

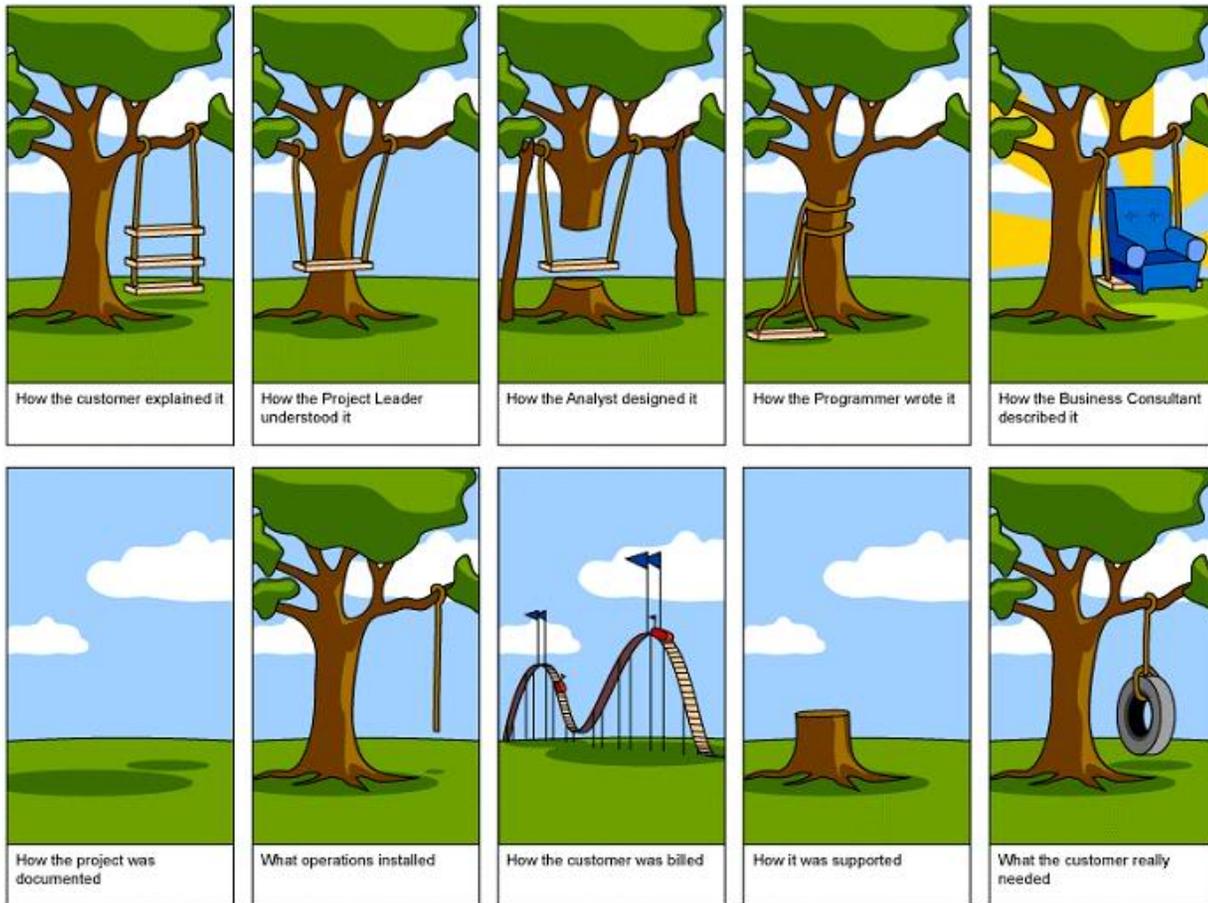
Engineering Requirements



Objectives

- ▶ Understand the properties of an engineering requirement and know how to develop well-formed requirements that meet the properties.
- ▶ Be familiar with engineering requirements that are commonly specified in electrical and computer systems.
- ▶ Understand the properties of the complete requirements specification, as well as knowing the steps to develop one.
- ▶ Be able to conduct advanced requirements analysis to identify tradeoffs.

The Problem



Bad Design Can Kill You!





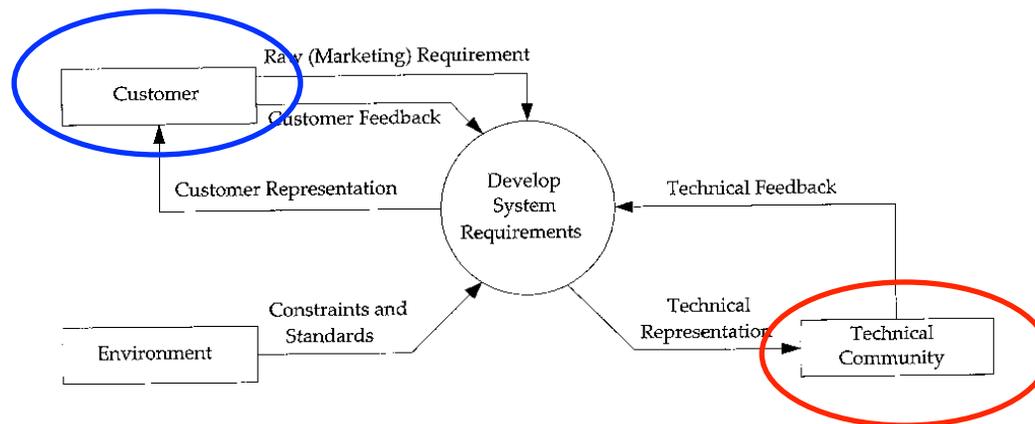
So What Can We DO?

- So we need a process to better understand what is needed
- We need to make sure our design will meet the goal of the customer.

Requirements Specifications Process

Overview of Requirements Specifications Process

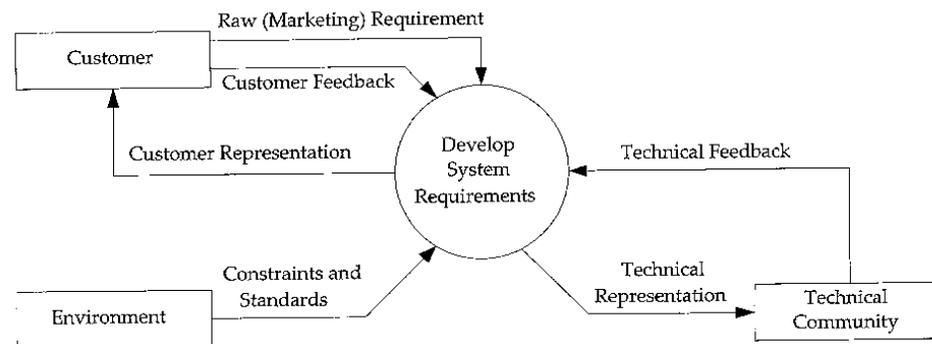
- Collection of
 - Marketing Requirements
 - Engineering Requirements
- Stakeholders
 - Customers
 - Environment
 - Technical community



IEEE Guide for Developing System Requirements Specifications: IEEE std. 1233-1998

Engineering Requirements

- Short statements stating the technical needs
 - *System should be able to supply 30 W power.*
- Initiated by the marketing requirements to satisfy customer needs





Engineering Requirements - Properties

- Abstract
 - Description of capabilities and conditions; Should be numerical.
 - Explain what it does **not** how it does it
- Verifiable
 - Ways to **measure and demonstrate** that it meets the needs
- Unambiguous
 - Short and **clear**
 - A one-sentence description of the requirement.
- Tractable
 - It can be **traced** to the original customer need
- Realistic
 - Must have **benchmark and releasable**
 - Realistic targets – tolerance (e.g., +/- to ppm)



Examples

- *The robot must have an average forward speed of 0.5 feet/sec.*
- *The robot must employ IP sensors to sense its surrounding temperature* ← **Not an abstract**
- *The robot must navigate* ← **Explaining conditions**
- *The guitarist must be able to use the tuning device to tune all strings of a guitar within 1% of the correct pitch within 5 minutes.*



Engineering Requirements - Constraints

- Design decision imposed by the environment
- Limits of the design
- **Typically violates the abstract**
- Example
 - *The system must use a PIC18F52.*



Engineering Requirements - Standards

- Ways of doing things to ensure interoperability
- Different levels of usage
 - User
 - Implementation
 - Developer
- Different standard types
 - Interfacing
 - Reliability and Performance
 - Safety
 - Documentation (ISO)
 - Programming language
 - Mechanical
 - Communications
 - Testing



Engineering Requirements - Categories

- Performance
- Functionality
- Economic
- Energy
- Environmental
- Safety
- Usability
- Legal
- Maintenance
- Operational
- Manufacturability
- Political
- Reliability and availability
- Social and cultural

notes



Engineering Requirement Examples

Performance

- *The system should detect 90% of all human faces in an image.*
- *The amplifier will have a total harmonic distortion less than 1%.*

Reliability & Availability

- *The system will have a reliability of 95% in five years.*
- *The system will be operational from 4AM to 10PM, 365 days a year.*



Engineering Requirement Examples

Energy

- *The system will operate for a minimum of three hours without needing*

Environmental

- *The system should be able to operate in the temperature range of 0°C to 75°C.*
- *The system must be waterproof and operate while submersed in water.*
- *to be recharged.*



Requirement Specifications Process



Requirements Specification – Characteristics of Properties

- Normalized (orthogonal) set
 - No overlapping or redundancy between requirements
 - Projection of one requirement to another is zero (dot product)
- Complete set
 - Contains all requirements
- Consistent
 - No conflicting requirement
- Bounded
 - Contain minimum acceptable bounds for targets
- Modifiable
 - Requirements must be evolutionary
 - Benchmarked against the baseline requirements



How do you VALIDATE Requirements?

- Ask the customer if the requirements meet their needs.
- Usually done in teams.
- For each *engineering requirement*
 - Traceable?
 - Verifiable?
 - Realistic & technical feasible?
- For the complete *Requirements Specification*
 - Orthogonal?
 - Complete?
 - Consistent?



Example

- **Marketing Requirements**
 1. **The system should have excellent sound quality**
 2. **The system should have high output power**
 3. **The system should be easy to install**
 4. **The system should have Low cost**
- **Requirement Specifications:**

Case Study – Car Audio amplifier

Marketing Requirements	Engineering Requirements	Justification
1, 2, 4	1. The <i>total harmonic distortion</i> should be <0.1%.	Based upon competitive benchmarking and existing amplifier technology. Class A, B, and AB amplifiers are able to obtain this level of THD.
1–4	1. Should be able to sustain an <i>output power</i> that averages ≥ 35 watts with a peak value of ≥ 70 watts.	This power range provides more than adequate sound throughout the automobile compartment. It is a sustainable output power for projected amplifier complexity.
2, 4	1. Should have an <i>efficiency</i> (η) >40 %.	Achievable with several different classes of power amplifiers.
3	1. <i>Average installation time</i> for the power and audio connections should not exceed 5 minutes.	Past trials using standard audio and power jacks demonstrate that this is a reasonable installation time.



Homework:

Consider the following Marketing Requirements for designing a hands-free device whose intent is to allow a driver to communicate with an iPod audio player while driving. Tabulate all your engineering requirements and justify each requirement as shown in previous slides.

1. System (the hands-free accessory) should not minimize or slow down the functional quality of the iPod.
2. System should provide clear understandable speech.
3. System should be able to understand voice commands from user.
4. System should be able to fit and operate in an automobile.
5. System should be easy to use.
6. System should be portable.
7. System user should be able to search for songs and artists and receive feedback on selection.



Analysis

Engineering Requirement - Analysis

- Understanding the tradeoffs between different conflicting requirements
- **Identifying engineering and marketing requirements**
- **Requirement correlations**
 - **Up Arrow: Positive correlation; Both goals can be simultaneously met**
 - **Down Arrow: Negative correlation; Improving one will compromise the other**

- **Polarity**
 - (+) indicates desirability
 - (-) indicates non-desirability

		Engineering Requirements					
		THD	Output Power	η , Efficiency	Install Time	Dimensions	Cost
		-	+	+	-	-	-
Marketing Requirements	1) Sound Quality	+	↑↑	↓		↓↓	↓↓
	2) High Power	+	↓	↑↑	↑	↓↓	↓
	3) Install Ease	+		↓	↑↑	↑	↓
	4) Cost	-	↓↓	↓		↓	↑↑

Correlations between Requirements

Tradeoff Matrix for Car Audio amplifier

		THD	Output Power	η , Efficiency	Install Time	Dimensions	Cost
THD	-		↓			↓	↓
Output Power	+			↑		↓	↓
η , Efficiency	+					↑	↓
Install Time	-					↓	
Dimensions	-						↓
Cost	+						

Engineering Tradeoff Matrix
between different engineering requirements

Remember:

Up Arrow: Positive correlation; Both goals can be simultaneously met
Down Arrow: Negative correlation; Improving one will compromise the other

Competitive Bench Mark
-Selecting the target
-Understanding realistic gains

	Apex Audio	Monster Amps	Our Design
THD	0.05%	0.15%	0.1%
Power	30 W	50 W	35 W
Efficiency	70%	30%	40%
Cost	\$250	\$120	\$100

Baseline requirement comparison

House of Quality

- Integrating various information
 - Marketing Requirements
 - Engineering Requirements
 - Engineering-marketing tradeoff matrix
 - Engineering tradeoff matrix
 - Engineering target requirements

TDH and Output Power have negative correlation (we cannot lower distortion while keeping output power high)

		THD	Output Power	η , Efficiency	Install Time	Dimensions	Cost
		-	+	+	-	-	-
1) Sound Quality	+	↑↑	↓			↓↓	↓↓
2) High Power	+	↓	↑	↑↑		↓↓	↓
3) Install Ease	+		↓		↑↑	↑	↓
4) Cost	-	↓↓	↓	↓		↓	↑↑
Targets for Engineering Requirements		< 0.1%	35 watts	> 40%	≤ 5 minutes	6 × 8 × 3 inches	≤ \$100



References

- IEEE Std. 1233, 1998 Edition, “IEEE Guide for Developing System Requirements Specifications,” [Adobe Acrobat pdf file] (1998, Dec. 8) Available at HTTP:
<http://ieeexplore.ieee.org/iel4/5982/16016/00741940.pdf?isNumber=16016&prod=STD&arnumber=741940&arSt=&ared=&arAuthor=>
- “Volere Requirements Specification Template,” [webpage] (2005, Jan. 24) Available at HTTP:
<http://www.systemguild.com/GuildSite/Robs/Template.html>
- IEEE Guide for Developing System Requirements Specifications – online slides

Engineering-Marketing Matrix

		THD	Output Power	η , Efficiency	Install Time	Dimensions	Cost
		-	+	+	-	-	-
1) Sound Quality	+						
2) High Power	+						
3) Install Ease	+						
4) Cost	-						

Engineering Tradeoff Matrix

		THD	Output Power	η , Efficiency	Install Time	Dimensions	Cost
		-	+	+	-	-	-
THD	-						
Output Power	+						
η , Efficiency	+						
Install Time	-						
Dimensions	-						
Cost	-						

Competitive Benchmarks

	Apex Audio	Monster Amps	Our Design
THD	0.05%	0.15%	0.1%
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Efficiency	70%	30%	40%
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Project Application: The Requirements Specification

A complete requirements document will contain:

- Needs, Objectives, and Background (See Chapter 2).
- Requirements.
 - marketing requirements
 - engineering requirements
 - Should be abstract, verifiable, and traceable
 - Some maybe constraints
 - Some may be standards
 - Advanced analysis
 - Engineering-marketing tradeoffs
 - Engineering-engineering tradeoffs
 - Benchmarks



Summary

- Properties of engineering requirements
- Examples of engineering requirements
- Properties of the Requirements Specification
- Advanced Requirements Analysis
 - Tradeoff matrices
 - Benchmarks