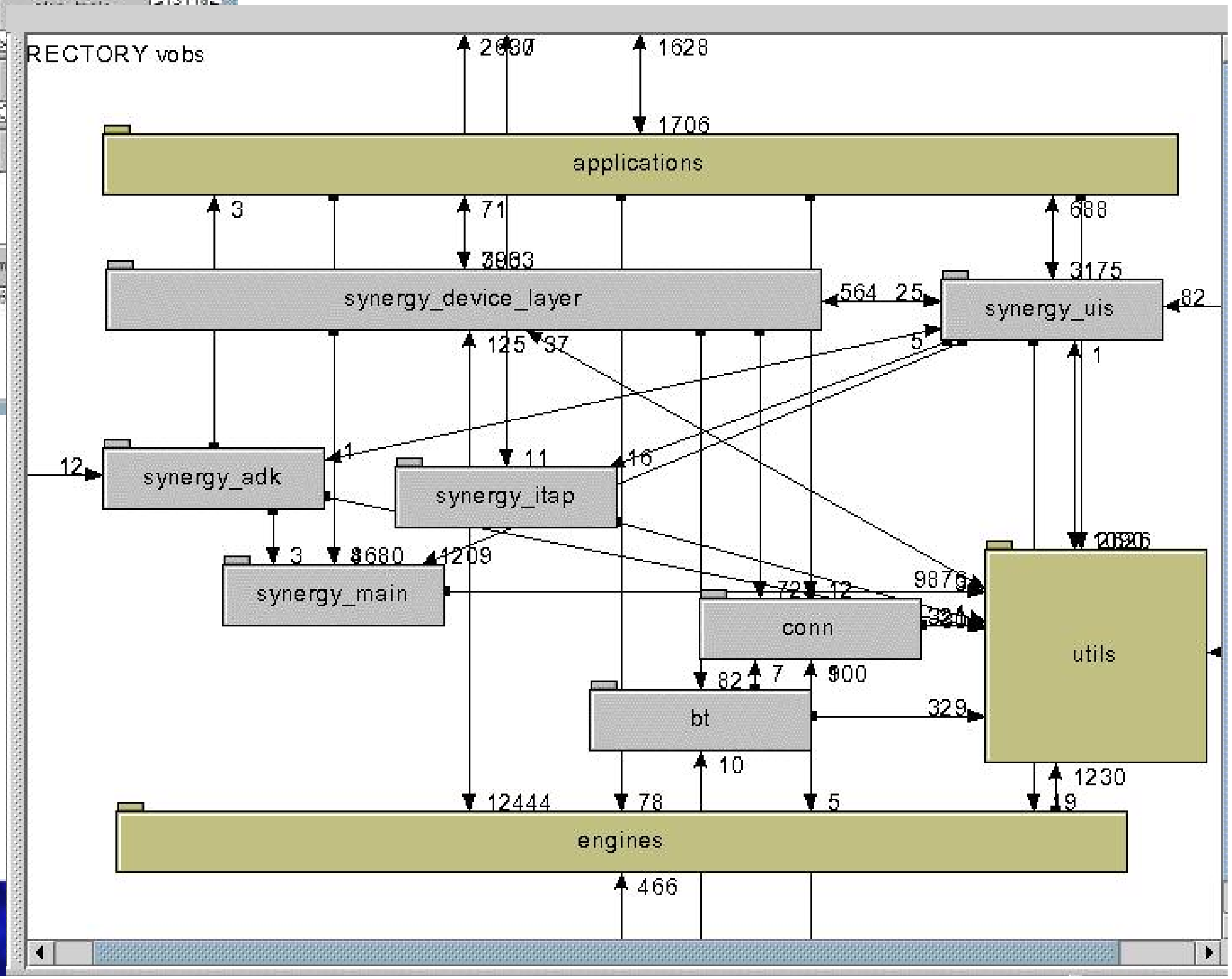
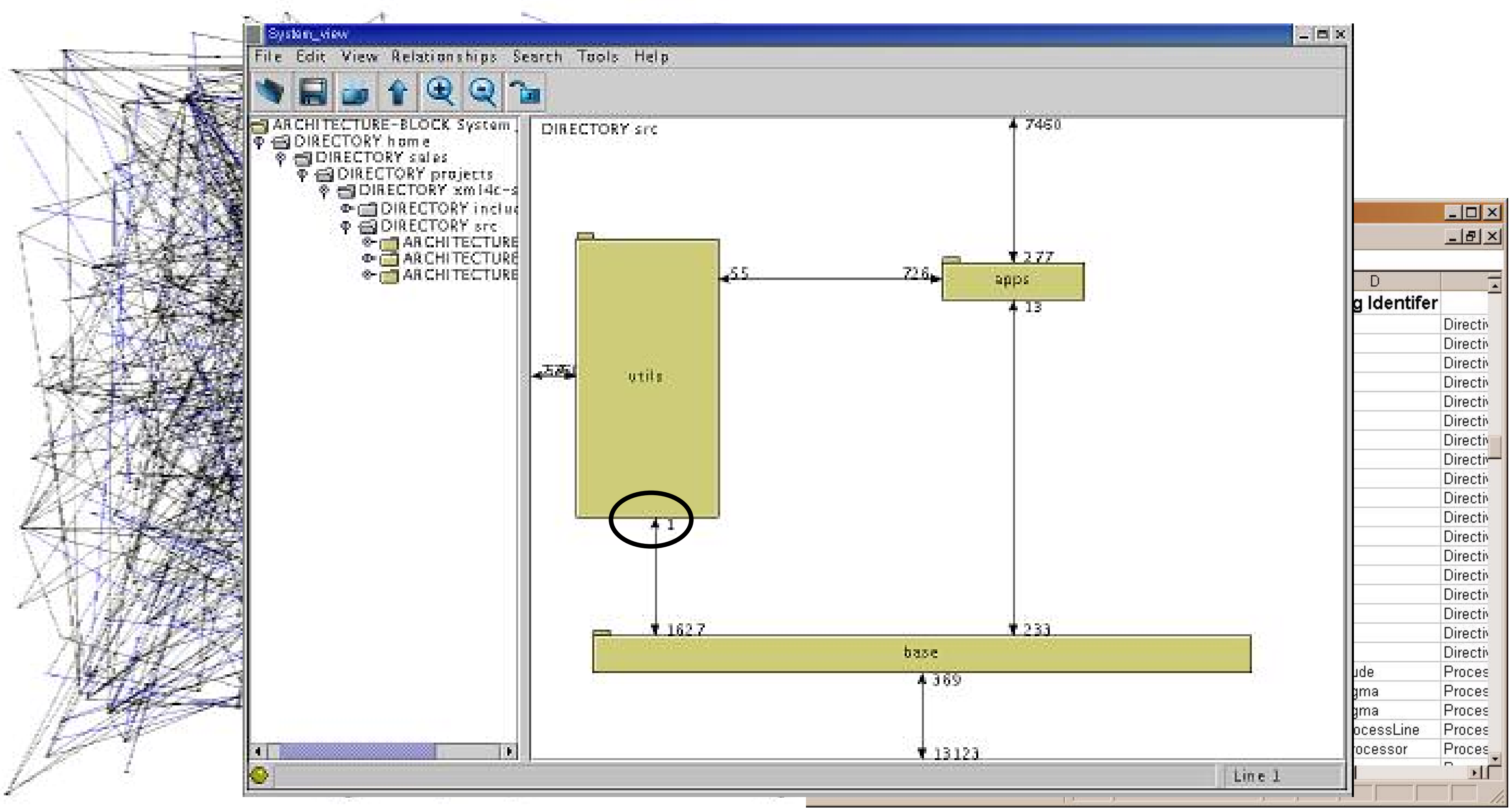


after

Why SW Architecture is so hard?

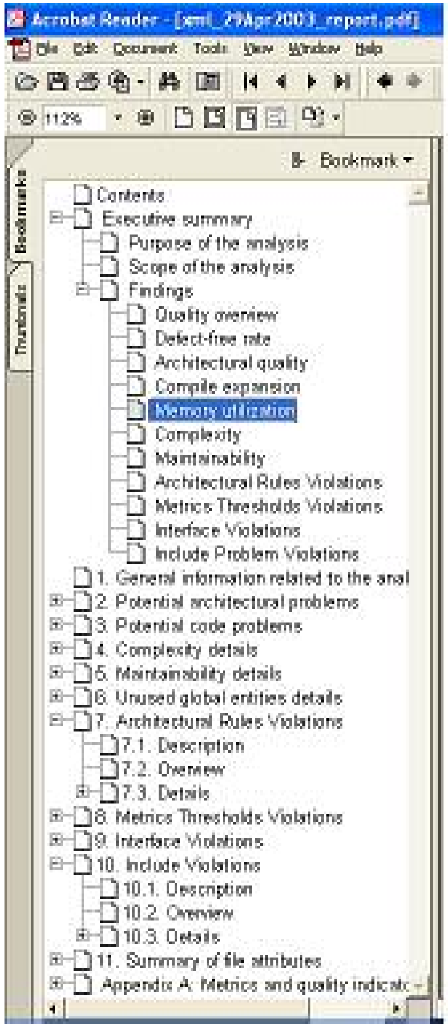
- **Because we think code is the most important thing our development teams produce**
  - Human beings will optimize any <u>single</u> indicator of success
- **Because architecture is not visible or tangible in any way**
  - You can’t manage what you can’t measure
- **Because all our processes and tools are focused on the “programming in the small” problems (i.e. code)**
  - code inspections processes
  - debuggers
  - xref
  - tools to measure code coverage under test
  - tools to detect memory leaks
  - run time profilers
  - IDE’s, Languages, SCM systems

OK – How do we manage it?



inForce System

SWOT Source Code Analysis



inForce System software analysis report

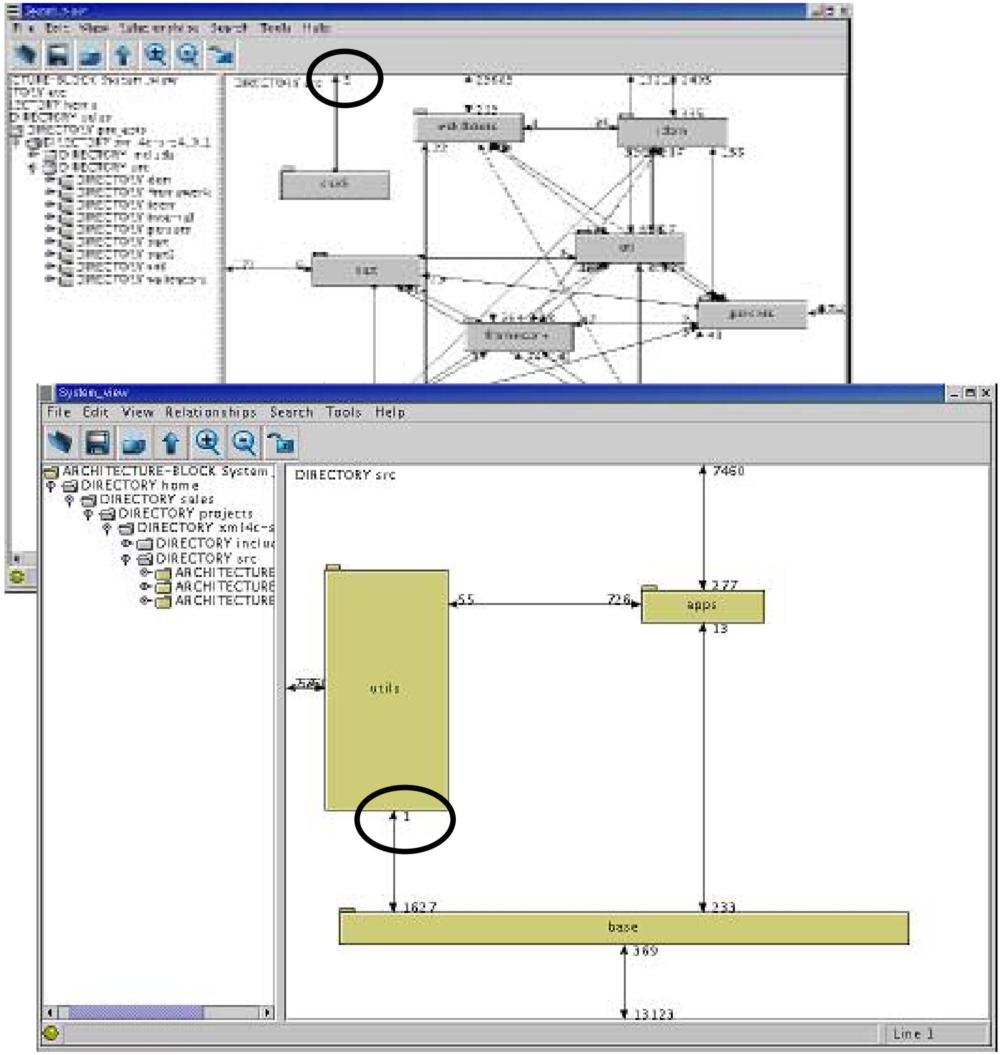
- **Comprehensive**
- **System level understanding**
- **Every build**

- **Architecture and design issues**
- **Code defects and metrics**

- **Coding and design rule violations**
  - Encapsulate build rules
  - Set baseline architecture
  - Define and enforce APIs

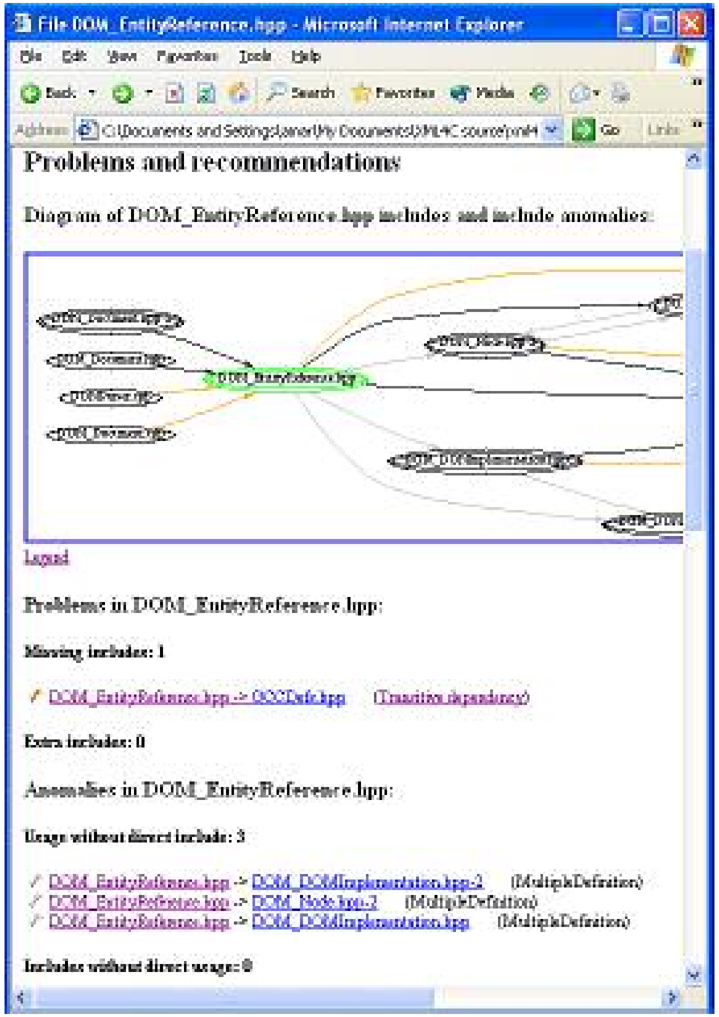
inSight Architect

Design Analysis



- **System Design**
  - Understand
  - Visualize
  - Customize
- **On-the-fly changes**
- **Every build**
  - "Analyze what you build": all compile flags, directives, macros expanded prior to analysis.
- **External environment**
- **Design anomalies**

inSpect System
Source Code Analysis

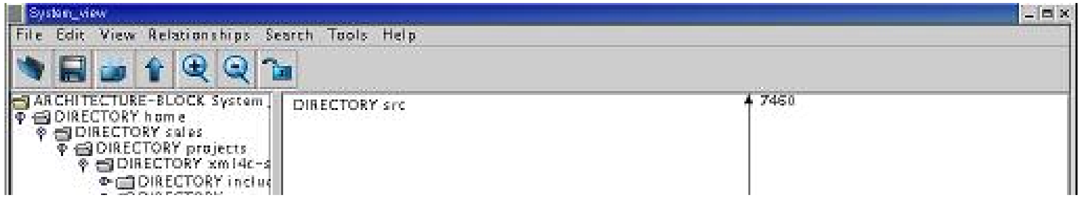


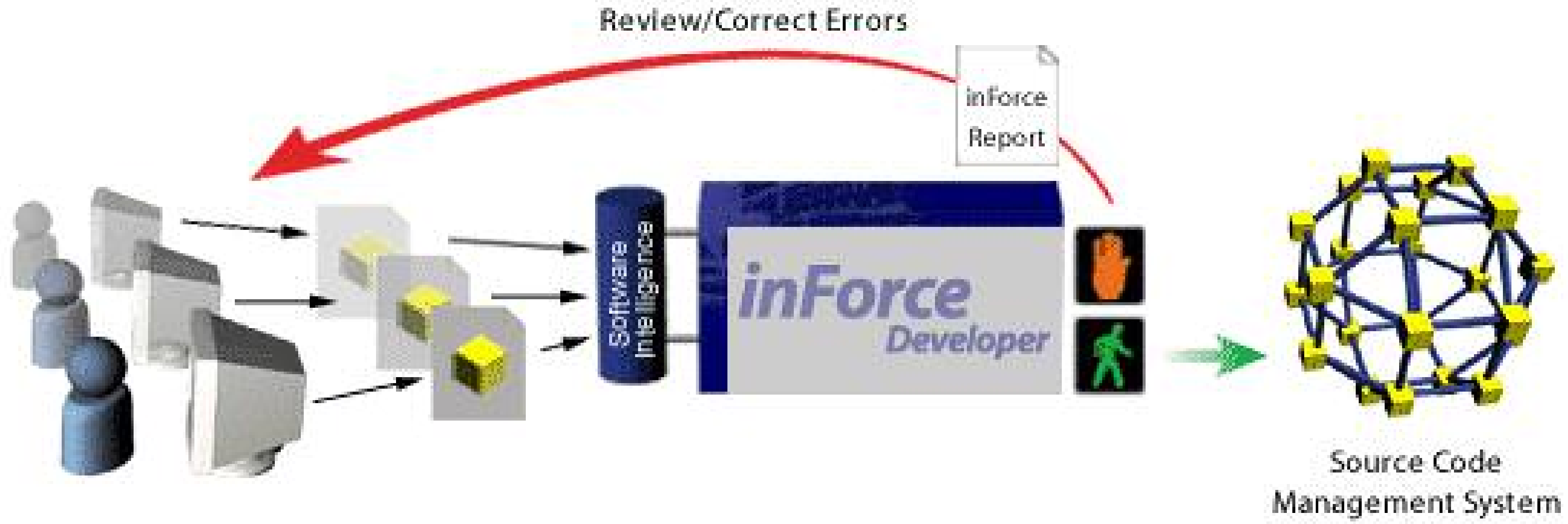
- Expansive hyperlinked report
- System-scoped recommendations
- Detailed dependency analysis

Managed Architecture: Enforcing Integrity

- **Architecture rules**
- **Metrics**
- **Strategies of enforcement**
  - Desktop
  - Clearcase
  - Post-build

…and how to enforce architecture?

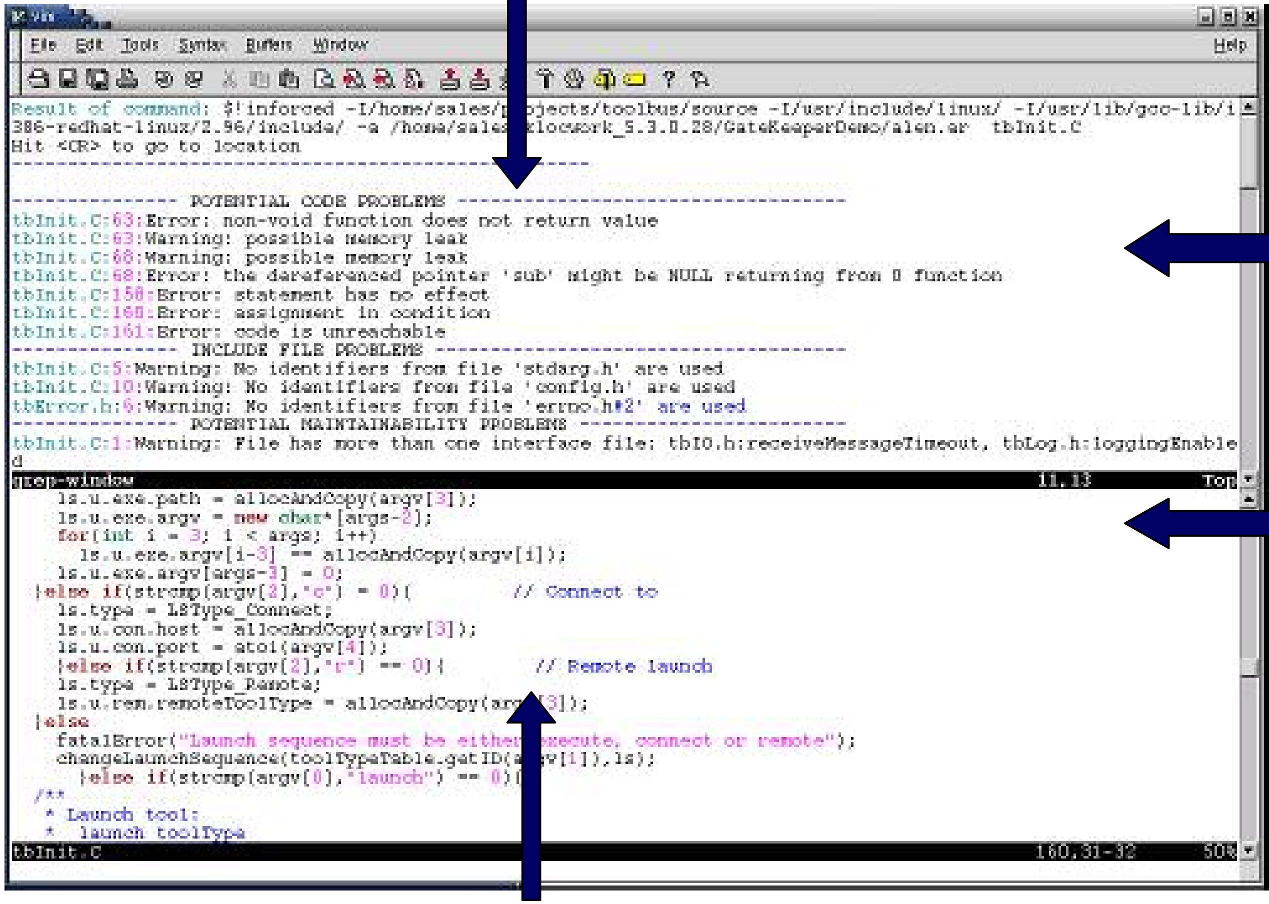




inForce Developer

Productivity and Quality Control

inForce Developer report in gvim editor



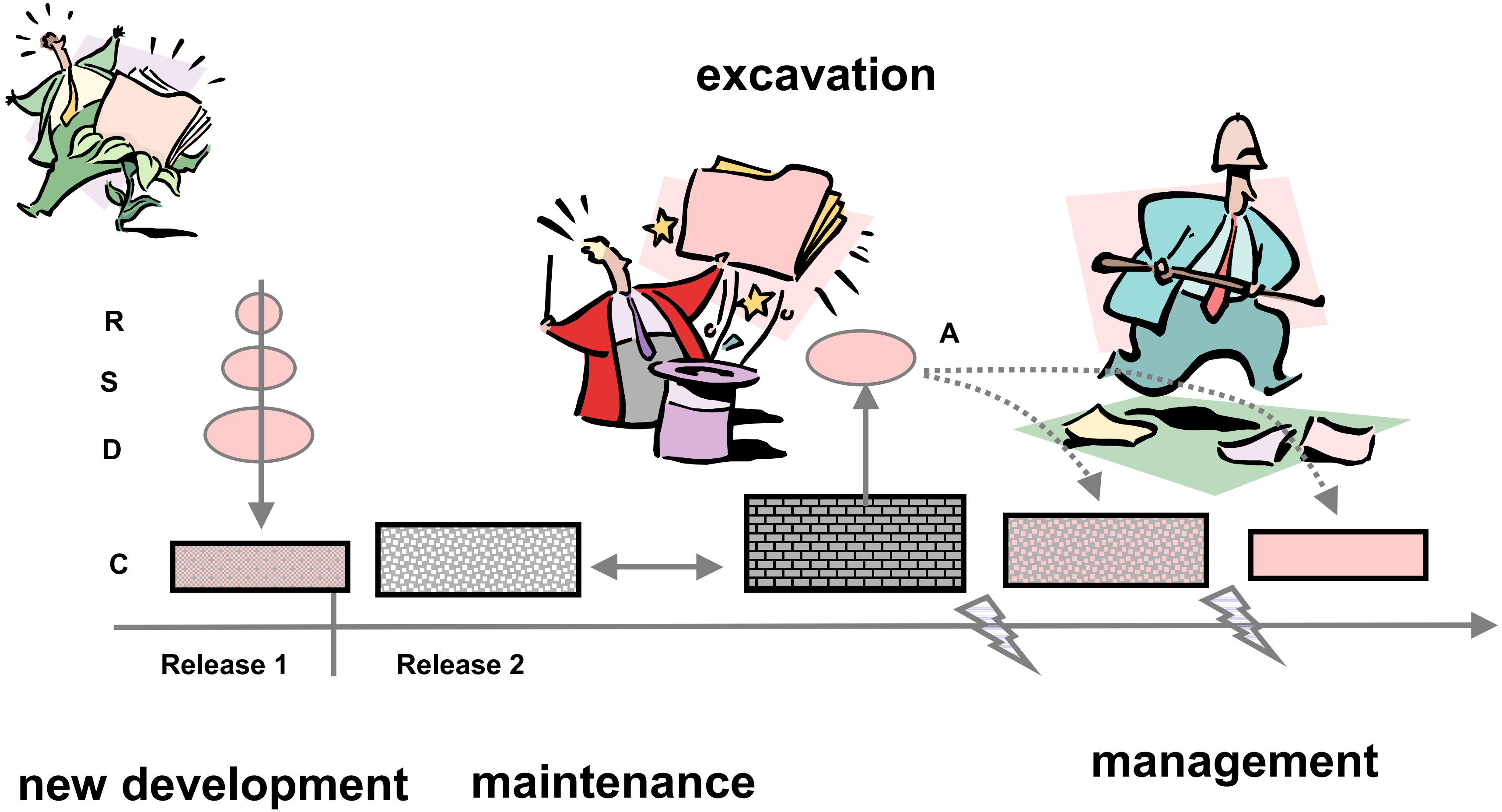
1- Pick a problem here

- Coding problems
- Security vulnerabilities
- Design infractions
- Metric violations
- Include anomalies

2- Jump to the line to analyze and fix it here

View and edit source code

Managed Architecture and Production cost



Managed architecture: Refactoring

- **Use the architecture model to proactively *refactor* software**
  - Initial refactorings to remove physical irregularities
  - Minor refactorings to restore architecture cohesion
  - Larger refactorings to improve architecture robustness
  - Major refactorings (modernizations, reuse, redevelopment)

Refactorings, supporting harvesting for reusable components

- Locate functionality to be reused, encapsulate in a new virtual component
- Identify additional dependencies of the new component
- Follow dependencies, analyze and add to the new component
- Refactor remaining dependencies (usually, inversion, or adaptor layer)
- Confirm results

Refactorings, supporting adoption of standard COTS components

- Locate functionality to be retired, encapsulate in a new virtual component
- Split new component into core and adaptor
- Identify architecture mismatches with the new COTS component
- Refactor to match
- Introduce placeholders for new components
- Identify new adaptor layer to the COTS component
- Implement refactoring
- Add missing functionality to placeholders
- Create stub for the new COTS component
- Confirm results

Refactorings, supporting platform changes and upgrades

Platform – all system software, including operating system, standard run-time libraries (e.g. graphical libraries), middleware, any other external 3rd-party run-time components (e.g. Web-browser, Web-server, Application Server, etc.)

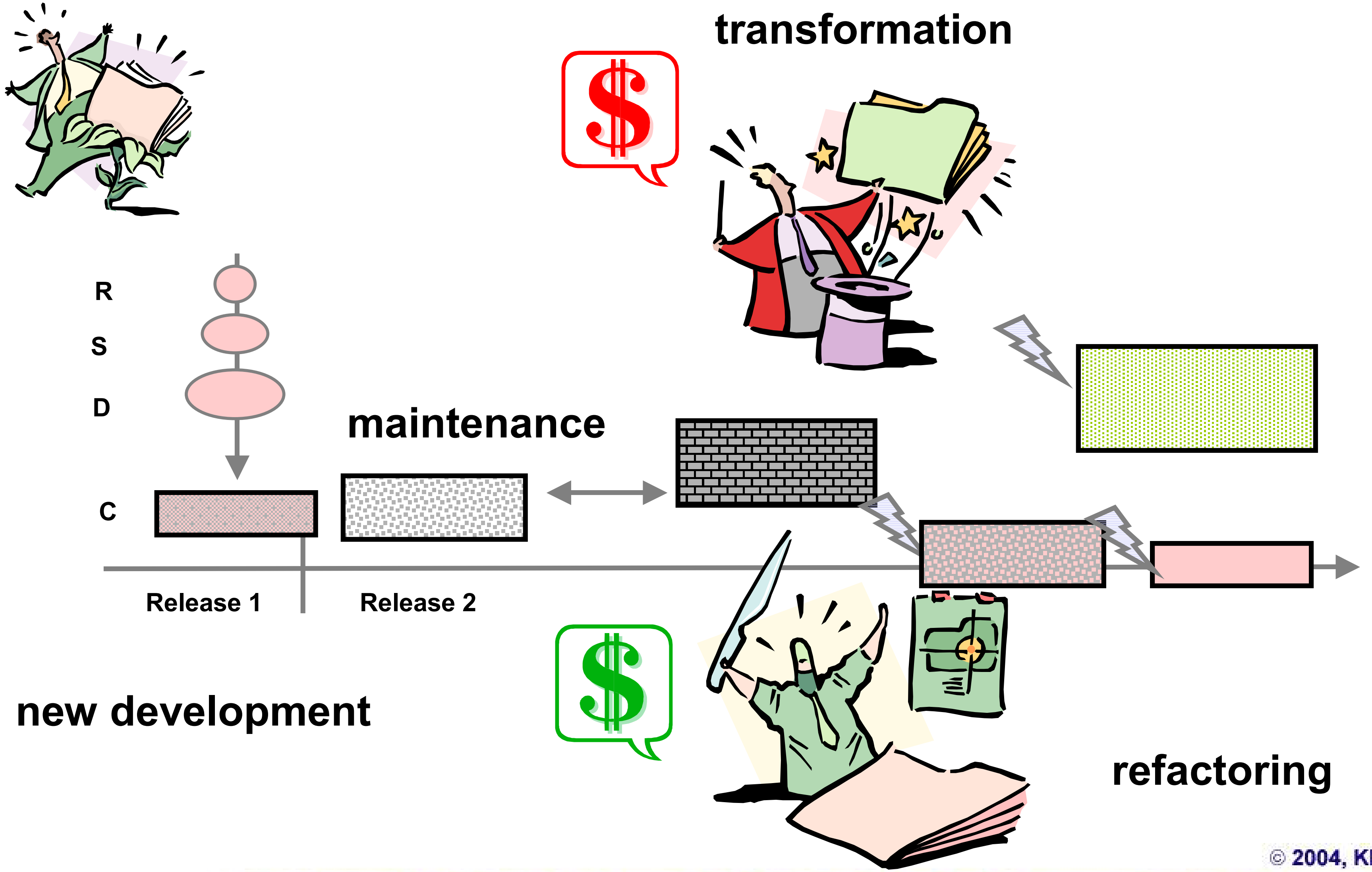
- Locate old platform usage, encapsulate in a new virtual component
- Identify adaptor layer
- Refactor adaptor
- Identify inverted dependencies
- Refactor inverted dependencies
- Introduce placeholders for new functionality

Refactorings, supporting modernization of sw development technology

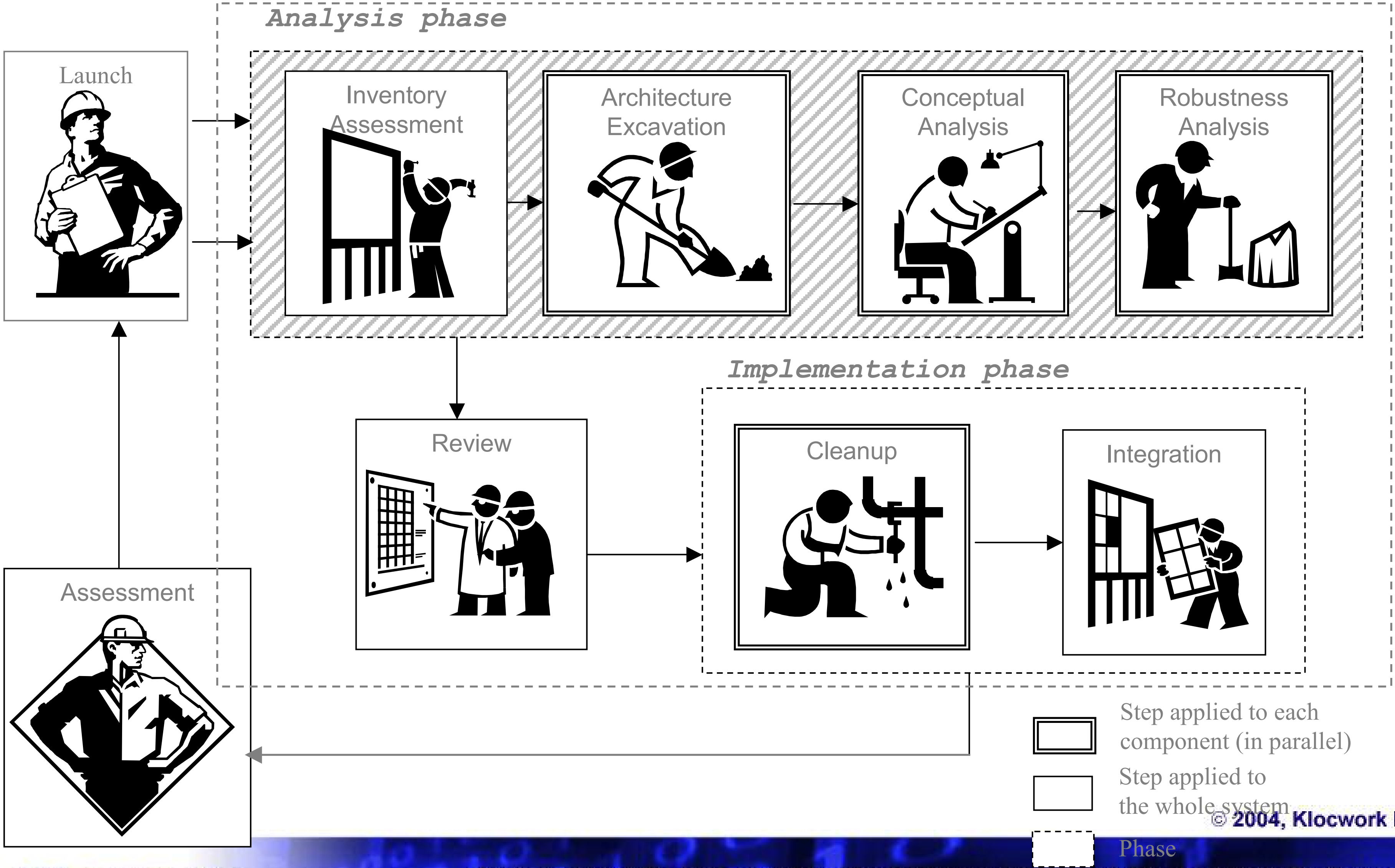
Software development technology – all modeling languages, programming languages, etc., and the corresponding tools (such as compilers, macroprocessors, build automation systems, code generators, simulators, etc.)

- Migration, related to the changes in the development environment
- Porting into another programming language
- Migration into MDA

Production cost: Big-Bang Transformation and Refactoring



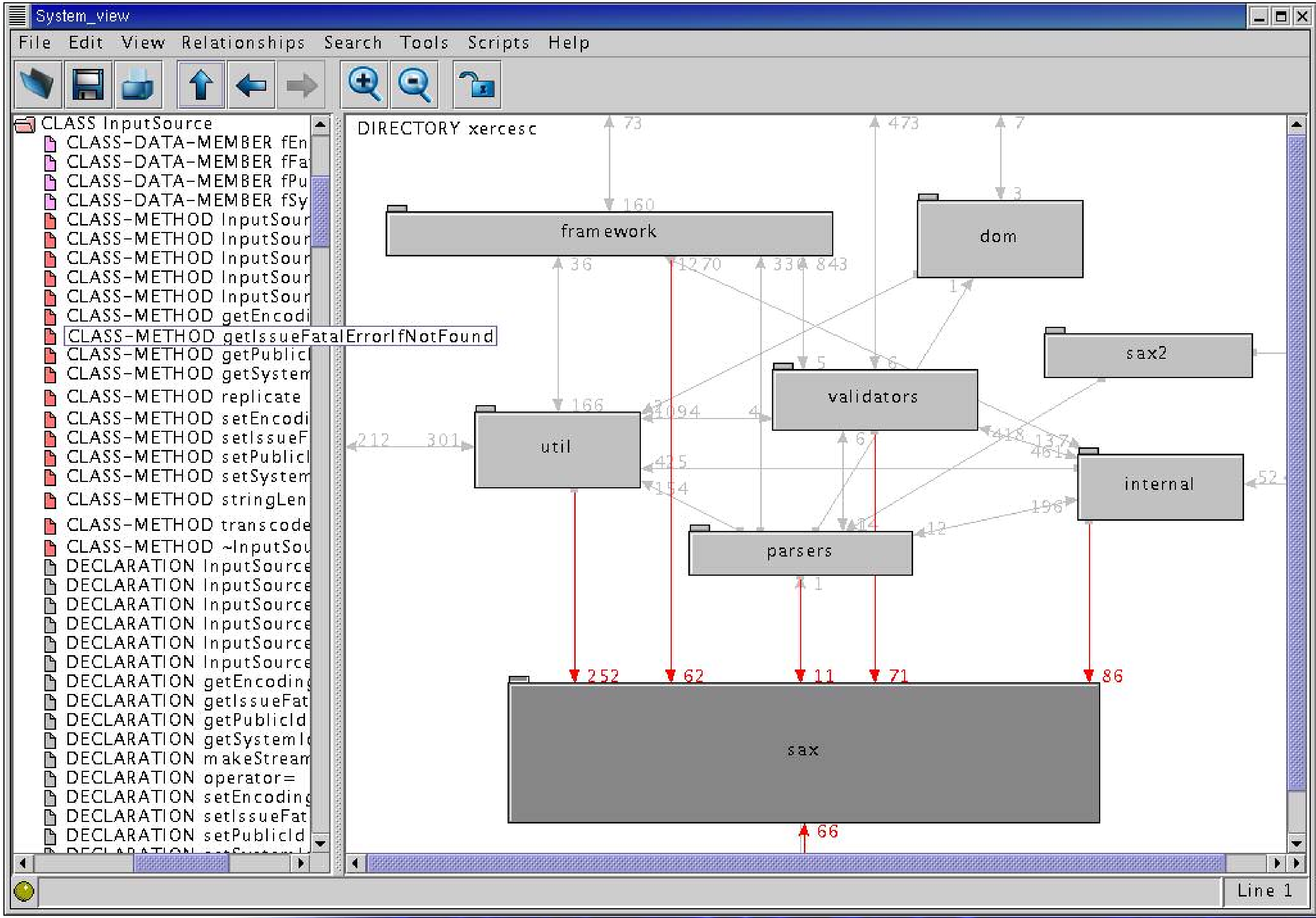
Software evolution with Managed Architecture



Transition to MDA

- Architecture Models for Managed Architecture are 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

Generating UML component view



Interface of the selected component

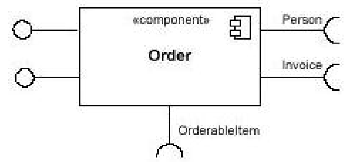
Internal interfaces of block "DIRECTORY sax" (74)

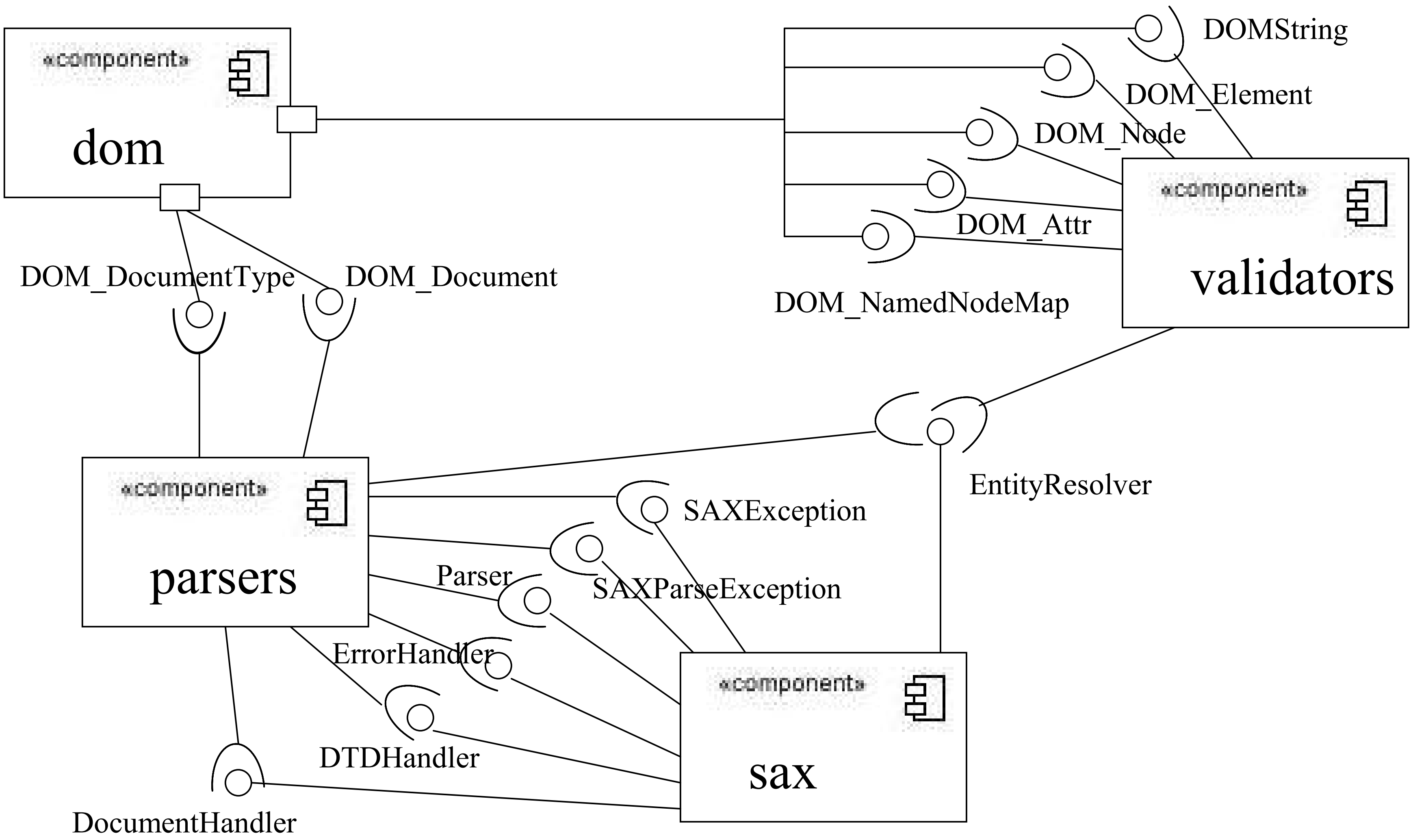
xercesc
sax

uses Identifier	in File	Density
	SAXParseException.hpp	8
	EntityResolver.hpp	7
	ErrorHandler.hpp	6
	Locator.hpp	4
	Parser.hpp	3
	DocumentHandler.hpp	2
	InputSource.hpp	13
	HandlerBase.hpp	1
	AttributeList.hpp	2
	SAXException.hpp	3
	DTDHandler.hpp	4
AttributeList	AttributeList.hpp	1
DocumentHandler	DocumentHandler.hpp	4
characters	DocumentHandler.hpp	1
endDocument	DocumentHandler.hpp	1
endElement	DocumentHandler.hpp	6
ignorableWhitespace	DocumentHandler.hpp	1
processingInstruction	DocumentHandler.hpp	1
resetDocument	DocumentHandler.hpp	1
setDocumentLocator	DocumentHandler.hpp	1
startDocument	DocumentHandler.hpp	1
startElement	DocumentHandler.hpp	3
DTDHandler	DTDHandler.hpp	6
notationDecl	DTDHandler.hpp	2
unparsedEntityDecl	DTDHandler.hpp	2
resetDocType	DTDHandler.hpp	2
InputSource	EntityResolver.hpp	10
EntityResolver	EntityResolver.hpp	16
resolveEntity	EntityResolver.hpp	4
ErrorHandler	ErrorHandler.hpp	20
warning	ErrorHandler.hpp	4

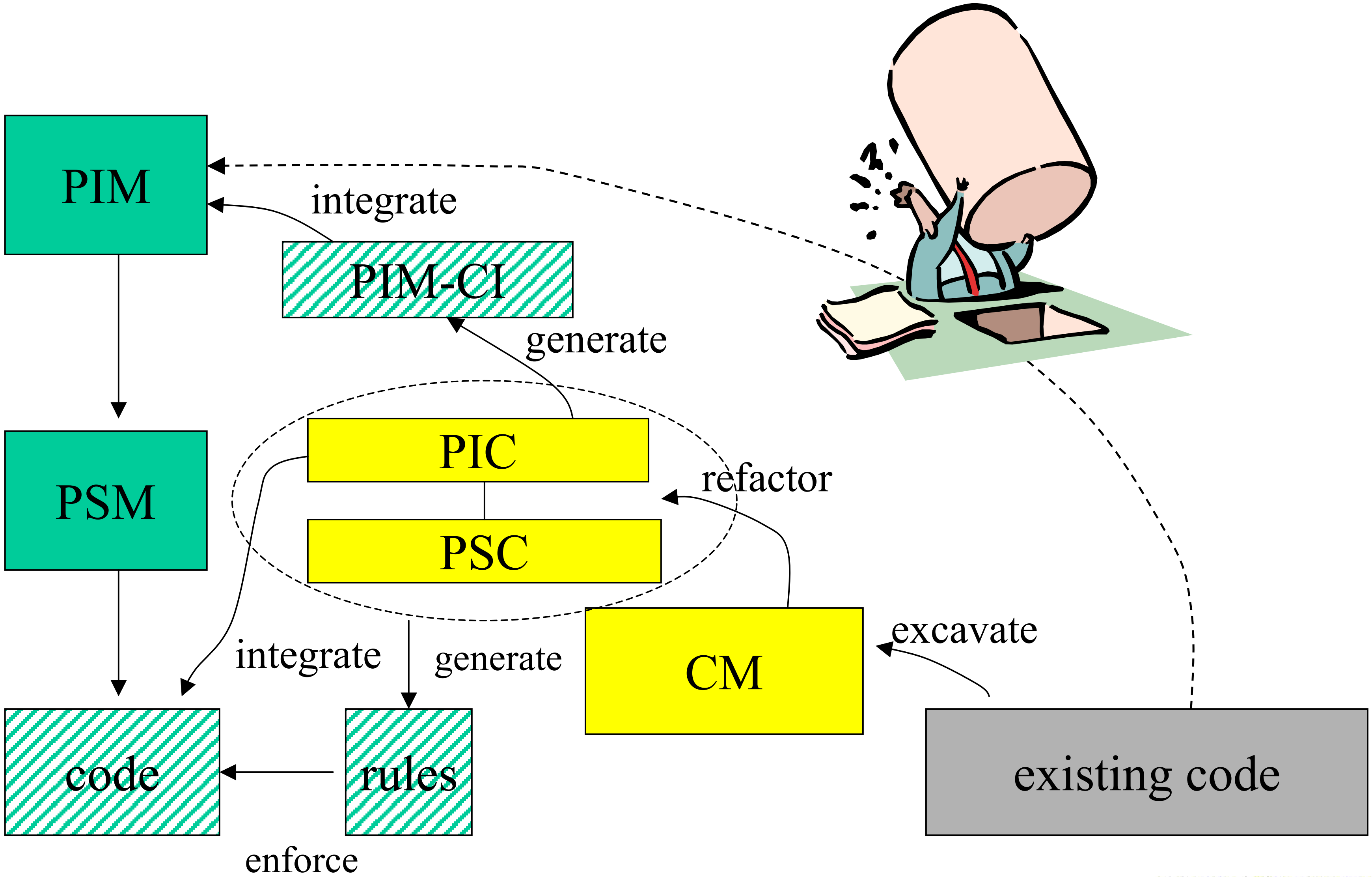
Export Relationships Close

UML 2.0 Component diagram





Architecture-driven migration to MDA



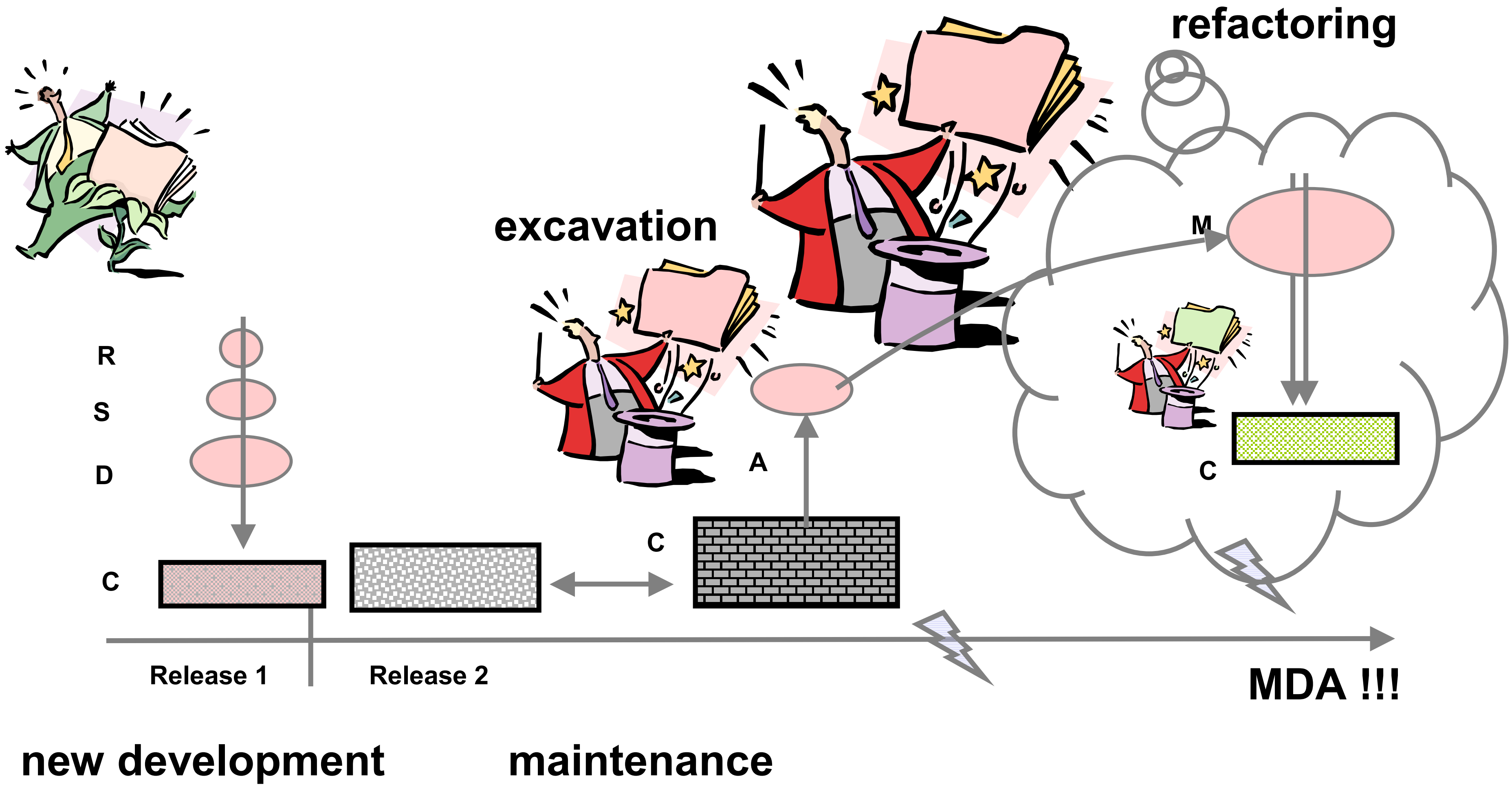
Architecture-driven migration to MDA

- **First step is to understand existing software assets**
- **Then identify and isolate platform-specific assets**
  - Refactor existing assets into platform-independent layer and platform-specific layer
- **Perform Architecture Excavation (recovery and refactoring)**
  - Top-level model
  - As many levels as necessary, as little as possible
  - physical irregularities are removed
- **Decoupling platform-specific from platform-independent layers**
- **Clean-up to improve design and architecture (optional)**

Architecture-driven migration to MDA– cnt’d

- **Generate UML model(s) for platform-independent components, import into UML tool**
  - Contains components and interfaces
  - Does not model behavior
  - Is precise with respect to the existing (re-factored) code
- **Use generated models to generate platform-specific skeletons (e.g. to migrate to new platform)**
- **Use generated model to interface newly developed components to it**
- **Generate Adaptors to integrate automatically generated code with legacy components (optional)**
- **Generate rules to enforce excavated design**

Managed Architecture can kick-start MDA



Remaining challenges

- Maturation of MDA tools
- Addressing behavior modeling, not just components and their interfaces

Conclusions/Key points

- **For vendors of software-intensive products the evolution of existing code base is a vital part of day-to-day software development and maintenance. Modernization is used when the regular maintenance can no longer address the changes.**
- **Managed Architecture is an new development approach focused at *evolution of existing software assets*. It emphasizes**
    - *excavation of an Architecture Model,*
    - proactive *enforcement* of architecture integrity
  - Addresses program comprehension challenge: re-capture preserve and accumulate the knowledge of the software,
  - Eliminates or slow down *architecture erosion* by visualization and impact analysis
  - *Refactoring* of the Architecture Model drives *modernizations*

Conclusions/Key points

- Transition to MDA has strategic, long-term benefits for organizations. Modernization in the context of MDA creates the model of the code for the purpose of importing it into MDA-enabled development environment
- Managed Architecture Approach can be used as a migration strategy into MDA for the projects where the upfront model is not available

Conclusions/Key points

- **Architecture-driven migration to MDA:**
  - the main priority is to gain intellectual control over the architecture of existing software.
  - Short-term benefits from gradually improving architecture and maintenance robustness of existing software
  - Use Managed Architecture approach to get
    - Big picture of the system: major components and structures, relations between them
    - Common context for documenting, developing and educating others about the system as it evolves, especially the legacy components
    - Common repository for all architectural and design artifacts related to
  - Use MDA tools to do
    - platform-independent modeling and validation
    - platform-specific modeling
    - Automatic code generation
    - Common context for documenting, developing and educating others about the system as it evolves
  - Use Managed Architecture techniques to enforce integrity of achieved architecture improvements