Chapter 3 – The Requirements Specification

1. **Describe the relationship (similarities and differences) between *engineering requirements* and *performance requirements.* [R]**

   Engineering requirements are requirements that are concerned with the technical aspects of the design (voltage, amperes, etc.). Performance requirements are a subset of the engineering requirements which are limited in scope and specify performance related issues (speed, refresh rates, etc).

2. **Describe the relationship between the *system requirements specification* and *subsystem design specification*. [R/A]**

   System requirements specifications are the most general specifications that apply to the entire project or system. In contrast, a subsystem design specification is a smaller more defined portion of a complex system.

3. **Describe the difference between *verification* and *validation*. [R]**

   Validation is the process of determining if the requirements meet the needs of the end-user. This answer the question – are we building the right product? Verification is the process of measuring or demonstrating that the requirements are met in the final realization. Verification answers the question – are we building the product right (does it meet the requirements).

   Validation is typically harder to determine.

4. **Explain how *validation* is performed for a Requirements Specification. [R]**

   Validation can be performed by being able to answer the following questions affirmatively:

   - **Is each requirement verifiable?** That is can it be measured or shown in the final system implementation.
   - **Is each requirement traceable to a user requirement?**
   - **Is each requirement realistic and technically feasible?** This may be hard to determine. It can be determined based upon benchmarks or system prototypes.
   - **Is the property of orthogonality met for the Requirements Specification?** Are the requirements established with no redundancy?
   - **Is the property of completeness met?** Are all the needs of the end-user addressed in the Requirements Specification?
   - **Is the property of consistency met?** The Requirements Specification should not be self-contradictory.

5. **For each of the engineering requirements below, determine if it meets the properties of abstractness, unambiguous, and verifiable as defined in Section 3.3. If a requirement does not satisfy the properties, restate it so that it does: [A]**

   a. **The TV remote control will be easy to use.**

      Abstractness: **Yes –** doesn't give details on implementation

Unambiguous: **Maybe** – there is not a clear definition of easy-to-use. It could be possible to develop some metrics for easy to use, such as size of buttons, number of buttons, etc.

Verifiable: **Maybe -** this relates back to the ambiguity of easy-to-use. If the easy-to-use property is defined, then it could be verifiable.

b. The robot will identify objects in its path using ultrasonic sensors.

Abstractness: **No** – provides a solution to the problem (ultrasonic sensors)

Unambiguous: **No** – it will identify objects in its path, is somewhat clear. However, could be better defined if its path were defined, as well as the distance of detection

Verifiable: **No** (Because it is not unambiguous.)

Restatement: "The robot will identify objects in its forward path within 3 feet of the robot."

c. The car audio amplifier will be encased in aluminum and will operate in the automobile environment.

Abstractness: **No** – provides a solution to the problem (aluminum case)

Unambiguous: **No** – it will operate in an automobile is not quite clear. Where in the automobile and what size should it be?

Verifiable: **No** – because it is not unambiguous.

Restatement: "The car audio amplifier will operate in the automobile passgenger compartment and not have a size that exceeds 12"x4"6" "

d. The audio amplifier will have a total harmonic distortion that is less than 2%.

Abstractness: **Yes** – doesn't give details on implementation

Unambiguous: **Yes** – THD < 2%

Verifiable: **Yes**

e. The robot will be able to move at speed of 1 foot/sec in any direction.

Abstractness: **Yes** – doesn't give details on implementation

Unambiguous: **No** – provides two requirements in one statement

Verifiable: **Yes**

Restatement: "The robot will be able to move at a speed of 1 foot/sec."

"The robot will be able to move in any direction."

f. The system will employ smart power monitoring technology to achieve ultra-low power consumption.

Abstractness: **No** – provides a solution to the problem (smart power)

Unambiguous: **Yes** – it will achieve ultra-low power consumption

Verifiable: **No** – there is no exact target value on the power

Restatement: "The system will achieve power consumption below XX watts."

g. The system shall be easy to use by a 12 year old.

Abstractness: **Yes –** doesn't give details on implementation

Unambiguous: **Maybe –** a 12 year old can use this device is clear, but as we saw in an earlier problem it is hard to determine ease of use without some sort of definition.

Verifiable: **Yes**

Note: *Problems 2.6-3.9 and 3.10 guide the student through the steps of building the Requirements Specification. This can be done in teams as well. We do find it valuable to go through this exercise prior to having the teams develop the requirements for the capstone project.*

6. Consider the design of a common device such as an audio CD player, an electric toothbrush, or a laptop computer (or other device that you select). Identify potential marketing and engineering requirements. Consider performance, energy, and environmental engineering requirements, as well as any others that are applicable to the problem. You do not need to select the target values, but should identify the measures and units. [A]

Marketing Requirements

- Should be lightweight
- Clean teeth well.
- Have a long battery life.
- Not shock the user (electric).
- Be easy to hold
- Be quiet.
- Easy to clean.
- Be lightweight.
- Allow multiple users.

Engineering Requirements

ENGINEERING REQUIREMENT	NOTES
Performance	
E1. Have ___ ft-lbs of torque (or translational force, depending upon design).	This addresses how much force it can apply in cleaning the teeth. This requirement does require assuming part of the solution.
E2. Should have a rotational/translational brush speed of ___ cycles/minute (Note some of the solution assumed here).	This addresses how quickly it the toothbrush operated.
E3. Must have a reliability of 95% at 5 years of service.	Reliability – may be a good idea to place an estimate on this. This is a real guess, and one would have to do more work to determine this one.
E4. Should emit < ___ dB of noise.	User wanted it to be quiet
Environmental	
E5. Must work in 100% humidity (could be submersed).	Works in a wet environment. Could be submersed.
E6. Must be able to withstand ___ drop from 6 feet and still operate motor (not brush head).	User could drop it. 6 feet is typical person height.
E7. Temperature range of ___ to ____ degrees Celsius.	
Energy	
E8. Should have an operating lifetime of > ___ hours on a single battery (or charge).	How long it will run for.
Packaging/Physical Characteristics	
E9. Toothbrush should weigh less than __ grams.	Do not want it to be too heavy.
E10. Should be ___ cm tall.	Height should be specified. Should not be too long nor too short.
Cost	
E11. Should cost no more than $___ to produce.	Cost is virtually always an issue.

7. Develop a marketing-engineering tradeoff matrix for the device selected in Problem 3.6. [A]

Using the results from the previous problem.

		E1. Torque	E2. Brush Speed	E3. Reliability	E4. Noise Level	E5. Humidity	E6. Physical Shock	E7. Temperatur e	E8. Battery Lifetime	E9. Weight	E10. Size	E11. Cost
		+	+	+	-	+	+	+	+	-	-	-
M1. Lightweight	-	↓		↓	↓		↑		↓	↑	↑	↓
M2. Cleans well	+	↑									↓	↓
M3. Long life	+	↓	↓				↑	↑	↑	↓		
M4. Electric shock	+					↑						
M5. Easy to hold	+	↓					↓		↓	↑	↑	↓
M6. Quiet.	+	↓	↓		↑						↓	↓
M7. Durable	+			↑		↑	↑	↑				↓

8. Develop an engineering tradeoff matrix for the device selected in Problem 3.6. [A]

Using the same engineering requirements found in the Engineering-Marketing Relationship Matrix in problem 3.7, a Engineering Tradeoff Matrix has been created on the next page.

		E1. Torque	E2. Brush Speed	E3. Reliability	E4. Noise Level	E5. Humidity	E6. Physical Shock	E7. Temperature	E8. Battery Lifetime	E9. Weight	E10. Size	E11. Cost
		+	+	+	-	+	+	+	+	-	-	-
E1. Torque	+		↓						↓	↓	↓	↓
E2. Brush Speed	+				↓				↓			↓
E3. Reliability	+					↑	↑	↑		↓	↓	↓
E4. Noise Level	-									↓	↓	↓
E5. Humidity	+									↓		
E6. Phys Shock	+									↓	↓	
E7. Temperature	+											↓
E8. Battery Life	+									↓	↓	↓
E9. Weight	-										↓	↓

E10.	Size	-										↓
E11.	Cost	-										

9. Consider the devices selected in Problem 3.6. Identify the constraints that apply to the design. Address all of the eight constraint categories presented in this chapter, and in each case provide a short description as to how it does or does not apply to the problem. [A]

Constraint Identification for the Electric Toothbrush

Comments are in parentheses.

Economic:

- The toothbrush should cost no more than $ ____. [This overlaps with engineering requirements which is fine].

Environmental:

- The toothbrush should work in very wet conditions as it will be under water and in user's mouth.
- It should be able to work in temperatures experienced in a typical household. [Could extend beyond this as people could use it outdoors].

Ethical

- Should not infringe on the patents of competing products or existing technology components. [This could be a real issue, depends upon the design].

Health & Safety

- Should not harm the users teeth and gums under normal force operating conditions.
- Should not shock the user.
- Must meet UL consumer product safety standards

Manufacturability

- The plastic housing should be able to be made using injection-molding techniques.
- Should be able to be assembled with simple retrofit of existing manufacturing line.
- Should have no more than 5 sub-assemblies.

Political

- Must meet all governmental regulations. [This one is a bit tough to argue, it may not apply. One could make the counter-argument].

Social

- People will have clean, white teeth, and minty breath. It will improve relationships! ☺[Another tough one – it is a pretty well accepted product. I would make the counter-argument – does not apply].

Sustainability
- Will have replaceable brush heads.
- Will be xx% at 5 years.

10. Identify the three levels of standards usage and what is meant by each one. [R]

The three levels of standards usage are user, implementation, and development. The **user level** simply incorporates the standard within the design without the need for technical knowledge concerning the standard. However, the **implementation level** requires an in-depth knowledge of the standard – developing hardware drivers and ensuring reliability requirements. As with the implementation level, the **development level** also requires knowledge of the standard in order to further develop and modify its predecessor.

11. Develop a list of potential standards that would apply to one of the devices proposed in Problem 3.6. For each case, indicate how they would apply. [A]

Standards for the Electric Toothbrush

Likely standards for this system include:

- UL (Underwriters Laboratory) and CE (Common European) safety standards. This is very common for consumer devices.
- ADA – American Dental Association. This would likely be a series of "standard" tests before branding ADA approval; therefore, showing that this system provides sufficient dental treatment.

12. Project Application. Develop a complete Requirements Specification document for your project that includes the requirements, tradeoffs, constraints, and standards that are applicable to the design. Make sure that the requirements, constraints, and standards are relevant for the particular problem. A format for documentation is provided in Section 3.8, along with a self-assessment checklist in Table 3.7. Also be sure to provide a justification that supports the realism of the requirements. [P]

Note: *The <u>Requirements Specification</u> is an important document in the design. Remember that requirement specifications are "living" and evolving documents. Thus it is a good idea to provide design teams with the opportunity to resubmit and revise the document. We use a two-step submission process. The first submission is worth 30% of the specification grade. This is reviewed and resubmitted to the team, who resubmits, and the second submission constitutes the remaining 70%. Of course, if the team gets it right on the first submission, there is no need to resubmit.*

Constraints. We have student teams identify at least five of eight constraints in their specification. They should be realistic. We don't require that they test each one in the final realization, but ensure that they are considered (this depends upon the complexity of the problem). However, the team should be able to that their system would meet some of the constraints.

Students may also make the counter argument for a constraint. For example, design team may consider a constraint category, and determine that it is not applicable. If a clear rationale is given, the team could document that. If a project has virtually no constraints, then must question whether or not it is an acceptable project.

Standards. We have students identify standards that may apply to their project. Of course, they may not know all of the applicable standards until they get to the design phase. However, realistic decisions can be made on the standards that will apply to the project. Some of them may be very beneficial to the design team. For example, following design standards, such as the IEEE software design standards can be of great help to the teams.

Checklist. We expect our student teams to also complete the self-assessment checklist for requirements provided in Table 3.7.

Oral Presentations. After the students complete the Requirements Specification, we have them make a presentation to a faculty group. This presentation covers the Problem Statement material from Chapter 2, the Requirements, Constraints, and Standards. The idea is for the faculty to make accept/reject the project idea, or more likely, request changes/corrections. We also pick one or two teams to present theirs to the entire class prior to the faculty presentations. This way students can critique a presentation beforehand.