Modern embedded electronic systems design: a bird’s-eye view

Lars Svensson
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Modern?

- Challenges:
  - Complexity
  - Performance
  - Power dissipation
  - Development rate
  - Manufacturing cost
  - …

Complexity

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- 1997
- SMS
- Alarm
- Individual rings

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- 2013
- Web browser
- Bluetooth
- WiFi
- Video
- Cameras
- Calendar
- MP3 player
- Android / Linux
- Color touch screen
- Multitouch

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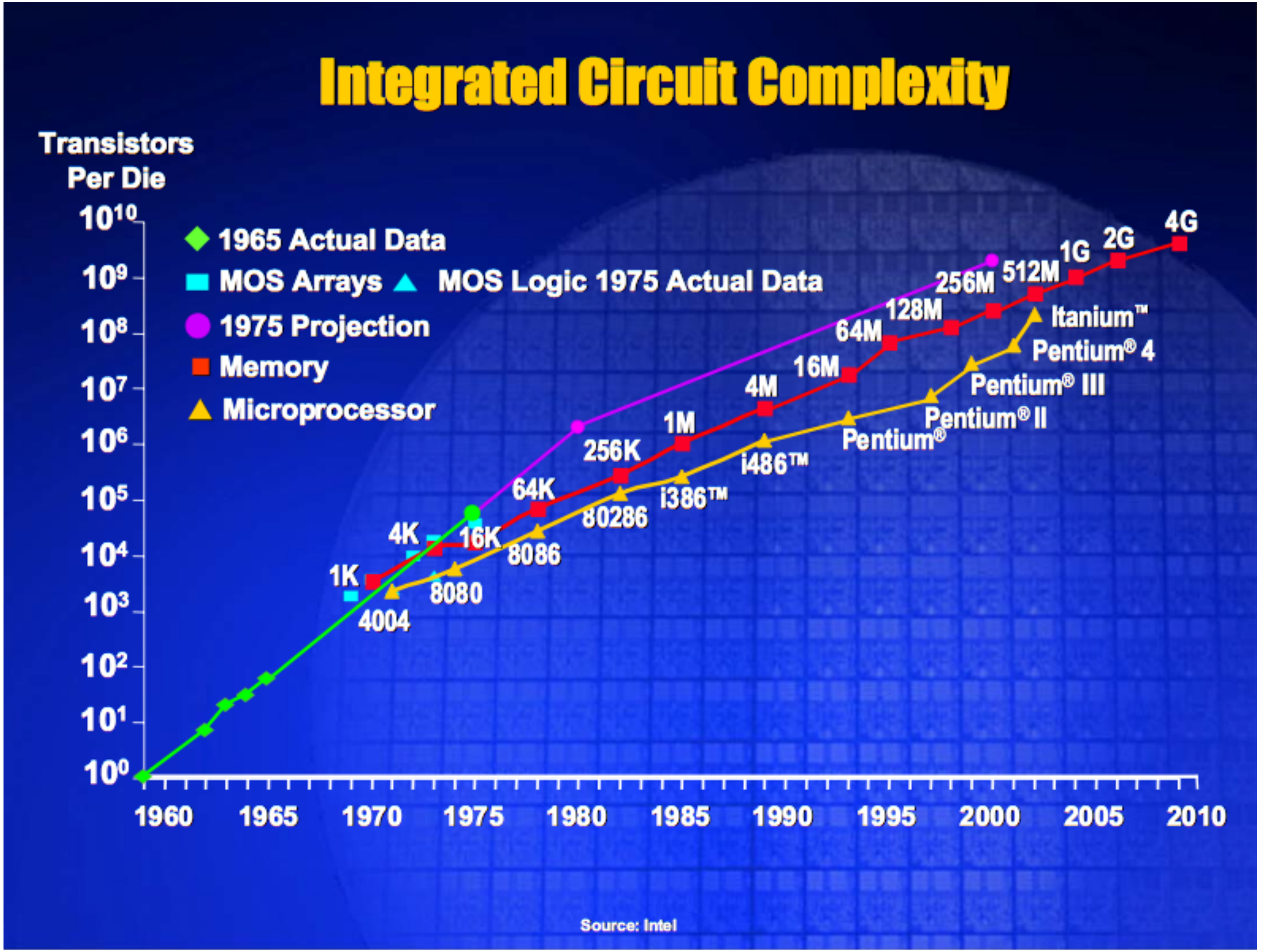
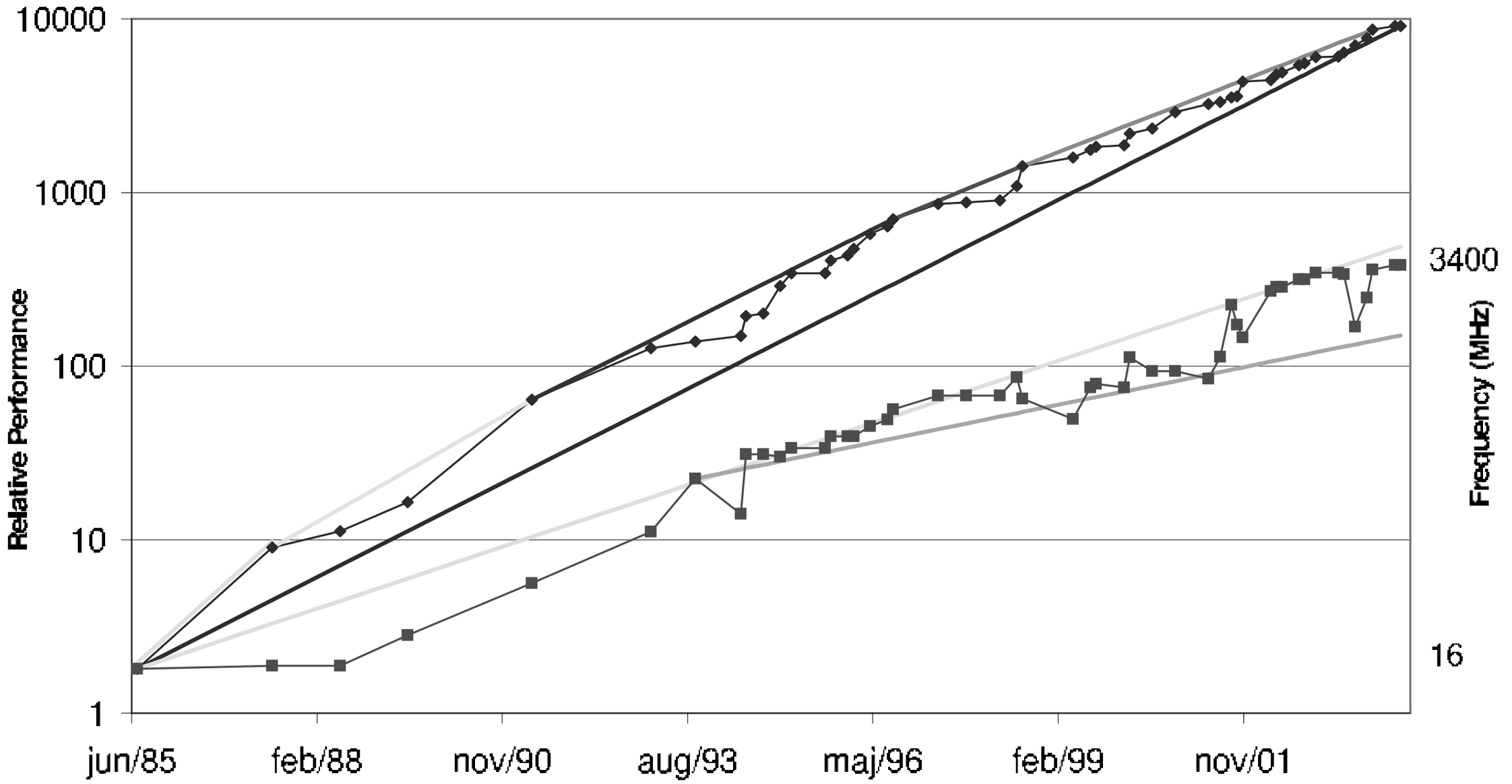
- Address book
- Continuous internet connection
- Social app support
- App store …

Integrated Circuit Complexity

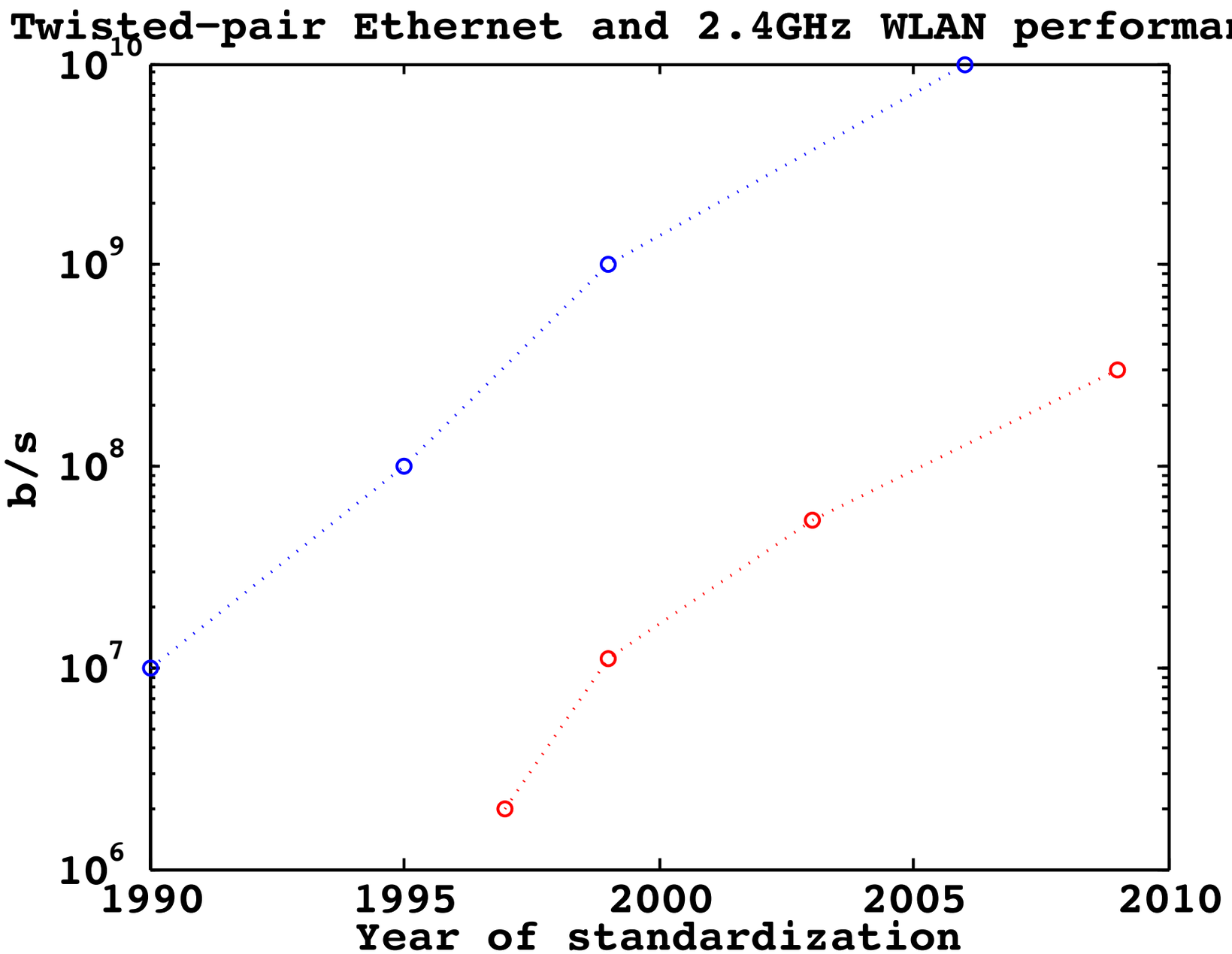


Performance

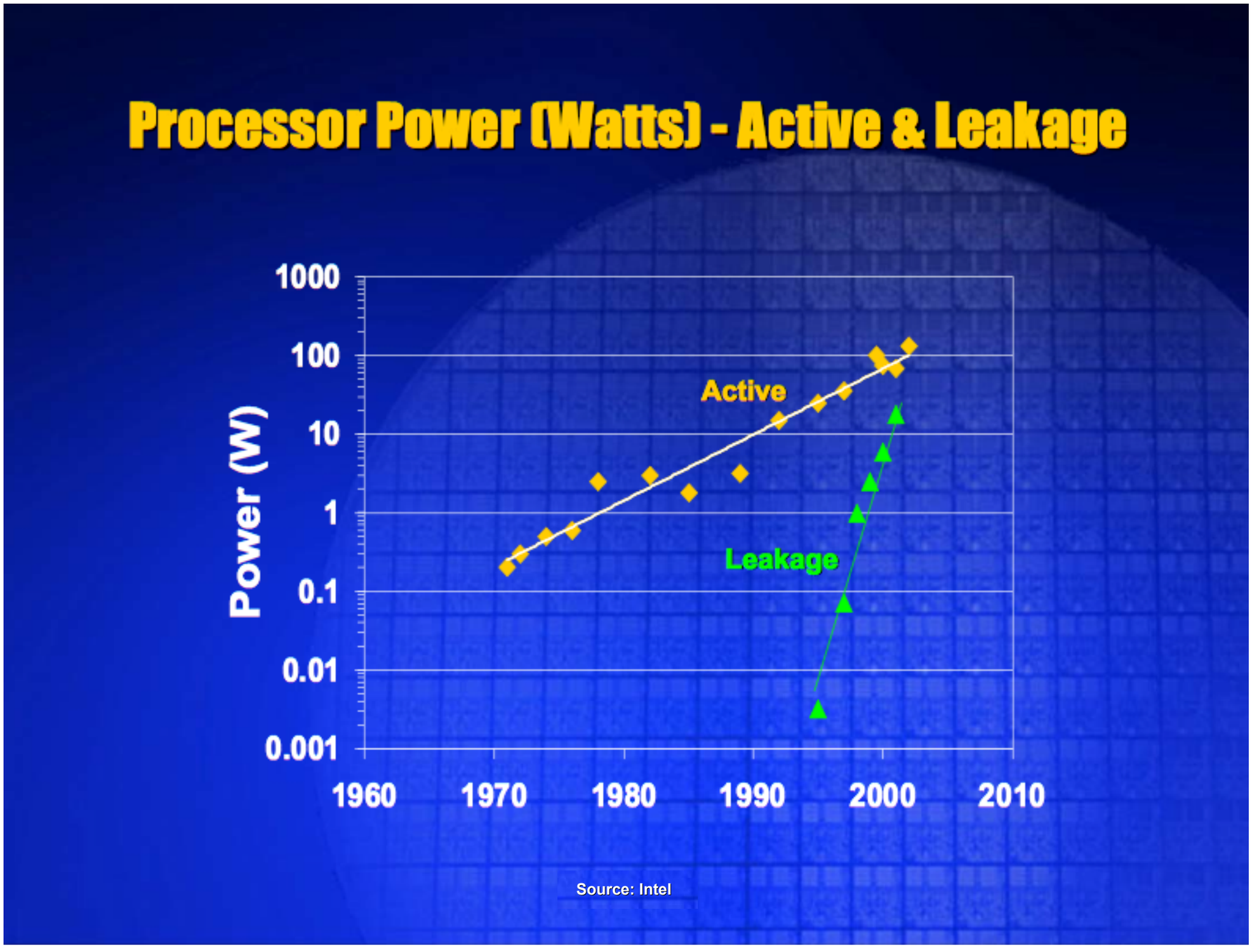


[Ekman, Warg, Nilsson 2004]

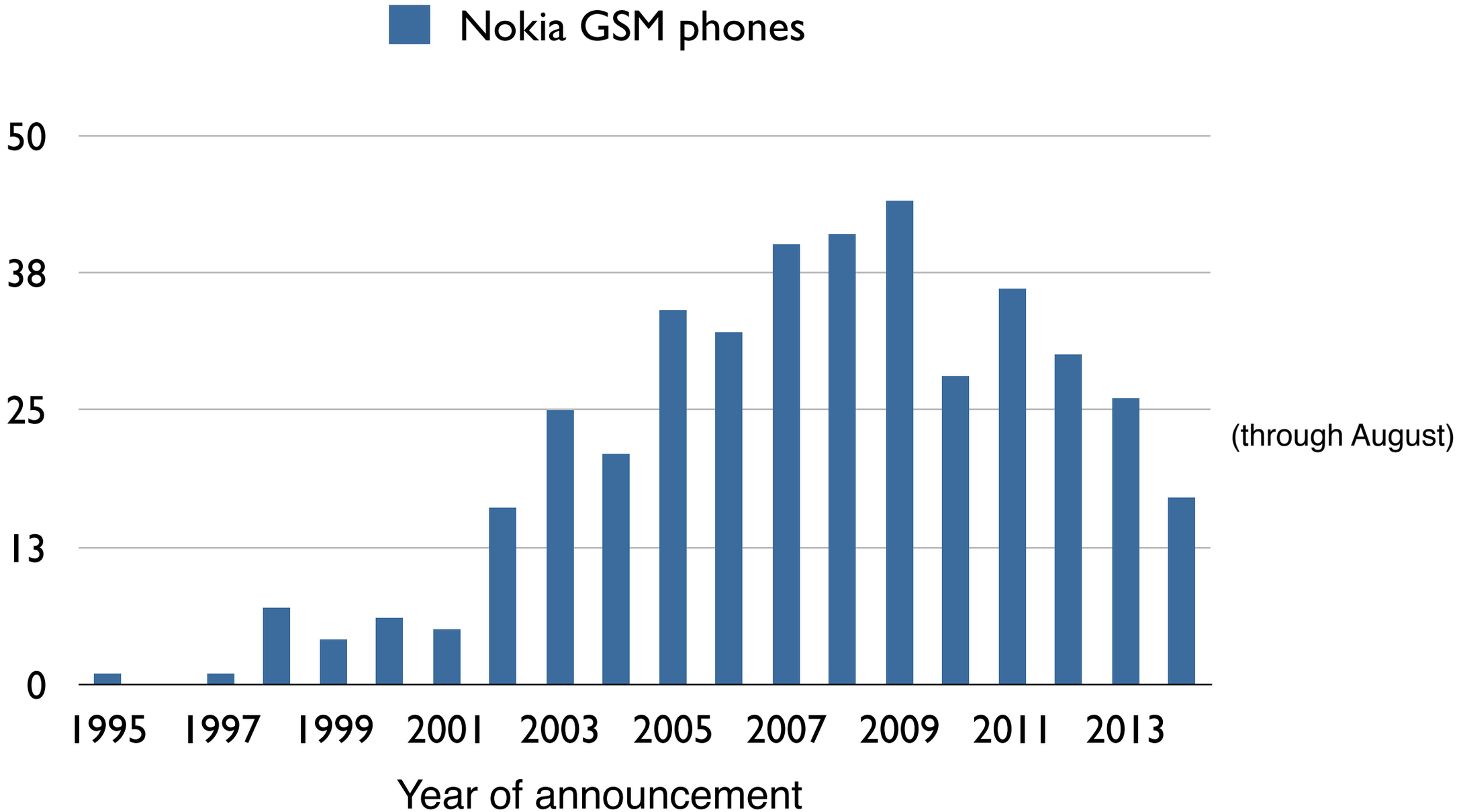
Performance



Power dissipation



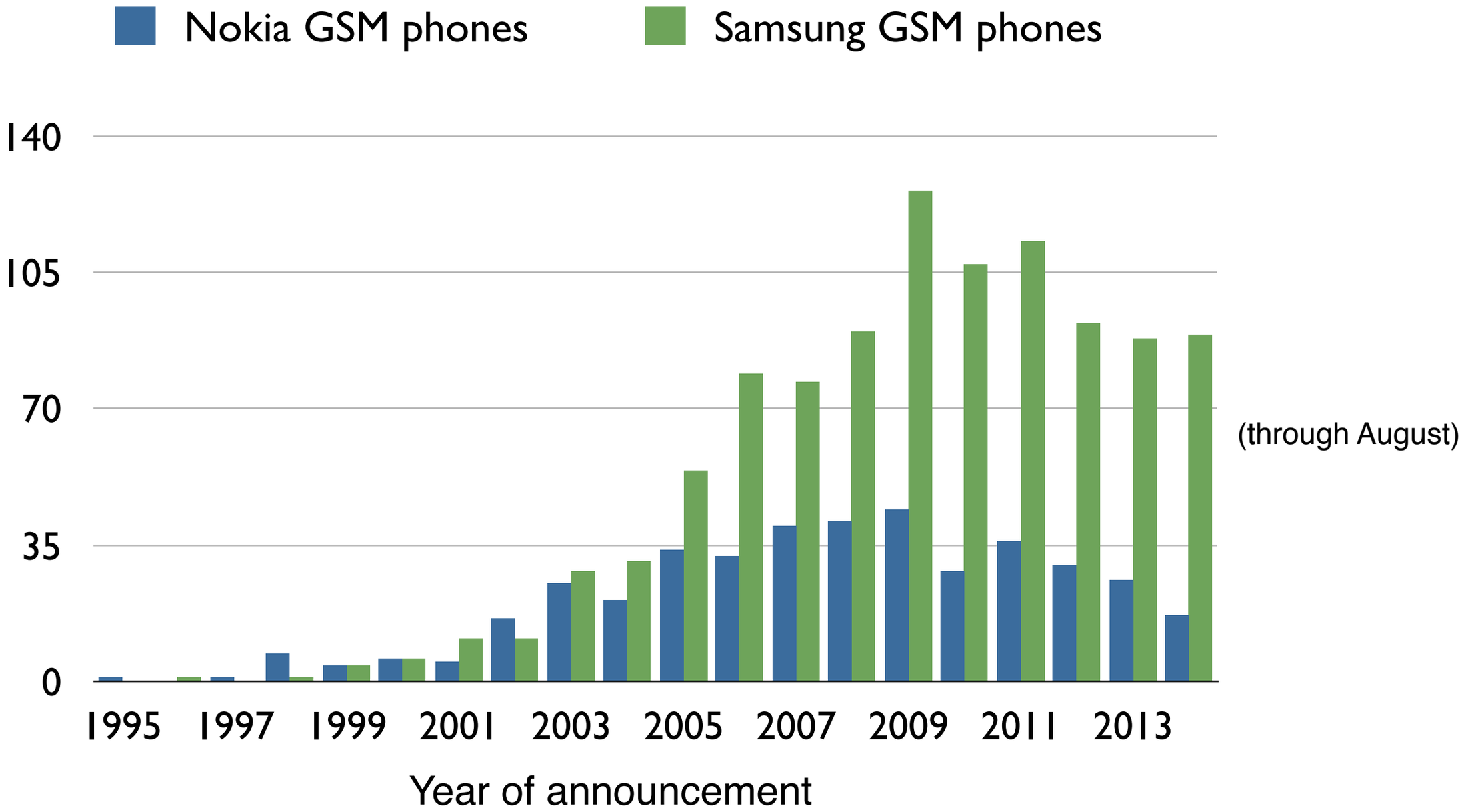
Development rate



(through August)

www.gsmarena.com

Development rate



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Typical class project (hw / sw)

- Scope: small
- Team: small (often size 1)
- Task: well-defined from start
- External dependencies: none
- Planning: simple
- Progress: linear
- Tools: well-known

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Typical real-world project (hw + sw + …)

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• Tools: well-known	Hmm… wonder what this does?

Big Issue

- "Everything" gets more difficult, often exponentially with time
- How handle this explosion?
- How to design and develop, today?

Q: How to design and develop, today?

- (Required) A: a design/development method, process, methodology, or approach, which handles…
  - …large and larger projects
  - …full range of development tasks
  - …many kinds of requirements
  - …activity scheduling, cost estimates, risk mitigation, etc
- Concept examples: Waterfall, Agile, Lean

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- Concept examples: Waterfall, Agile, Lean

1. Waterfall model

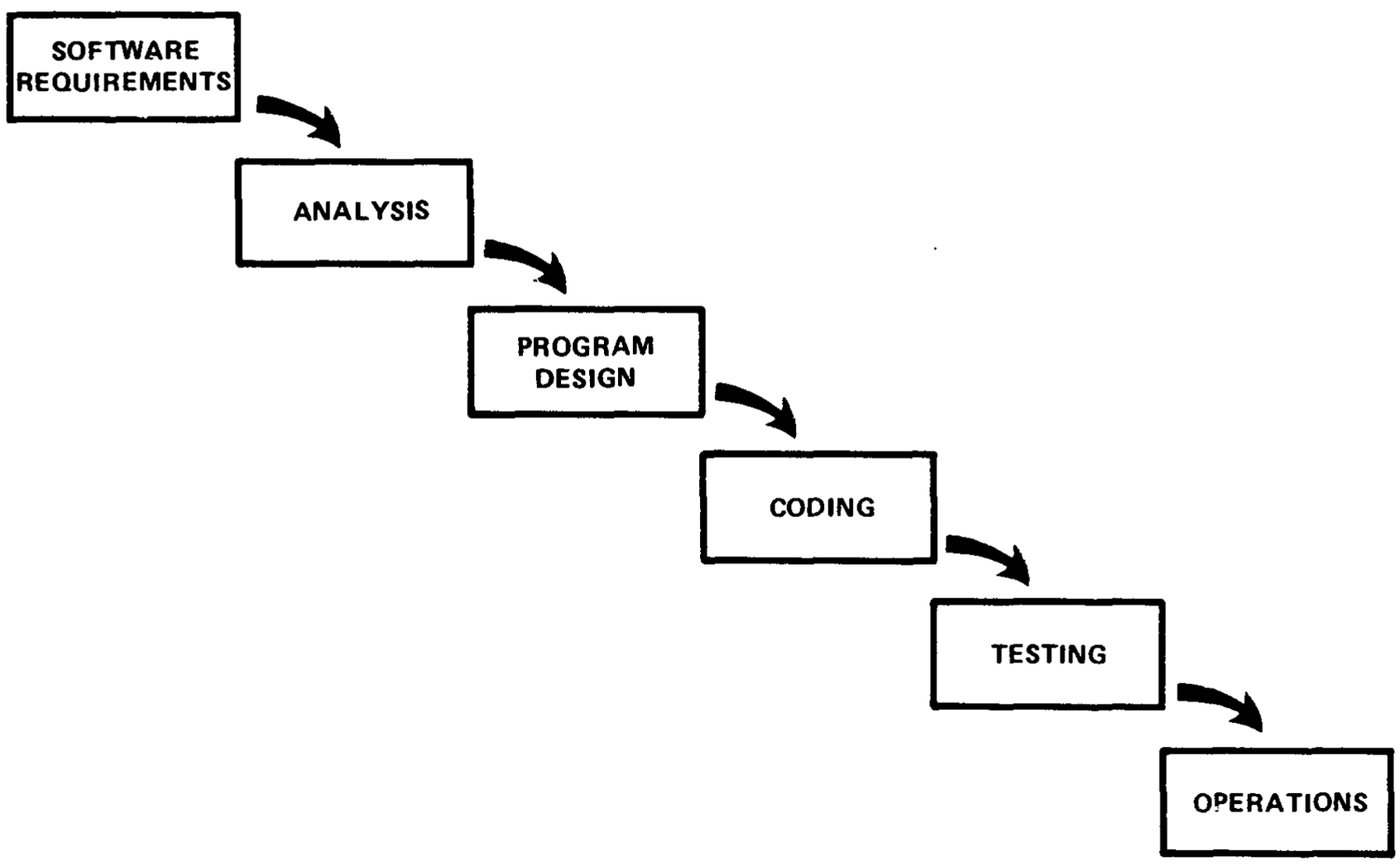
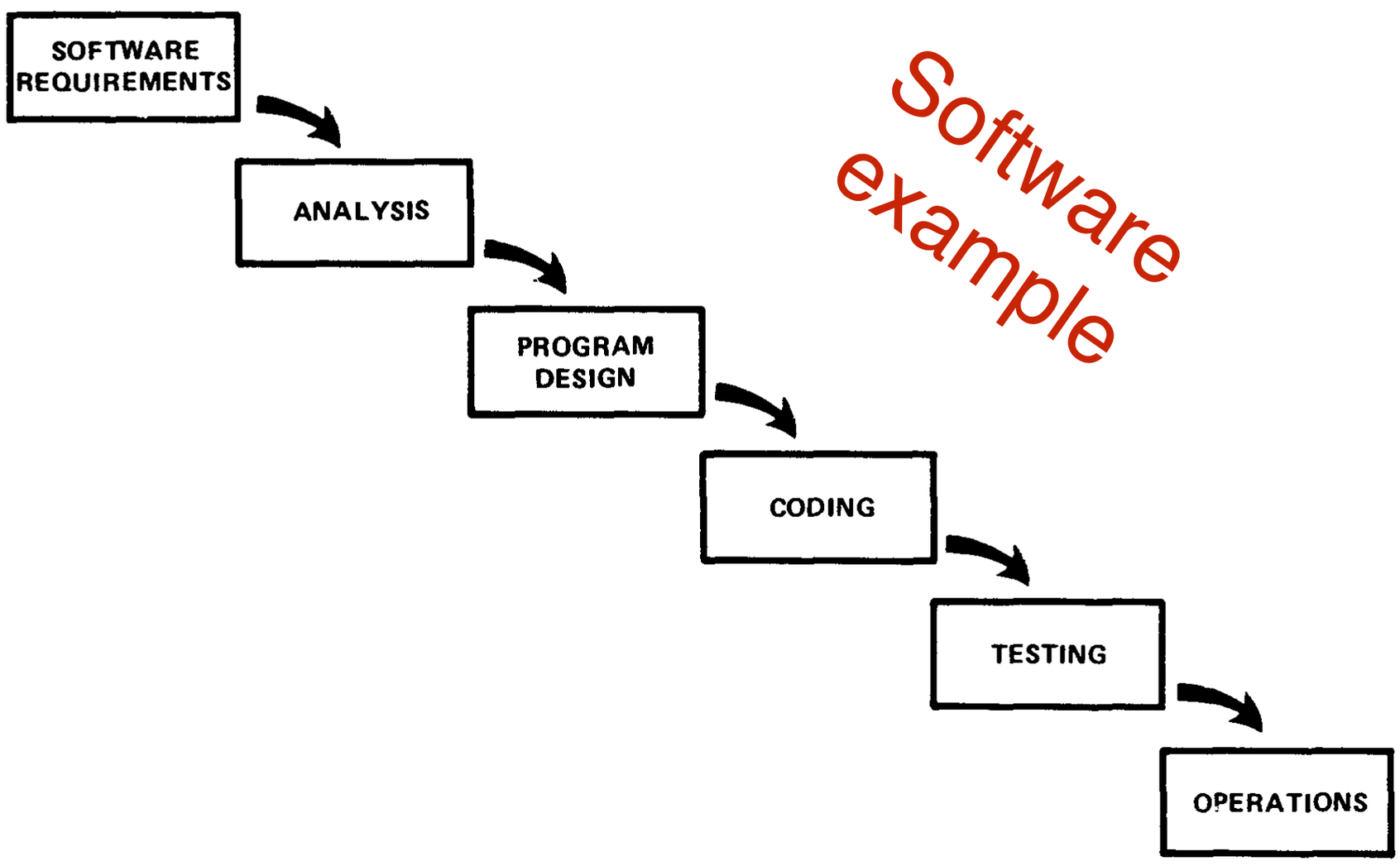


Figure 2. Implementation steps to develop a large computer program for delivery to a customer.

[Royce 1970]

1. Waterfall model



Software example

Figure 2. Implementation steps to develop a large computer program for delivery to a customer.

[Royce 1970]

Waterfall characteristics

- Proceed in orderly fashion from step to step
- Finish each task before starting the next one (never backtrack)
- Scrupulously document everything
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Why?

Selected Waterfall problems

- Monolithic; no provisions for design re-use
  - Very few projects start with clean sheet
- Assumes static environment
  - Late spec changes are not handled
- “Clean” hand-offs are rare
  - Iterations necessary in practice
- Late-stage resources idle at start

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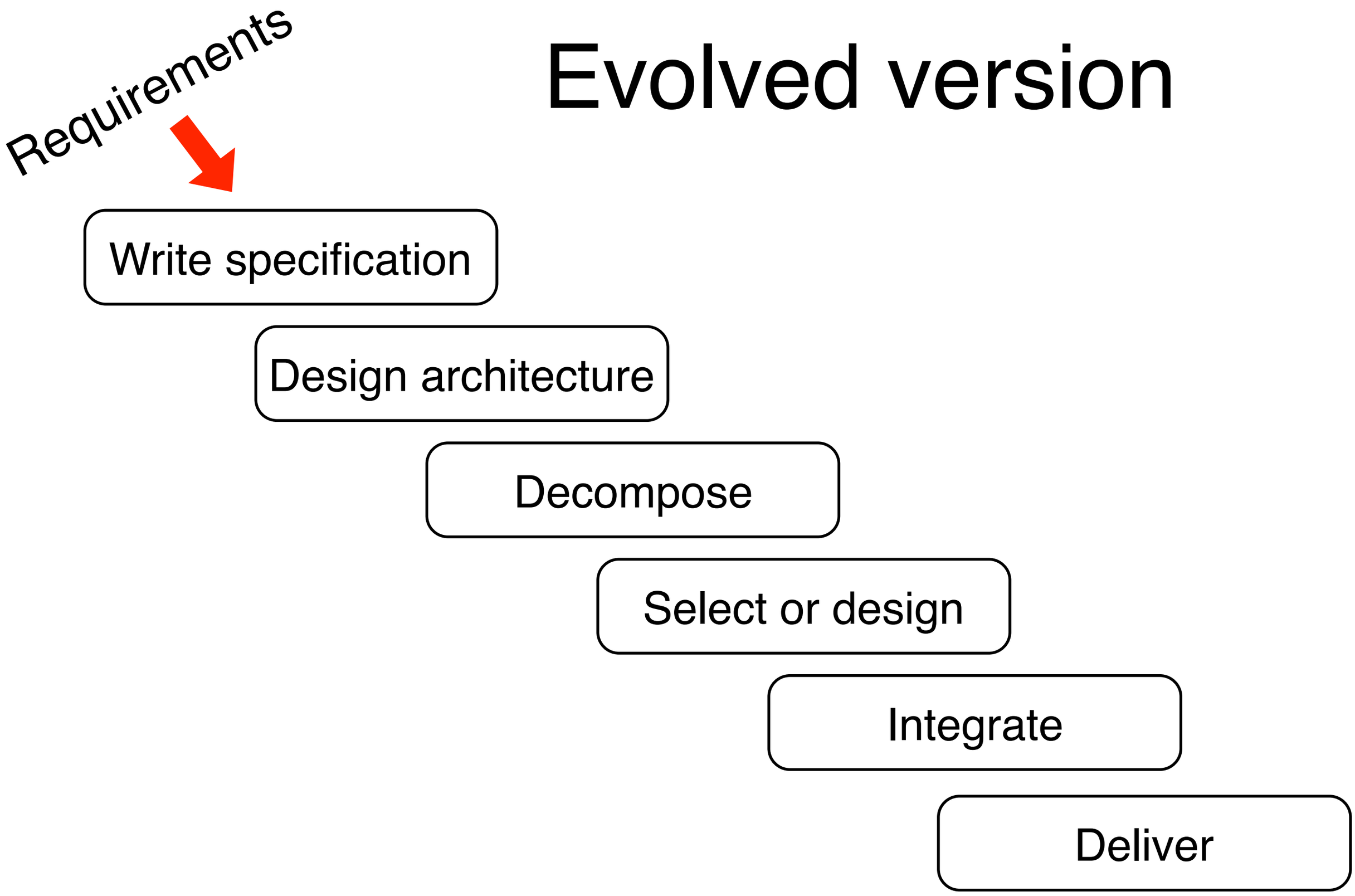
DOES NOT SCALE

Evolved version



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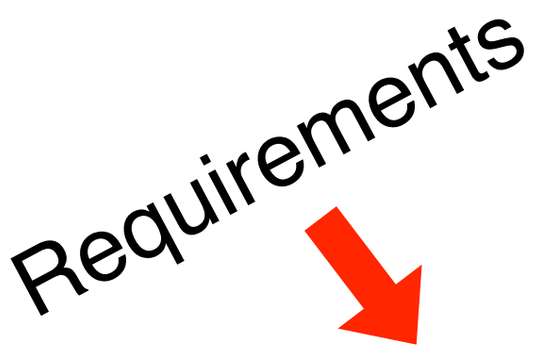


Write specification

Full detailed specification!

Design architecture

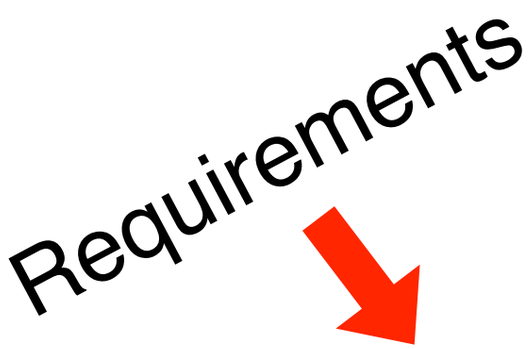
Decompose

Select or design

Integrate

Deliver

Evolved version



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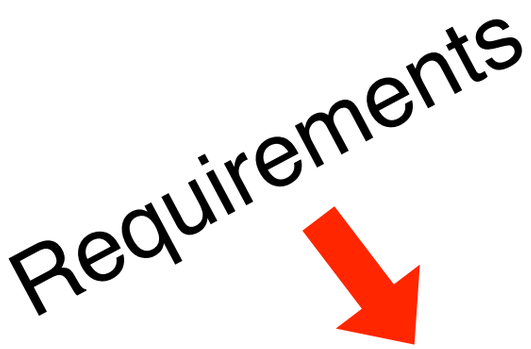

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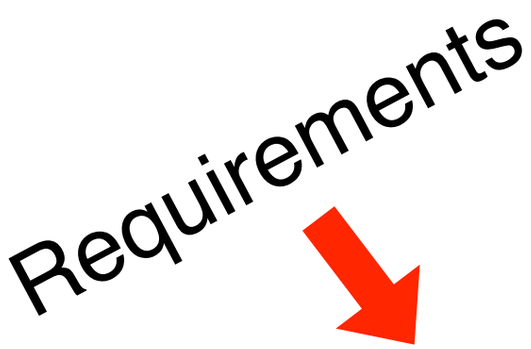

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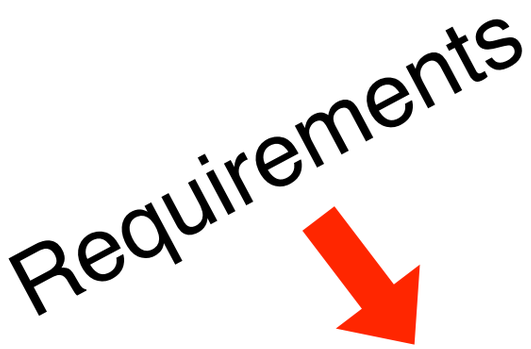

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Verify that reqs are met

Select or design

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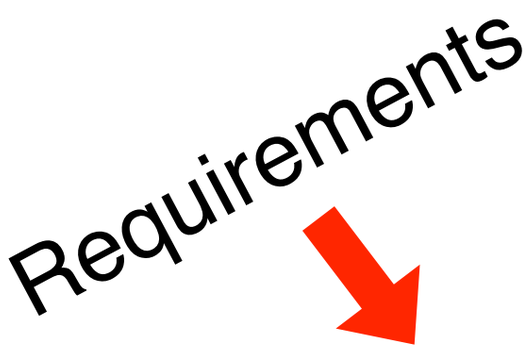

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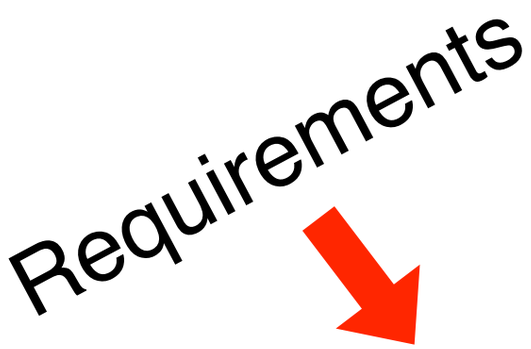

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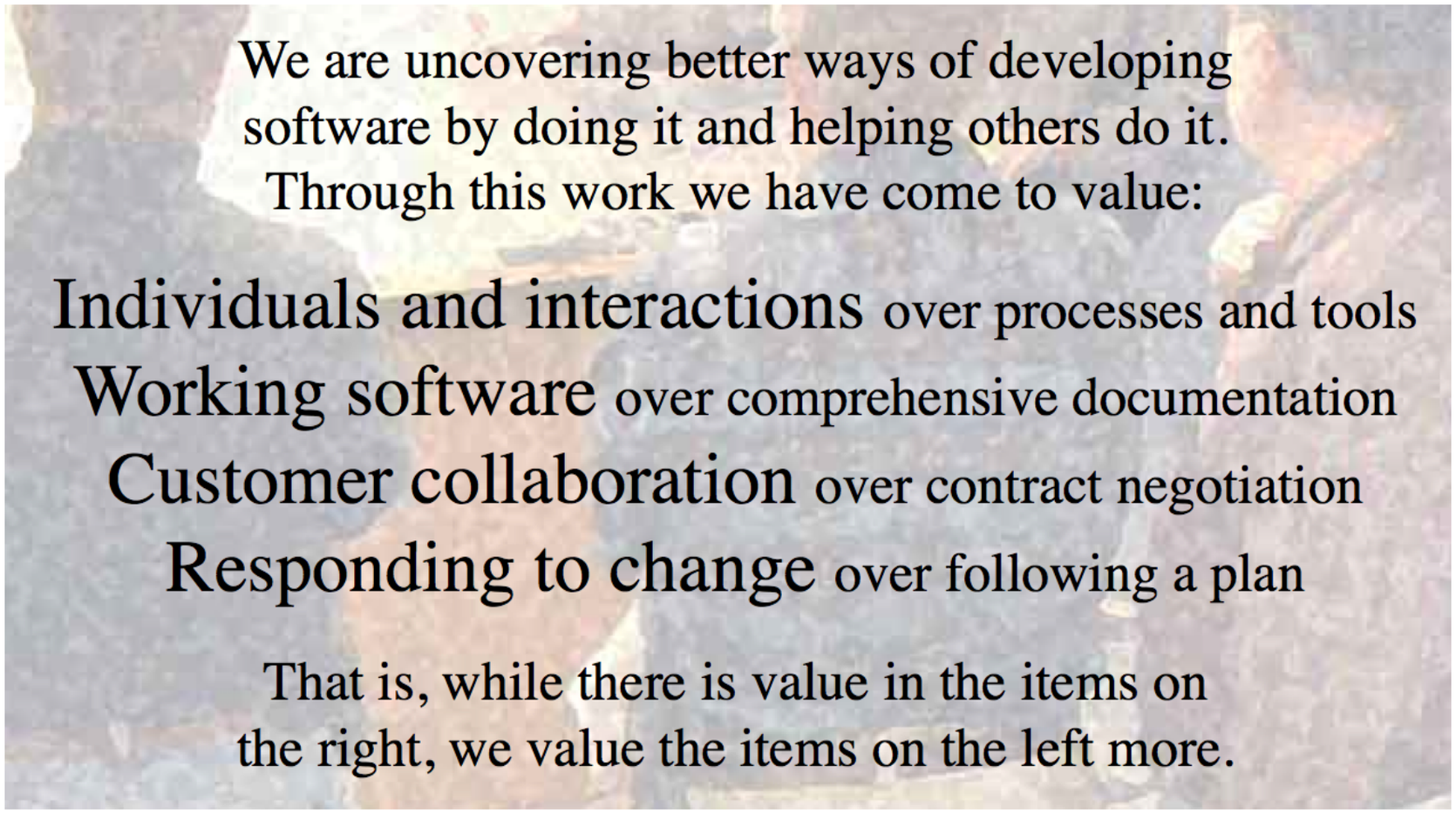
Remaining issues?

$$:-)

Deliver

2. Agile methods

- Less of a blueprint, more of a philosophy
  - Principles, practices, tools embody the philosophy
- Manifesto:



 [www.agilemanifesto.org]

Agile practices (examples)

- User stories define final product
- Test-driven development relies on automatic application of functionality tests
- Repeated refactoring for incremental design during implementation
- Pair programming reduces risk for “smart” solutions which work for only 99% of the cases
- Release early + often to get feedback

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3. Lean development

- Origin in manufacturing rather than in software development
  - "Lean manufacturing" @ Toyota, 1980's
  - Introduced in software development ~2000 (Poppendieck & Poppendieck)
- Key ideas:
  - Optimize the whole
  - Eliminate waste
  - Build quality in
  - Learn constantly
  - Deliver fast
  - Engage everyone
  - Keep getting better

[Poppendieck & Cusumano, 2012]

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Similarities w/ Agile?

[Poppendieck & Cusumano, 2012]

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Similarities w/ Agile?

Differences wrt Waterfall?

[Poppendieck & Cusumano, 2012]

Software vs. system development

- Here, “system” == software + digital hardware + analog circuits + packaging + services + …
- Software development methods cannot be applied blindly!
- Principles of Agile and Lean inspire engineering development in all fields today

Pitfalls (for <u>any</u> approach)

- Focus on tools or practices, w/o understanding <u>why</u> they are important
- Missing the big picture
- Lack of skills and knowledge of specific topic area

It is really all about learning.

- Designers / developers need knowledge and skills
  - You'll learn some in University courses
- Design and development <u>is</u> learning

Skills / knowledge: aspects of design

1. Specifications

- Many kinds:
  - Documents in natural language (English, etc)
  - Executable specifications
  - Formal specifications

- Must include:
  - functionality/behavior
  - interfaces (to hardware and software)

- May include:
  - timing
  - performance
  - power
  - testability …

LABS

DAT096

1. Specifications

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What makes each kind useful?

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- May include:
  - timing
  - performance
  - power
  - testability …

LABS

DAT096

2. System architecture

- Major design decisions
  - Hardware vs. software **DAT096**
  - Analog vs. digital **DAT116**
  - Mechanical construction **MKM105**
  - Processor/memory hierarchies **EDA332 DAT105**
  - … **EDA283**

3. Hard vs Soft

- Hardware: inflexible, high performance capability
- Software: flexible (well…), limited performance
- Reconfigurable hardware: flexible, intermediate performance, high cost per part
- More in later lecture

4. Analog vs Digital

- Digital embedded electronic systems interact with analog world
- Where to draw the A/D border?
- Often major influence on performance, cost

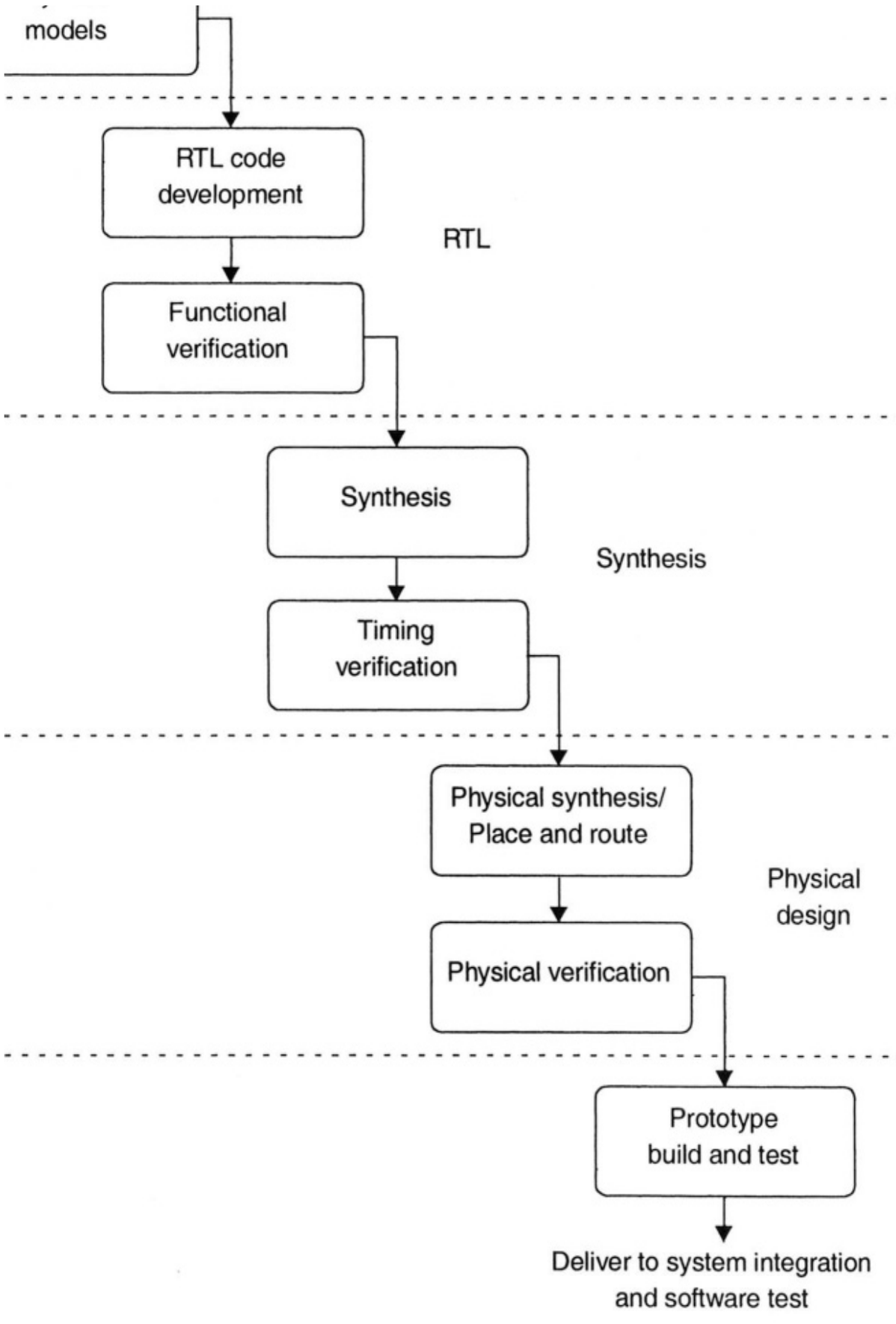
DAT116

5. Digital design (or selection)

- Design what's not available off-the-shelf
  - Hardware Description Languages **LABS**
- Design methods rely heavily on CAD tools **DAT110**
- Still necessary to understand the underlying circuit behavior **MCC092**
  - Determines achievable performance

Digital design flow

- Stages as in this diagram
  - Additions, deletions common
- Iterations typically necessary



[Keating, Bricard 2002.]

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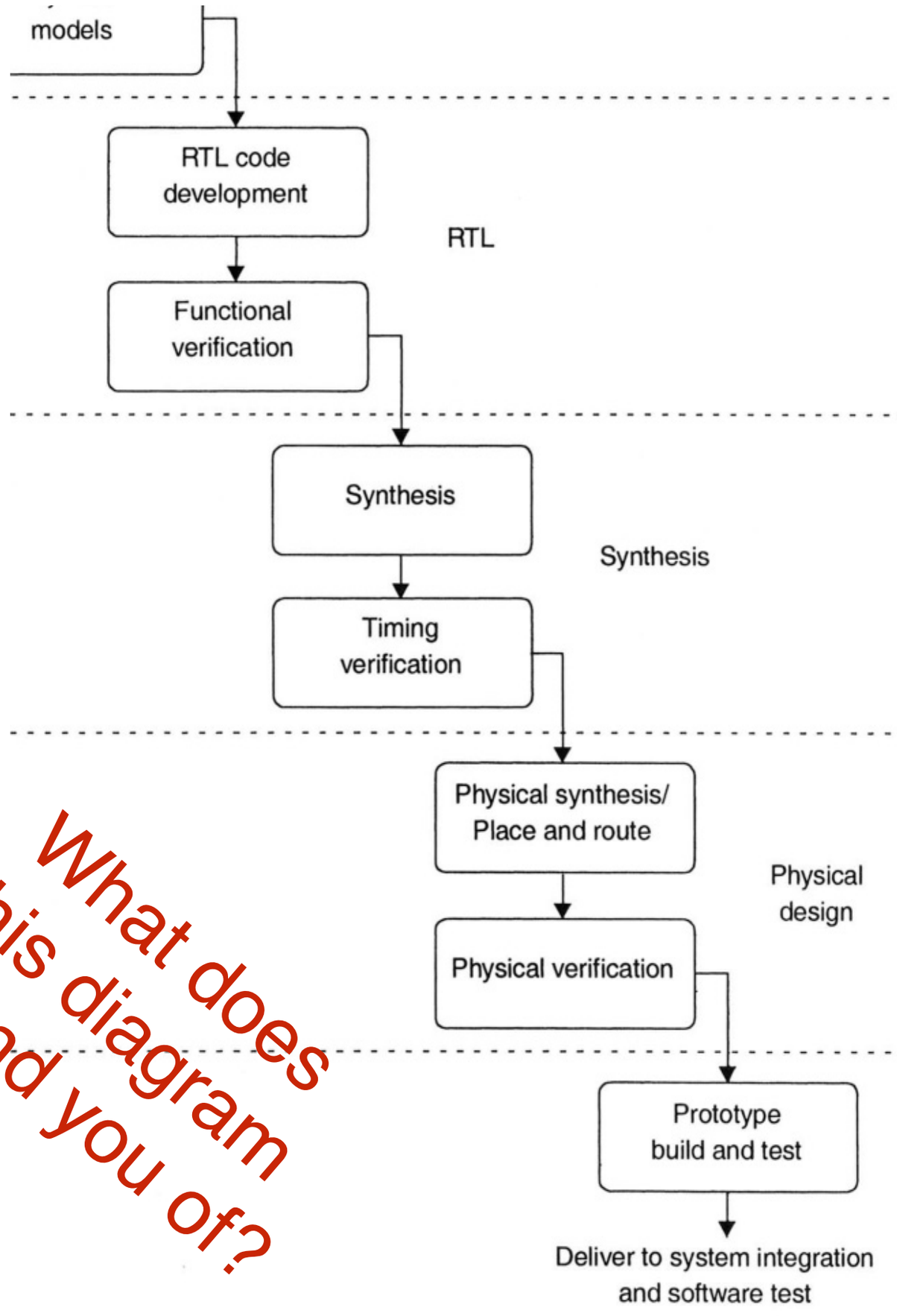

What does this diagram remind you of?

[Keating, Bricard 2002.]

6. Integration & verification

- Putting the pieces together
- Very time-consuming process!
  - Must be considered from the outset!
- Errors must be patched
  - Software vs. hardware

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Summary

- Electronic-system design complexity ever-growing
  - Includes software, analog/digital, packaging, batteries, …
- Design process is much more than putting electronic components together!
  - Designer needs “vertical” insight
- Career typically starts at implementation level, moves “up”

This week

- Two more lectures by Sven Knutsson
  - VHDL + the lab series
  - Note: room EF, EE (two floors up)
- VHDL kick-start workshop
  - Wednesday (+ Friday)
- Readings on design approaches (final slide)

To do:

- Get registered for the course!
- Verify access to PingPong web system!
- Fill out the pre-workshop survey!
  - In Ping-Pong, under “Contents”
- Watch VHDL movie (again)!
- Optionally complete your VHDL library!

Background reading

- Royce: Managing the development of large software systems (1970) [available in PingPong]
- Wikipedia-article on Agile Software Development
- Poppendieck, Cusumano: Lean Software Development: a tutorial (2012) [available in PingPong]