

Software Development

Harvey Mudd College

CS 121

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Data

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"Software Development"

- Called "Software Engineering" (SE) most places.
- At HMC, the "E" word is owned by another interest group.
- Prior to 1992, was "Large-scale Software Development" (LSD).

Software Development vs. Programming

- Requirements
- Planning
- Specification
- Architecture
- Design
- *Programming*
- Validation
- Assessment
- Maintenance
- Management

A Crude Analogy

- Programming : Software Development
- Plumbing : Building Construction

Importance of Software Development

- Society increasingly relies on software to accomplish its tasks, for leisure activities, and for communication in general.
 - Business
 - Transportation
 - Entertainment productions
 - Defense

Overview of the Field

- SWEBOK =
"Software Engineering Body of Knowledge"
- <http://www.swebok.org/>
- Download 200 page PDF

Some Topics in this Course

- Project management processes
- Team organization
- Object-oriented design techniques
- Notations, such as UML
- Design patterns
- Software testing

Career Considerations

- Many people educated in engineering or the sciences end up doing software development in some form.
- Would they advance more quickly having devoted a greater share of their education to the topic?

Scientific Considerations

- Is there a **science** to software development?
- SD is becoming increasingly more scientific, with new research and tool development. The field is young.
- There are still elements of **art**, as well as science.

Richard Feynman in Lectures on Computation

- "Computer science also differs from physics in that it is not actually a science. It does not study natural objects. Neither is it, as you might think, mathematics; although it does use mathematical reasoning pretty extensively. Rather, computer science is like engineering - it is all about getting something to do something ..."
- [Who was Richard Feynman? Did he ever work for a computer-related company?]
- [Does "science" need to study only "natural objects"?]
 - [Consider "digital physics" (Edward Fredkin).]

For the Theorist:

- Software development is often the “proving point” of computer science.
- Having a result published in a paper is nothing like producing a working product based on the result.

Do the techniques of SD
apply to other fields?

How might a typical software developer
spend his/her time?

___% interacting with customer, management, and
other developers

___% writing requirements, specification, design

___% writing code, debugging

___% testing

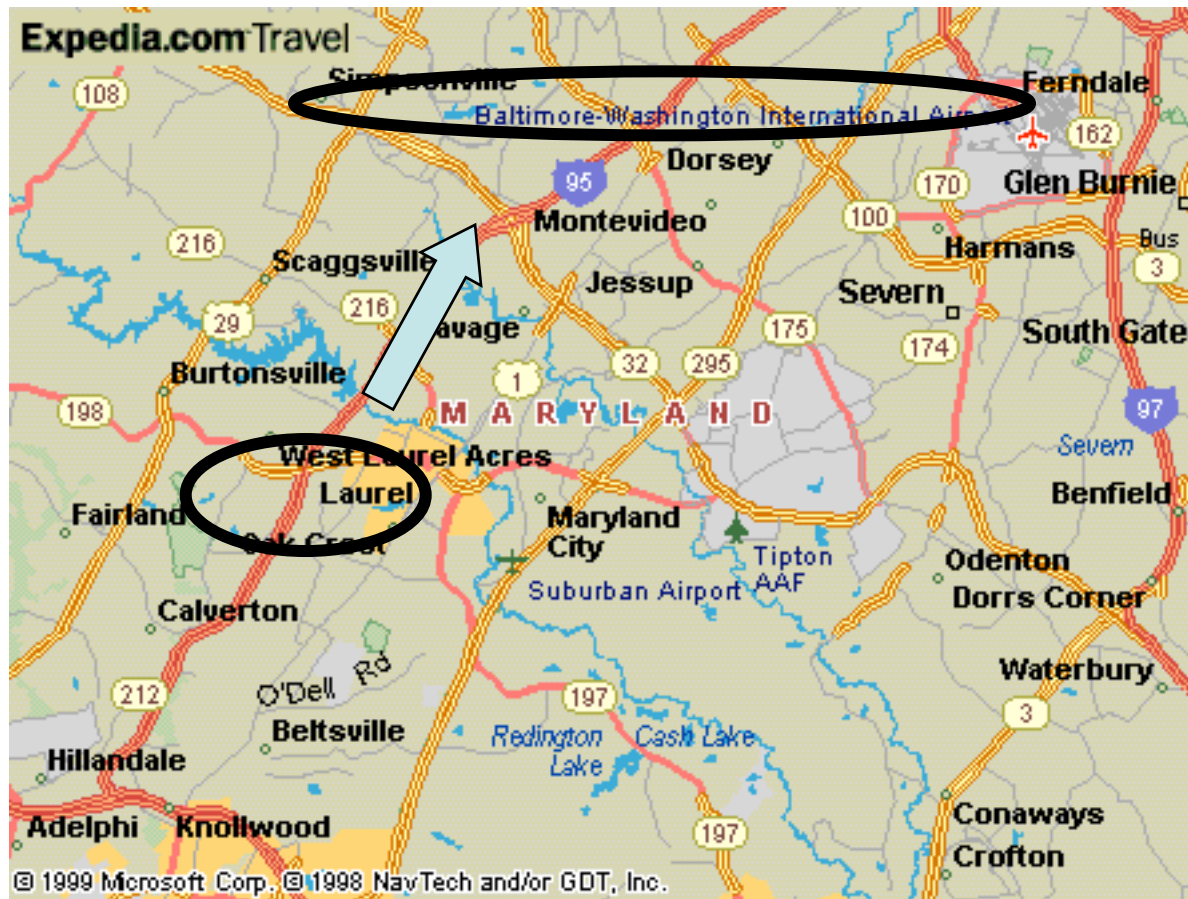
A Common Issue

- The management of complexity is common to several areas.
- Some information systems probably qualify as the most complex systems ever built.
- *Un-needed* complexity is not a feature; Software engineering attempts to prevent it.

Global Impact of a Single Software Development Project

Example: An Early Route Advising System

10 mi.



Output reported in 20.62, Oct. 1, 1999

Excerpts from **Expedia Maps** (*then Microsoft*) directions:

From: **Laurel, Maryland**

To: **Baltimore-Washington International Airport, Maryland**

Driving Distance: 5865.1 miles

Time: 9 day(s) 3 hour(s) 22 minute(s)

Time (hour:minute)	Instruction
0:00	Depart Laurel, Maryland
1:01	Entering Delaware
1:17	Entering New Jersey
3:24	Entering New York
3:51	Entering Connecticut
5:51	Entering Massachusetts
7:29	Entering New Hampshire
7:44	Entering Maine
12:20	Entering New Brunswick
20:20	Take the North Sydney-Argentia Ferry
34:32	Entering Newfoundland
36:35	Turn left onto Local road(s) (4543.1 mi)
219:22	Arrive Baltimore-Washington International Airport, Maryland

Current Version

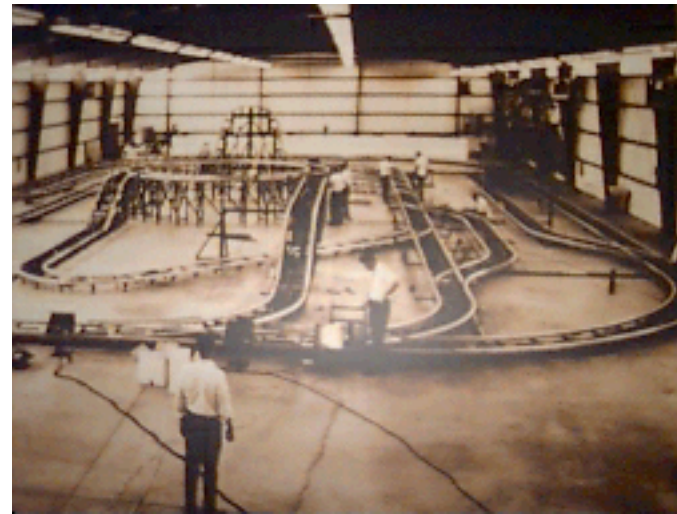
Directions	Distance	Time
Start: Depart Start on SR-198 [Gorman Ave] (East)	3.5	0:06
1: Take Ramp (RIGHT) onto SR-295 [Baltimore Washington Pkwy] (MD-295 / Balt./Wash. Pkwy. / Baltimore)	9.5	0:10
2: Take Ramp (RIGHT) onto I-195 (I-195 / Bwi Airport)	1.8	0:03
3: Road name changes to Local road(s)	0.1	0:01
4: Bear RIGHT (South) onto Local road(s) (Arriving Flights / Hourly Parking)	0.4	0:02
5: Turn RIGHT (South) onto Local road(s)	0.1	< 1min
End: Arrive End	< 0.1	< 1min
Total Route	15.4 mi	22 mins

Example:

FAA Advanced Automation System

- Announced in 1981, to modernize air-traffic control.
- IBM awarded contract in 1989 after 4 year bid process. Estimated 1.5 million lines of code, **\$2.5 billion**, to be deployed by 1991.
- Estimate increased to **\$4.3 billion** in 1987, deployment slipped to 1995.
- Determined in 1994 that the **project would never be completed**, and the project was cancelled.
- Scaled-down version awarded to Loral (which bought IBM FSD) at estimated cost of \$1.5 billion, to be deployed by 1997. The revised project was completed two weeks early.

Example:
New (1995) Denver Airport (1)



[BAE Automated Systems, Inc.](#)

New Denver Airport (2)

- Contract of \$193 million in June 1992 to begin work on the baggage-handling system.
- Involved 100 computers, 56 laser scanners, 400 radio systems.
- Baggage system failures:
 - Continued to unload bags despite jam on conveyor belt.
 - Loaded bags onto full carts, causing bags to fall onto tracks.
 - Bags wedged under carts due to timing problems.
 - Lost track of carts themselves, due to above types of incidents.
- Airport is said to have been "losing \$1 million per day" due to the baggage system upon opening.

Read More: New Denver Airport

<http://www.cs.mdx.ac.uk/research/SFC/Reports/TR2002-01.pdf>

Software Forensics Centre Technical Report TR 2002-01

A Case Narrative of the Project Problems with the Denver Airport
Baggage Handling System (DABHS)

by

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Therac-25 Accelerator Treatment Facility

(see IEEE Computer, Vol. 26, No. 7, July 1993, pp. 18-41.)

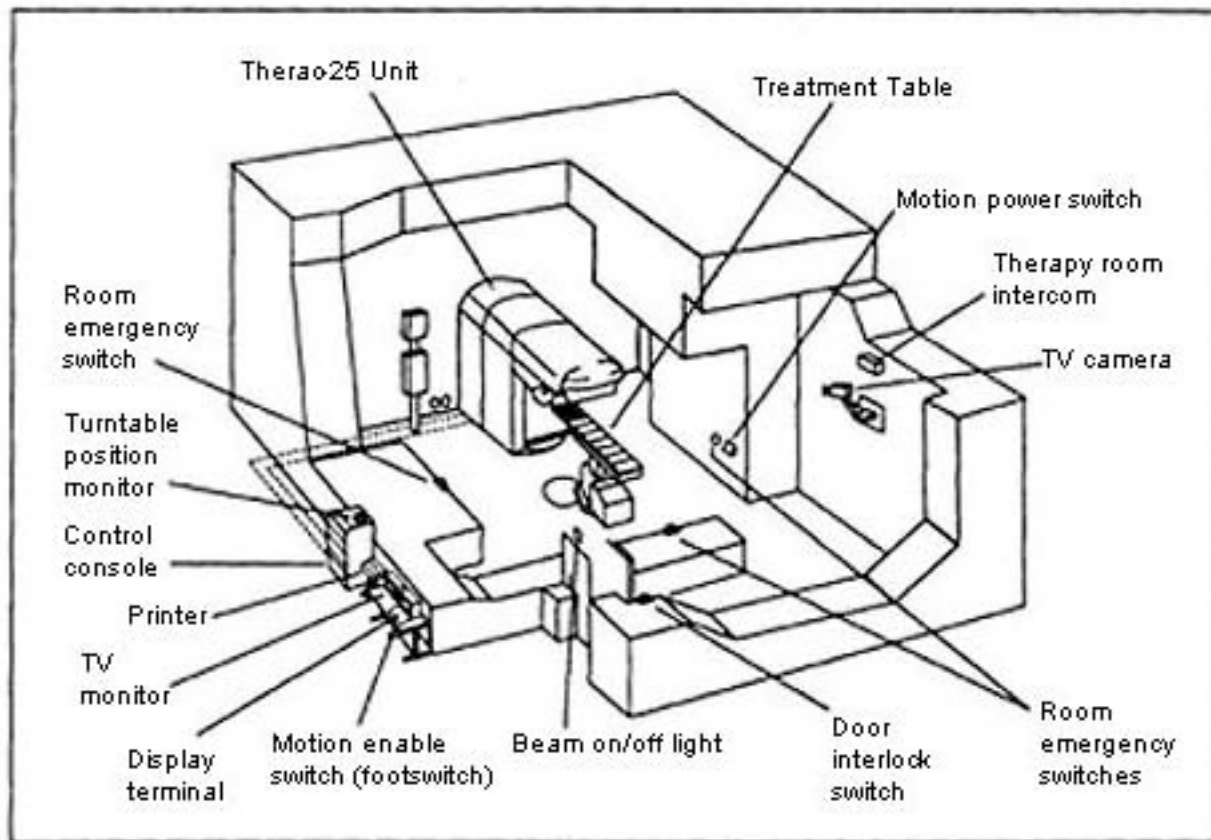


Figure 1. Typical Therac-25 facility

Therac-25: Overdoses caused by "incorrect software"

http://www.cse.msu.edu/~cse470/Public/Handouts/Therac/Therac_1.html

- Six massive-overdose accidents between 1985 and 1987.
- Incidents (dose of > 1000 rads can be fatal):
 - 3 June 1985: Marietta, Georgia, patient receives **overdose** (est. dose: 15,000-20,000 rads).
 - 26 July 1985: Hamilton, Canada, patient **severely burned**, later **dies** November 3, 1985 (est. dose: 13,000-17,000 rads)
 - 21 March 1986: Tyler, Texas, patient receives **overdose**, patient **dies** later (est. dose: 16,500 - 25,00 rads).
 - 11 April 1986: Tyler, Texas, another patient receives **overdose**, patient **dies** in 3 weeks (est. dose: 4,000 rads).
 - 17 January 1987: Yakima, Washington, patient receives **overdose**, patient **dies** 3 1/2 months later (est. dose: 8,000 - 10,000 rads).
- Recalled in 1987 for extensive design changes, including hardware to safeguard against software errors.

Therac-25 Software Errors

(source: <http://kachina.kennesaw.edu/~mking/courses/is8070/lectures/ethics4.html>)

- The user interface was weak: **error messages were cryptic.** Operator's manual for the Therac-25 did not contain a reference to error messages. Some errors would pause the machine waiting for the operator to press a key to resume. It was assumed these errors were trivial. Other errors forced a restart of the system: these errors were assumed to be serious. This intuitive assessment of the errors was not valid. The overdoses occurred when the system paused.
- One specific error was the **incrementation of an integer counter in a one-byte address.** When the system was reset for the 256th time, the counter indicated 0, signifying a valid status for the component being tested.
- Another specific error occurred when the **system failed to properly check for input from the keyboard.** If the operator wanted to make changes to the set up, these could be done while parts of the system were initializing. Parts of the system received the modified set-up instructions, and other parts did not. Experienced users were more prone to invoke this error.

Risks Digest

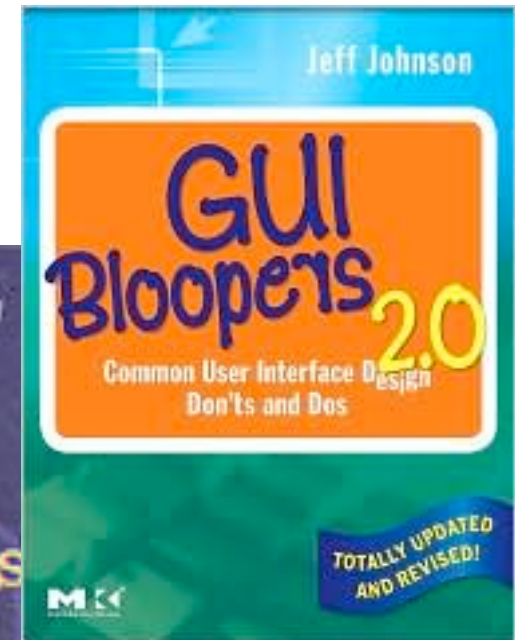
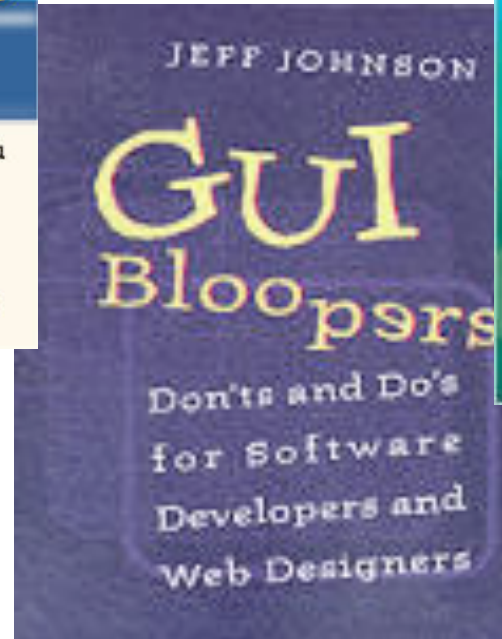
- Consult the Risks digest for many other examples.
- <http://catless.ncl.ac.uk/Risks/>

ComputingCases.org
(NSF-supported)



ComputingCases.org

Usability Concerns



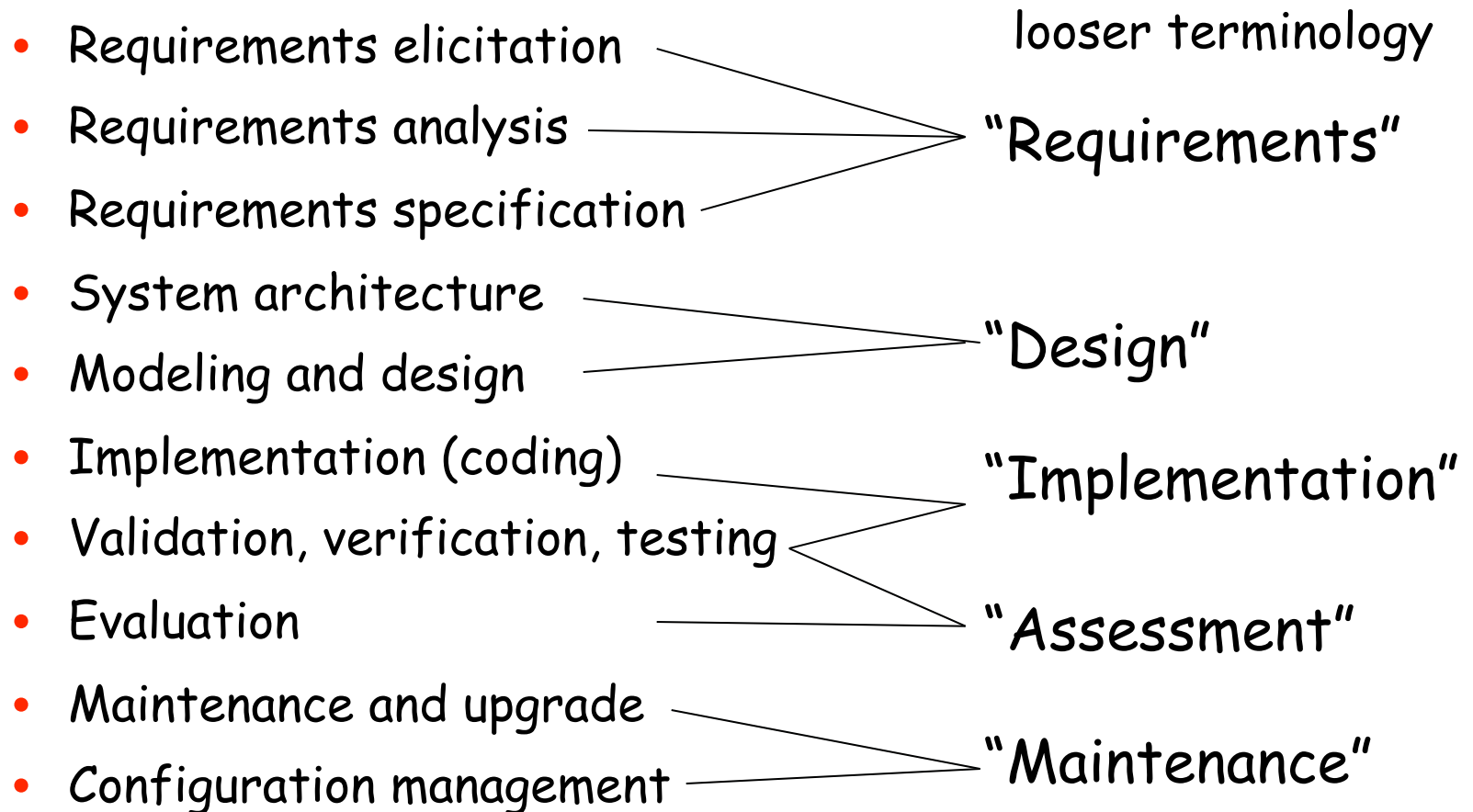
Transition

- The preceding examples of flaws are a few of many.
- What can we do about it?
- Software development **processes** must promote management of quality software development.

Class Activity (10 mins)

- Brainstorm a list of the **three most critical problems** that you think face software development organizations today.
 - First make your own list.
 - Second, try to convince a partner that the items on your list are the most critical.
 - Form a combined list, again restricting to what you and your partner think are the **three most critical problems**.
 - Transcribe your list of three to a viewgraph slide.
 - Put your and your partner's name at the top of the slide.

Facets of Software Development



Spectrum of Development Philosophies

No Universally-Accepted Approach

- Rigidly-structured
 - Classical "waterfall"-based
 - Spiral
 - ...
 - Scrum
 - Extreme programming
- Loosely-structured

Requirements Analysis

Before software is developed, it *may* be important to **specify** as clearly as possible the requirements for the ultimate system, in order to:

- estimate the costs and time involved
- serve as a starting point for design
- provide a reference point for the validation of results

Specification

In order to carry out analysis, design, and evaluation in rigorous terms, may be important to have a clear specification of the system, using, for example:

- "Use Cases", scenarios
- structured forms of English
- specification languages
- clearly-stated assumptions

Models and Design

For larger systems, with many facets, it may be important to have models, design methods, and tools that

- fit well with the software specification techniques
- provide a framework according to which further development proceeds
- permit tracing from implementation back to initial requirements

Towards "Software Architecture" (1)

- **Building-architecture** has achieved its stature because it deals with large and expensive systems that affect the lives of many people.
- It has developed methodologies and standards for design.



Towards "Software Architecture" (2)

- Software now often falls into this category of being large, expensive, and affecting the lives of many people.
- The methodologies and standards for software architecture are in their infancy compared to those of building architecture.

Examples of Emerging Architectural Techniques

- Specialized architectural (as opposed to programming) **languages**, such as **UML**
- **Software tools** for
 - Requirements management
 - Modeling
 - Design
 - Validation
 - Configuration management
- **Standards**
 - Communication protocols
 - Data languages, such as XML (see <http://xmlsucks.org/>)
 - User interfaces

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Monday, 19 January 2009

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Debate: Are Standards the
Enemy of Innovation?

Implementation

- Implementation concerns the development of code modules that constitute a system.
- *Ab initio* implementation is increasingly cost-prohibitive.
- *COTS* (commercial, off-the-shelf) software, although an option, is not a panacea; it often is not sufficiently customizable.
- *Standardized reusable modules* ("components") especially ones that have been formally specified and certified achieve a certain economy without as much sacrifice of flexibility.

Validation

Validation refers to ascertaining that software systems, once developed, meet the requirements. This topic covers:

- Formal testing methods
- Mathematical verification methods
- Model-checking
- Management techniques for paths from requirements to testing and verification

Software Development Process

(not to be confused with "processes" in the sense
of concurrent operating-system tasks)

Process

- The next few slides list *possible components* of a software development process, but not necessarily in the order in which those components are executed.

Components of a Software Development Process

- Program Construction
 - Writing the program, debugging, unit testing
 - *All projects have this component.*

Components of a Software Development Process

- Program Validation
 - Establishing, as thoroughly as is feasible, that the program performs as desired by the *customer*.
 - All *worthwhile* projects have this component.

Components of a Software Development Process

- System Design
 - Determining structural aspects of the program or system *prior* to programming
 - *Most* successful and within-budget projects of significant size have this component.

Components of a Software Development Process

- Requirements Specification
 - Specifying how system is to behave, from the user's viewpoint.
 - Occurs prior to design or programming
 - Most *funded* projects will have this component.

Components of a Software Development Process

- Requirements *Elicitation*
 - Getting the client's view of what the requirements are, through dialog
 - Typically less "technical" than specification

Components of a Software Development Process

- *Requirements Analysis*
 - Translating the understanding derived from requirements elicitation into a specification

Ordered Summary of a Software Development Process

- Requirements
 - Elicitation
 - Analysis
 - Specification
- System Design
- Program Construction
- Validation

Requirements

(Elicitation, analysis,
specification, documentation,
etc.)

SRS = "Software Requirements Specification"

- The SRS should contain *all, and only*, information that *defines* the software product.
- The SRS should *not* contain ancillary information about how the product is to be constructed or developed, although this might be part of a contract or statement of work (SOW) that *refers to* the SRS.
- Adding the second type of information as a requirement might overly constrain the product construction, preventing the best techniques from being used.

Requirements ≠ Design

- Requirements are the “what”, not the “how”.
- They dictate the **problem**, not the **solution**.
- Requirements typically **don't** specify the internal structure of the product.
- They *might* specify that a certain programming language be used (because source is a deliverable).
- They *might* specify that a specific design notation, such as UML, must be available as a by-product.

Fred Brooks'

"No Silver Bullet" paper

<http://www.lips.utexas.edu/ee382c-15005/Readings/Readings1/05-Broo87.pdf>

- "The hardest single part of building a software system is **deciding precisely what to build.**
- No other part of the conceptual work is as difficult as establishing the detailed technical requirements, including all the interfaces to people, to machines, and to other software systems.
- No other part of the work cripples the resulting system if done wrong.
- No other part is more difficult to rectify later."

Other Brooks' Quotes

http://en.wikiquote.org/wiki/Fred_Brooks

- [Brooks' Law]: Adding manpower to a late software project makes it later.
- The management question, therefore, is not whether to build a pilot system and throw it away. You will do that. ... Hence **plan to throw one away; you will, anyhow.**



Economic Importance of Requirements

- Conventional wisdom: Cost of addressing incorrect or absent requirement “skyrockets” as project approaches deployment.

Project phase	Relative cost to correct requirement defect.
Requirements	1%
Design	3%
Code	8%
Test	18%
Operation	110%

Requirements Philosophy not Universal

- Not every methodology agrees about how requirements are expressed and captured.
- For discussion purposes, you should adopt the appropriate context.
- In the real world, we often don't get a choice.

Software Requirements Specification (SRS)

Typical Elements

- **Background information**
 - Type of product and its purpose
 - Intended users of product
 - Glossary of terms, both domain-specific and product-specific
- **“Functional” requirements**
 - Behavioral descriptions of software use, including how exceptional circumstances are to be handled.

Elements of an SRS (cont'd)

- **“Non-functional” requirements**
 - Performance requirements (speed, memory use, disk space)
 - Constraints, including security requirements
 - Collateral requirements (other software)
 - Hardware platforms supported
 - User documentation to be provided
 - Maximum-size requirements (for input data, etc.)
 - What language?
 - What artifacts?

Not in an SRS itself (why?), but in other documents

- Acceptance tests to be used
- Cost estimate of doing the project
- Delivery schedule
- Design process to be used
- Development plan, milestones
- Management structure
- Market analysis
- Stakeholders in the project

SRS Examples

- Examples of requirements qualities and flaws:

<http://www.processimpact.com/articles/qualreqs.html>

- Examples of a student-written requirements document:

http://www.cs.hmc.edu/courses/2002/spring/cs121/chimmp/web/CHIMMP_SRS.html

Desirable Properties of an SRS

- **Consistency:** No conflicting requirements.
- **Completeness:** All requirements present.
- **Clarity:** Unambiguous statements.
- **Coherent presentation**
- **Organized Hierarchically:** Group related topics.
- **No Gold-Plating:** (no unnecessary frills).

Desirable Properties of an SRS, continued

- Feasible (e.g. does not try to solve the halting problem).
- Written so that requirements are ultimately traceable to and testable in the final product.
- Prioritized by
 - Degree of necessity
 - Desired completion order
- Evolvable

FURPS+ mnemonic

software product properties ("ilities")

- **Functionality** - Feature set, Capabilities, Generality, Security
- **Usability** - Human factors, Aesthetics, Consistency, Documentation
- **Reliability** - Frequency/severity of failure, Recoverability, Predictability, Accuracy, Mean time to failure
- **Performance** - Speed, Efficiency, Resource consumption, Throughput, Response time
- **Supportability** - Testability, Extensibility, Adaptability, Maintainability, Compatibility, Configurability, Serviceability, Installability, Localizability, Portability
- The model, developed at Hewlett-Packard, was first publicly elaborated by Grady and Caswell. The + was later added to the model after various campaigns at HP to extend the acronym to emphasize various attributes. "FURPS+ is now widely used in the software industry."

source: wikipedia

Ways to "capture" requirements

- Customer writes fully (rare).
- Interview customer (elicitation) (common).
- You write, customer approves.
- Iterative combination of the above.

Requirements Elicitation Exercise

- Instructor plays the role of client.
- Class members play the role of requirements elicitor.
- Write-up an SRS for the next class meeting.

Requirements Engineering

- The requirements engineer is a specialist that provides interfaces between both stakeholders and developers.
- This is elaborated on the following 3 slides.
- Source:

<http://cs.wwc.edu/~aabyan/435/Requirements.html>

Client and Other Stakeholders

- may not be able to accurately describe what they do (knowledge may be tacit),
- may not know what is technically feasible,
- may change their minds once they see the possibilities more clearly, and
- often do not appreciate the complexity inherent in software engineering, and the impact of changed requirements

Developers desire specifications that are:

- clear, unambiguous, and, where appropriate, quantitative.
- nonprescriptive
- correct, complete, concise
- precise and verifiable
- consistent
- traceable
- modifiable

Requirements Engineer has

- technical skills,
- ability to acquire an understanding of the application domain, and
- interpersonal skills to help build consensus between heterogeneous groups of stakeholders.

Potential Mismatch

- The customer's language might not be your preferred language.
- It will typically be non-computerese.
- The customer's and users' needs, rather than the designer's or implementor's favorite approaches, should be what drives the project.

Roger Pressman's Requirements Engineering Checklist

- Is there a written request for the work to be done?
- Does the written request outline the problem to be solved, the output to be produced, and the input that will be required?
- Does the written request have a single named author?
- Does the named author have authority to make decisions about the request?
- Is the person doing requirement elicitation familiar with the business area under consideration?
- Is the person doing requirement elicitation familiar with local jargon, business issues, personnel and politics?
- Has a formal meeting been requested with the customer?
- Has an agenda for the meeting been established; have ground rules for the meeting been defined; have all people who need to attend been invited?
- Has a "definition mechanism" been defined?
- Is the customer willing to attend the meeting(s)?
- Have context-free questions (SEPA, 5/e, p. 275) been asked and answered?
- Have written usage scenarios been developed as part of the elicitation activity?
- Has the customer walked through the usage scenarios? Have inaccuracies and modification been specified?
- Have basic output objects been fully defined?
- Have input objects been defined?
- Have the functions to be implemented been defined, decomposed and tied to usage scenarios?
- Has the behavior of the system been fully defined (from the customer's viewpoint) under various operating conditions?
- Have user interface characteristics been discussed and defined?
- Has earned value been determined for customer requirements?
- Have constraints and limitation been identified?
- Have requirements been ranked by importance to the customer?
- Have review(s) been conducted for all information collected as part of requirements elicitation?