



Design Thinking in Practice

Week 4: First Lecture

Innovation emerges through deliberate iteration

Product Design

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**DESIGN
EXPLORATION
RESEARCH
GROUP**



Religion is
important and
interesting, and
discovering
God's purpose
for you is a
worthwhile
pursuit.

Ross Douthat
Award Winning Journalist

Goal

Practice design thinking methods as an integrated, iterative process rather than a linear checklist.

Begin to embrace the systematic nature of Engineering Design.

Outline

- **Business**
- **Grand Rounds**
- **Requirements, Requirements, Requirements**
- **Sketching**
- **Closing**

	Su	M	T	W	Th	F	S	
Week 0								Design Philosophy & Engineering Design Essentials
Week 1								
Week 2								Complete Opportunity Development -- Initiate
Week 3								
Week 4			L	D	L			Complete Opportunity Development – User Insights
Week 5			L	D	L			
Week 6			L	D	L			Complete Concept Development
Week 7			L	D	L			
Week 8			L	D	L			
Week 9			L	D	L			Complete Sub-System Engineering
Week 10			L	D	L			
Week 11			L	D	L			Complete System Refinement
Week 12			L	D	L			Complete Product Pitch
Week 13			L					
Final Exam								Design Portfolio Due as Final Exam

Grand Rounds

A Case Study Discussion

Design Brief | Dyson Airblade Tap

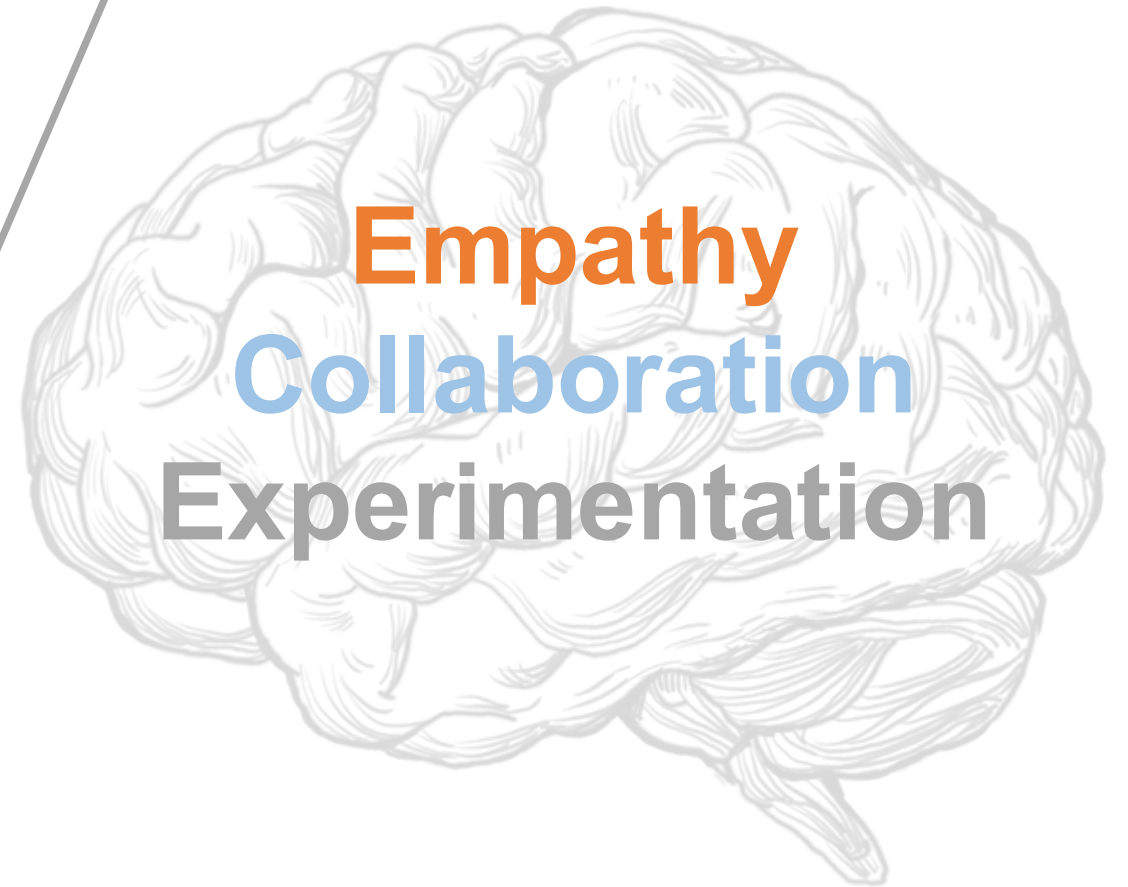
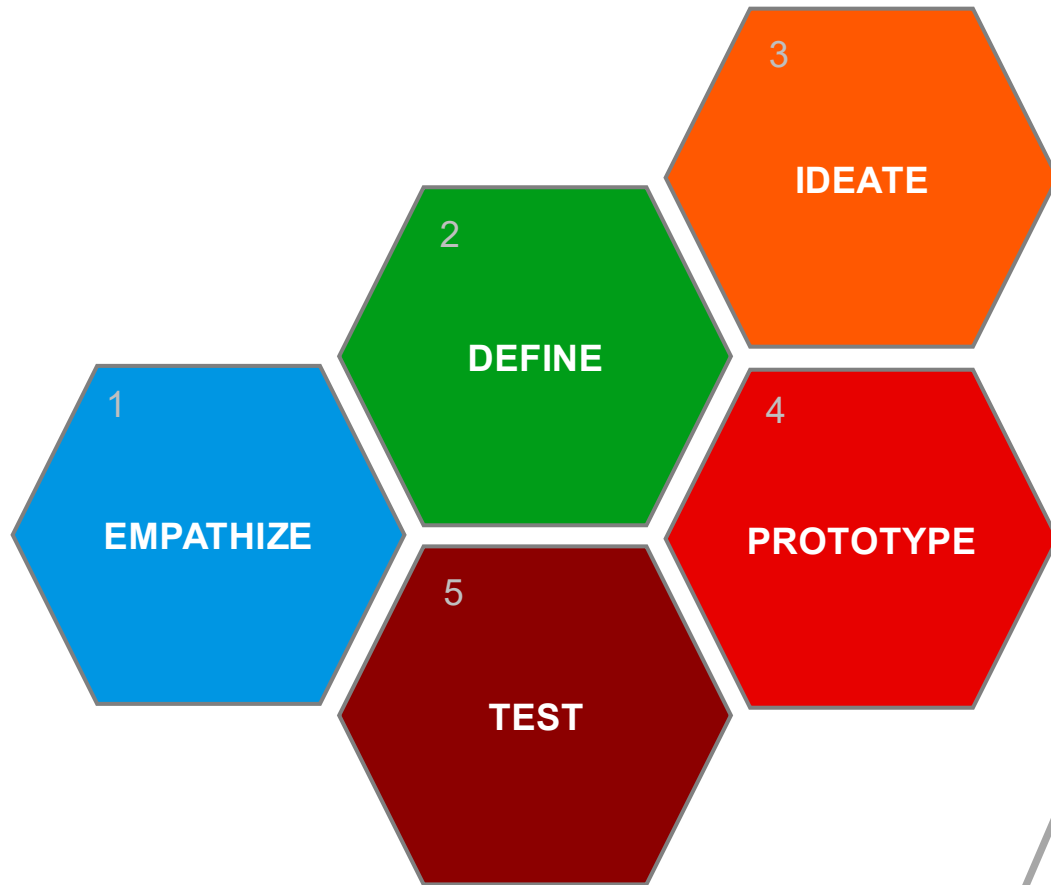
Dyson introduced the Airblade Tap to integrate hand drying into the faucet, aiming to prevent water dripping across restroom floors. However, reviews and forums documented splashback onto clothing and sinks when hands neared the airblade exit. One commenter noted: *“Looks like water goes all over the place ... just distance your hands!”*. CHOICE users also reported water pooling at the base and moisture blown onto nearby walls, degrading surfaces. While Dyson’s marketing claimed “no water on the floor”, real-world variation in hand placement and environment undermined that promise.

Post Mortem: Reverse engineer the design process

(decomposition, MCM/I, personas, journey maps, HMW, etc)



Design Thinking as a **Process**



Design Thinking as a **Mindset**

Readings

Thought Questions (Week 4, selection from all articles)

- [1] The article argues for rapid prototyping even when ideas are rough. What's the smallest- fidelity prototype you can produce in 24 hours that still resolves a key uncertainty?
- [2] Where might an “output-focused” culture in your project be masking weak learning, and how will you shift the conversation to evidence gained per the article's mindset?
- [3] How will you balance optimism (needed to explore boldly) with the skepticism required for honest iteration, and what artifact will keep that balance visible?
- [4] Clustering highlights the ethical dimension of interpretation: whose perspective shapes the frame? How do you ensure that marginalized voices in empathy research are not lost during clustering?
- [5] Identify a counterproductive habit you have developed; which anecdote offers a practical intervention, and what outcome will signal success?

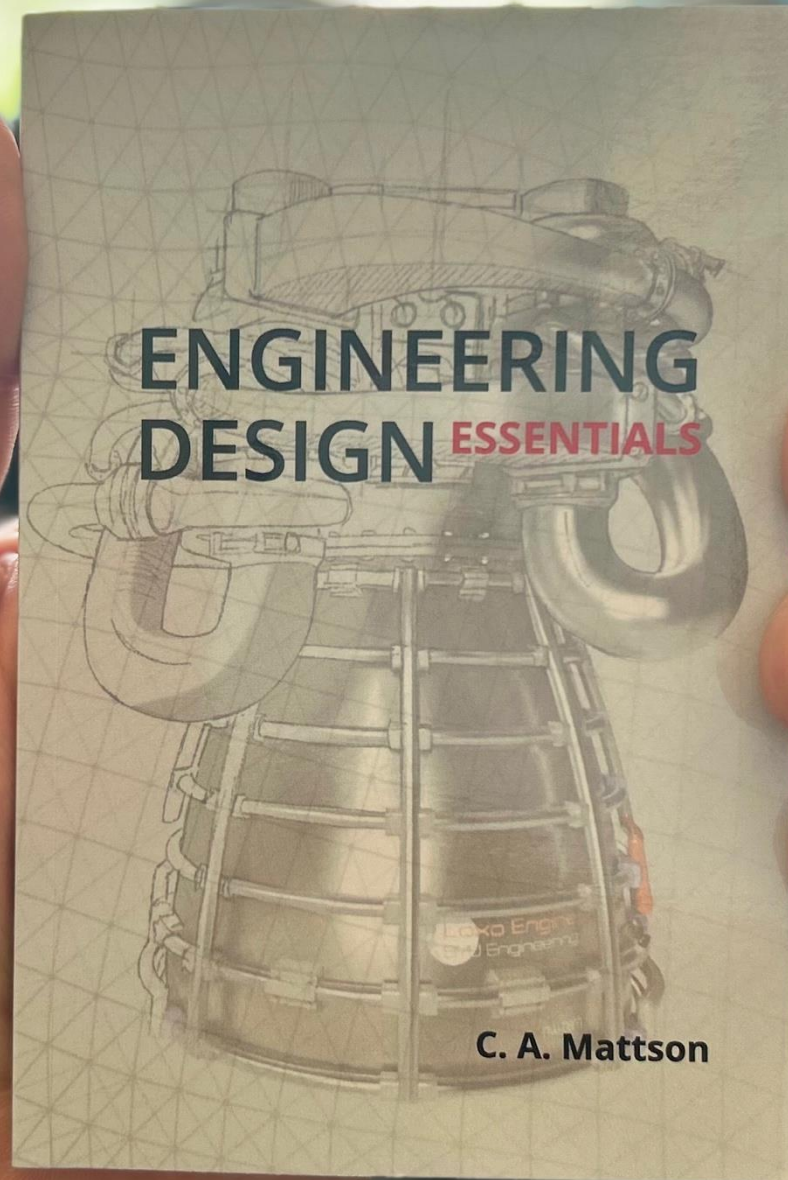
Design Methods

Decomposition
Recombination (Table)
Most Critical Module/Interface
Geometry-Material-Process Decisions
Observations (+Thoughtless Acts)
Nucor's Circle (Hedgehog Concept)
5W Problem Framing Framework
Double Diamond Process
Conversation Starters
Design Thinking Process
Stages of Development
Design Thinking
How Might We Statements
Personas
Primary Research
Secondary Research
Empathy Map
Journey Map
Revisioning (formalizing iteration)
Requirements Matrix
Requirements List
Requirements Hierarchy
Product-Focused Requirements Statements

Requirements Matrix

Friend or Foe?

● Go to Page 77



11.55 Requirements Matrix

Capture all information about meeting the market requirements in one place

The requirements matrix is a convenient place to store the requirements in a way that is clear, unambiguous, and easily transferable. More importantly, however, it is a powerful tool for translating broad market requirements into specific performance measures that are generally quantitative. To be useful, it is important that the requirements matrix be updated frequently and used to track development progress.

Sections of the requirements matrix

There are six main sections (A–F) to the requirements matrix. Each is discussed briefly below. The inset image in the example on the facing page indicates the locations of A–F.

Market requirements (A)

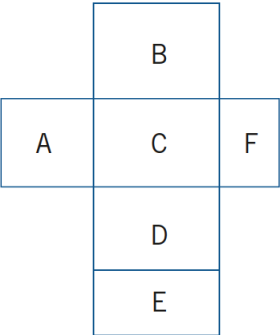
These are the top-level requirements for the product to be successful in the market. They are often identified/clarified by interviewing clients, end users, and experts, and by benchmarking and other forms of research. Market requirements are statements about *what* the market wants in the product, and are often subjective.

Optionally, the relative importance of each requirement can be assigned. More important wants have larger importance numbers. The scale used to measure importance is generally relatively coarse.

Often, the market requirements are the primary requirements from a requirements hierarchy.

Performance measures and units (B)

These are specific characteristics of a product that can be measured to determine how well a product meets the market requirements. They can be thought of as *how* the market requirement will be evaluated or measured. It is generally preferable to have objective performance measures. When subjective performance measures are necessary, they should be unambiguously evaluated. In general, there are multiple performance measures for each market requirement. Likewise a performance measure can often apply to multiple market requirements. The units of the performance measure are listed next to the measures.



Product: DRILL Subsystem: N/A		Market Requirements (Whats)		Importance		Units		Performance Measures																Market Response																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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140	-	220	-	250	100	9	1	ft	Maximum borehole depth	1	●	2	min	Time required to cut through 6 inches of rock	2	●	3	lbs	Downward drilling force	3	●	4	ft-lbs	Torque applied to drill bit	4		5	%	Compatible with X% existing drill bits	5		6	psi	Water pressure down the pipe	6		7	%	Percentage of water that leaks through sides	7		8	%	Percentage volume of cuttings removed	8		9	ft	Depth cut per 8 hours of drilling	9		10	people	Number of required people	10		11	lbs	Weight of heaviest subassembly	11		12	in	Longest dimension (l.w.h) of biggest subassembly	12		13	%	Percentage of drill manufacturable in Tanzania	13		14	USD	Cost to produce 1 drill after development	14		15	hr	Time required to learn how to operate	15		16	ft	Height of hand operated parts	16		17	n/a	Feels comfortable	17		18	n/a	The Drill is attractive	18		19	n/a	The Drill interests investors	19			Excellent																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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Product: DRILL
Subsystem: N/A

Subsystem Engineering



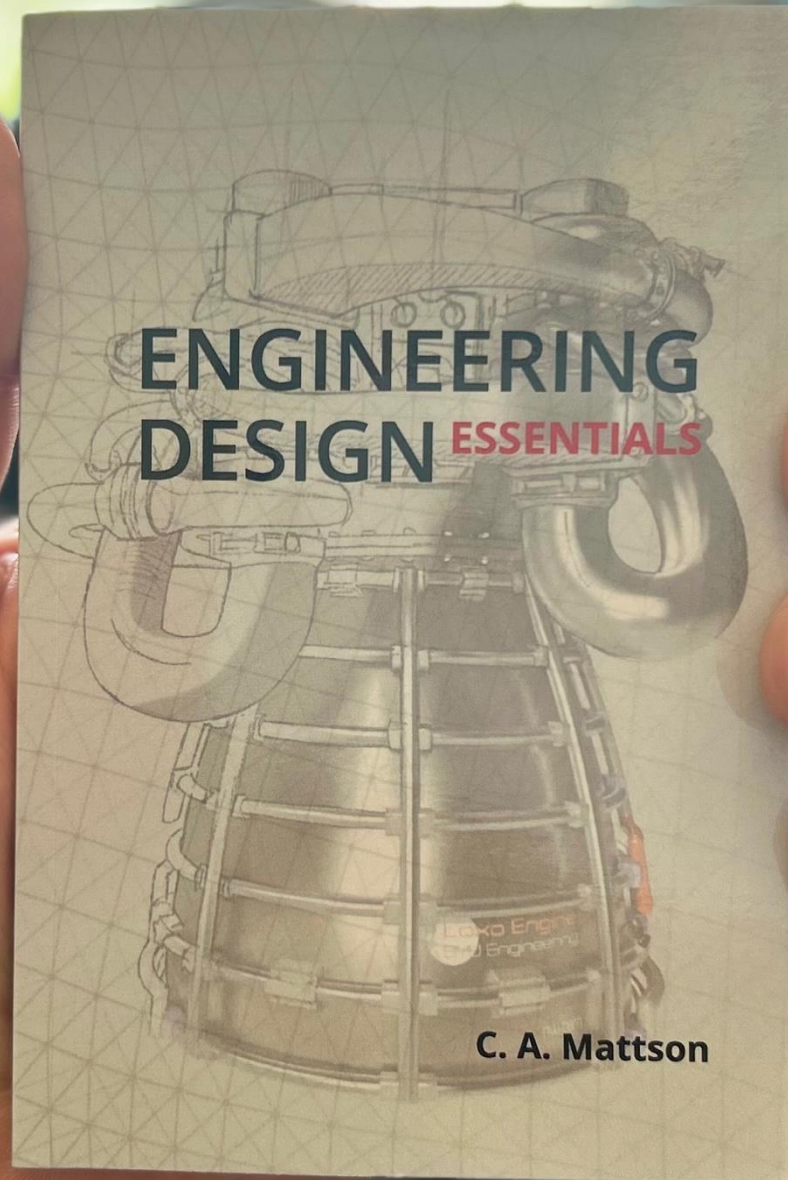
Product: DRILL
Subsystem: N/A

Product: DRILL Subsystem: N/A			Market Requirements (Whats)Importance		Performance Measures																Units		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Market Response	
			Maximum borehole depth	Time required to cut through 6 inches of rock	Downward drilling force	Torque applied to drill bit	Compatible with X% existing drill bits	Water pressure down the pipe	Percentage of water that leaks through sides	Percentage volume of cuttings removed	Depth cut per 8 hours of drilling	Number of required people	Weight of heaviest subassembly	Longest dimension (l,w,h) of biggest subassembly	Percentage of drill manufacturable in Tanzania	Cost to produce 1 drill after development	Time required to learn how to operate	Height of hand operated parts	Feels comfortable	The Drill is attractive	The Drill interests investors		
			ft	min	lbs	ft-lbs	%	psi	%	%	ft	people	lbs	in	%	USD	hr	ft	n/a	n/a	n/a		
1	The Drill reaches potable water beyond 100 ft	9	●	●																		Excellent	
2	The Drill cuts through rock	1		●	●	●																Acceptable	
3	The Drill uses existing drill bits	3					●															Excellent	
4	The Drill seals borehole sides to prevent cave in	3						●	●													Very Good	
5	The Drill removes cuttings from the borehole	3						●		●												Excellent	
6	The Drill works at an efficient speed	3									●											Excellent	
7	The Drill uses only manual labor to function	9			●	●						●										Acceptable	
8	The Drill is affordable	9													●	●					●	Very Good	
9	The Drill requires simple training to operate	9															●					Excellent	
10	The Drill is portable	9											●	●								Acceptable	
11	The Drill is comfortable to operate	1																●	●			Very Good	
12	The Drill is attractive	1																		●		Excellent	
13	The Drill attracts investors	3																		●		Excellent	
			Importance	9	10	10	10	3	6	3	3	3	9	9	9	9	9	9	1	res 1	4	to ay 12	

Requirements Lists

Actually, we're talking about how to compile them

● Go to Page 40



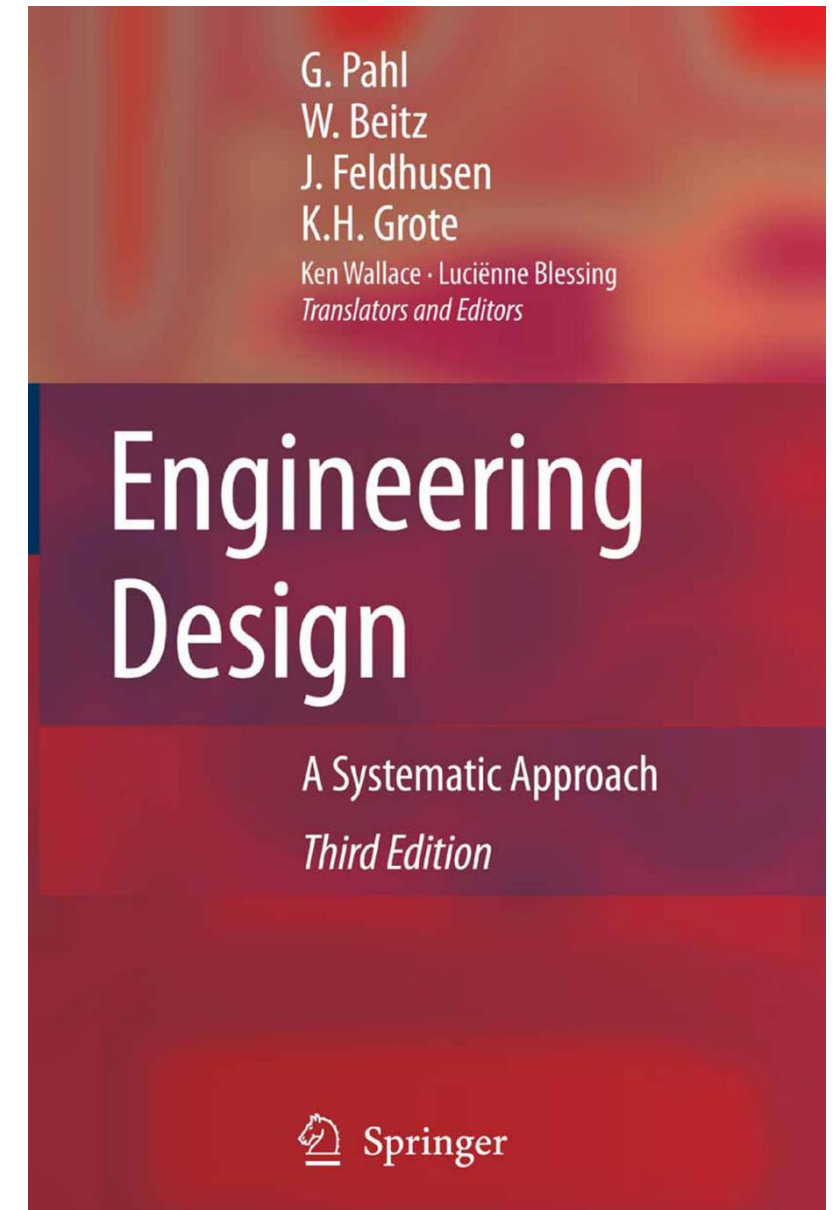
ACTIVITY (10 minutes)

Purpose: Construct a Preliminary Requirements list

Task:

1. Work alone (individual activity)
2. Consider your chosen domain
3. **Write out** requirements while considering the following lists
 - 3 minutes: Pahl and Beitz,
 - 3 minutes: Delft Design Guide
 - 3 minutes: Engineering Design Essentials (pp 48-51)
4. Shoot for at least 10 requirements inspired by these lists

Main headings	Examples
Geometry	Size, height, breadth, length, diameter, space requirement, number, arrangement, connection, extension
Kinematics	Type of motion, direction of motion, velocity, acceleration
Forces	Direction of force, magnitude of force, frequency, weight, load, deformation, stiffness, elasticity, inertia forces, resonance
Energy	Output, efficiency, loss, friction, ventilation, state, pressure, temperature, heating, cooling, supply, storage, capacity, conversion.
Material	Flow and transport of materials. Physical and chemical properties of the initial and final product, auxiliary materials, prescribed materials (food regulations etc)
Signals	Inputs and outputs, form, display, control equipment.
Safety	Direct safety systems, operational and environmental safety.
Ergonomics	Man-machine relationship, type of operation, operating height, clarity of layout, sitting comfort, lighting, shape compatibility.
Production	Factory limitations, maximum possible dimensions, preferred production methods, means of production, achievable quality and tolerances, wastage.
Quality control	Possibilities of testing and measuring, application of special regulations and standards.
Assembly	Special regulations, installation, siting, foundations.
Transport	Limitations due to lifting gear, clearance, means of transport (height and weight), nature and conditions of despatch.
Operation	Quietness, wear, special uses, marketing area, destination (for example, sulphurous atmosphere, tropical conditions).
Maintenance	Servicing intervals (if any), inspection, exchange and repair, painting, cleaning.
Recycling	Reuse, reprocessing, waste disposal, storage
Costs	Maximum permissible manufacturing costs, cost of tooling, investment and depreciation.
Schedules	End date of development, project planning and control, delivery date



1. PERFORMANCE What main functions does the product need to fulfil? What functional properties should it have (speed, power, strength, precision, capacity, etcetera)?

2. ENVIRONMENT What kind of environmental influences does the product need to withstand during production, transport and use (temperature, vibrations, moisture, etcetera)? What effects of the product to the environment should be avoided?

3. LIFE IN SERVICE With what intensity will the product be used and how long should it last?

4. MAINTENANCE Is maintenance necessary and possible? What parts need to be accessible?

5. TARGET PRODUCT COST Target Product Cost: What is a realistic price for the product, considering similar products? What margin does it need to deliver?

6. TRANSPORT What requirements are set by transport of the product during production and to the location of usage?

7. PACKAGING Is packaging needed? Against what should it protect?

8. QUANTITY What is the amount of units to be produced? in batches or in continuous production?

9. PRODUCTION FACILITIES Should the product be designed for existing production facilities, or is it possible to invest in new production resources? Will (part of) production be outsourced?

10. SIZE AND WEIGHT Are there boundaries to the size and weight of the product due to production, transport or use?

11. AESTHETIC, APPEARANCE AND FINISH Which preferences do buyers and users have? Should the product fit a house style?

12. MATERIALS Should certain materials (not) be used (because of safety or environmental reasons)?

13. PRODUCT LIFE SPAN How long is the product expected to be produced and sold?

14. STANDARDS, RULES AND REGULATIONS What standards, rules and regulations (nationally and internationally) apply to the product and to the production process? Should standardisation within the company or within the industry be taken into account?

15. ERGONOMICS What requirements result from observing, understanding, handling, operating (etcetera) the product?

16. RELIABILITY What chance of failure is acceptable? What kind of failure and consequences to the functioning of the product should be avoided at all cost?

17. STORAGE Are there long periods of storing time during production, distribution or usage of the product? Does this call for specific storage measures?

18. TESTING What quality tests are conducted on the product, both inside and outside the company?

19. SAFETY Should specific precautions be taken with regards to the safety of users and non-users?

20. PRODUCT POLICY Are there requirements resulting from the company's current product portfolio?

21. SOCIETAL AND POLITICAL IMPLICATIONS What opinions are there currently in society concerning the product?

22. PRODUCT LIABILITY For what kinds of design, production or usage mistakes can the producer be held accountable?

23. INSTALLATION AND INITIATION OF USE What requirements result from assembly outside the factory, installation, connecting to other systems and learning how to handle and operate the product?

24. REUSE, RECYCLING Can the material cycle be extended by reuse of parts and materials? Are parts and materials easy to separate for recycling or waste processing?

DELFT DESIGN GUIDE

UNIVERSITY OF TECHNOLOGY / FACULTY OF INDUSTRIAL DESIGN ENGINEERING

PERSPECTIVES - MODELS - APPROACHES - METHODS



BIS PUBLISHERS

Main headings	Examples
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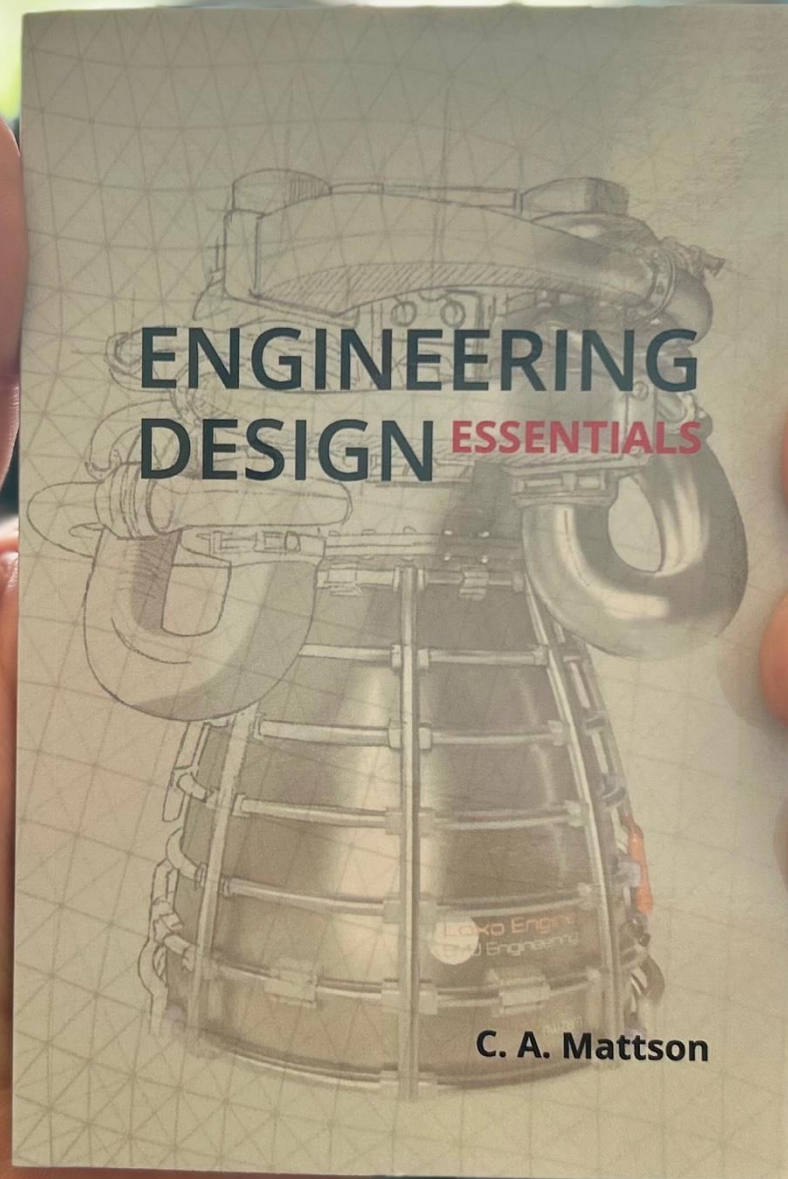
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● Go to Page 48-51 (Blue Pages)



Requirement Groupings

Formally in Mattson and Sorensen as **Requirements Hierarchy**

Capstone students were asked to develop a piece of playground equipment that would generate electricity while students played on it. The electricity would be used to charge batteries that would power LED lanterns to provide light in the school classrooms as well as for doing homework. They developed a merry-go-round that drove a generator.



11.54 Requirements Hierarchy

Develop a comprehensive list of market requirements

A requirements hierarchy is a list of market requirements that is organized into groups of related requirements, with each group given a descriptive title. The requirements hierarchy allows the design team to capture market requirements in a way that will be very useful for guiding product development.

How to do it

The first step in developing a requirements hierarchy is to obtain input from potential users. This can be done in several ways, including surveys, focus groups, interviews, direct observation, and more. The user input should always be captured in the user's own words to the extent possible.

Next, the user statements are rewritten as *product-focused requirement statements*, as described in Product-Focused Requirement Statements (11.48.)

The requirements statements are then organized. The set of product-focused requirement statements needs further work to be of most use in product development. There may be hundreds of requirement statements in the list, which is too many for the design team to effectively consider. Some requirements statements will be very specific, while others will be general. For most cases, the requirements hierarchy will be most helpful if it contains between five and twenty requirements, all of which are at approximately the same level of generality.

The requirements statements are organized by grouping related requirements statements, eliminating duplicates, and writing new requirement statements that effectively summarize all of the statements in the group. These primary requirement statements have all the attributes of the product-focused requirement statements, except that they summarize the group of related requirements, rather than restating each of the requirements in the group.

The primary requirements are then placed in the requirements matrix as the market requirements.

See also

Development Reference: Product-Focused Requirement Statements (11.48), Requirements Matrix (11.55).

Primary requirement statement	Original requirement statements
Equipment is safe to use	Equipment feels safe Equipment prevents user from falling off or sliding out Equipment feels like it will not break Equipment prevents blistering of hands Equipment prevents injuries to users
Equipment reliably provides electricity	Equipment parts prevent slipping Equipment generates sufficient current and voltage to light one classroom for an hour per hour of play Equipment fits on or into normal Ghanaian school ground
Equipment works well in Ghana	Equipment withstands the heavy rain and dust storms of Ghana Equipment withstands many children using it at the same time Equipment can be manufactured in Ghana
Equipment challenges the users	Equipment allows “push it to the limit” Equipment provides a competition that can last a long time Equipment is a proving ground (prove to others) Equipment makes the user feel powerful Equipment gives the user an opportunity to show off Equipment allows the user to impress him- or herself with strength Equipment builds confidence in self (prove to self) Equipment provides an accomplishable challenge
Equipment provides fun motion	Equipment provides a long time of motion Equipment is big and fast Equipment allows the user to move Equipment moves fast
Equipment is fun and exciting	Equipment looks fun to play with Equipment is new and exciting Equipment resembles something exciting to children in Ghana Equipment provides a thrill for the user Equipment allows friends to gather Equipment holds multiple children safely
Equipment may be used creatively	Equipment may be used creatively

Product-Focused Statement

This is part of being systematic

11.48 Product-Focused Requirement Statements

Obtain high-quality statements of product requirements

Product-focused requirement statements are requirement statements derived from user statements about the product that have been rewritten to be of most use in the product development process.

How to do it

To create a product-focused requirement statement, we begin with a statement from a user about what would be desirable in a product. The user statement is then rewritten so its expression has the following attributes:

Positive, not negative, phrasing: Sometimes the user will say what they want the product *not* to be or do. Rather than capturing what would be undesirable in the product, it is more effective to express positive characteristics of a desirable product.

As specific as the user statement: It is important to capture the user's intent as faithfully as possible. Teams will want to generalize user statements, but the generalization should happen later, after related requirement statements have been grouped.

A requirement of the product, not the environment or the user: Some user statements will be expressed in the form of statements about the environment, rather than about the product. Since the team is focusing on designing the product, requirements should be expressed for the product.

A requirement, rather than a performance measure: Users will often make statements that define performance measures and desired values of the measure. These performance measures should certainly be captured in the requirements matrix. However, the user-stated desired value is only one data point, and should generally be used to help define the ideal values, rather than being used as the ideal value. Furthermore, the team will learn much more about the requirements if the user is asked *why* the performance measure is important to the user. Often one or more requirements will be discovered by probing the reasons for stated performance measures.

A requirement, rather than a product feature: Users who have thought carefully about products will often have specific suggestions about ways to achieve desired performance. When user statements suggest specific features, it is more helpful to the design team to identify the requirements behind the suggested feature. By doing this, the team is free to consider other ways to meet the requirement, which may be more effective than the user's suggestion.

Independent of importance: As users express opinions about the product, they often include statements about the importance of various requirements, features, and performance measures. These statements of importance are valuable and should be captured by the team. The requirements matrix has entries for the importance of both requirements and performance measures. User statements of importance should be considered as the team determines relative importance of the requirements, rather than be directly included in the product-focused requirement statements.

1. **Positive, not negative, phrasing**
2. **As specific as the user statement**
3. **A requirement of the product not the user**
4. **A requirement, rather than a performance measure**
5. **A requirement, rather than a product feature**
6. **Independent of importance**

Product: Battery Powered Circular Saw



Guideline	Customer Statement	Good Requirement Statement	Inferior Requirement Statement
Express the requirement with positive, not negative, phrasing	It just doesn't have the torque of a corded saw and will choke in a slight bind while cutting plywood sheets.	The saw resists binding when cutting plywood.	The saw doesn't bind when cutting plywood.
Express the requirement as specifically as the user statement	I wish it had a case to protect it from dents and dings	The saw is resistant to dents and dings	The saw is rugged
Express the requirement as a requirement of the product, not the environment or the user	The trigger safety interlock is aggravating! I have incredibly large hands and still find the trigger interlock a stretch to reach.	The saw can be started easily by most people, even with safety interlock features active.	People can easily reach the safety interlock.
Express a requirement, rather than a performance measure	The battery lasts for three hours of typical carpentry work.	The battery lasts a long time. <i>Or</i> the battery life allows typical carpentry work.	The battery lasts for three hours.
Express a requirement, rather than a product feature	Having the blade on the left side gives a right-handed user a great line of sight.	The saw provides clear sight to the cut.	The saw has the blade on the left side.
Express the requirement independent from its importance	The saw does not have a light which I miss.	The saw illuminates the cut area.	The saw should illuminate the cut area. <i>Or</i> the saw must illuminate the cut area.

Bringing it Together

This is when it becomes real, or it remains a hurdle

Product: DRILL
Subsystem: N/A

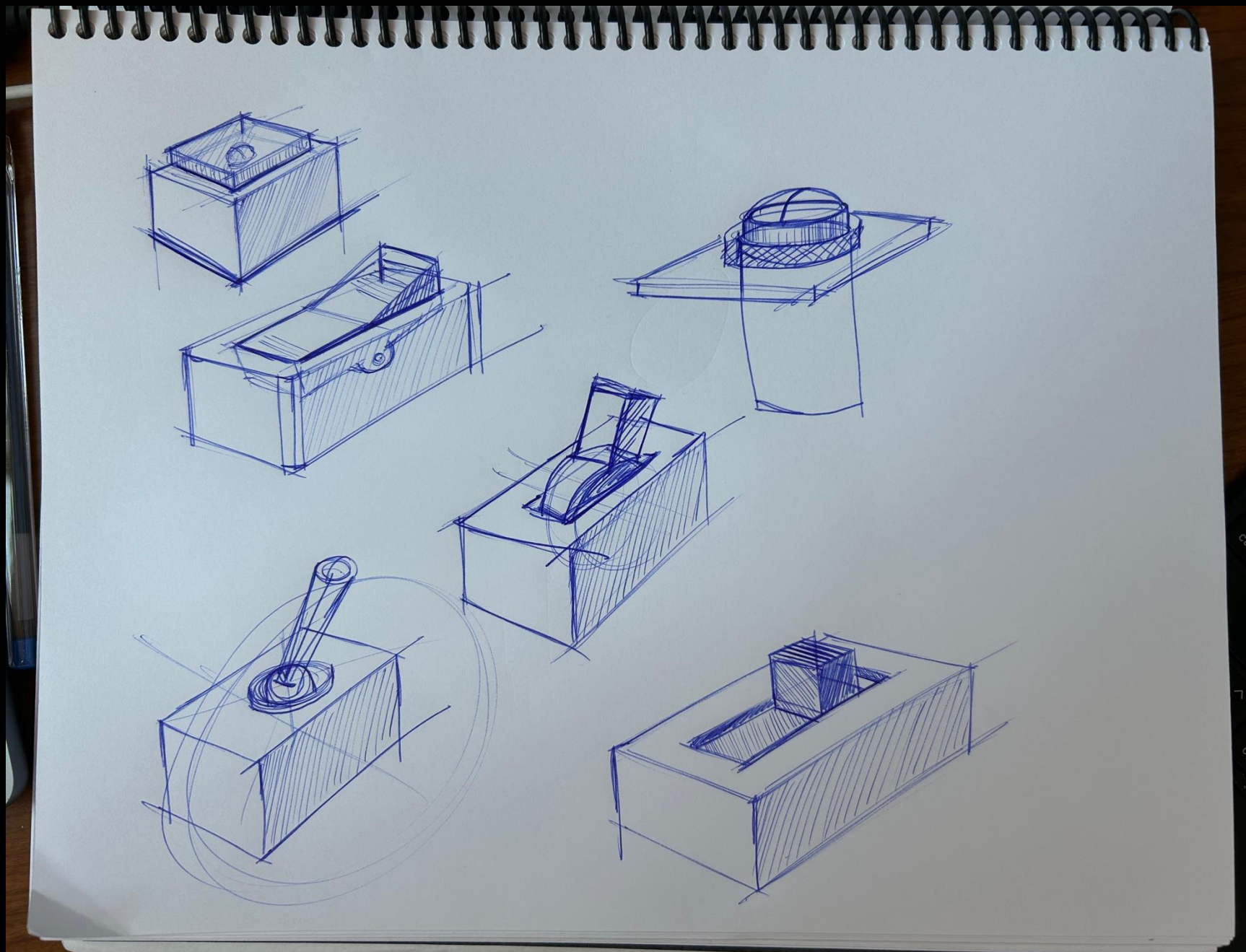
Product: DRILL Subsystem: N/A					
			Performance Measures		Units
			Maximum borehole depth	ft	
			Time required to cut through 6 inches of rock	min	
			Downward drilling force	lbs	
			Torque applied to drill bit	ft-lbs	
			Compatible with X% existing drill bits	%	
			Water pressure down the pipe	psi	
			Percentage of water that leaks through sides	%	
			Percentage volume of cuttings removed	%	
			Depth cut per 8 hours of drilling	ft	
			Number of required people	people	
			Weight of heaviest subassembly	lbs	
			Longest dimension (l,w,h) of biggest subassembly	in	
			Percentage of drill manufacturable in Tanzania	%	
			Cost to produce 1 drill after development	USD	
			Time required to learn how to operate	hr	
			Height of hand operated parts	ft	
			Feels comfortable	n/a	
			The Drill is attractive	n/a	
			The Drill interests investors	n/a	
			Market Response		
Market Requirements (Whats)			Importance		
1	The Drill reaches potable water beyond 100 ft	9			
2	The Drill cuts through rock	1			
3	The Drill uses existing drill bits	3			
4	The Drill seals borehole sides to prevent cave in	3			
5	The Drill removes cuttings from the borehole	3			
6	The Drill works at an efficient speed	3			
7	The Drill uses only manual labor to function	9			
8	The Drill is affordable	9			
9	The Drill requires simple training to operate	9			
10	The Drill is portable	9			
11	The Drill is comfortable to operate	1			
12	The Drill is attractive	1			
13	The Drill attracts investors	3			
Importance					
		9			
		10			
		10			
		10			
		3			
		6			
		3			
		3			
		3			
		9			
		9			
		9			
		9			
		9			
		1			
		1			
		4			
		12			

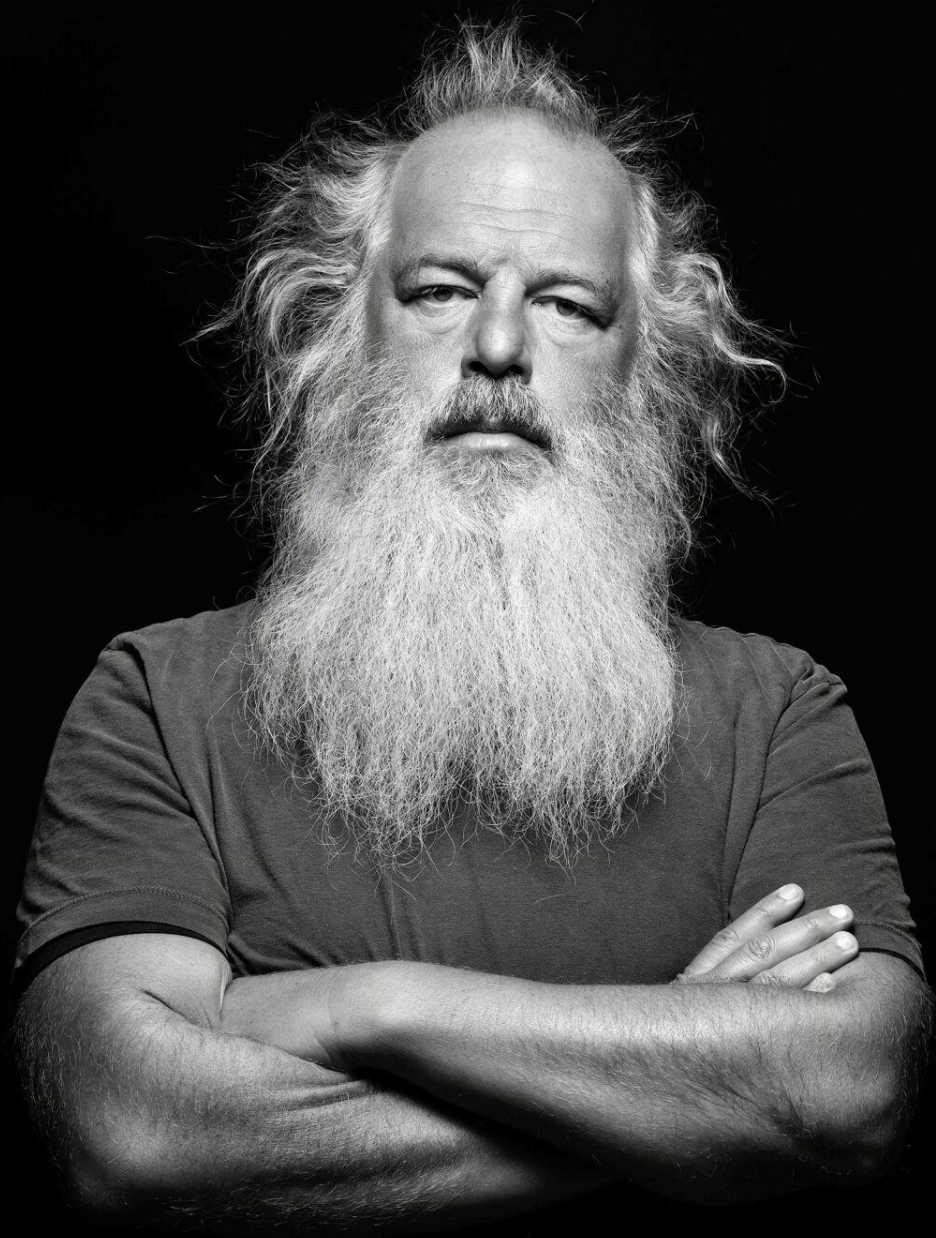
Sketching

SKETCH (8 minutes)

Sketch electrical
flip, push button,
toggle switches.

Do it by combining
simple shapes.





“Any framework, method, or label you
compose on yourself is just as likely to
be a **limitation** as an **opening**.”

Rick Rubin
Music Producer

What to do now

- Use the Study Guide
 - Work on the Project Watch Your Time
 - Complete the out of class Designette
- Focus on evolving (iterating) your design artifacts