WHAT THE CUSTOMER WANTED
WHAT THE CUSTOMER REQUESTED
WHAT THE CONTRACTOR ORDERED

WHAT ENGINEERING DESIGNED
WHAT MANUFACTURING BUILT
WHAT FIELD SERVICE INSTALLED
Requirements Engineering: Introduction

- Why RE?
  - Why RE in SysE?
  - Software Lifecycle and Error Propagation
  - Case Studies and The Standish Report

- What is RE?
  - Role of Requirements

- How to do RE? -> RE Processes

Sources of Material
Software Lifecycle Revisited

- Systems Engineering
  - Requirements Analysis
    - Software Architecture and Design
      - Implementation
        - Testing
          - SQA and Metrics
            - Maintenance

Projects:
- Project Planning and Mgmt
- Software Process
- Configuration Mgmt
- Evolution And Re-engineering

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Why RE?

Error Propagation in Lifecycle [Mizuno82]

Simplified Lifecycle

Cumulative Effects of Error

Requirements Specification
- correct spec.
- erroneous spec.

Design
- correct design
- erroneous design
- design based on erroneous spec.

Implementation
- correct program
- erroneous program
- prog based on erroneous design
- prog based on erroneous spec.

Testing
- correct functions
- correctable errors
- uncorrectable errors
- hidden errors

Maintenance
- Imperfect program products

How big is the erroneous spec.? How costly is it?

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Why RE?

How big is the "erroneous specification"?

† Bell Labs and IBM studies
80% of all defects are inserted in the requirements phase. Improving the requirements definition process reduces the amount of testing and rework required.
And the above figures do not include the end user losses who have to live with poor software on a daily basis. [Testing Techniques Newsletter]

† U.S. Air Force projects
36% of all defects were due to faulty requirements translation. Only 9% of these errors were resolved (in the requirements phase). [Sheldon92]

† Voyager and Galileo spacecraft
Of the 197 significant software faults found during integration & system testing, only 3 of those errors were programming errors; the vast majority of the faults were requirements problems. [Lutz93]

† Application Specific Integrated Circuits [ASICs]
>1/2 are faulty on first fabrication. A majority of these faults are related to reqs. errors.

† [UK Health and Safety] Executive
Specification 44.1%  Operation and Maintenance 14.7%
Design and Implementation 14.7%  Changes after commissioning 20.6%
Installation and Commissioning 5.9%  
[Her Majesty’s Stationary Office 1995 ISBN 0 7176 0847 6]
What Factors Contribute to Project Success?

The CHAOS Ten

<table>
<thead>
<tr>
<th>Project Success Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Executive Management Support</td>
</tr>
<tr>
<td>2. User Involvement</td>
</tr>
<tr>
<td>3. Experienced Project Manager</td>
</tr>
<tr>
<td>4. Clear Business Objectives</td>
</tr>
<tr>
<td>5. Minimized Scope</td>
</tr>
<tr>
<td>6. Standard Software Infrastructure</td>
</tr>
<tr>
<td>7. Firm Basic Requirements</td>
</tr>
<tr>
<td>8. Formal Methodology</td>
</tr>
<tr>
<td>9. Reliable Estimates</td>
</tr>
<tr>
<td>10. Other</td>
</tr>
</tbody>
</table>

yearly since 1994, survey of close to 300,000 projects
What Factors Contribute to Project Failure?

The CHAOS Ten

**Project Challenged Factors**
1. Lack of User Input
2. Incomplete Requirements & Specifications
3. Changing Requirements & Specifications
4. Lack of Executive Support
5. Technology Incompetence
6. Lack of Resources
7. Unrealistic Expectations
8. Unclear Objectives
9. Unrealistic Time Frames
10. New Technology

**Project Impaired Factors**
1. Incomplete Requirements
2. Lack of User Involvement
3. Lack of Resources
4. Unrealistic Expectations
5. Lack of Executive Support
6. Changing Requirements & Specifications
7. Lack of Planning
8. Didn't Need It Any Longer
9. Lack of IT Management
10. Technology Illiteracy
“The definition of insanity is doing the same thing over and over again and expecting a different result.”
[Albert Einstein]
**Size Is Important: Success by Project Size**

Standish Group, ‘99 (www.standishgroup.com)

![Bar chart showing success rate by project size](Image)

- **Success Rate (%)**
- **Project Size ($)**

**Why?**
Why RE?

How costly are requirements errors?

- [Lindstrom93]
  Get the requirements wrong, you’ll destroy the project.

- [Boehm87]
  COST (correcting design/implementation errors)
  \[ \text{COST} = 100 \times \text{COST (correcting requirements errors)} \]

- [Humphrey, Managing the Software Process, Ch1, p11-12]
  a useful rule of thumb: It takes about 1 to 4 working hours to find and fix a bug through inspections and about 15 to 20 working hours to find and fix a bug in function or system test.

- [Curtis88]
  Three most frequent problems plaguing large software systems:
  - communication and coordination
  - thin spread of domain application knowledge
  - changing and conflicting requirements

**Defining the problem is The Problem**
The High Cost of Requirement Errors

The 1-10-100 Rule

Requirements Time

- .5 - 1
- 2.5
- 5
- 10
- 25
- 100

Design

Coding

Unit Test

Acceptance Test

Maintenance

"All together, the results show as much as a 200:1 cost ratio between finding errors in the requirements and maintenance stages of the software lifecycle."

Relative cost to repair errors:
When introduced vs. when repaired.

Average cost ratio 14:1

[Grady 1989]  [Boehm 1988]

Why?
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Sources of Material
What is RE?

"... Requirements Engineering is the branch of Systems engineering concerned with real-world goals for, services provided by, and constraints on software systems. Requirements engineering is also concerned with the relationships of these factors to precise specifications of system behavior and to their evolution over time and across system families..."

[Zavc94]
What is RE?

Role of requirements

- agreement regarding the requirements between system developers, customers, and end-users.
  - legal contract (flexible, inflexible)
  - multi-party
    - communication and coordination
    - conflicting views
    - changing views
- the basis for software design
  - defect-free as much as possible
  - technically feasible
- support for verification and validation
- support for system evolution
  - system evolution – change (old system, new system)
  - change (old requirements, new requirements)

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Systematic Decision Making is Essential

- Requirements Engineering is about determining
  - problems with the current status (As-Is)
  - objectives to achieve
  - changes to bring about
  - for a better future (To-Be)

We want to make a change in the environment
We will build some system to do it
This system must interact with the environment
What’s Essential?

- Modeling
  “A model is a pattern, plan, representation (especially in miniature), or description designed to show the main object or workings of an object, system, or concept” [Wikipedia]

- Systematic decision making
  “Decision making can be regarded as an outcome of mental processes (cognitive process) leading to the selection of a course of action among several alternatives. Every decision making process produces a final choice. The output can be an action or an opinion of choice” [Wikipedia]
What is RE?

Not all RE projects are similar

🌟 Customer-driven projects
- involve a customer who needs a system that solves a particular problem
- often one-shot

<table>
<thead>
<tr>
<th>Customer</th>
<th>Project</th>
<th>Developer</th>
</tr>
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<tbody>
<tr>
<td>Navy</td>
<td>Missile Tracking</td>
<td>Raytheon-E-Sys</td>
</tr>
<tr>
<td></td>
<td>Weapon Inventory</td>
<td>TRW</td>
</tr>
<tr>
<td>Sprint</td>
<td>MAN</td>
<td>Nortel</td>
</tr>
<tr>
<td>MCI</td>
<td>Accounting</td>
<td></td>
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</table>

🌟 Market-driven projects
- involve a developer who needs to develop a system that is to be sold to the market
- often hard to determine what the customer really wants

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<tr>
<td>Office workers?</td>
<td>Groupware</td>
<td>Microsoft</td>
</tr>
<tr>
<td>Casual users?</td>
<td>Multimedia</td>
<td>Fujitsu</td>
</tr>
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* Examples are hypothetical
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Sources of Material
What is RE Really about?

Can You Stop the rain?

Rain, Rain Go Away!
Go Away!
Abracadabra!!!

... It’s snowing!

What is it you really want?

What does the customer really want?

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Sources of Course Material
Some basic material

Introduction to RE  [Davis.Ch1; LK.Ch1]

Requirements Engineering Processes  [LK.Ch2]
  RE evolutionary process
  RE basic process
  RE in software lifecycle
  Process vs. product specifications

Requirements Analysis, Modeling and Specification  [LK.Sec4.1 -4.2]
  Requirements Elicitation:  [LK.Ch3]
    Scenario Analysis  [Martin & Odell. Ch28]

Enterprise Requirements:  [LK.Sec4.3]
  Modeling Techniques
    Agent-oriented enterprise modeling
    Business modeling with UML
    Conventional enterprise modeling techniques

AS-IS or TO-BE?

Functional Requirements: Semi-formal Structural Models  [LK.Sec4.3; Davis.Ch2]
  Structured analysis

Functional Requirements: Formal Structural Models
  A Formal OO-RML/Telos
    Deficiencies of SA
    RML/Telos Essentials
    A Formalization
    A Brief Survey of FMs

Metamodeling
  Models, Metaclasse, Metamodels
  Metamodels for UML and other notations

Functional Requirements: Behavioral Models  [Davis.Ch4]
  Decision-oriented
  State-oriented
  Function-oriented behavioral models

Non-Functional Requirements  [CNYM, 2000; LK.Ch5; Davis.Ch6]
  Why NFRs
  What – definitions and classifications
  How – product- and process-oriented approaches

Another possible topic: Model Checking
Parts of Lecture Notes Come From

- Plus other references as in the syllabus
- Plus some selected articles (on the next slide)
- Plus articles and web resources as indicated in individual modules
Parts of Lecture Notes Come From

Some selected articles

Parts of Lecture Notes Come From

Some selected articles

Some Questions

Trials and Errors: Why Science Is Failing Us
http://www.wired.com/magazine/2011/12/ff_causation/all/1

(reductionist vs. causalist?)

1 + 1 = 2?

Do stakeholders fall down from the sky when you need them?

Is my pain your pleasure?