The Big Idea

Software Architecture

The Origins

- Software Engineers have always employed software architectures
  - Very often without realizing it!
- Address issues identified by researchers and practitioners
  - Essential software engineering difficulties
  - Unique characteristics of programming-in-the-large
  - Need for software reuse
- Many ideas originated in other (non-computing) domains

Software Engineering Difficulties

- Software engineers deal with unique set of problems
  - Young field with tremendous expectations
  - Building of vastly complex, but intangible systems
  - Software is not useful on its own e.g., unlike a car, thus
  - It must conform to changes in other engineering areas
- Some problems can be eliminated
  - These are Brooks' "accidental difficulties"
- Other problems can be lessened, but not eliminated
  - These are Brooks' "essential difficulties"

Accidental Difficulties

- Solutions exist

  Possibly waiting to be discovered
- Past productivity increases result of overcoming

  Inadequate programming constructs & abstractions
  - Remedied by high-level programming languages
  - Increased productivity by a factor of five (20%)
  - Complexity was never inherent in program at all

Accidental Difficulties (cont'd)

- Past productivity increases result of overcoming (cont'd)
  - Viewing results of programming decisions took long time
    - Remedied by time–sharing
    - Turnaround time approaching limit of human perception
  - Difficulty of using heterogeneous programs
    - Addressed by integrated software development environments
    - Support task that was conceptually always possible

Essential Difficulties

- Only partial solutions exist for them, if any
- Cannot be abstracted away

Complexity
Conformity
Changeability
Intangibility

Complexity

- No two software parts are alike

  If they are, they are abstracted away into one

- Complexity grows non-linearly with size

  E.g., it is impossible to enumerate all states of program

  Except perhaps “toy” programs

Conformity

- Software is required to conform to its
  - Operating environment
  - Hardware
- Often "last kid on block"
- Perceived as most conformable

Changeability

- Change originates with
  - New applications, users, machines, standards, laws
  - Hardware problems
- Software is viewed as infinitely malleable

Intangibility

- Software is not embedded in space
  - Often no constraining physical laws
- No obvious representation
  - E.g., familiar geometric shapes

Pewter Bullets

- Ada, C++, Java and other high–level languages
- Object-oriented design/analysis/programming
- Artificial Intelligence
- Automatic Programming
- Graphical Programming
- Program Verification
- Environments & tools
- Workstations

Promising Attacks On Complexity (In 1987)

- Buy vs. Build
- Requirements refinement & rapid prototyping
  - Hardest part is deciding what to build (or buy?)
  - Must show product to customer to get complete spec.
  - Need for iterative feedback

Promising Attacks On Complexity (cont'd)

- Incremental/Evolutionary/Spiral Development
  - Grow systems, don't build them
  - Good for morale
  - Easy backtracking
  - Early prototypes
- Great designers
  - Good design can be taught; great design cannot
  - Nurture great designers

Primacy of Design

- Software engineers collect requirements, code, test, integrate, configure, etc.
- An architecture-centric approach to software engineering places an emphasis on design

  Design pervades the engineering activity from the very beginning
- But how do we go about the task of architectural design?

Analogy: Architecture of Buildings

- We all live in them
- (We think) We know how they are built
  - Requirements
  - Design (blueprints)
  - Construction
  - Use
- This is similar (though not identical) to how we build software

Some Obvious Parallels

- Satisfaction of customers' needs
- Specialization of labor
- Multiple perspectives of the final product
- Intermediate points where plans and progress are reviewed

Deeper Parallels

- Architecture is different from, but linked with the product/structure
- Properties of structures are induced by the design of the architecture
- The architect has a distinctive role and character

Deeper Parallels (cont'd)

- Process is not as important as architecture
  - Design and resulting qualities are at the forefront
  - Process is a means, not an end
- Architecture has matured over time into a discipline
  - Architectural styles as sets of constraints
  - Styles also as wide range of solutions, techniques and palettes of compatible materials, colors, and sizes

More about the Architect

- A distinctive role and character in a project
- Very broad training
- Amasses and leverages extensive experience
- A keen sense of aesthetics
- Deep understanding of the domain
  - Properties of structures, materials, and environments
  - Needs of customers

More about the Architect (cont'd)

- Even first-rate programming skills are insufficient for the creation of complex software applications

  But are they even necessary?

Limitations of the Analogy…

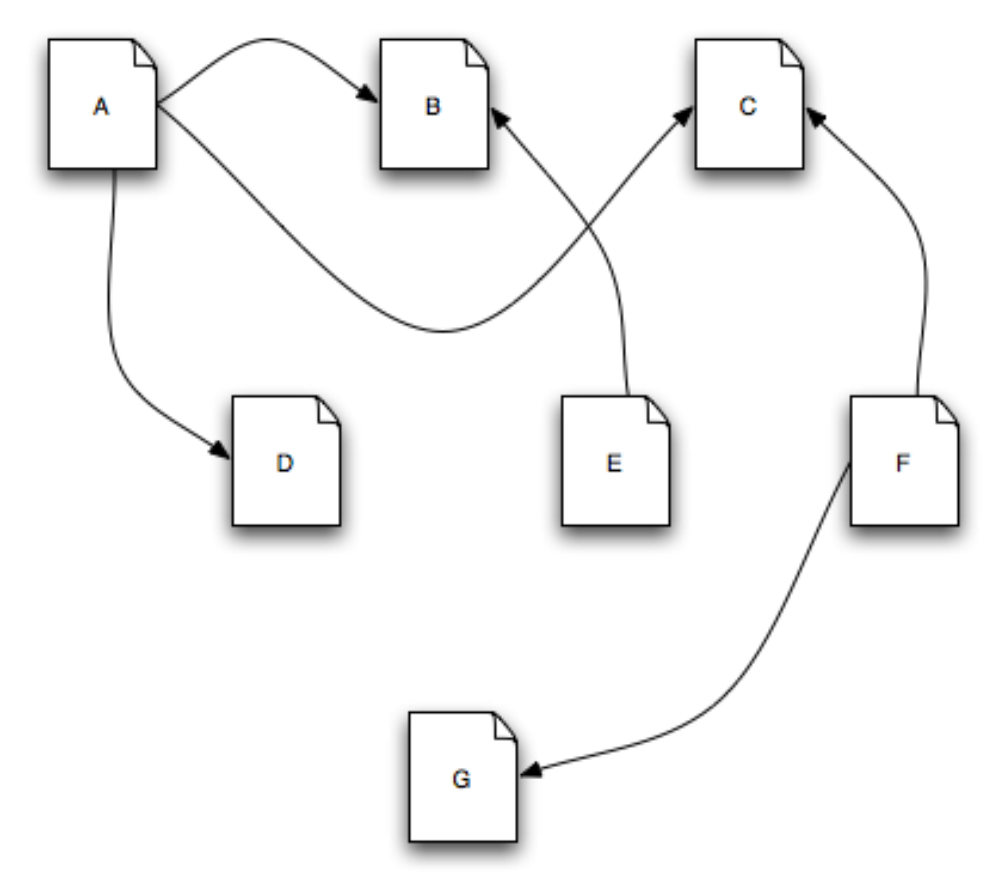
- We know a lot about buildings, much less about software
- The nature of software is different from that of building architecture
- Software is much more malleable than physical materials
- The two "construction industries" are very different
- Software deployment has no counterpart in building architecture
- Software is a machine; a building is not

…But Still Very Real Power of Architecture

- Giving preeminence to architecture offers the potential for
  - Intellectual control
  - Conceptual integrity
  - Effective basis for knowledge reuse
  - Realizing experience, designs, and code
  - Effective project communication
  - Management of a set of variant systems
- Limited-term focus on architecture will not yield significant benefits!

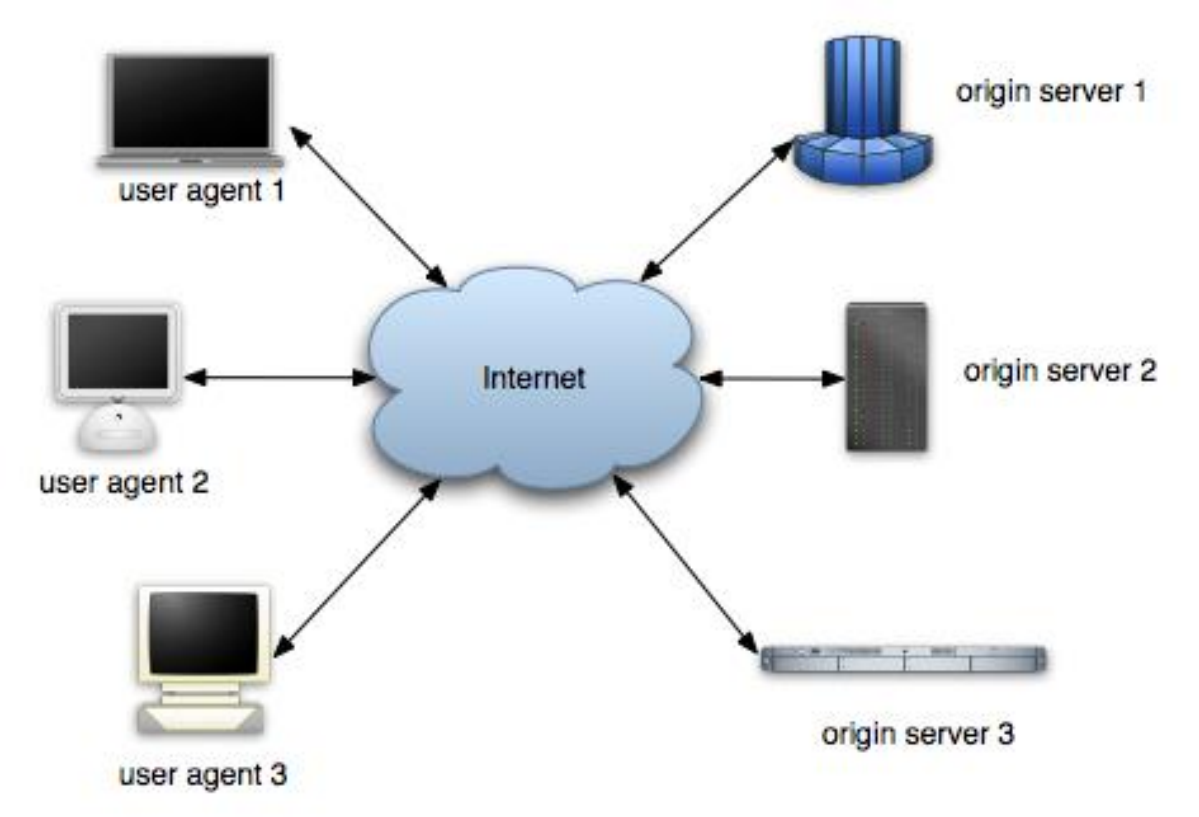
Architecture in Action: WWW

- This is the Web



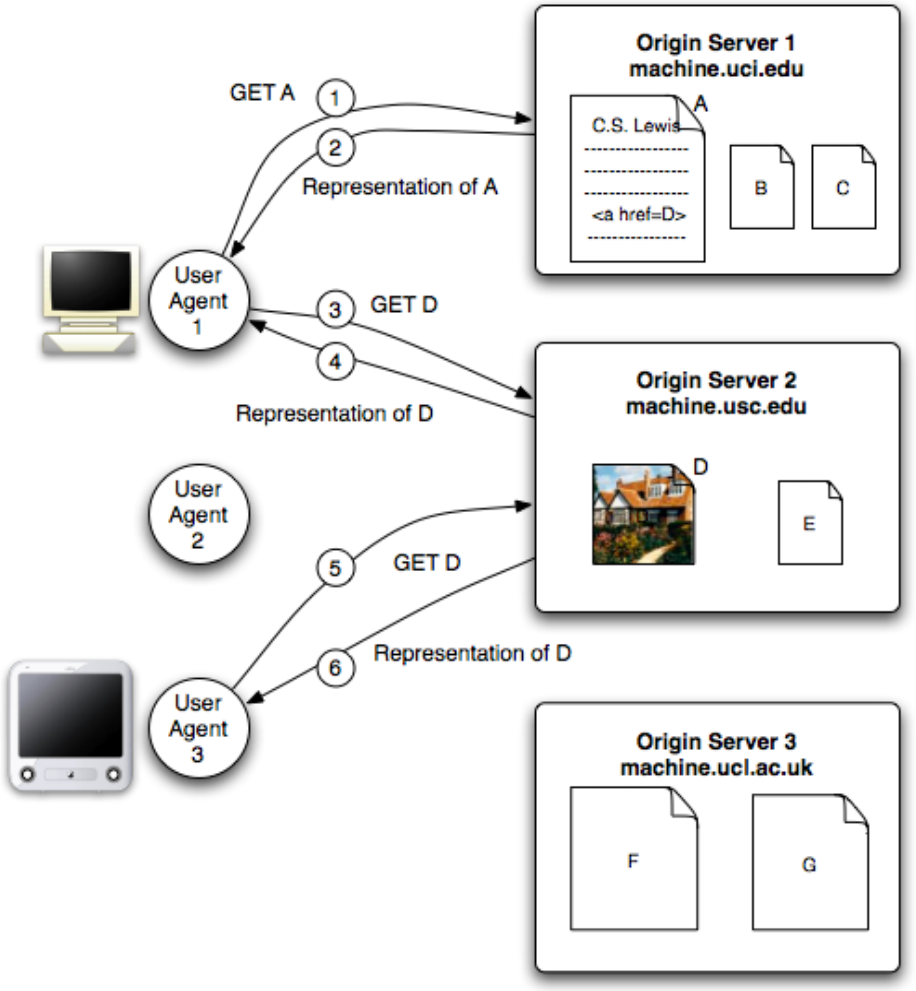
Architecture in Action: WWW

- So is this



Architecture in Action: WWW

- And this



WWW in a (Big) Nutshell

- The Web is a collection of resources, each of which has a unique name known as a uniform resource locator, or "URL".
- Each resource denotes, informally, some information.
- URL's can be used to determine the identity of a machine on the Internet, known as an origin server, where the value of the resource may be ascertained.
- Communication is initiated by clients, known as user agents, who make requests of servers.

  Web browsers are common instances of user agents.

WWW in a (Big) Nutshell (cont'd)

- Resources can be manipulated through their representations.

  HTML is a very common representation language used on the Web.
- All communication between user agents and origin servers must be performed by a simple, generic protocol (HTTP), which offers the command methods GET, POST, etc.
- All communication between user agents and origin servers must be fully self-contained. (So-called "stateless interactions")

WWW's Architecture

- Architecture of the Web is wholly separate from the code
- There is no single piece of code that implements the architecture.
- There are multiple pieces of code that implement the various components of the architecture.

  E.g., different Web browsers

WWW's Architecture (cont'd)

- Stylistic constraints of the Web's architectural style are not apparent in the code

  The effects of the constraints are evident in the Web

- One of the world's most successful applications is only understood adequately from an architectural vantage point.

Architecture in Action: Desktop

- Remember pipes and filters in Unix?

  ls invoices | grep –e august | sort
- Application architecture can be understood based on very few rules
- Applications can be composed by non-programmers

  Akin to Lego blocks
- A simple architectural concept that can be comprehended and applied by a broad audience

Architecture in Action: Product Line

- Motivating example

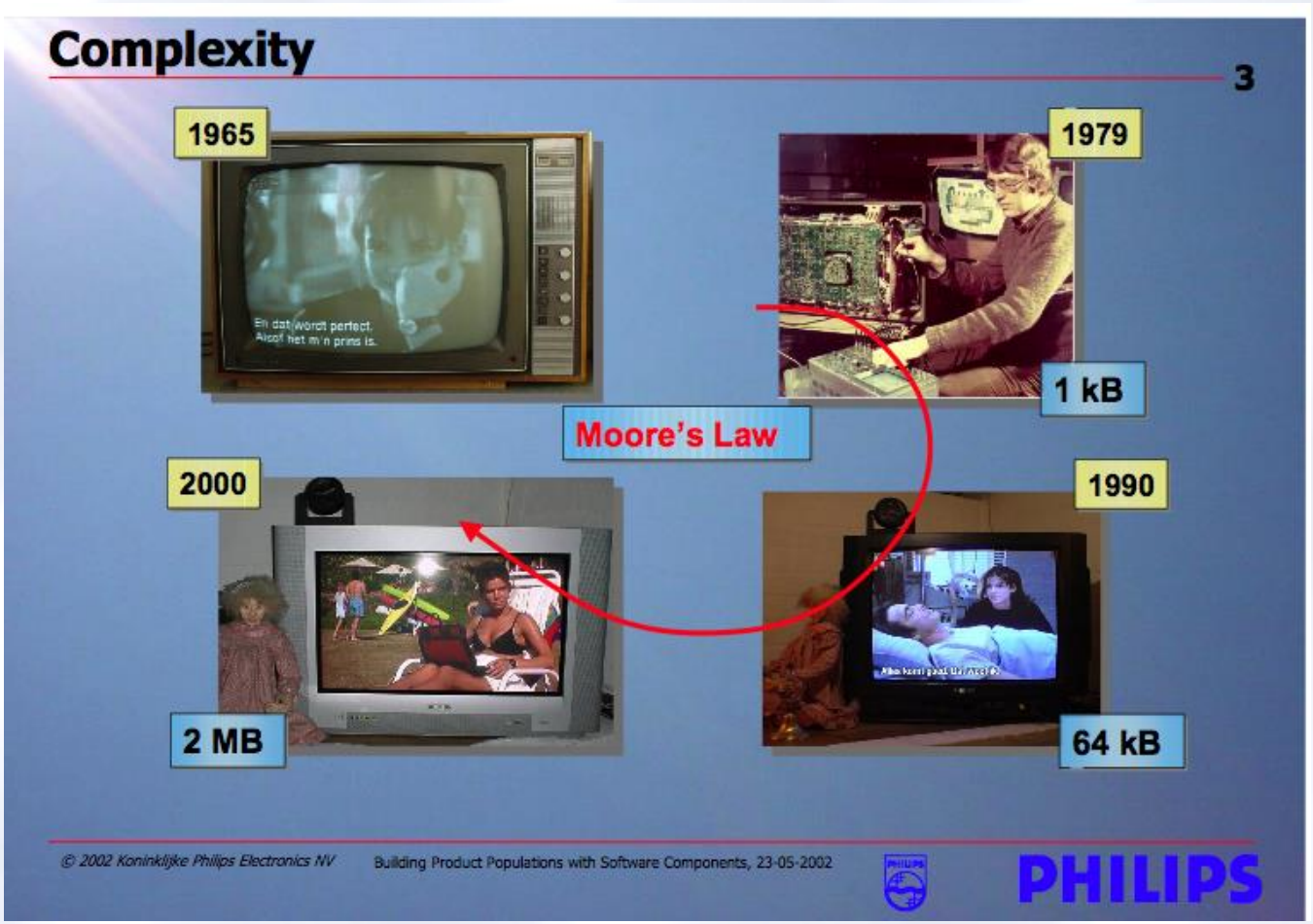
  A consumer is interested in a 35-inch HDTV with a built-in DVD player for the North American market.

  Such a device might contain upwards of a million lines of embedded software.

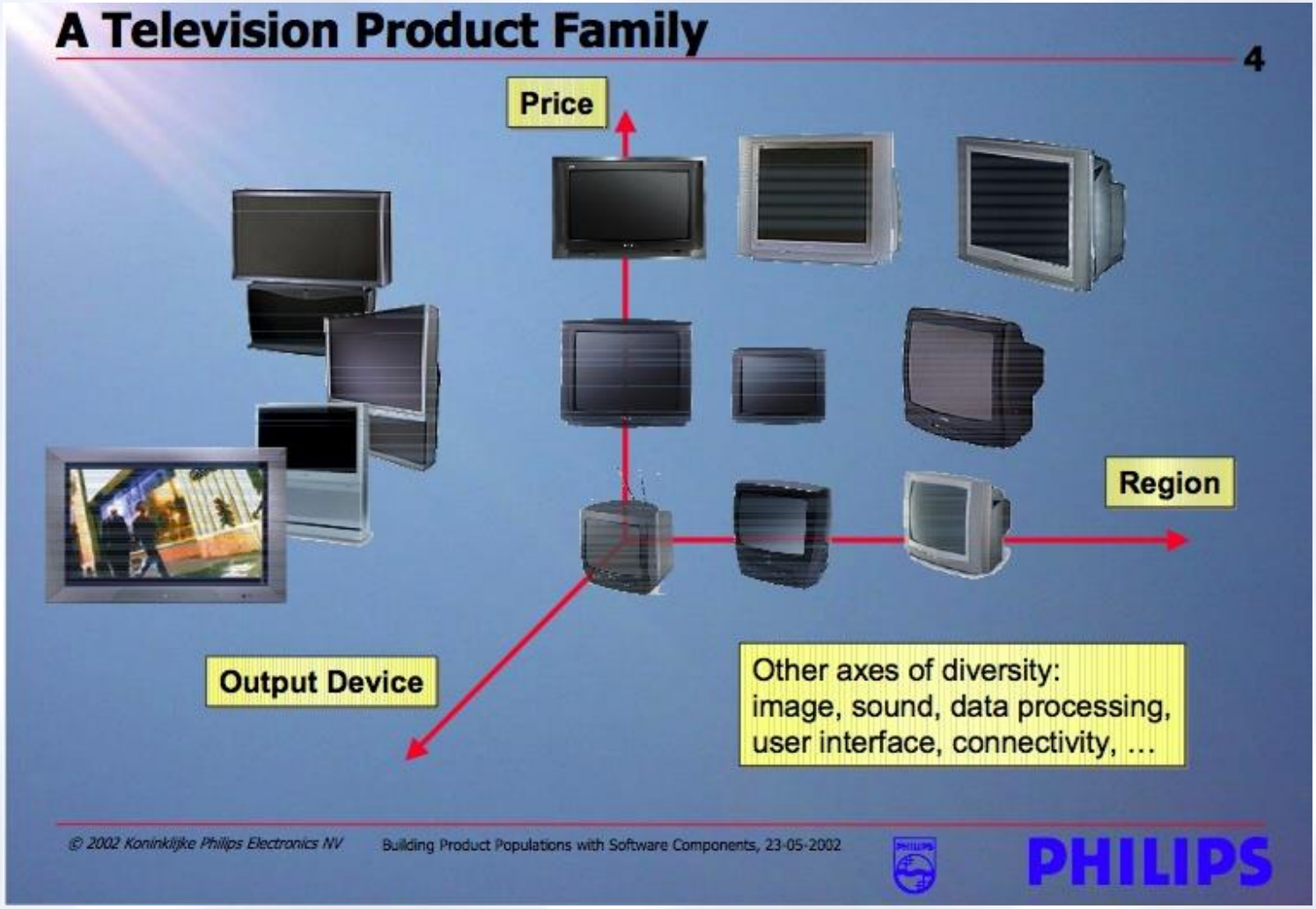
  This particular television/DVD player will be very similar to a 35-inch HDTV without the DVD player, and also to a 35-inch HDTV with a built-in DVD player for the European market, where the TV must be able to handle PAL or SECAM encoded broadcasts, rather than North America's NTSC format.

  These closely related televisions will similarly each have a million or more lines of code embedded within them.

Growing Sophistication of Consumer Devices



Families of Related Products



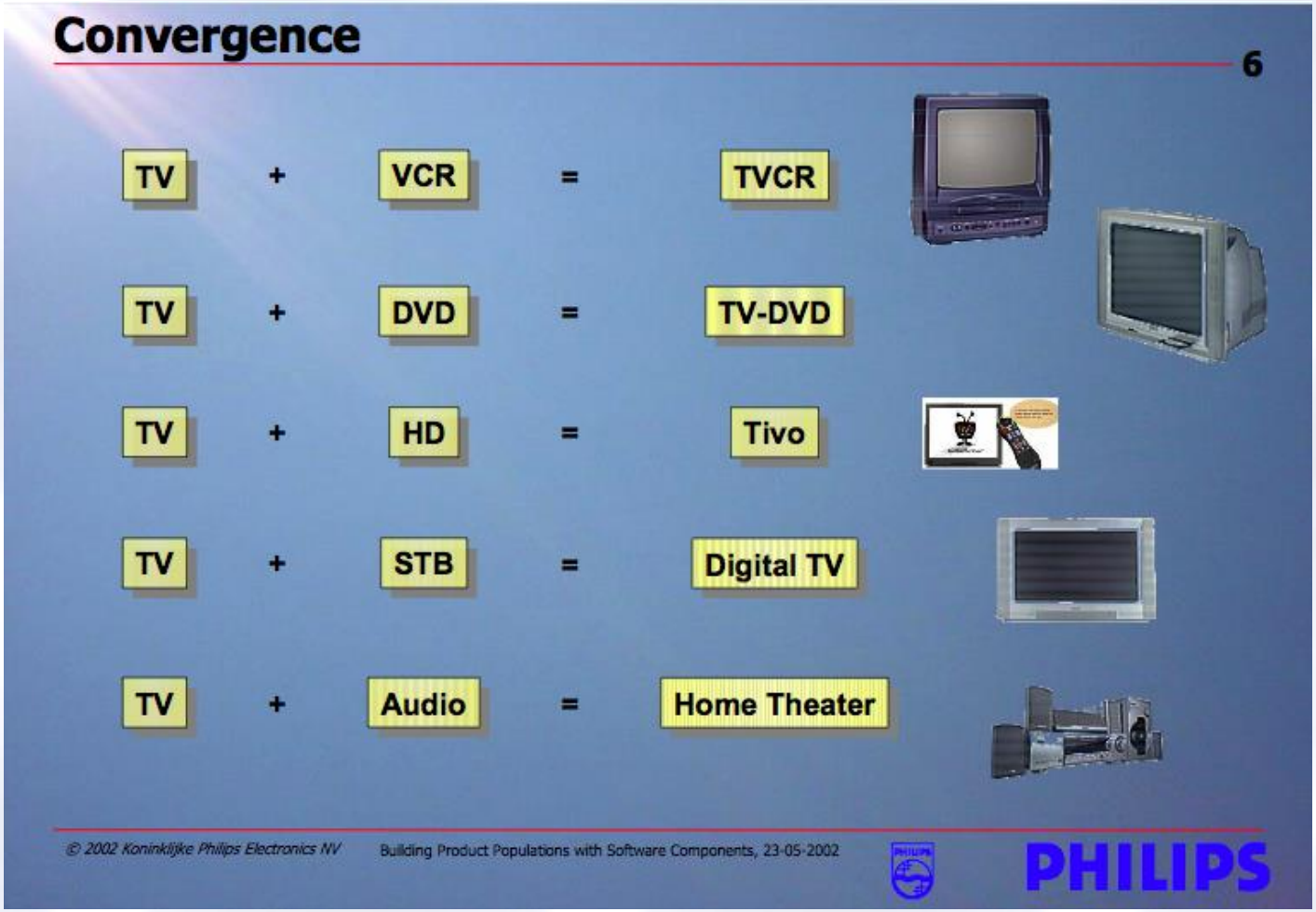
The Necessity and Benefit of PLs

- Building each of these TVs from scratch would likely put Philips out of business
- Reusing structure, behaviors, and component implementations is increasingly important to successful business practice
  - It simplifies the software development task
  - It reduces the development time and cost
  - it improves the overall system reliability
- Recognizing and exploiting commonality and variability across products

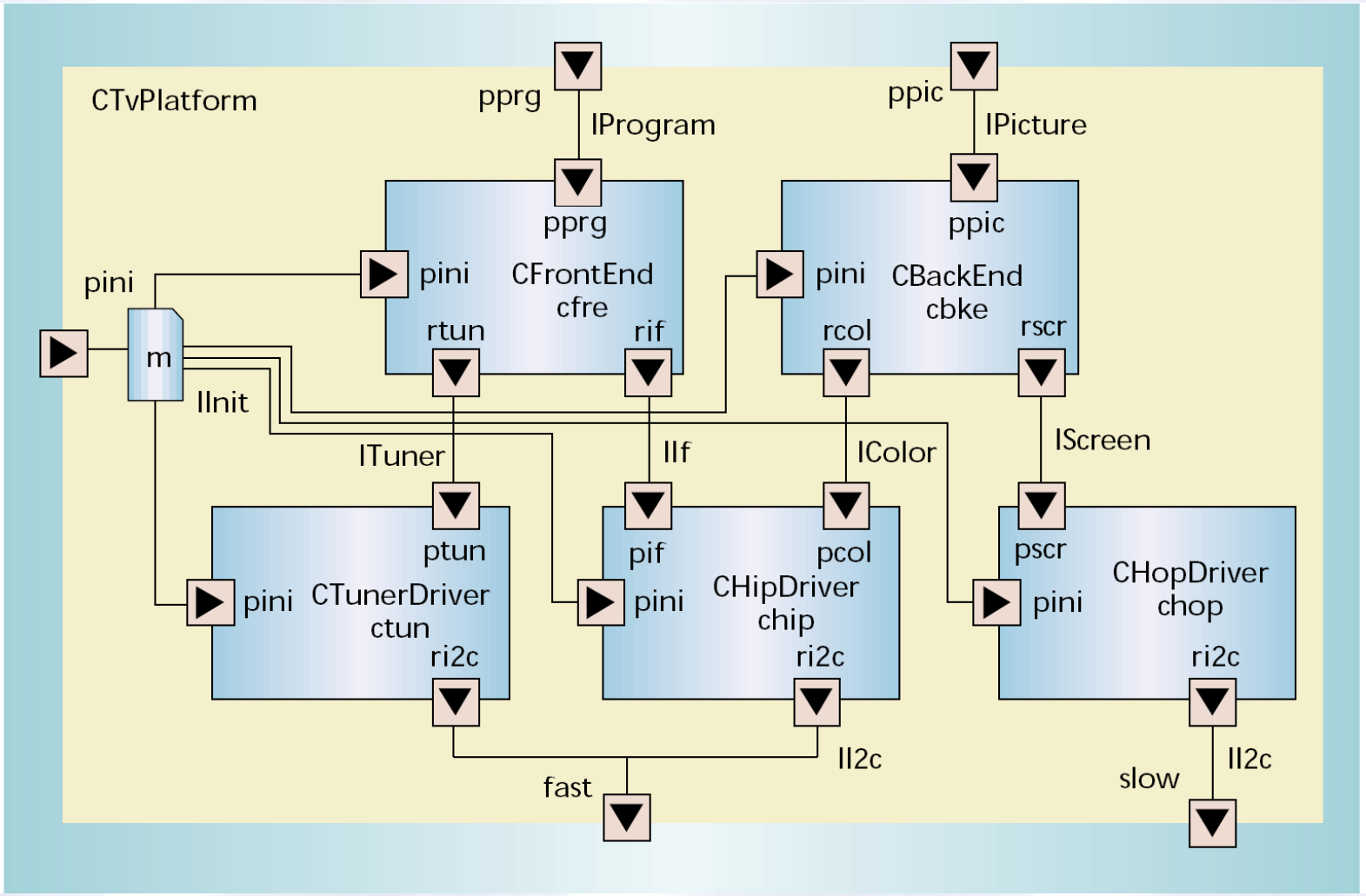
Reuse as the Big Win

- Architecture: reuse of
  - Ideas
  - Knowledge
  - Patterns
  - engineering guidance
  - Well-worn experience
- Product families: reuse of
  - Structure
  - Behaviors
  - Implementations
  - Test suites…

Added Benefit – Product Populations



The Centerpiece – Architecture



Summary

- Software is complex
- So are buildings
  - And other engineering artifacts
  - Building architectures are an attractive source of analogy
- Software engineers can learn from other domains
- They also need to develop—and have developed—a rich body of their own architectural knowledge and experience