Georgia Tech College of Engineering
George W. Woodruff School of Mechanical Engineering

COMMUNICATING ENGINEERING DESIGN

Webb Communication Program
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COVER QUICK FACTS

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Font
Times New Roman or Roboto, 12 pt
(Available for free from Google Fonts: Download Roboto)

Alignment
Left-Aligned
(Use at all times--*e.g., in tables, etc.*--because other alignments impair accessibility; the only exception is for equations which should be centered with right-aligned numbering.)

Headers
Left-Aligned, Bold, 12 pt

Sub-Headers
Left-Aligned, Indented 0.5", Italic, 12 pt

Page Numbers
Bottom-Right Corner, 12 pt, #/# format (ex. 2/5)

Margins
1" Top, Bottom, Left, and Right

New Paragraph Signaling
New line, Indentation

Spacing
Single spacing

Figure Captions
Numbered in order of appearance; aligned left with figure (NEVER CENTERED); above figure for tables, below figure for images. No titles.

Legends
Meaningful descriptions (and units)

Export File
.svg from SolidWorks,
no background

Accessibility
Use blue and orange indicators

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HOW TO USE THIS GUIDE

Throughout this guide, you will encounter design tools, reports and presentations, visuals, argument structures, writing practices, and technical conventions. These are not separate skills. They work together to make engineering reasoning understandable and usable by others.

What makes communication useful depends first on its audience, purpose, and genre.
You don't make communication decisions in the abstract. You make them in response to an audience, purpose, and genre, and then evaluate whether the resulting communication is trustworthy, actionable, intuitive, and appropriate to that genre.

- **Audience**: Who will use this communication, and what do they already know?
- **Purpose**: What does the audience need to understand, evaluate, decide, or do?
- **Genre**: What kind of communication are they expecting, and how does that genre normally help them accomplish that purpose?

Before deciding what evidence to include, what to emphasize, how much detail to provide, or how to organize and visualize information, engineers need to understand who will use the communication, what they need it to accomplish, and what kind of deliverable they expect. Those factors shape the communication decisions made throughout the engineering process.

The four questions below help you evaluate whether those communication decisions work together effectively for that audience, purpose, and genre.

1. TRUSTWORTHINESS
Can this audience evaluate and believe your work?

- Provide sufficient evidence, reasoning, precision, context, and acknowledgment of limitations for the audience to judge your claims.

2. ACTIONABILITY
Can this audience use the information for its intended purpose?

- Make clear what the information means for the decision, recommendation, next step, design direction, or future work the communication is meant to support.

3. INTUITIVENESS
Can this audience understand and use it without unnecessary effort?

- Use organization, visuals, language, and emphasis to make important relationships and takeaways easy to recognize.

4. GENRE USE
Does the deliverable work the way this audience expects this kind of communication to work?

- Use the conventions of reports, presentations, design tools, meetings, figures, and other genres to help the audience find, interpret, and use the information appropriately.

There is no universally "good" communication choice. An effective choice is one that helps a particular audience accomplish a particular purpose—and trustworthiness, actionability, intuitiveness, and genre use give you four ways to judge whether it does.

A single decision can affect all four. For example, a well-designed evaluation matrix can make evidence easier to understand (intuitiveness), expose the reasoning behind a design choice (trustworthiness), support selection of a concept (actionability), and meet the expectations for how an evaluation matrix should function (genre use).

PART 1: ENGINEERING DESIGN COMMUNICATION

Engineering communication is not separate from engineering work. It is part of how engineering work becomes understandable, trustworthy, and actionable for others.

When engineers communicate, they are not simply transferring information or documenting completed work. They are helping audiences evaluate evidence, understand constraints, assess risks, compare alternatives, and make decisions. Because of this, communication itself becomes a form of engineering design.

Effective engineering communicators make intentional decisions about:

- what information to include or exclude,
- how information should be organized,
- how evidence should be framed,
- when claims should be introduced,
- and how audiences are expected to use the communication.

These decisions are shaped by audience, genre, uncertainty, risk, and the broader engineering situation.

Engineering itself is fundamentally the process of making decisions under constraints. Communication is how those decisions become visible, interpretable, and usable to others. Engineers therefore have a responsibility not only to make sound decisions, but also to communicate those decisions in ways audiences can appropriately evaluate, trust, and act upon. This means engineers must consider:

- what audiences need to understand,
- what assumptions require justification,
- what tradeoffs require defense,
- what risks require clarification,
- and what information is necessary for informed decision-making.

This section introduces the foundational concepts that guide engineering design communication:

- audience awareness,
- genre expectations,
- argumentative structure,
- communication risk,
- engineering judgment,
- and the role of design tools in making reasoning visible.

The goal of this section is not to provide rigid templates or formulas. Instead, it is to help engineers understand why communication decisions matter and how those decisions influence usability, professionalism, trust, and decision-making quality.

Strong engineering communication does not happen because information exists. It happens because information is intentionally designed for use by leveraging basic genre and structural expectations. For example, the need for topic sentences to clarify the main point (usable value) of the paragraph.

ENGINEERING COMMUNICATION AS DESIGN

Engineers design information under constraints to support trustworthy, actionable understanding with minimal unnecessary cognitive load.

When engineers communicate, they are not simply "sharing information" or documenting completed work. They are helping audiences:

- understand constraints,
- evaluate evidence,
- assess tradeoffs,
- interpret uncertainty,
- compare alternatives,
- and make decisions.

Because of this, communication itself becomes a form of engineering design. The table below illustrates some of the parallels between engineering design processes and communication design processes.

Engineering Design	**Communication Design**
Understanding the Problem: Define customer needs and refine them through research and tools such as the House of Quality.	**Understanding the Situation:** Analyze the rhetorical situation (audience, purpose, role, constraints, genre, and context).
Setting Requirements: Identify constraints (cost, materials, safety, performance) and establish measurable specifications.	**Setting Communication Requirements:** Identify communication constraints (genre expectations, audience knowledge, time, format, accessibility, delivery conditions).
Generating Concepts: Develop and compare multiple possible design approaches.	**Generating Communication Strategies:** Explore possible organizational structures, visual strategies, evidence arrangements, and levels of detail.
Evaluating Trade-Offs: Make decisions under constraints by balancing feasibility, efficiency, risk, usability, and performance.	**Evaluating Communication Trade-Offs:** Balance clarity, trustworthiness, actionability, cognitive load, completeness, and accessibility.
Testing & Refining: Prototype, test, and refine designs using evidence and feedback.	**Testing & Refining Communication:** Revise communication based on audience feedback, usability, peer review, and evolving engineering decisions.

Importantly, communication expectations are not fixed across all engineering situations. Different deliverables support different forms of engineering work, and expectations often evolve as projects move through the design process. For example:

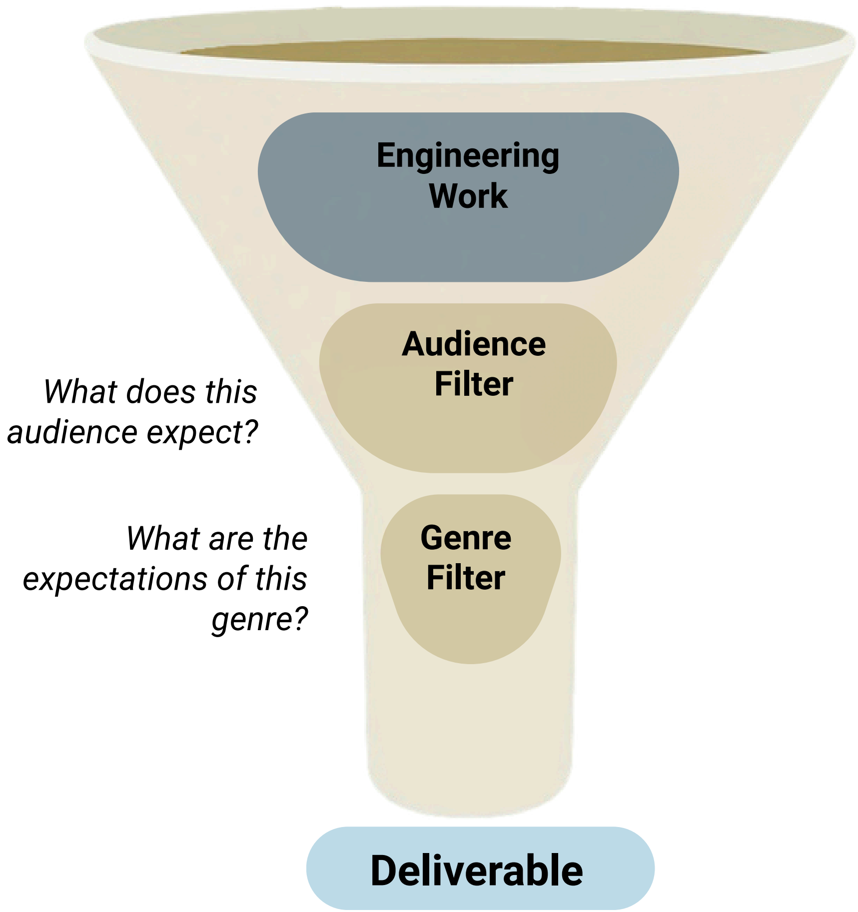
- early-stage concept discussions may prioritize exploration, assumptions, and tradeoff visibility,
- prototype reviews may emphasize testing methods, iteration logic, and feasibility,
- while final reports may prioritize justification, validation, implementation readiness, and risk mitigation.

Professional engineering communication is therefore not merely documentation. It is the intentional design of information to support engineering judgment and decision-making.

UNDERSTANDING COMMUNICATIONS FILTERS

When preparing for a meeting, oral presentation, writing a report or any communications deliverable, think of these 2 filters:

1. **Audience** filter: (is it your colleagues, your supervisor, or an external client)
   a. How much do they know about the situtation/problem?
   b. What is their level of technical expertise?
   c. What they want: Why are they reading this section?
   d. What do they want to be able to do with this information?
   e. What are their likely expectations for this section? Make decisions about what to in/exclude based on the needs of that sections' user/reader.
   f. This guide covers five common audience examples, also known as avatars. Avatars are provided as a concrete tool that engineers can use to guide communication decisions; a professional heuristic to support clearer, more intentional engineering communication. In your courses, you may have more or others to consider.
2. **Genre** Filter: (is it a report, oral presentation, or a video)
   a. Determines how much time you have with the audience, how they will receive your information, and whether or not they will engage with you (synchronously or asynch)
   b. Refer to the beginning of Section 2 of this guide for types of genre, aka types of engineering design documentation.



When communicating engineering work, you'll make decisions about what to include and exclude and how to present that information appropriately.

From the work you produce, you'll select information to include by considering what deliverable (genre) you've been asked to give and what is expected from that genre. You'll couple this with an understanding of the audience and what they want from the information. The image to the left demonstrates how you'll use audience and genre to filter all possible content into the most usable documentation.

AUDIENCE EXAMPLES

It is easier to make effective communication decisions when you know more about your audience. The purpose of the avatars below is to provide you with some insights into the kinds of audiences you are likely to encounter when communicating design, particularly those who you should be prepared to interact with at an event with a range of audiences, such as Capstone EXPO.

JON FOX
Design Supervisor

Values: Expects clear, efficient reports with unquestionable technical feasibility. Values concise insights, annotated visuals, and recommendations that align with strategic goals.

Annoyances: Dislikes wordy explanations, unclear visuals, and focus on tools over outcomes. Frustrated by reports that waste time or lack strategic alignment.

Encounters: Manages multiple teams while justifying innovations and expenditures to executives. Reviews reports quickly before meetings, reusing key insights in presentations.

MARCUS JOHNSON
Intellectual Property Attorney

Values: Committed to ethical practices, legal compliance, societal and environmental positive impacts, and the importance of clear and comprehensive documentation.

Annoyances: Frustrated by projects that lack originality, fail to acknowledge legal issues and potential pitfalls, or neglect to establish a clear connection to industry interests.

Encounters: Attends university and company expositions to stay up-to-date on new innovative technologies. Has over two decades of IP experience and enjoys mentoring new engineers on industry best practices.

ANGELA REED
VP of HR; Community Leader

Values: Motivated by equity in design, corporate responsibility, long-term community benefits, and ethics. Open to ideas that clearly demonstrate thoughtfulness and responsibility toward social good.

Annoyances: Cautious about potential empty promises or “tech for tech’s sake.” Skeptical of projects that don’t account for community impact. Bothered by presentations that come across as overly abstract or elitist.

Encounters: Attends university and community events to understand the up and coming generation’s understanding of the broader impact on the community, advocating for corporate responsibility and community relations. Has many years of experience with leading efforts in corporations and within the community.

AUDIENCE EXAMPLES

SARAH MITCHELL
Sponsor/Client

Values: Final deliverables; practical and efficient project management that communicates and justifies resource and time needs quickly.

Annoyances: Annoyed with presentations that dwell on class assignments, social impact, or an extensive explanation of the design process. She prefers presentations that get straight to the point and address her specific requirements.

Encounters: Attends university expositions to scout potential hires. Has a decade of engineering experience with her company and can quickly tell if you're a good fit for her team.

HANNAH ZIEGLER
Current/ Future Team Member

Values: Transparent processes, reasoning behind decisions, details, comprehensive documentation.

Annoyances: Gaps in logical decision making, missing methodology, imprecise specifications, undocumented fabrication details. She needs to be able to replicate your work if necessary.

Encounters: Verifies and validates design decisions, evaluates for feasibility, facilitates next steps for product to be put to market, defends past design decisions.

Engineering design audiences expect to be able to quickly and confidently understand design outcomes and actionable next steps after employing your work to design and evaluate feasible solutions. Therefore, our communications must consider genre and audience as filters that help you make decisions on how to control attention, risk, and credibility.

Communication Design Check:
What is the cost of getting this deliverable wrong - for this audience, at this moment?

HOW AUDIENCE WILL SCAN/READ YOUR REPORTS

"How the audience reads" is not a personality trait; it's a function of decision type. In professional practice, report readers often behave as follows:

- Clarity
  - I understand what was done and why.
- Justification
  - I can trace claims to evidence and constraints.
- Confidence
  - I believe this work is safe, credible, and ready for its next step.

Audiences will decide the thresholds for trustworthiness and actionability based on their needs and values.

AUDIENCES EXPECT ACTIONABILITY

Engineering communication is not only shaped by who the audience is, but also by what kind of communication situation the audience believes they are entering.

When an audience asks for a particular deliverable—a report, presentation, meeting, memo, prototype review, or design expo—they are not simply asking for information. They are also invoking a set of expectations about:

- what kinds of information will be included,
- how that information will be organized,
- what level of detail is appropriate,
- how evidence should be presented,
- and what the communication is intended to help them do.

These shared expectations are called genre expectations.

In engineering practice, genre functions as a kind of credibility contract between the communicator and the audience. The audience agrees to engage with the communication under the assumption that the communicator understands:

- the purpose of the deliverable,
- the norms associated with it,
- and the audience's expected way of using it.

The communicator, in turn, agrees to design the communication in ways that support those expectations appropriately.

When genre expectations are violated, audiences often begin to question not only the communication itself, but also the communicator's professionalism, judgment, or understanding of the situation.

Different Genres Support Different Engineering Work
Different engineering genres exist because different engineering situations require different forms of communication.

A **standup meeting**, for example, is typically designed to support rapid coordination and shared situational awareness within a team. Audiences expect concise updates about:

- progress,
- blockers,
- dependencies,
- and immediate next actions.

An excessively detailed technical explanation during a standup meeting may frustrate the audience because it interferes with the genre's primary function: efficient operational coordination.

A **prototyping and design embodiment report**, however, serves a different purpose. Audiences often expect:

- documentation of design evolution,
- justification of embodiment decisions,
- evidence gathered through prototyping,
- discussion of constraints and tradeoffs,
- and analysis of how testing informed iteration.

In this context, brevity alone is not necessarily valued. The audience may need sufficient detail to evaluate engineering reasoning and understand why particular design directions were pursued or abandoned.

ENGINEERING DESIGN COMMUNICATION MAKES CLAIMS

Engineering communication is not neutral information transfer or data documentation.

Whether engineers are writing reports, giving presentations, leading meetings, creating posters, or presenting prototypes, they are almost always helping audiences reach conclusions, evaluate options, or make decisions.

Because of this, engineering communication is fundamentally argumentative. This does not mean engineering communication is argumentative in the conversational sense of "arguing" or conflict. Rather, engineering communication makes claims supported by evidence, reasoning, and engineering judgment. For example, engineers may communicate claims such as:

- this design direction is preferable,
- this prototype demonstrates feasibility,
- this recommendation is sufficiently justified,
- this risk is acceptable,
- this method is appropriate,
- or this solution should move forward.

Even communication that appears informational often contains implied arguments about:

- what matters,
- what should be prioritized,
- what evidence is trustworthy,
- and what actions are reasonable.

Because engineering communication makes claims, engineers must make decisions about how those claims should be presented to audiences.

Appropriateness Depends on Audience and Genre

Neither direct nor indirect communication is universally "better."

The appropriate structure depends on:

- the audience,
- the genre,
- the communication situation,
- the level of uncertainty,
- and the purpose of the communication.

For example:

- A standup meeting may favor direct communication because the genre prioritizes rapid coordination.
- A Capstone expo pitch may begin directly with the problem and value proposition to quickly orient listeners.
- A final design report may combine structures, using direct recommendations in executive summaries while using more indirect reasoning development in technical sections.
- A prototyping or embodiment discussion may require indirect development so audiences can understand tradeoffs and iteration logic before evaluating conclusions.

Strong engineering communicators therefore do not simply choose a preferred style. They design argumentative structures intentionally based on how audiences are expected to use the communication.

Effective engineers recognize that the way a claim is introduced can shape audience understanding, trust, usability, perceived professionalism, and decision-making quality.

DESIGN TOOLS ARE COMMUNICATION INFRASTRUCTURE

DESIGN TOOLS AS ENGINEERING COMMUNICATION

Reference to design tools should always support the communication's assertive purposes. Doing otherwise (mere discription, listing with no rationale) increases cognitive load with no benefit.

Engineering design tools (e.g., House of Quality matrices, decision matrices, morphological charts, function trees, Pugh charts, requirements tables) are not simply formats for displaying completed work. They are part of the engineering reasoning process itself.

In professional practice, these tools often serve two interconnected purposes at the same time:

- They help engineers analyze problems, compare alternatives, identify tradeoffs, and make decisions.
- They help teams communicate the logic, priorities, constraints, and justification behind those decisions to others.

Because of this, design tools should not be treated as decorative add-ons or documentation completed after the "real" engineering work is finished. Constructing and refining these tools, especially as part of a team of stakeholders, is integral to the design process.

A well-developed design tool:

- makes reasoning visible,
- clarifies priorities and relationships,
- supports collaboration across teams,
- reduces ambiguity during decision-making,
- and creates a record that others can inspect, critique, revise, or build upon.

Design tools function as both analytical infrastructure and communication infrastructure.

When discussing these tools, do not simply state that the tool was completed. Instead, explain:

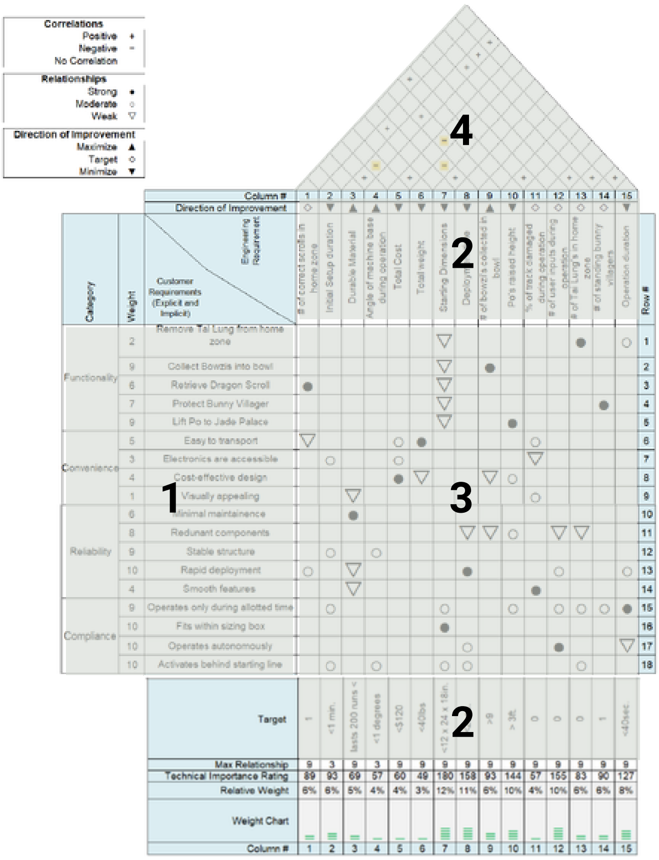
- what engineering question the tool helped answer,
- how it informed decisions,
- what tradeoffs or patterns became visible through its use,
- and why the resulting conclusions were reasonable.

The value of the tool is how it shaped engineering judgment and enabled others to understand and evaluate that judgment. They are a way to structure and then communicate your brainstorming and background research process.

If a design tool is included in a submission, the reader is expected to review it. Therefore, discussion of design tools should focus on defense of decisions made when drafting the tool. For example, a reader can use common sense to understand that the customer requirement expressing "easy to lift" is directly related to an engineering requirement of "must be under 20 lbs." The relationship between these requirements is intuitive, but a specific reason why 20 lbs was chosen as the target metric should be discussed.

Design Tool	**What It Provides**	**What *You* Must Argue**
HoQ	A prioritized strategy	Why certain CR's are prioritized over others, and why the ER target metrics quantitatively define success.
Spec Sheet	Thresholds	Why these target values and units are sufficient.
Function Tree	Decomposition	Why these functions embody the strategy.

HOUSE OF QUALITY



SECTIONS COVERED FOR STAKEHOLDERS

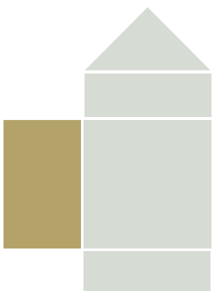
1. Customer needs
2. Engineering requirements and target values
3. Relationship Matrix
4. Correlation matrix

House of Quality (HoQ) synthesizes the customer's wants and background research into actionable engineering metrics for success. Because it is your team's interpretation, you are discussing the direction with the customer and other stakeholders by summarizing key thoughts and logic across all the sections, so the purpose is to leverage these sections together.

The goal for the design process when discussing the HoQ is to set up the specification sheet and future design decisions while iterating. Therefore, the points you choose to discuss should flow throughout your report or presentation.

The following sections provide examples relevant to the listed section, however, there is overlap from other section topics. This is the nature of how design decisions are made simultaneously and how your thoughts are synthesizing. Also notice how the good sentence examples bring thoughts together to make new ideas beyond just showing the visual.

1. CUSTOMER NEEDS



On the HoQ, customer needs are broadly objectives which define and prioritize your understanding of what it would mean to solve a problem for the user. When presenting these, the high priority and low priority needs are clearly stated and well-supported with background research or engineering principles so anyone outside of your team can understand in a short amount of time. The combination of which needs your team chooses to prioritize and which needs are de-prioritized establishes a design strategy.

Everything else you do in the design process should be for the purpose of producing evidence to support an argument that the design satisfies these customer-driven requirements.

HOUSE OF QUALITY

1. CUSTOMER NEEDS (CONT.)

Common causes of confusion when discussing customer needs stem from:

Vagueness

- ”The provided customer needs are split into four groups, and shown in the figure.”

Too Much Detail

- ”The twenty customer needs are split into four groups: safety, compliance, usability, and other. Safety has 3 needs: user, environment, long term. Compliance has 4 needs:...”

Lack of Variation in Prioritization

- ”Comfortable use, aesthetics, durability, safety, repeatability, maintenance, compliance with environment, are the most important needs with a max weighting of 10 .”

Note that these statements don’t inform how your team is approaching the project and rely on information that can be gathered from the visual.

INSTEAD, HIGHLIGHT THE ANALYSIS WHICH LED TO THE DECISIONS WHICH THE TOOL MAKES VISIBLE OR POSSIBLE (FORMALIZES).

Highlight Prioritized Needs and Their Reasons

- ”Autonomous reaction to hazards, ease of set up, and consistency in performance are the top needs that contribute to safety of the end product.”

This example highlights that safety is a top priority. Based on the audience and genre, additional sentences expanding on why safety is a unique case you are making in the following sentences, otherwise it does not expand beyond the visual.

Use Market Standards and Background Research

- ”Based on top competing products such as __ and __; user safety, policy compliance, and versatility to environments are highly prioritized to provide a significant value when compared to competitors.”

The second example is similar, where expansion is required to show how close you are to pre-existing products and how you are “meeting and exceeding current market expectations.”

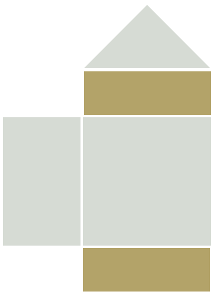
Present Opportunities for Innovation

- ”Additional emphasis on reducing travel time over passenger comfort and transportation mode durability reaches a new customer base that is willing to trade higher costs for faster arrival times on busy days.”

The third example uses tradeoffs to show innovation in the stakeholder’s direction.

HOUSE OF QUALITY

2. ENGINEERING REQUIREMENTS AND TARGET VALUES



Engineering requirements are the measurable metrics used to verify that customer needs are met. Their associated target values define the quantifiable criteria for success. Together, the requirements and target values form the beginnings of the specification sheet, establishing how the project's higher-level goals will be translated into measurable outcomes.

Because engineering requirements are often derived from customer needs, the correlations in the relationship matrix help guide their selection. This ensures that the discussion flows logically from customer needs to the engineering metrics that address them.

Building upon the customer needs examples, similar pitfalls can occur when expanding on engineering requirements and target values.

Vagueness
- "The engineering requirements support the top three customer needs."

Too Much (Irrelevant) Detail
- "For the most detailed need of transporting cargo cross country, the engineering requirements include: maximum weight capacity of 12 tons, 5 indicators when above weight and volume capacity, and top speed of 120 miles per hour under all conditions."

These examples don't provide new information or a clear direction on your team's direction. Standards are called such because they apply to all products within that industry, so, save the detail and industry standards for the specification sheet.

Within the House of Quality, engineering requirements and target values should focus on convincing stakeholders that the proposed approach effectively addresses customer needs.

Solution Agnostic
- "Deliver torque of 1Nm"

This is a functional requirement defining what it would mean for the motor to do its job. Or in other words, how good is good enough? This requirement must not presume what the solution will be in order to allow for innovation and creativity.

Design Specific
- "Rotate at 50rpm"

This is a specific design decision which may or may not be functional. Regardless, it is inappropriate for this stage of design because it will lead to arbitrary requirements such as the use of a motor when it may not even be necesary to use a motor in order to deploy the desired function.

HOUSE OF QUALITY

2. ENGINEERING REQUIREMENTS AND TARGET VALUES (CONT.)

Within the House of Quality, engineering requirements and target values should focus on convincing stakeholders that the proposed approach effectively addresses customer needs.

Highlight Directionally Key Requirements AND Target Values

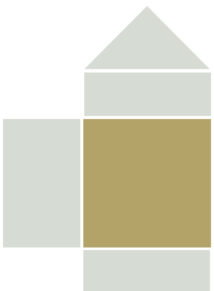
- "The unique functionality of exercising small pets within apartment spaces led to linear dispensing range of 10 feet, based on average apartment dimensions, and 3 meters per second, based on average human treat throwing speed."

Present Opportunity for Innovation

- "An increase in top passenger transportation speed to 40 miles per hour for supertall and megatall buildings while maintaining ASME 17.1 industry standard specifications, aligns with the need of reducing overall travel time."

Good requirements connect measurable targets to customer needs and clearly explain the rationale for their selection. Strong statements may also highlight opportunities for innovation, showing how the team's approach advances beyond simply meeting existing standards. Referencing customer needs or elements of the specification sheet is acceptable and even encouraged when it adds depth and clarity to the statement.

3. RELATIONSHIP MATRIX



Because customer needs are complex and cannot be directly measured, the engineering argument for whether or not customer needs have been met must be justified through the use of engineering requirements. Multiple engineering requirements are typically required to fully satisfy a single customer need. The relationships being visualized in the relationship matrix clarify which metrics correlate to which customer needs and how strongly.

Information that may be highlighted in a discussion of the relationship matrix:

- Customer needs with high and low amounts of correlation
- Alignment of correlations with priority weightings
- Engineering requirements with high influence (i.e., multiple strong correlations)

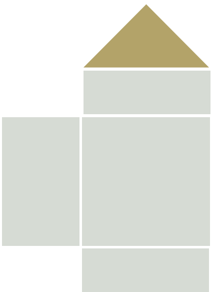
The information above reveals any dissent between the customer needs and engineering requirements. For example, a highly weighted customer need with few or weak correlations to may indicate that insufficient consideration of verification methods to address that need.

The relationship matrix should therefore reinforce any design justifications presented. In general, customer needs with higher priority weightings should be associated with a greater number of correlations, demonstrating that the team has carefully developed corresponding testing metrics. Conversely, misalignment between weightings and correlations can reveal areas that require further refinement when updating the House of Quality (HoQ).

Discussion about this section should focus on any connections or lack of connections that require defense.

HOUSE OF QUALITY

4. CORRELATION MATRIX



The correlation matrix illustrates engineering tradeoffs and synergies within the team's design direction. Similar to the relationship matrix, it is not always emphasized in reports or presentations. However, it provides a compact way to visualize constraints and inherent design challenges that must be considered when developing solutions.

Importantly, the correlation matrix does not need to be fully populated, many requirements do not directly influence one another.

Examples of Direct Correlations
- Total Weight and Maximum Size
- Power Input and Speed
- Acceleration and Mass

Examples of Indirect Correlations
- Weight and Speed
- Power Input and Mass
- Size and Run Cycles

COMMUNICATING TRADEOFFS UNDER CONSTRAINT(S)

The correlation matrix is a map of trade-offs, so consider them carefully and ensure your communication matches what is documented in your Correlation Matrix.

For each individual Engineering Requirement, consider whether more or less of it is a good thing.

▼ translates to "Prioritize making this target value as small as possible - even if that means compromising on other features or performance"

◇ translates to "The target value specified is optimal"

▲ translates to "Prioritize making this target value as large as possible - even if that means compromising on other features or performance"

Choose which trade-offs to emphasize in the communication based on the needs of the audience and the genre
of the deliverable. Consider which compromises will require defense, what will an evaluator question you on?

When there is a high number of stong correlations involving related requirements, be sure to consider the implications and discuss how they are related. This often indicates a specifically challenging or complex aspect of the project, and should be approached carefully.

Engineers are not paid to build things. They're paid to make defensible decisions under constraints.

HOUSE OF QUALITY

4. CORRELATION MATRIX (CONT.)

Examples of Direct Correlations

- Total Weight and Maximum Size
- Power Input and Speed
- Acceleration and Mass

Examples of Indirect Correlations

- Weight and Speed
- Power Input and Mass
- Size and Run Cycles

These examples, drawn from previous student teams, demonstrate how correlations can be debated. While many relationships may appear related, not all represent direct cause-and-effect. Applying engineering principles and equations is the most reliable way to determine whether a correlation is direct.

For instance, power input is often misinterpreted as an outcome rather than a resource. A higher power input can increase achievable speed if other factors remain constant; however, power input does not directly alter mass. Audience confusion arises from conflating the requirements for making a design function with the functional outcomes themselves. In most cases, teams should focus on defining the output force or performance that results from input power, rather than treating input power as the end requirement.

SPECIFICATION SHEET

				Issued:		
			For:		Page:	
			Specification			
No.	Date	D/W	Requirements	Responsible	Source/Rationale	How Validated
General						
Physical Characteristics						
			1	2	3	4
Electrical						
Mechanical						
1	5/22/25	D	Deliver 500Nm of torque	Powertrain team	Motor is capable of developing up to 250Nm. Represents a safety factor of 2.	Dynamometer
2	5/22/25	D	Withstand 200,000 non-towing miles	Powertrain team	correlated to reliability and service life. Customers expect transmissions to last the life of the vehicle.	Simulated road testing
Perform						
3	5/22/25	W	Produce <50dB noise levels	Powertrain team	Quiet performance enhances perception of quality and enhances customer comfort. Motor produces 50db peak noise.	Decibel Meter

SECTIONS COVERED FOR STAKEHOLDERS

1. Requirements and associated criticality (Demand or Want)
2. Responsible
3. Source / Rationale
4. How Validated

EXCEL TEMPLATE

A specification sheet functions as a standard against which every prototype is measured: each engineering requirement is a quantitative target traceable to a customer requirement, with units and a pass/fail threshold rather than a vague qualifier. A spec sheet defines what it means for your project to be both “done” and “good enough,” or in other words, a minimum viable product.

When writing about specifications, distinguish **Demands** (critical to function) from **Wants** (nice-to-have enhancements). Keep the language solution-neutral, referring to functions like "store energy" or "activate release" rather than specific components. Beyond analyzing prototypes performance, the spec sheet prioritizes time investment: subsystems falling short of a demand warrant iteration, while those already meeting their targets do not justify further investment. Treating the sheet this way in your writing shows it driving decisions, not just documenting them.

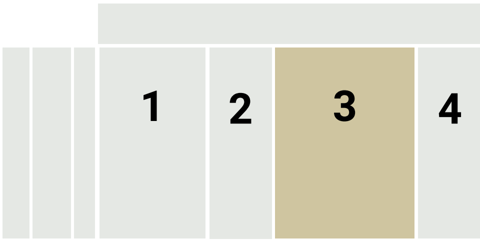
In addition to what key specs were chosen and what values were deemed appropriate, it is the purpose of the engineering report to communicate the reasons why specific metrics, target specs, and units were chosen as representative of the customer’s needs.

The following pages introduce how the audience influences selected information. These examples focus on catering to different audiences. Provided examples are relevant to the listed specification sheet sections above, however, there is overlap from other section topics and sections. This is the nature of how the specification sheet supports the HoQ and conceptual designs.

SPECIFICATION SHEET

Note that the highlighted sections are what the specific audience may prioritize based on the listed primary interest. This does not mean they are not interested in the other sections. Assume that all stakeholders will read all sections, so make sure everything is justified.

Examples are provided on the follow pages for the corresponding audience.



MARCUS JOHNSON
IP Lawyer

Primary Interest: Ethical and legal compliance

Source and Rationale (Section 3) aligns best with Marcus because they are critical to his job function in understanding and communicating how an invention is practical, useful, and feasible.

Effective Uses

"For the in-patient wearable health tracking alternative designs, IEEE 360 standards for wearable technology are used as the baseline specification to meet."

By basing project requirements on well-established industry standards, the specification gains credibility and reduces risk. Always leverage industry standards, if they exist.

"The retraction function must store at least 2.5 J of mechanical energy and deliver a minimum peak output force of 18 N at the point of release. Because prior art relies on gear motors and lead screws for actuation, a passive mechanical energy-storage function falls outside those claims, maintaining patentability and freedom to operate."

The second example is similar where expansion is required to show how close you are to pre-existing products and how you are "meeting and exceeding current market expectations.

Ineffective Uses

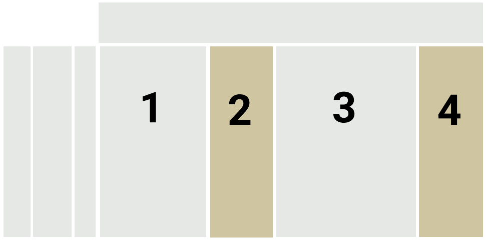
"Policy compliance and ease of medical observations are the highest rated needs, so 100% listed policy compliance and 360 degree overhead view accomplish these needs."

This example links customer needs to specifications, but stops at restating the connection rather than justifying the targets. It does not explain why a 360-degree view is the right threshold (versus 270 or 180), what evidence supports it, or how the metric will be verified. Effective writing about specifications should expand on each target. Cite the calculation, benchmark, or observation from which it was set. The reader must understand not just what the requirement is, but why that value is the threshold for "good enough."

SPECIFICATION SHEET

ANGELA REED
VP of HR

JON FOX
Design Supervisor



Primary Interest: Ethical and environmental accountability

Responsibility and Validation (Sections 2 and 4) align best with Angela and Jon. Angela wants to know how the promised specification is getting done and how those responsible are planning on achieving it. The design supervisor wants to assess whether the team is using a reliable method to verify that they met the requirement.

Effective Uses

"The wearable technology specifications are met by the design engineering team, verified by the consumer electronics team, and then the prototypes are approved for use by the user research testing team."

The first example shows accountability for user comfort and electronics safety during user testing. It is clear which teams are included in which part of the process and there are specialty experts.

"The product lifespan minimum of 20 years, material usage of 50% recycled materials, and 90% recyclable at end of life disposal at approved centers address concerns for environmental impact and footprint. Tested prototypes are weighed by material to calculate pre- and post-production percentages, and wear conditions are simulated to estimate lifespan."

This example pairs each environmental specification with the method used to verify it, giving the reader a clear path from target to evidence. Naming the validation approach (accelerated wear testing, component-level mass measurement) lets a sustainability-focused stakeholder follow up on test conditions, sample sizes, or whether the recycled-content figure reflects inputs or finished mass. Writing this way builds credibility because it does not ask the reader to take the targets on faith.

Ineffective Uses

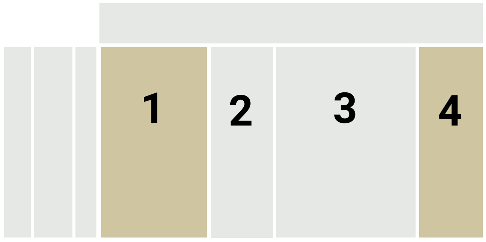
"The coding team aims for 100% accuracy in distance detection for the soap dispenser. This is a simple coding task so one week of testing with a 10-person user group is planned to complete this task before the packaging team integrates the code into physical components."

The third example provides team accountability and validation method, however, there is no supporting evidence for either selected method. The value of 100% is statistically rare and it's not clear how the value is calculated. The decision of a user group and selected timeline are unclear. Providing evidence to clarify these points adds to the trustworthiness of these decisions.

SPECIFICATION SHEET

JON FOX
Design Supervisor

SARAH MITCHELL
Sponsor/Client



Primary Interest: Meeting and delivering standards

Specification (Section 1) and Validation (Section 4) align best with Jon and Sarah because their job is to ensure that the customer requirements are demonstrably met.

Effective Uses

"The force required to secure the wearable health device is around 30N, the average hand strength of a teenager's non-dominant hand. To confirm the metric, a force gauge will be used to measure tested users' pull force and grip force along with their rate of success at securing the device."

The first example explains the metric, how the initial metric is validated, and how the metric can be empirically verified. The explanation is understandable by multiple audience groups and covers possible user research stakes.

"Equipment rental costs must fall within the reimbursement range of the three most common regional insurance policies ($200-325 per month), and measurements must be accurate to within ±2 mmHg. Together, these targets are projected to reduce follow-up visits by an average of 4 appointments per case."

The second example is eye-catching to high influence audiences that have the purchasing power or policy making power to support this product. The provided values need support or explanation of calculation and can be directly used as evidence for the product's value.

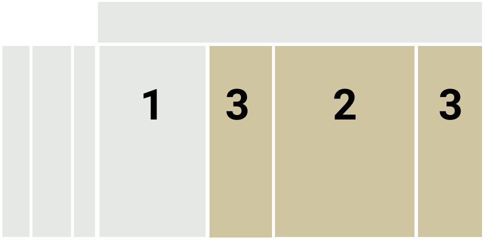
Ineffective Uses

"The input power is 120V to 240V to ensure usability in households worldwide. At least two indicators, one visual and one audial, are incorporated when the input power drops below or above 5% the expected input voltage."

This example states two specifications but gives the reader nothing to engage with. The 120V–240V range is so broad that it reads as a generic nod to international compatibility rather than a deliberate engineering choice. There is no explanation of which regional standards were surveyed, why this range was selected over a narrower or wider one, or how the device must handle a transition between voltages. The 5% deviation threshold for indicators is similarly unsupported. The reader cannot tell whether this metric comes from a safety standard, a component tolerance, or an arbitrary guess.

SPECIFICATION SHEET

HANNAH ZIEGLER
Current/Future Team Member



Primary Interest: Mutual liability and task division

Source/Rationale (Section 2) and Validation (Section 3) align best with Sarah because she wants to know if the specification is trustworthy and actionable. As a future team member, she would be liable as well if metrics are not met or incorrect.

Effective Uses

“The force required to secure the wearable health device is estimated to be around ____, the average hand strength of a teenager’s non-dominant hand. The non-dominant hand is selected as a baseline assumption for less than full strength and it is assumed that older users have caretakers who can secure the device for them. There is no agreed upon recorded value for at-home patients, so to confirm the selected value, a force gauge will be used to measure tested users’ pull force and grip force along with their rate of success at securing the device.”

The first example is an expansion of Jon’s first example. The emphasis is on the rationale for the initial value and how it will be adjusted since there are no recorded values as a baseline.

”For returning patients, a snapshot of their vitals means doctors are drawing conclusions from incomplete data. To ensure collected health data is adding to doctors’ ability to treat their patients, emphasis is placed on accuracy and repeatability metrics. These are led by and the first priority of the consumer electronics team and coding team.”

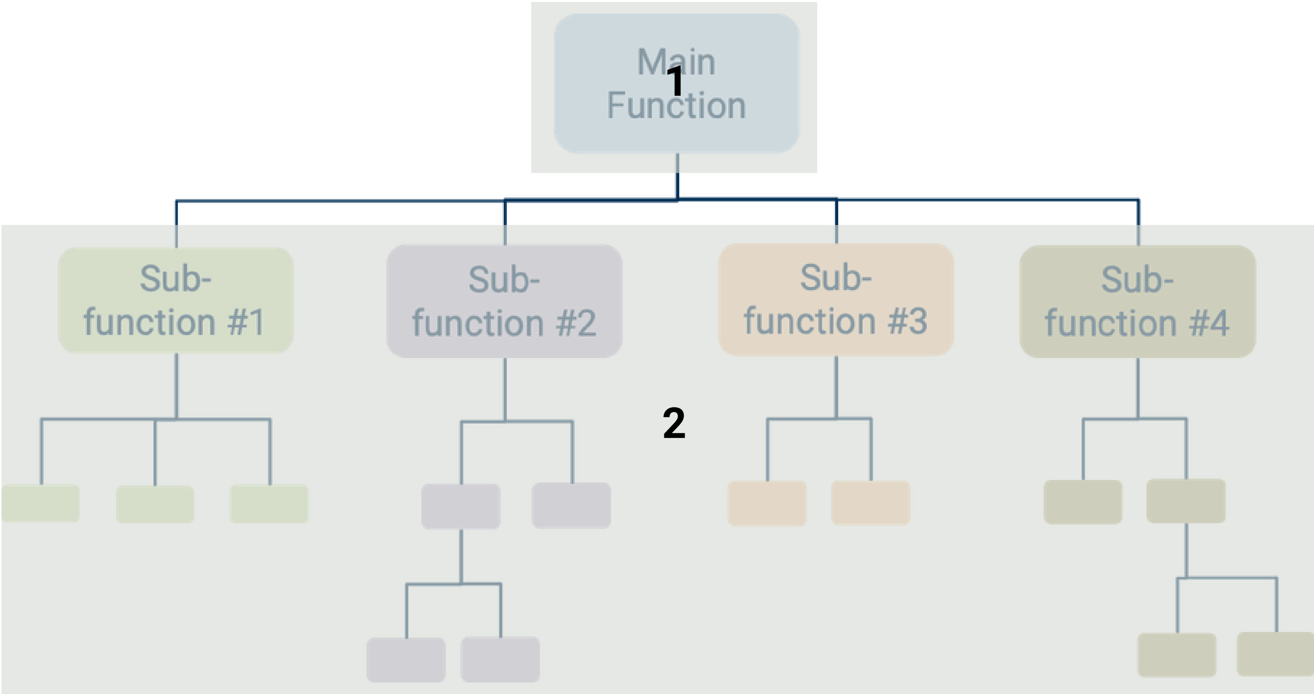
The second example demonstrates importance of certain specifications by providing the rationale with the priority in assigned responsibility. It is clear who Sarah goes to and collaborates with for tasks related to accuracy and reliability.

Ineffective Uses

“To ensure specifications are met, there is a secondary team assigned to each specification that will be the first point of contact for assistance to the primary team.”

The third example informs Sarah of the internal process with generic phrasing. It does not show prioritization within the process or an initial direction, which can make achieving the metrics chaotic and create time crunches. Specific information by explaining how it applies to a few specifications or providing a prioritization plan are two ways to resolve some of the ambiguity.

FUNCTION TREE



SECTIONS COVERED FOR STAKEHOLDERS

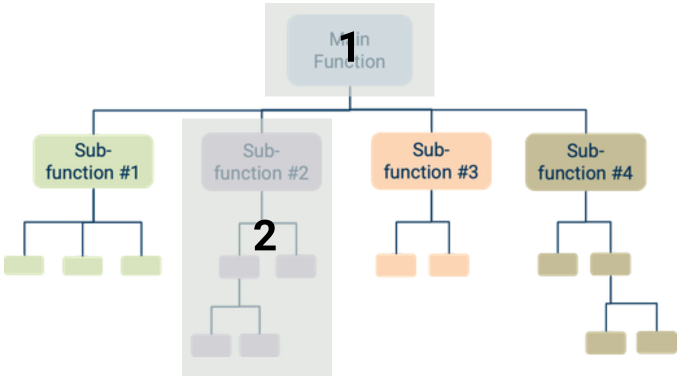
1. Main Function
2. Branches decomposing functionality into logical subsystems

A precise, systematic function tree is the foundation of your design strategy, breaking the main function into independent, verifiable sub-functions. In a report or presentation, a logical organization of functions enables the audience to focus on a subset that best supports the claims at hand (such as such as a mobility subsystem being distinct from a subsystem that applies force), by providing a visual organization of functional relationships.

This addresses a common difficulty in design reporting: avoiding chronological or purely reflective writing, instead of systematic, function-based defense of design decisions. It is not appropriate to narrate the function tree without relevant design claims. In other words, do not list functions to the audience.

The following pages introduce how discussing different sections of the function tree support different arguments. The goal is to connect your problem understanding section and conceptual design with this supported design strategy. As the engineer, your job is to highlight the applicable sections and emphasize in supporting text what is situational to the audience. Note that these are common groupings and there are more options beyond this example that can better fit your argument.

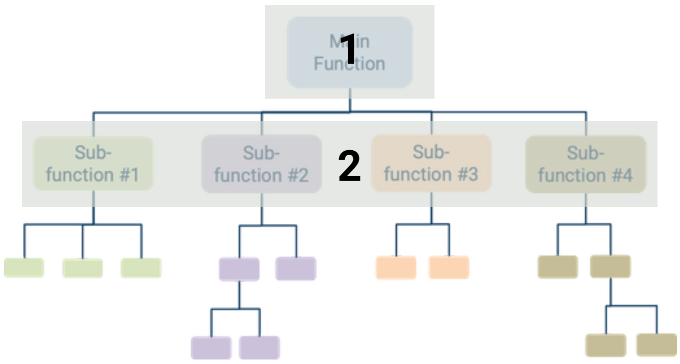
FUNCTION TREE



ONE SUB-FUNCTION BRANCH

Discuss entire subsystems to explain the deployment of a critical function. The success of these functions are high priority to the success of the overall system.

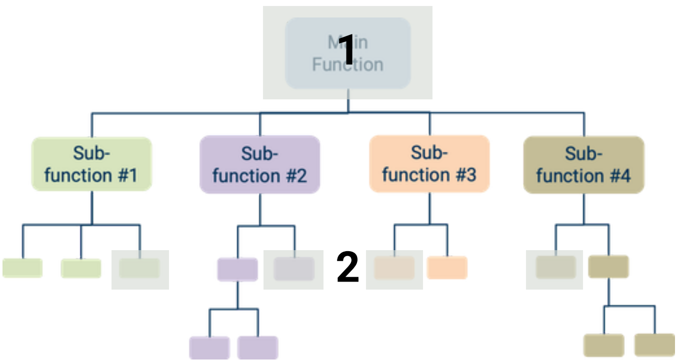
Ex. “The dexterity of surgical assistive systems for suturing is critical, since the distance between sutures is 4 mm and placement accuracy must be <1.0mm.”



ALL SUB-FUNCTIONS AT A LEVEL

Discuss sub-functions when the stakeholder needs to understand how the design strategy delivers the required functionality.

Ex. “Heating water was excluded as a critical function since customers in the target market typically have access heated water in their office break rooms.”

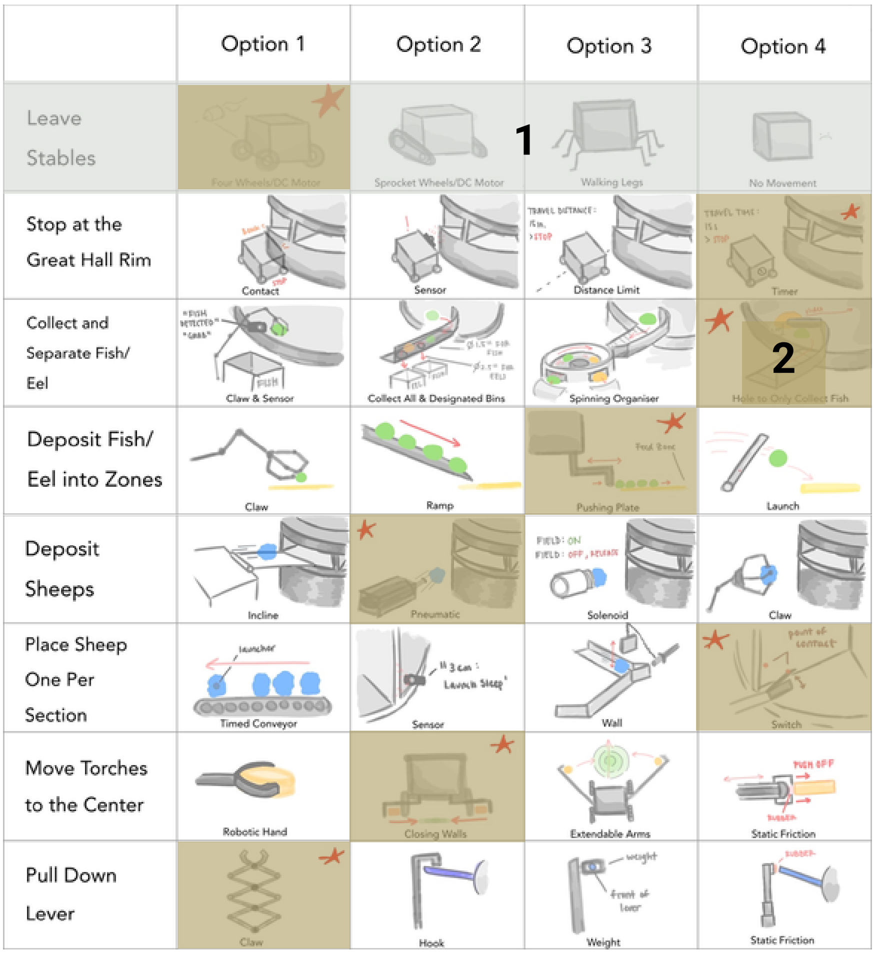


MULTIPLE SUB-FUNCTIONS FROM DIFFERENT BRANCHES

Highlight synergy or correlations of the sub-functions when there are mutually beneficial or detrimental relationships impacting the performance of the main function. Don’t forget to tie these correlations and relationships back to the House of Quality.

Ex. “Tracking a pet and releasing a treat are mutually beneficial to ensuring accurate delivery distance.”

MORPHOLOGICAL CHART



Fall 2025: Dylan Burkey, Lena Nguyen, Aaron Qu, Albert Liu

SECTIONS COVERED FOR STAKEHOLDERS

1. Entire Row of Sub-function Node
2. Selected Options for a Full System Design

Key for Sections Covered

Entire Row of Sub-function Node

Selected Options for a Full System Design

The morphological chart, or morph chart, organizes visual design ideation for all the nodes of a corresponding function tree. The table connects the functional breakdown with an easy-to-view format for ideation of subsystems that can come together into full systems.

In communication, ***parts of the morph chart are discussed*** to assert that a recommended solution is the best fit for the design strategy.

The ***morph chart in its entirety is reviewed*** to provide a rationale for concept selection as well as to defend rejection of weaker ideas through visual juxtaposition.

The following page provides two examples for effective visual communication of morphological charts. An entire morph chart often extends beyond a few pages or slides and is overwhelming to follow. By re-arranging the presentation of the chart, the audience can digest the intended takeaway in a shorter time frame, giving them bandwidth to draw other analyses.

MORPHOLOGICAL CHART

Fall 2025: Dylan Burkey, Lena Nguyen, Aaron Qu, Albert Liu

SIDE-BY-SIDE HIGHLIGHTING OPTIONS FOR FULL ALTERNATIVE SYSTEMS

Useful when comparing multiple alternative systems together. Sets up discussion for pros and cons of each system since selections are side-by-side. (Here is an example of a topic sentence)

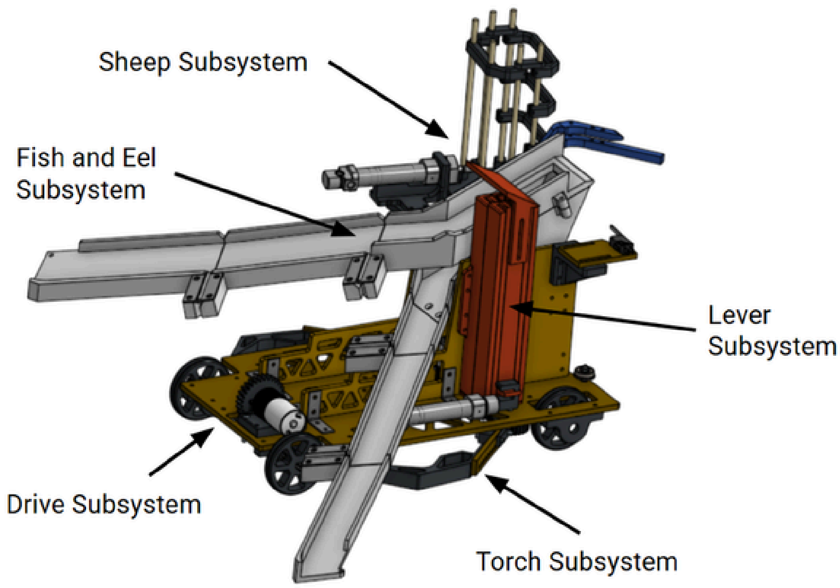
Ex. Design perspectives for each design, ex. youth, elderly, dexterity,

Full Alternative Designs

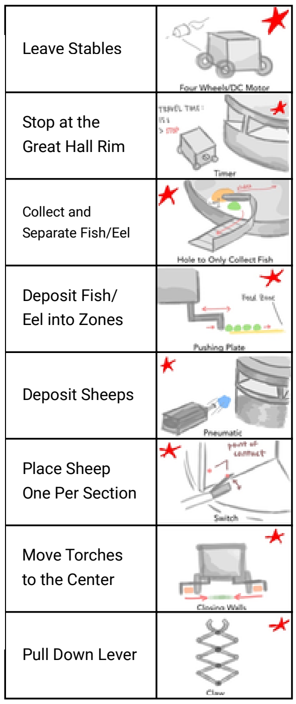
- 4-Wheeled Dragon Racer
- TANK: An Absolute Unit
- Multi-dimension(al) Extension

RE-ARRANGED OPTIONS COMBINED INTO FULL ALTERNATIVE SYSTEM

Communicates an overview and intended functionality of a full system.
Sets up discussion for analysis of the full system and how the subsystems integrate.



Fall 2025: Dylan Burkey, Lena Nguyen, Aaron Qu, Albert Liu



EVALUATION MATRICES

There are three levels of evaluation matrices which can compare the same products on the same criteria. The difference between the three are the ***fidelity of analysis*** and the ***stage in the design process*** they are used. While you may present them once for an audience, they are iteratively used as design ideas are cycled through, adapted, and adjusted based on feedback to ensure that the selected design is the best option to move forward with.

SECTIONS COVERED FOR STAKEHOLDERS

1. Criteria
2. Ratings from Important Criteria
3. Relative Rankings and Relative Totals

1

Criteria	Plunge Stop	Master Cylinder	Ratchet	Rubber Brake
Ease of handling	Datum	S	-	S
Ease of use		S	-	-
Readability		S	+	S
Dose accuracy		S	S	S
Durability		S	S	S
Ease of manufacture		+	-	-
Portability		+	S	+
Σ+	0	2	1	1
ΣS	7	5	3	4
Σ–	0	0	3	2
Total				
Rank				

3

First level Evaluation Matrix example of four insulin pen designs. Courtesy: Dr. Tom Kurfess.

The first level is for the earlier stages of design, where there are the most ideas to compare. The focus is on what ideas are inherently better or worse to quickly identify which ideas merit another round of evaluation. It is good practice to discuss an idea's potential to meet customer requirements (criteria), since they are relative to a datum, before fully eliminated.

1

Criteria	Plunge Stop	Master Cylinder	Ratchet	Rubber Brake
Ease of handling	4	3	4	4
Ease of use	4	3	4	4
Readability	1	2	3	3
Dose accuracy	1	3	3	3
Durability	4	2	3	2
Ease of	4	3	2	2
Portability	4	3	3	3
Total	22	19	22	21
Relative Total (div by 28)	0.79	0.68	0.79	0.75
Rank				

3

Second level Evaluation Matrix example of four insulin pen designs. Courtesy: Dr. Tom Kurfess.

The second level is a medium fidelity, earlier stage evaluation for design ideas that have passed previous round(s) and been adjusted based on feedback. This level considers "how much better" the idea is for specific criteria. It also reveals how well rounded or specialized an idea may be.

1

Criteria	Importance	Plunge Stop		Master Cylinder		Ratchet		Rubber Brake	
		Rating	Weighted Total	Rating	Weighted Total	Rating	Weighted Total	Rating	Weighted Total
Ease of handling	10	4	40	3	30	4	40	4	40
Ease of use	8	4	32	3	24	4	32	4	32
Readability	8	1	8	2	16	3	24	3	24
Dose accuracy	9	1	9	3	27	3	27	3	27
Durability	7	4	28	2	14	3	21	2	14
Ease of manufacture	7	4	28	3	21	2	14	2	14
Portability	7	4	28	3	21	3	21	3	21
Total		173		153		179		172	
Relative Total (div by 224)		0.77		[illegible]		0.80		0.77	
Rank									

2

3

Third level Evaluation Matrix example of four insulin pen designs. Courtesy: Dr. Tom Kurfess.

The third level is the highest fidelity pass for final design ideas. The selected design comes from this level because these ideas have passed: multiple rounds of evaluation from first and second level evaluations, lo-fidelity prototyping testing, and feedback from audiences. This level may also be used to break ties from a lower level evaluation because it incorporates the importance of each criteria.

In a report or presentation, multiple matrices are used at a time to verify or show additional comparisons. You as the engineering team need to determine which verification or comparison is appropriate for the deliverable without unnecessary redundancy.

EVALUATION MATRICES

The matrices provide quantitative values, but the evaluations themselves are subjective to the team, so it is important to account for discussions and feedback that can stem from the provided matrices and supporting text. This builds trustworthiness for the audience.

Below is a combination example of a second and third level matrix, which is appropriate for a final or close to final design report, demonstrating possible points of discussion. A legend is not provided to save space in this example, however, they should be included in your report outs.

“The Plunge Stop and Ratchet design are comparable, tied with highest relative scores of 0.79, when viewing the criteria without importance weightings. However, the third level matrix shows the Plunge Stop’s low rating for readability and dose accuracy making the Ratchet a better initial design to move forward with. For daily insulin users, both of these criteria highly impact their well-being, with importance ratings of 8 and 9 reflecting this importance.”

Table 1. Second level Evaluation Matrix of four insulin pen designs. Ratings are 1 as the worst, 4 as the best capability.

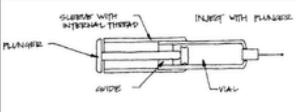
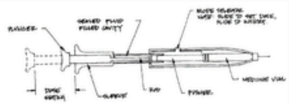
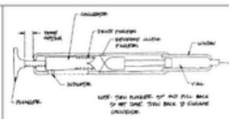
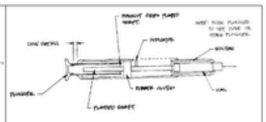
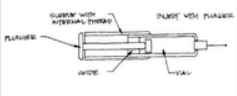
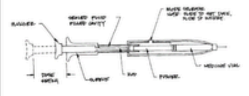
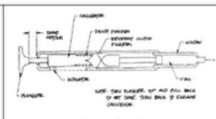
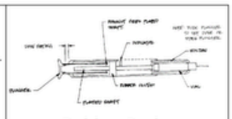
Criteria	 Plunge Stop	 Master Cylinder	 Ratchet	 Rubber Brake
Ease of handling	4	3	4	4
Ease of use	4	3	4	4
Readability	1	2	3	3
Dose accuracy	1	3	3	3
Durability	4	2	3	2
Ease of	4	3	2	2
Portability	4	3	3	3
Total	22	19	22	21
Relative Total (div by 28)	0.79	0.68	0.79	0.75
Rank				

Table 2. Third level Evaluation Matrix of four insulin pen designs. Ratings are 1 as the worst, 4 as the best capability. Importance ratings are carried over from the House of Quality with 1 as the lowest, 10 as the most importance.

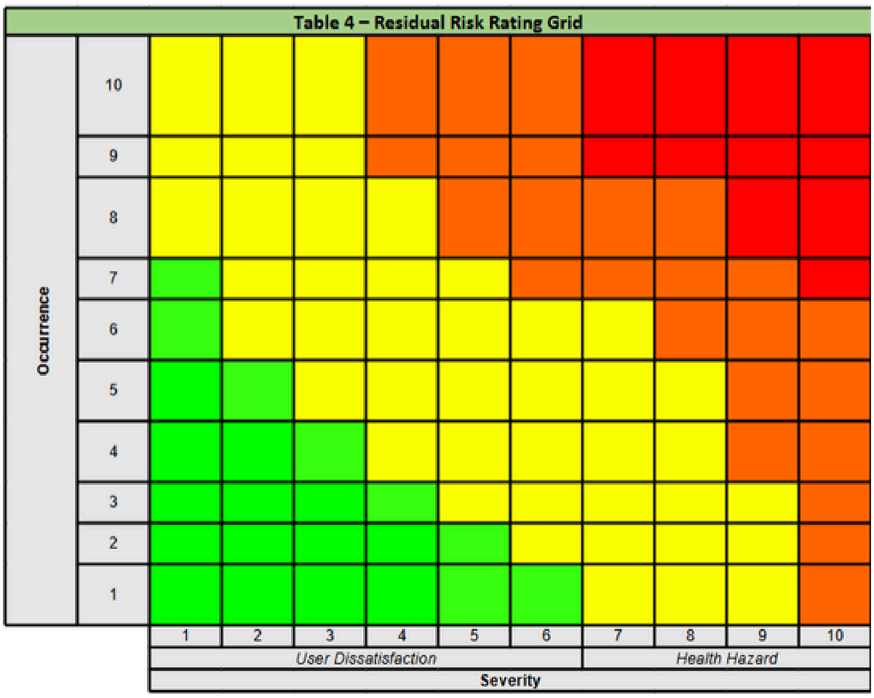
Criteria	Importance	 Plunge Stop		 Master Cylinder		 Ratchet		 Rubber Brake	
		Rating	Weighted Total	Rating	Weighted Total	Rating	Weighted Total	Rating	Weighted Total
Ease of handling	10	4	40	3	30	4	40	4	40
Ease of use	8	4	32	3	24	4	32	4	32
Readability	8	1	8	2	16	3	24	3	24
Dose accuracy	9	1	9	3	27	3	27	3	27
Durability	7	4	28	2	14	3	21	2	14
Ease of manufacture	7	4	28	3	21	2	14	2	14
Portability	7	4	28	3	21	3	21	3	21
Total		173		153		179		172	
Relative Total (div by 224)		0.77		0.68		0.80		0.77	
Rank									

FMEA AND RCA

Failure modes and effects analysis (FMEA) and root cause analysis (RCA) are industry methods for identifying the underlying reasons for design failures or performance issues in engineering projects. While both have multiple possible visuals, the goal with the selected visual is to communicate the underlying central cause of a problem and how to mitigate it in the future.

It is good practice to confirm with your supervisor if there is an expected template or style already in place for your company or industry. If you choose to portray the information in a different formant, such as correlations when tracing across the Five Whys or a Fishbone Diagram, use the requested format first to build upon your additionally selected format.

Note that FMEAs are predicting risks inherent to the design under ideal conditions whereas RCA is during and after testing when problems arise. So, when translating information from an expected format to a new one, make sure you can explain the added usefulness for and correct usage of the new format.



Example figure of a dFMEA risk rating grid.

Occurrence ratings are 1 - failure unlikely, 10 - failure is inevitable. Severity ratings are 1 - no impact at all, 10 - catastrophic health hazard that can cause death.

Based on ISO14971.

SECTIONS COVERED FOR STAKEHOLDERS

Depends on the audience and how the information is presented

Note that discussed sections depend on the industry or audience. Example of user-specific general guiding questions to determine topic sentences are:

- Is the focus on occurrence or severity?
- How likely is the possibility of death?
- If this is for the medical industry, is it invasive for someone to continue living their life?
- OR, is this a product that would be nice to have and would make it easier for someone to juice fruits more than current products on the market?

FMEA AND RCA

Now beyond the initial concerns of injury to the user or loss of function of the product, what is your audience concerned about?

- **Is there a risk of a high frequency sound that deters wildlife and pets during use?**
- **Is there a moving component that rarely jams and requires minor troubleshooting?**
- **Is there vibration during operation that loosens the wheel causing uneven lawn lines?**

Below are examples of topic sentences for FMEA with Marcus, Angela, and Sarah as the audience.

MARCUS JOHNSON
IP Lawyer;
Industry Expert

Effective Uses

”A robotic wheelbarrow axle fails when the wheelbarrow is loaded with the labelled maximum load of 500 lbs of rocks. This risk could be mitigated by comparing the design requirements against the engineer's calculations and engineering specification drawings to figure out the axle’s factor of safety.”

The first example captures risks inherent to the design under ideal use conditions, ideal manufacturing conditions, with ideal software design and functionality. It provides an actionable solution by suggesting review with a team of qualified peers.

ANGELA REED
VP of HR;
Community Leader

”The bike frame fractures at the handlebars during head-on collisions above 10 mph. This causes cuts in addition to bruises for riders if they impact the bike frame. This risk could be mitigated by adding a safety feature to “pad” the user from the frame and test if possible vibrations within the material are causing the localized fracture.”

The second example is similar following a structure of: what could go wrong, what is the consequence, why did it happen, and how it can be mitigated.

SARAH MITCHELL
Sponsor/Client

Ineffective Use

”The grinding of the brakes’ material when the machinery stops is above decibels safe for human hearing, potentially causing long term damage for frequent operators. To mitigate this, all operators will take a mandatory training on hearing safety.”

The third example follows the structure but instead of adjusting the design, it puts the responsibility of safety on the user.

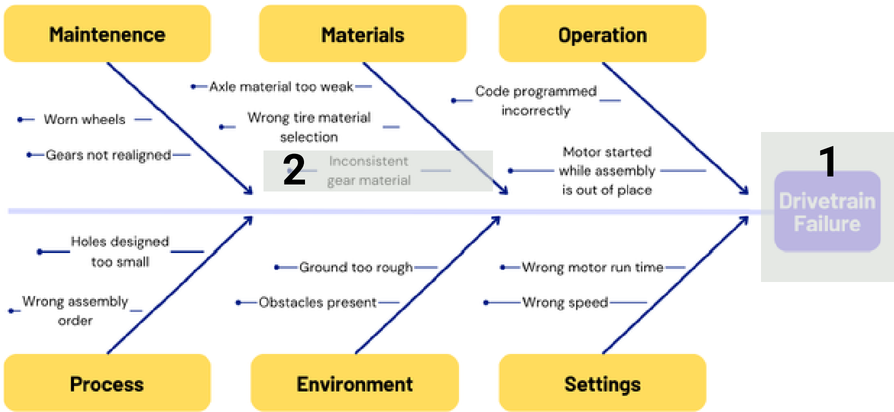
FMEA AND RCA

SECTIONS COVERED FOR STAKEHOLDERS

1. Failure mode or effect
2. Specific cause that is part of the takeaway

Example Fishbone diagram of a drivetrain RCA failure during testing.

Courtesy: The Beavers' from Summer 2025.



Note that this example is not the only way to represent RCA; as long as the focus is on the how and why of the cause and a remedy is provided. Annotated, individual images and an in-depth testing log for note taking purposes are good documentation practices, and pulling a specific entry is appropriate if that specific cause of the failure mode is the takeaway.

Below are examples of topic sentences for RCA with Jon and Hannah as the audience.

JON FOX
Design Supervisor

HANNAH ZIEGLER
Current/Future Team Member

Effective Uses

”The axle snapped during operation from the additional weight causing drivetrain failure. Metal dowels replace the wooden dowels providing more strength and ductility, allowing the axles to flex and maintain shape with vibrations or weight rather than snapping.”

The first example provides a cause and effect, and analysis with the proposed improvement. Addresses the cause provides the actionability.

”The wheel well is too small for the selected wheels, causing friction between the wheel system and the body and leading to a slower rate of travel than expected. The following iteration increased the width of the well-hole by 1/2-inch on each side, resolving the friction.”

The second example shows a process cause and has a similar structure as the first example. Note that it focuses on the process, not the team.

Ineffective Uses

”The design team measured the travel distance incorrectly causing the drivetrain to run into obstacles, damaging the wheels. With the correct measurements, damage to the wheel was avoided.”

The third example focuses on a team error. While relevant as a cause, it does not reflect on the design intention.

PLANNING TOOLS

Planning tools are important to the completion of a project. When working with multiple people and/or collaborating across teams, having planning tools to reference relieves cognitive load from the individual to track or remind others of timelines. Additionally, if two teams remember different timelines, it can cause friction during collaboration.

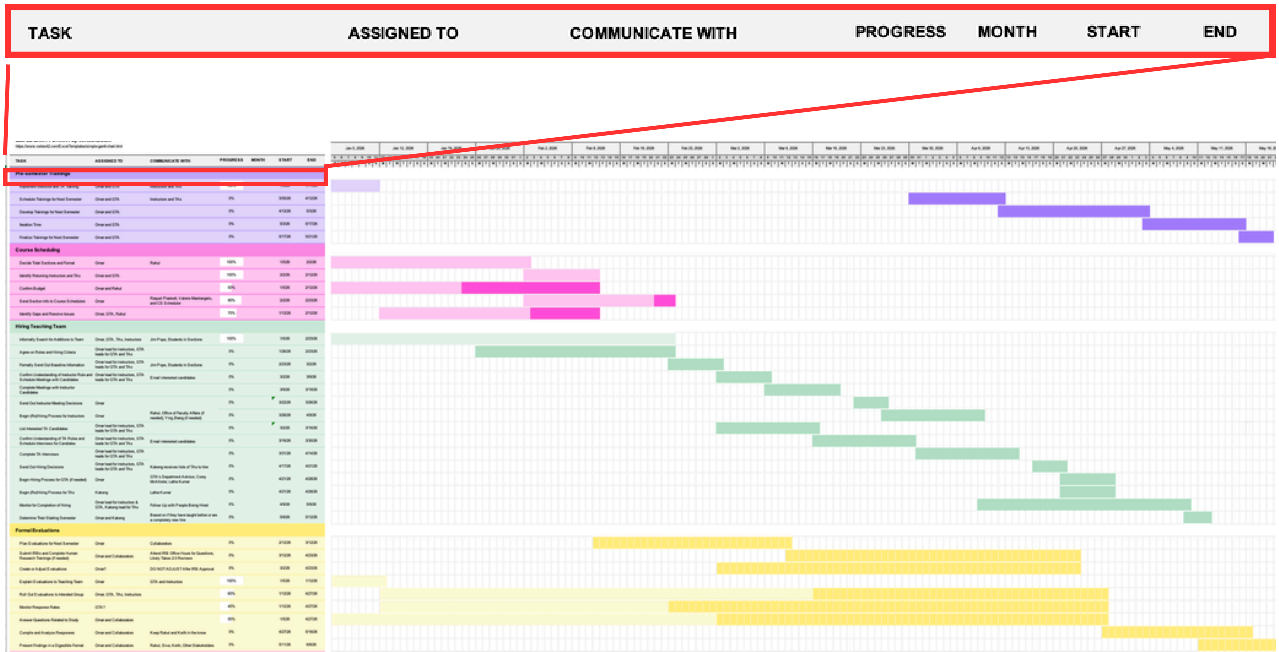
The tools you encounter in 2110 and Capstone include but are not limited to:

- Bill of materials
- Gantt chart
- Relationship matrix

The listed tools assist with scheduling milestones, tracking success and guiding hand off of subtasks. They are the backbone to documenting and maintaining progress.

Planning tools go through iteration during the project to evolve with the project. A common mistake is for teams to create planning tools at the end of a project instead of at the beginning. This leads to tools that the audience wants to see since the progress has been done rather than tools used as an agreed upon resource for accountability.

Below is an example of a Gantt chart with headers zoomed in for legibility.



Example figure of a Gantt chart for a curriculum design project. Courtesy: Nisha Detchprohm.

This planning tool example is effective to multiple audiences because of the thematic consistency in subsections, visuals that increase understanding, and assigned communication roles. Points to reference evolve with the stage of the project, starting with an overview of decisions at the beginning, and details or changes from iteration during milestone checkpoints.

PLANNING TOOLS

Below are examples of topic sentences for other planning tools without an example figure. Note the takeaways and points of confusion with each example.

Effective Uses

✓ ”The frame subsystem is made up of 80/20 1010 aluminum, with initial lengths outlined in the Bill of Materials. This allows placement adjustments of the attached hanging subsystems during the proof-of-concept testing.”

The first example highlights the information on the planning tool and expands on its importance. The analysis beyond what can be inferred from the planning tool makes supports trustworthiness.

✓ ”The selected design must be finalized before logos and wraps are added, since those processes are outsourced to a third party vendor. There is a three-month period for the completion of the aesthetics to account for any shipping or supplier delays. A detailed breakdown of the vendor interactions are in the V3.2 Gantt chart.”

The second example highlights a process decision without framing it as “the team decided.” It also notes external factors and time for communication, rather than leaving external interactions as a mystery timeline.

Ineffective Uses

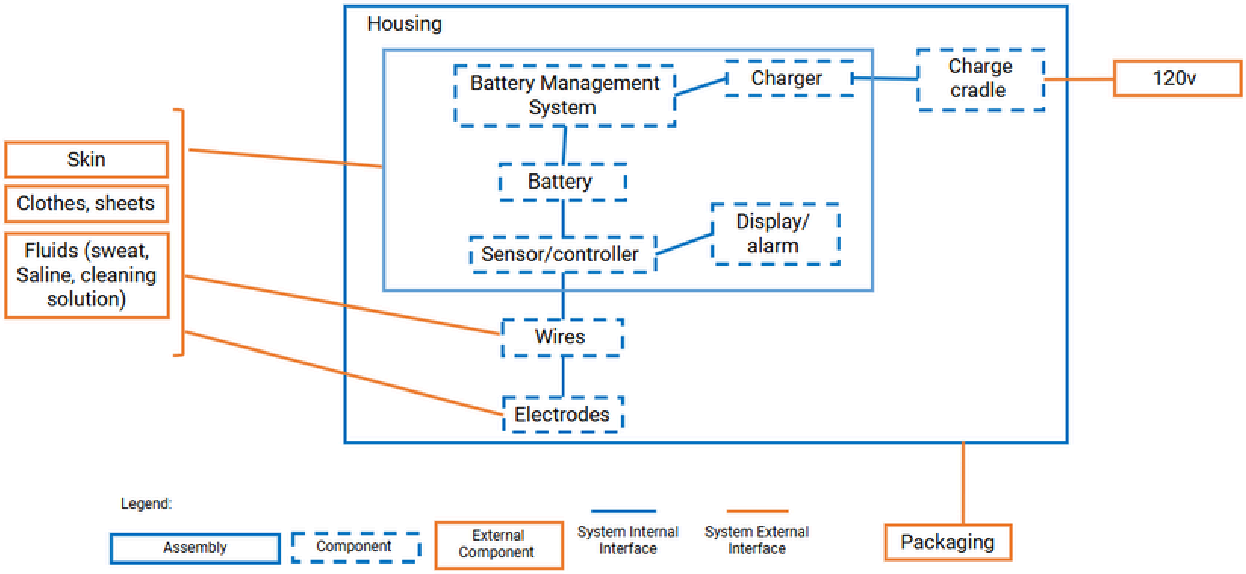
✗ ”The subtasks are organized by external stakeholder check-ins, individual team progress, collaboration sprints, and communication deliverables. Weekly stand-ups open discussion if any timelines need to change or support is requested.”

The third example lists decisions made. While relevant to the completion of the project it does not reflect on the steps towards success or the design intention.

Documentation can be tedious to create, however, strong documentation is something people like to use. It gives them head start without having to spend resources learning the lessons you have already learned. This reflects the importance of updated and well-thought out planning tools, especially in industry when future teams and other parts of the company will reference something the you have worked on.

SYSTEM BLOCK DIAGRAMS

A block diagram visually represents a system by defining its essential parts and the connections between them. A well-constructed block diagram answers three questions at a glance. First, it defines the **scope** of the system by drawing a firm boundary around what belongs inside. This is critical for establishing budgets as well as building a verification and validation plan, because everything outside the scope of development does not need to be designed or tested. Second, it identifies the **interfaces** that cross the boundary, the inputs the system receives and the outputs it produces. Third, it exposes the dependencies and **relationships** among the internal blocks, showing how information, power, or material moves from one subsystem to the next.



Example System Architecture Diagram for a wearable health monitoring device.

Effective Uses

The device partitions into a controller subsystem that reads bioimpedance through skin-contact electrodes, a power subsystem built around a managed battery and external charge cradle, and a user-alert path driving the display and alarm, all enclosed in a housing that isolates the internal electronics from the fluids and fabrics of the patient environment. Note that the electrodes and wires cross this boundary, so they must be self-sufficient in their resistance to sweat, saline, and cleaning solution, while every component inside the housing inherits that protection by default.

In this example, key subsystems are labeled. But insights are also gained by identifying key implications of the structural design of the system which may impact development efforts.

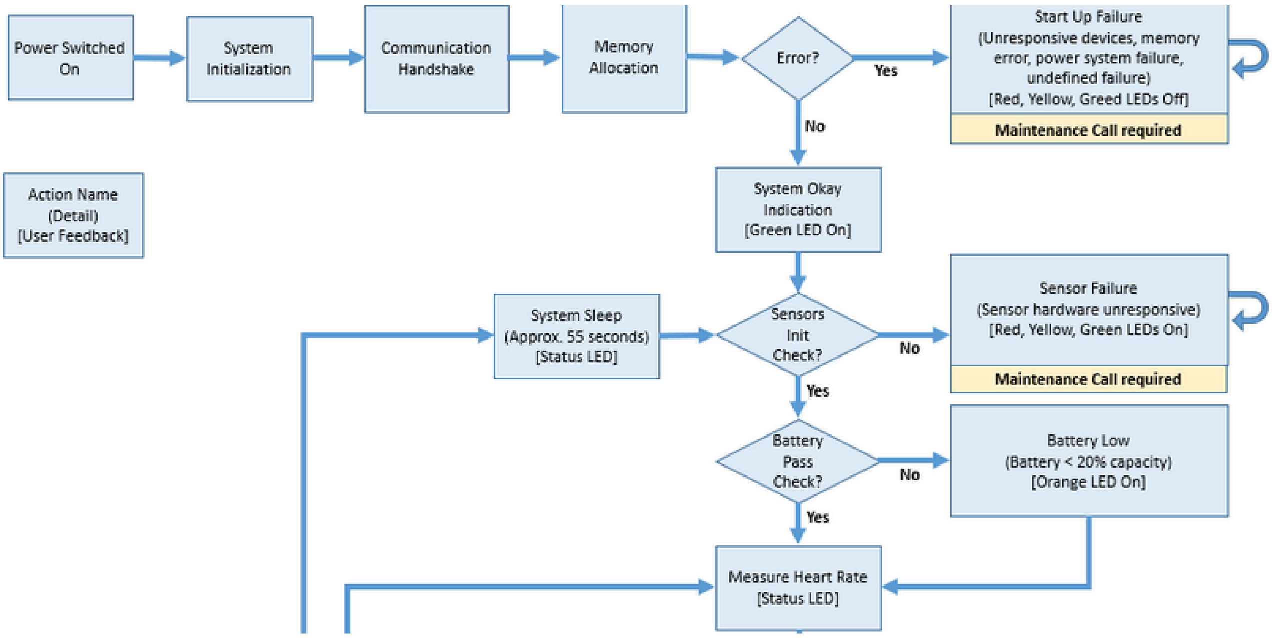
Ineffective Uses

Figure 1 shows the block diagram of the health monitoring device, which includes a Battery Management System, Battery, Sensor/controller, and Display/alarm inside the housing, along with several external components it connects to.

The ineffective sentence announces that a figure exists but merely restates what is clearly visible in the figure.

SOFTWARE FLOW CHARTS

Software flow charts are critical to define the logic which will be followed to perform the required functions. A typical flow chart should define user actions, internal logic structure and routing of information, as well as outputs in the form of user feedback, data being sent outside the system, changes in controls states, or physical motion.



A portion of a software architecture flow chart for a wearable medical device.

Effective Uses

The firmware executes a linear startup sequence, initializing the controller, establishing communication, and allocating memory before signaling readiness, then enters a periodic monitoring loop that samples heart rate roughly once per minute. Each decision node in the loop acts as a gate that must pass before measurement proceeds, and any failed check diverts execution to a fault state with a distinct LED signature, isolating a sensor, battery, or electrode problem for the user without halting the wider routine.

This description emphasizes the one-time startup from the recurring loop, the single most important distinction the diagram encodes. It then reads the decision nodes as a design pattern rather than a list, recognizing that each check is a guard condition and that the fault branches share a common purpose: mapping a specific failure to a specific signal so the fault is diagnosable at a glance. That is reasoning from the control logic, not narrating the arrows.

Ineffective Uses

Figure 2 shows the flowchart for the device software, which starts by powering on and initializing, then checks for errors and runs through the sensor, battery, and heart rate steps before going to sleep and repeating.

This version walks the reader box by box in page order. It reports the sequence of steps without naming the two things a control-flow diagram exists to convey: which stages are one-time setup versus a repeating loop, and what each decision gates. The reader can follow the arrows but learns nothing about the logic driving them.

PART II: ENGINEERING DESIGN DOCUMENTATION

Engineering work rarely exists in isolation. Engineers communicate through recurring genres that support different forms of collaboration, evaluation, coordination, and decision-making.

Different genres, such as reports, presentations, standup meetings, prototype reviews, specification sheets, design expos, evaluation matrices, and technical figures all exist because they help audiences perform specific engineering tasks. Each deliverable carries its own expectations:

- what information should appear,
- how much detail is appropriate,
- how evidence should be presented,
- what audiences are likely to prioritize,
- and how the communication is expected to function.

Importantly, these expectations are not fixed across all situations. Expectations for the same deliverable may evolve depending on the stage of the design process, the level of uncertainty, the maturity of the work, and the kinds of decisions audiences are prepared to make. For example:

- early-stage design reviews may prioritize exploration, assumptions, and tradeoff analysis,
- mid-stage prototype reviews may emphasize testing logic, iteration, and feasibility,
- while final design reports may prioritize justification, validation, implementation readiness, and risk mitigation.

As engineering situations evolve, communication expectations evolve with them. Because of this, effective engineering communication is not simply about "writing clearly." It is about designing deliverables that appropriately support engineering work within a particular situation.

This section focuses on how communication principles are applied within common engineering design deliverables. The discussions emphasize:

- supporting engineering decision-making,
- controlling cognitive load,
- making reasoning visible,
- communicating tradeoffs,
- structuring evidence appropriately,
- and helping audiences quickly understand what matters.

The goal is not to encourage formulaic communication. Different engineering situations require different communication strategies. Effective engineers adapt their communication based on:

- the audience and
- the genre.

With phrasing and details concerning factors such as,

- the stakes of the decision,
- the level of uncertainty,
- and the purpose of the deliverable.

Professional engineering communication is therefore not merely documentation. It is the intentional design of information to support engineering judgment, coordination, and decision-making.

WHY ENGINEERING USES DIFFERENT DELIVERABLES

GENRES PROVIDE COMMUNICATORS WITH DIRECTION

Engineering communication does not occur through a single universal format. Engineers communicate through many recurring deliverables and interaction types. These recurring forms of communication are called genres.

When audiences request a particular deliverable, they are usually not simply requesting "information." They are requesting information designed to help them perform a specific kind of work. For example:

- a standup meeting helps teams coordinate immediate work and identify blockers,
- a prototype review helps audiences evaluate feasibility and testing progress,
- a specification sheet helps engineers verify measurable requirements,
- a design presentation helps audiences quickly understand design direction and tradeoffs,
- and a final report helps preserve traceability, justification, and implementation rationale.

Genres therefore function as a kind of professional coordination infrastructure. They help engineering teams establish shared expectations about:

- what information is important,
- how much detail is appropriate,
- how information should be organized,
- what evidence is required,
- and what decisions or actions the communication is intended to support

Because of this, effective engineers do not simply ask: "What information should I include?" They also ask: "What kind of engineering work is this communication helping the audience perform?"

GENRES REQUIRE PURPOSEFUL STRUCTURING

Because genres support different forms of engineering work, they also shape how audiences expect information and evidence to be organized.

Some communication situations require audiences to quickly identify conclusions and determine what actions should be taken. Other situations require audiences to carefully evaluate assumptions, methods, tradeoffs, and uncertainty before accepting a recommendation or decision.

As a result, effective engineering communication is not only about what information is included, but also about how engineering reasoning is arranged for the audience. One of the most important communication design decisions engineers make is determining when and how claims should be introduced relative to supporting evidence.

Therefore, arrangement is not stylistic decoration; arrangement changes how engineering evidence becomes usable.

ARGUMENT STRUCTURES: DIRECT AND INDIRECT STYLE

In engineering, an argument is not a debate or an opinion. It is a defensible claim supported by evidence and reasoning that enables a decision. The arrangement of that argument is not a neutral or mechanical choice; it is a deliberate design decision shaped by **audience**, risk, uncertainty, and purpose. Effective technical communication means choosing when to introduce a claim based on the **audience**, **purpose**, and **risk of the decision being supported**.

There are two common and legitimate argument structures; neither is inherently better; each is effective when used in the appropriate context. Engineers are expected to adapt argument structure to context. Effective professional communication requires situationally chosen arrangements.

DIRECT STYLE: FRONT-LOADED CLAIM/ DECISION-ORIENTED REPORTS

Typical structure:
Claim → Conditions/Assumptions → Evidence → Implications

When this structure is effective:

- The reader needs to quickly assess relevance or impact.
- The decision being supported carries limited or bounded risk.
- The report supports analysis, testing, or validation.
- The audience is time-constrained (e.g., managers, clients, teams).

Why engineers use it; front-loading the claim allows readers to immediately understand:

- What conclusion the engineer reached.
- Whether the report applies to their needs.
- Where to focus their attention in the evidence.

This structure increases efficiency and reduces the risk that key conclusions are missed.

Common pitfalls:

- Making a claim that is too broad or insufficiently qualified.
- Failing to clearly state assumptions or constraints.
- Treating evidence as a formality rather than justification.

INDIRECT STYLE: EVIDENCE-LED/ DESIGN JUSTIFICATION REPORTS

Typical structure:
Context → Methods → Results → Interpreted Claim

When this structure is effective:

- The reader is technically expert and skeptical.
- The decision being supported carries elevated uncertainty, visibility, or risk.
- The report justifies a design choice among alternatives.
- Credibility depends on demonstrating process rigor.

Why engineers use it; in complex or uncertain design situations, readers may need to:

- Evaluate the validity of the approach.
- Examine tradeoffs and constraints.
- Assess results before accepting a conclusion.

Delaying the claim allows the engineer to build confidence before asking the reader to agree. **Even in evidence-led arguments, the final claim should be explicit, not left for the reader to guess.**

Common pitfalls:

- Burying the conclusion so deeply that its significance is unclear.
- Over-reporting results without interpretation.
- Assuming the reader will infer the claim without explicit guidance.

ARRANGEMENT IS DECIDED BY HOW READERS EVALUATE EVIDENCE, NOT HOW WRITERS THINK.

When deciding which structure to use, ask yourself the following questions:

Reader needs

- Does my reader need to decide quickly whether this report matters?
- Does my reader need to be convinced that my process justifies my conclusion?

Risk and consequences

- What is the cost of misunderstanding or premature agreement?
  - Higher risk generally favors delayed claims.

Genre simulation

- What genre does this document simulate?
  - Analysis reports and test summaries often differ from design justification reports.

MIXED STYLE

A design report is not one argument. It is a sequence of related decisions. Argument style should follow the decision burden of each section.

Each section exists because:

- Someone needs to decide something,
- Or someone needs to trust how a decision is being earned.

That means argument style can—and should—change as the reader's task changes. You should mix and alternate between styles in some instances:

1. **Use indirect argument when the reader must evaluate reasoning before accepting a claim.**
2. **Use direct argument when the reader needs clarity to act.**

SECTION-BY-SECTION DECISION PROCESS

You are not choosing one argument style for a design report.
You are choosing argument styles section-by-section based on what the reader needs to decide.

Remember:

- **Indirect ≠ chronological**
- **Direct ≠ unsupported**

Effective design reports often combine indirect argumentation in exploratory sections with direct argumentation in decision-oriented sections.

SECTIONS THAT *OFTEN* BENEFIT FROM <u>DIRECT</u> ARGUMENT

These are places where the reader needs clarity, orientation, or decision support:

- Executive summary
- Design requirements
- Selected concept justification
- Final recommendations
- Implementation plan
- Constraints and compliance checks

Here, delaying the claim increases cognitive load and frustrates the reader.

SECTIONS THAT *OFTEN* BENEFIT FROM <u>INDIRECT</u> ARGUMENT

These are places where the reader must trust the reasoning process before accepting the conclusion:

- Problem framing / background
- Design space exploration
- Concept generation and screening
- Modeling assumptions
- Trade study rationale
- Sensitivity analysis
- Risk analysis

In these sections, it is appropriate—even expected—to:

- Delay commitment
- Build logic through criteria and evidence
- Let conclusions emerge

Trying to force direct claims here often feels premature or unearned.

DIRECT AND INDIRECT STYLE ARRANGEMENT/ORGANIZATION

Most American writers are taught **direct argument style** first. This style is clear in its straightforwardness. You're likely familiar with the following writing structure from secondary school:

- Claim (Topic Sentence) → Evidence → Commentary → Evidence → Commentary → Take Away

You can find a thorough discussion of direct style in the Analytical Division Style Guide. The remainder of the discussion here will focus on comparing direct and indirect styles and avoiding indirect style pitfalls.

DIRECT ARGUMENT EXAMPLE

A belt-driven transmission is the most appropriate mechanism for the system because it meets client needs and maintains safety parameters. Compared to a gear train, the belt drive reduces transmitted vibration and allows for easier alignment tolerance while still meeting the required torque range. Preliminary calculations show that the selected belt profile can transmit up to 18 N·m with a safety factor of 2.1, whereas the comparable gear train introduces higher stiffness and requires tighter alignment control. For these reasons, a belt-driven transmission best satisfies the system's functional and integration constraints.

INDIRECT ARGUMENT EXAMPLE

Several transmission options were evaluated with respect to vibration sensitivity, alignment tolerance, and torque capacity. Belt-driven configurations exhibited lower transmitted vibration and greater tolerance for minor misalignment than gear-based alternatives, while still satisfying the required torque range. Preliminary sizing calculations indicate that the selected belt profile can transmit up to 18 N·m with a safety factor of 2.1. In contrast, gear-based configurations introduce higher stiffness and impose tighter alignment requirements, increasing sensitivity to assembly variation. Taken together, these considerations suggest that a belt-driven transmission offers a more robust solution for the current system constraints.

In some reports, recommendations emerge gradually through interpreted evidence rather than being stated up front. In these cases, topic sentences should guide the reader toward increasingly supported conclusions, even if final recommendations appear later in the report.

The **indirect paragraph** above works because:

What makes it indirect

- The first sentence frames the evaluation, not the decision.
- Tradeoffs are revealed through criteria, not declared.
- The recommendation emerges from comparison.

What keeps it professional and useful

- The paragraph still interprets, not lists.
- Constraints (vibration, alignment, torque) drive the reasoning.
- The conclusion points clearly toward a preferred design direction.
- The claim remains falsifiable (another option could outperform under different constraints).

The **indirect style** uses the same ingredients as direct, but changes when and how strongly the claim appears. The indirect version uses the same ingredients, but changes when and how strongly the claim appears.

- Interpretive Framing → Evidence → Commentary → Evidence → Commentary → Qualified Takeaway

COMMON PITFALL - CHRONOLOGICAL WRITING

Indirect arguments delay certainty, not responsibility.

Technical writers new to indirect style sometimes fall into the “chronology trap”; Chronological writing often feels safer because it cannot be wrong—but that is exactly why it is not useful for decision-making. Remember these distinctions:

- Indirect argument is interpretive.
- Chronological writing is procedural.

Indirect Argument	Chronological Writing
Organizes by reasoning and decision *criteria*	Organizes by time or steps
Interprets evidence	Reports activity
Moves the reader toward a conclusion	Moves the reader through events
Answers “What does this mean?”	Answers “What happened next?”

Indirect arguments delay conclusions, but they do not follow time. They follow logic. In indirect arguments, topic sentences still interpret evidence; they do not describe steps or sequence, for example:

- **Chronological** (not okay): “First, the belt drive was modeled. Next, the gear train was analyzed.”
- **Indirect** (okay): “Modeling results highlight clear differences in vibration sensitivity between belt- and gear-based transmissions.”

In indirect arguments, topic sentences should not announce final conclusions—but they must announce how the evidence should be understood/contextualized.

INDIRECT ARGUMENT EXAMPLE

Modeling results reveal that vibration response is more sensitive to alignment variation in the gear-based configuration than in the belt-driven alternative. While both systems satisfy torque requirements, the gear train’s higher stiffness amplifies vibration under realistic assembly tolerances. These findings suggest that vibration robustness, rather than torque capacity, is the dominant factor differentiating the two designs.

CHRONOLOGICAL EXAMPLE

The belt drive was modeled first using MATLAB. Then the gear train was modeled using the same parameters. After that, vibration response was analyzed for both systems. Finally, torque capacity was calculated.

FINAL THOUGHT

Students transform into professionals when they move from “showing work” to “justifying decisions.” Design reports are not a single argument but a sequence of decisions with varying levels of uncertainty and risk. In professional practice, engineers routinely use indirect argumentation to earn trust in exploratory sections (such as design space exploration, modeling, and trade studies) where readers must evaluate assumptions, methods, and tradeoffs before accepting conclusions. At the same time, engineers rely on direct argumentation in decision-oriented sections (such as executive summaries, selected design justification, and recommendations) where clarity and actionability are paramount.

COMMUNICATING ENGINEERING LOGIC

ALWAYS COMPLETE THE LOOP

Professional engineering communication must demonstrate how engineering evidence justifies engineering decisions.

Audiences are rarely satisfied by:

- isolated calculations,
- unexplained figures,
- disconnected testing results,
- or descriptions of completed work.

Instead, engineering audiences expect communication that clearly connects:

- design goals,
- requirements and specifications,
- evidence,
- interpretation,
- and resulting decisions or next steps.

Effective engineering communication therefore "completes the loop" between:

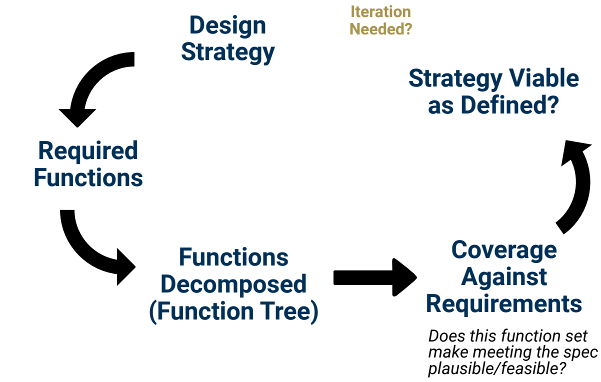
1. what the design is intended to accomplish,
2. what evidence was gathered,
3. how that evidence was interpreted,
4. and what conclusions or actions reasonably follow.

This reasoning structure appears repeatedly throughout engineering communication:

- in conceptual design,
- prototyping,
- validation,
- testing,
- trade studies,
- and recommendation sections.

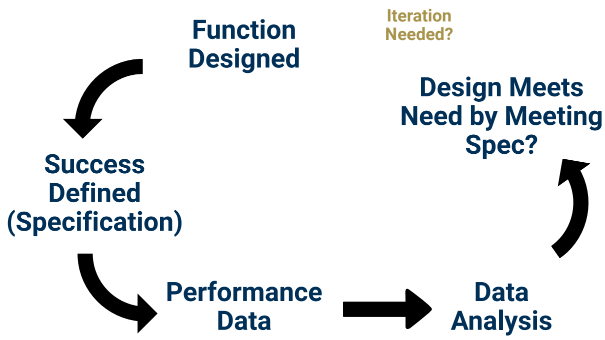
While the specific evidence may change across engineering situations, the underlying expectation remains consistent: engineering decisions must be justified through interpretable evidence connected to requirements, feasibility, or performance criteria.

Feasibility Logic for Conceptual Design



Topic Sentence → Strategy
Evidence → Function Tree
Commentary → Analysis / Interpretation
Takeaway → Decision / Next step

Prototyping Validation Logic



Topic Sentence → Function / Claim
Evidence → Data
Commentary → Analysis / Interpretation
Takeaway → Decision / Next step

EXPECTED LOGIC STRUCTURES

Topic sentences, evidence, commentary, and takeaways are not arbitrary writing rules; they are representations of an expected sequence in engineering logic that apply across most genres.

When evidence is presented without interpretation or connection to engineering goals, audiences are forced to reconstruct the reasoning process themselves, increasing cognitive load and reducing confidence in the work.

COMMUNICATING WITH VISUALS

Engineering visuals are not decorative; they are designed representations that help audiences assess and perform engineering work.

In professional engineering practice, visuals are often one of the **primary ways audiences inspect evidence**, **evaluate reasoning**, **understand systems**, **identify tradeoffs**, and make decisions. Because of this, engineers must make intentional decisions about:

- what kind of visual representation to use,
- what level of detail to include,
- what information to prioritize,
- what assumptions are visible,
- and how audiences are expected to use the visual.

Different visual types support different forms of engineering work. For example:

- **photographs** help audiences inspect real-world conditions, manufacturing variation, testing outcomes, wear, and failure,
- **CAD models** help audiences understand geometry, assemblies, dimensions, and design intent,
- **engineering drawings** support manufacturing and verification,
- **plots and graphs** help audiences identify trends, relationships, and comparisons,
- **diagrams** help audiences understand systems, workflows, and interactions,
- **FEA and simulations** help audiences evaluate predicted behavior under modeled conditions,
- and **tables** help audiences compare precise values and specifications efficiently.

Because different visuals support different kinds of interpretation, effective engineers select visuals based on:

- audience needs,
- genre (and evidence) expectations,
- uncertainty,
- precision requirements,
- decision risk,
- and the engineering purpose of the communication.

For example:

- a *standup meeting* may prioritize fast interpretability and simplified visuals,
- a *design review* may require detailed annotated CAD and tradeoff visualizations,
- a *prototype review* may prioritize photographs of testing conditions and observed failures,
- while a *design report* may require traceable figures, validated data displays, and manufacturing-ready drawings.

Engineers must design visuals that appropriately support audience understanding, trust, inspection, and decision-making.

Visuals are not decorations for engineering work. They are part of **how engineering reasoning becomes visible**. If your figure is doing its job, the communication becomes easier—because you're explaining a decision the figure already makes visible.

HOW A FIGURE BECOMES EVIDENCE

- **During design:** Positional accuracy vs. points earned was plotted to see where constraints intersected.
- **Decision moment:** The plot showed Option B met requirements with adequate margin; Option A did not.
- **In a report:** “The blue shaded region of Figure 5 demonstrates that Option B is within the required 10mm spherical target region.”

REPRESENTING ENGINEERING EVIDENCE: PICTURES VS. CAD & DRAWINGS

Choose forms of evidence representation based on audience needs and engineering purpose.

Pictures are effective for presenting real-life detail and variations from environmental impacts that the audience may need to reference or analyze closely. CAD models or drawings, on the other hand, are powerful for illustrating ideal cases and functional assumptions in a visually appealing and easier to comprehend way.

PICTURES

Real Images, Real Conditions:

Wear and Tear: when you need to show the impacts of continual use or points of failure.

Manufacturing Differences: when you need to present the manufactured or prototyped differences from the drafted design OR differences between iterations.

Applied Details and Testing:

Material Selection: when showing visual testing results between or major design differences due to different materials.

Dimension Fine Tuning: when system dimensions are adjusted from the theoretical model for better functionality due to environmental impacts

Examples of Appropriate Use of Pictures in Engineering Reports:

Failure Points: Highlighting a hairline breakage in a component and how it happens in a similar manner in the same moving component after replacement.

Iterations Over Time: Comparing improved versions of a supporting base in side-by-side images.

Prototyped Model: Presenting a complete manufactured prototype created from the theoretical design.

CAD & DRAWINGS

Clean Designs, Ideal Case:

Theoretical Design: when you need to polish present the team's design and its capabilities before spending notable time, material, and money.

Dimension, Fit, Tolerance: when you need to present precise numerical values and tolerances to be manufactured.

Functional Assumptions:

Movement and DoF: when you need to show different states or stages of functionality

Assembly and FEA: when you need to show how subsystems come together or theoretically analyze possible physical outcomes

Examples of Appropriate Use of CAD in Engineering Reports:

Design Selection: Comparing and contrasting alternative designs to a variety of audience groups.

Technical Analysis: Confirming how the components impact each other when assembled together by showing FEA models under possible load conditions

REPRESENTING ENGINEERING EVIDENCE: TABLES VS. CHARTS

Tables are effective for presenting detailed, precise, and varied data that the audience may need to reference or analyze closely. They are also essential for small datasets and for providing comprehensive data comparisons. Charts, on the other hand, are powerful for illustrating trends, patterns, and making data more visually appealing and easier to comprehend at a glance.

TABLES

Precise Data Representation:

Exact Values: when you need to present precise numerical values; allows reader to see specific numbers rather than general trends or patterns.

Complex Data:

Multiple Variables: when using data that has multiple variables or dimensions needing simultaneous presentation.

Mixed Data Types: when data includes different types of information (e.g., numerical values, text, dates), tables can accommodate this variety effectively.

Examples of Appropriate Use of Tables in Engineering Reports:

Material Properties: Listing the properties of different materials such as density, tensile strength, thermal conductivity, etc.

Specifications: Providing detailed technical specifications of components, parts, or systems.

Schedules and Timelines: Presenting project schedules, timelines, and milestones in a clear and organized manner.

Comparison of Alternatives: Comparing different design alternatives, costs, or performance metrics side by side.

CHARTS

Visualizing Trends and Patterns:

Demonstrate Change: when you need to present precise numerical value show how data changes over time or across different conditions.

Visualize Patterns: when you need to present precise numerical value highlight trends, correlations, and distributions.

Simplifying Complex Data:

Summarize: use to provide a visual summary of large datasets to make overall trends easier to grasp.

Emphasize: use to demonstrate the big picture rather than the details.

Examples of Appropriate Use of Charts in Engineering Reports:

Performance Over Time: Plotting performance metrics (e.g., stress-strain curves, temperature changes) over time or under varying conditions.

Comparative Analysis: Comparing the efficiency or output of different systems or processes.

Distribution Analysis: Showing the distribution of data points, such as histograms for frequency distributions or scatter plots for correlations.

DESIGN REPORTS

DESIGNING ENGINEERING REPORTS

Engineering reports are designed artifacts. Just as engineers design systems, products, experiments, or models to help users accomplish goals under constraints, engineers must also design reports that help audiences use technical information effectively.

A strong engineering report is not simply "well written." It is intentionally designed to support engineering work:

- understanding technical situations,
- evaluating evidence,
- making decisions,
- identifying risks,
- coordinating action,
- and documenting reasoning.

Because of this, writing a report is not separate from engineering thinking. Communication decisions are engineering decisions.

ENGINEERING REPORTS HAVE USERS

Engineering reports are used by people with different goals, expertise, responsibilities, and constraints. A *non-exhaustive* list includes:

A **client/sponsor** may want to understand:

- whether a recommendation is trustworthy,
- what action should be taken,
- and what risks or tradeoffs are involved.

A **technical reviewer** may want to inspect:

- assumptions,
- methods,
- calculations,
- uncertainties,
- or limitations.

A **manager** may want to quickly identify:

- project status,
- key findings,
- resource implications,
- or next steps.

A **teammate** may need the report to:

- continue work later,
- replicate a process,
- troubleshoot a system,
- or justify future decisions.

These audiences often interact with different sections of a report differently. Some may primarily read the executive summary and conclusions. Others may focus heavily on figures, methods, appendices, or results tables.

Because of this, engineers must think carefully about:

- who will use the report,
- what they need from it,
- how they will navigate it,
- and what information they need to act confidently in their respective roles.

ENGINEERING REPORTS HAVE CONSTRAINTS

Like all engineered products, reports must function within constraints.

Engineering reports operate within genre expectations:

- expected sections,
- recognizable sequencing,
- disciplinary conventions,
- standards for evidence,
- levels of formality,
- and audience expectations for technical credibility.

For example, readers often expect reports to include sections such as those listed in the following pages.

These conventions are not arbitrary rules. They exist because they help readers locate and interpret information efficiently. Ignoring genre expectations can increase cognitive load, reduce trust, and make information difficult to use—even when the underlying engineering work is strong.

At the same time, effective engineers understand that templates and conventions are tools, not rigid formulas. Communication decisions should support understanding and usability rather than mechanically following structure for its own sake.

A design report is an argument that your engineering decisions translate client needs into defensible specifications under real constraints. (This is traceability.)

DIFFERENT READERS USE THE SAME SECTION DIFFERENTLY

A design report is not read by one generic audience. Different readers may enter the same section with different responsibilities and different decisions to make. For example, a sponsor may read the Final Design section to decide whether the solution is worth continued support; a manufacturing engineer may read it to understand whether the design can be fabricated or assembled; a marketing reviewer may read it to understand how the product appears to users; and a future team may read it to determine what can be continued, modified, or improved.

Because of this, section content should not simply answer “What did we do?” It should help varied likely readers answer: “What do I need to understand, evaluate, decide, approve, fund, manufacture, regulate, or continue?”

Report user	Typical question they bring to the report
Sponsor / client	Is the solution credible, valuable, and worth continued support?
Manufacturing engineer	Can this be fabricated, assembled, replicated, maintained, or scaled?
IP / legal reviewer	Is the design novel, protectable, or legally risky?
Marketing / user-facing reviewer	How does the design compare to alternatives, serve users, and communicate value?
Investor / funder	Is the design viable enough to justify additional resources?
Future team	What decisions, evidence, limitations, and next steps should guide continued work?
Government / regulatory reviewer	Does the design satisfy safety, compliance, public-health, or environmental responsibilities?

In the following sections, you’ll notice a suggested argumentative style. The recommended style reflects the primary readers’ tasks in that section, not a hierarchy of correctness. Argument style should be chosen based on what the reader needs to do in that section.

Report movement	Common style tendency	Why
Context and problem framing	More indirect	Readers need to understand why the problem, constraints, and criteria matter before accepting claims.
Concept generation and selection	Indirect → direct	Readers need to see alternatives, tradeoffs, and decision logic before accepting the chosen direction.
Final design and implementation	More direct	Readers need a clear explanation of what the design is, how it works, and what decisions follow.
Risk and limitations	Indirect → direct	Risks should be evaluated transparently, but mitigations and responsibilities should be stated clearly.
Conclusions and future work	Direct	The report must translate evidence and uncertainty into justified next steps.

DESIGN REPORT SECTIONS EVOLVE WITH ENGINEERING COMPLEXITY

Genres are stable enough to create shared expectations, but flexible enough to adapt to project complexity, audience needs, and engineering scope. Engineering report sections are not arbitrary formatting conventions. Sections exist because audiences need to locate, interpret, evaluate, and use different kinds of engineering information efficiently. Engineering design reports are organized around the progressive decisions engineers and stakeholders must make as projects move from problem definition to implementation.

2110 Sections	**Capstone Sections**
Abstract	Executive Summary
Introduction & Background	Introduction & Background
Problem Understanding (with Product Functions Subsection)	Existing Products, Prior Art, & Applicable Patents
	Codes and Standards
	Customer Requirements & Engineering Specifications
N/A	Market Research / Potential Impact
Conceptual Design	Design Concept Ideation
	Concept Selection & Justification
N/A	Industrial Design
Fabrication, Testing, and Validation Plan	Detailed Technical Analyses, Experimentation, and Performance Prediction
	Mockup & Prototyping
Design Overview	Final Design
Final Fabrication (with Performance Results)	Manufacturing
N/A	Societal, Environmental, & Sustainability Considerations
DFMEA (homework)	Risk Assessment, Safety, and Liability
N/A	Patent Claims & Considerations
Conclusions & Future Work	Conclusions & Future Work

As projects become more technically complex, higher risk, more interdisciplinary, or closer to implementation, communication expectations often become more specialized and detailed. Because of this, sections that appear broad or combined in one engineering situation may become expanded into multiple focused sections in another because of new rhetorical burdens created by engineering maturity.

Effective engineers adapt organization expectations based on:

- project scope,
- technical complexity,
- audience expectations,
- engineering risk,
- implementation needs,
- and the kinds of **decisions readers must make.**

The comparison table illustrates how the sophomore-level ME 2110 design report uses broader, more generalized sections appropriate for a smaller-scope design challenge, while Capstone reports often require more specialized sections to support larger-scale engineering evaluation, implementation planning, and professional review.

HOW TO USE THE SECTION BREAKDOWNS

This guide explains how common engineering design report sections function as part of a larger design argument. It is meant to help you understand what different sections are usually trying to accomplish, what readers need from them, and how evidence should be organized to support engineering decision-making.

This guide is not a universal template. Different courses, instructors, projects, and clients may require different sections, names, levels of detail, or formatting expectations. Always follow the specific requirements for your course and project first.

However, even when section names differ, many design reports perform similar communicative work. For example, one course may combine design ideation and concept selection into a broader "Conceptual Design" section, while another may separate those tasks into more specialized sections. These differences usually reflect changes in project scope, technical complexity, audience expectations, and implementation maturity.

Use this guide to decide:

- what kind of engineering question each section should answer,
- what evidence readers need in that section,
- how directly or indirectly the section should make its claim,
- what information belongs in the main body versus an appendix,
- and how your section should help readers make decisions about the design.

Some guidance in this resource will apply more strongly to earlier-stage reports, such as ME 2110. Other guidance will apply more strongly to later-stage reports, such as Capstone. **Your job is not to include everything listed on every page. Your job is to determine which guidance applies to your project's current level of design maturity, evidence, and course requirements.**

A strong design report should not simply document everything the team did in the order it happened (i.e., it's **not** a chronology). Instead, it should organize engineering work around the claims, evidence, decisions, and implications readers need to evaluate the design. In other words: Do not use this guide to fill sections mechanically. Use it to design a report that helps readers understand, evaluate, and act on your engineering work.

BEFORE WRITING EACH SECTION, ASK

- What decision or judgment does this section help the reader make?
- What claim does this section need to support?
- What evidence will make that claim trustworthy?
- What information would distract from that purpose?
- What belongs in the main body, and what belongs in an appendix?
- What course-specific requirements must this section satisfy?

If a section does not help readers understand the design, evaluate evidence, trace decisions, or act responsibly, it probably needs to be revised, moved, shortened, or placed in an appendix.

A final report should stand on its own. Readers should not need earlier reports, presentations, team memory, or instructor feedback to understand the project's problem, decisions, evidence, and conclusions.

When courses require sprint-based testing data, **use the main body to interpret the most important trends, changes, or design implications across sprints**. Place full sprint data tables in the appendix when appropriate, but explain in the report how the data affected design decisions, validation claims, or future refinement.

REPORT SECTIONS

ABSTRACT

Key Audiences
Device Client,
Engineering Superiors

Primary User Task
- Determine whether the project direction, reasoning, and outcomes warrant deeper review.

Common Design Tools
N/A

Argument Tendency
More Indirect / Process-Oriented

Typical Arrangement
Engineering Situation / Problem → Design Approach → Key Evidence or Findings → Overall Outcome or Implication

Abstracts often compress and foreground the engineering situation, scope, and reasoning trajectory so readers can quickly determine the relevance, feasibility, and overall outcome of the engineering work before reading the full report.

- Briefly explain the engineering problem or design challenge being addressed.
- Establish why the problem matters to the client, user, or engineering situation.
- Summarize the team's overall design strategy or approach.
- Identify the primary design concept, selected solution direction, or major engineering approach.
- Highlight the most important engineering requirements, constraints, or priorities that shaped the design.
- Summarize the key evidence used to justify the design direction (analysis, modeling, prototyping, testing, trade studies, etc.).
- Present the most important performance outcomes, feasibility findings, or validation results.
- Clearly state the main engineering conclusion, recommendation, or takeaway.
- Indicate the project's current status, next steps, or future work if the design is still iterative or incomplete.
- Allow a reader to quickly understand what problem was addressed, what design direction was pursued, why that direction was selected, whether the approach appears feasible, and what engineering decisions or actions reasonably follow.

Topic Sentence Example:
- "Safety and efficiency limitations in current roadside debris removal practices motivated the development and evaluation of a portable collection device."

Takeaway Sentence Example:
- "These findings suggest that the proposed design provides a practical balance between manufacturability, usability, and functional performance."

REPORT SECTIONS

EXECUTIVE SUMMARY

Key Audiences
Sponsors, Mfg. Engineers, IP lawyers, Marketing, Investors, Future Teams, Governmental Entities

Primary User Tasks
- Understand the project's engineering direction, major outcomes, risks, and recommended actions.
- Determine whether the proposed design appears feasible, credible, and ready for implementation, funding, approval, or continued development.

Common Design Tools
N/A

Argument Tendency
More Direct

Typical Arrangement
Recommendation / Design Direction → Key Justification → Evidence → Implications / Next Steps

Executive summaries often foreground the selected design direction, major findings, recommendations, or implementation implications early.
- Clearly identify the engineering problem or project objective.
- Briefly establish why the problem matters to the client, organization, users, or broader engineering situation.
- Quickly present the selected design direction, recommendation, or major engineering outcome.
- Summarize the most important evidence supporting the design decision:
    - testing results,
    - analysis,
    - trade studies,
    - feasibility findings,
    - validation data,
    - or implementation considerations.
- Highlight major engineering constraints, tradeoffs, or risks that influenced decision-making.
- Emphasize the most important performance outcomes or validation results.
- Identify implementation readiness, manufacturing considerations, cost implications, or deployment concerns when relevant.
- Clearly communicate what decision, approval, funding, action, or next step is being recommended.

Because executive summaries are highly compressed and decision-oriented, engineers must carefully prioritize information that supports rapid interpretation, trust, and actionability without overwhelming readers with unnecessary detail.

Topic Sentence Example:
- "A modular debris collection system is recommended for roadside maintenance operations because testing and feasibility analysis indicate improved worker safety, reduced cleanup time, and strong manufacturability potential."

Takeaway Sentence Example:
- "Although additional testing is still required, current results suggest the proposed system is a viable solution within the project's operational and manufacturing constraints."

REPORT SECTIONS

INTRODUCTION & BACKGROUND

Key Audiences
Device Client,
Engineering Superiors,
IP lawyers, Marketing,
Investors,
Future Teams

Primary User Tasks

- Understand the engineering situation, project context, and significance of the problem.
- Understand why the project exists, what constraints shape it, and what engineering work the report will address.
- Establish sufficient context to interpret later design decisions, tradeoffs, and recommendations.

Common Design Tools
Function Tree (2110)

Argument Tendency
Indirect

Typical Arrangement
Engineering Situation → Problem Context → Constraints / Stakeholder Needs → Project Direction

- Clearly explain the engineering problem, opportunity, or need being addressed.
- Establish why the problem matters to users, clients, organizations, or broader engineering contexts.
- Introduce important operational, technical, environmental, social, economic, or safety constraints and terminology as needed.
- Introduce relevant prior art, existing products, standards, or regulatory requirements/pathways (though details might be covered in later sections as appropriate/needed).
- Introduce key stakeholder or user needs that shape the project direction.
- Establish the broader engineering situation that motivates the project.

Because this section establishes the interpretive foundation for the rest of the report, engineers should prioritize clarity, relevance, and contextual usefulness over exhaustive detail. Information should help audiences understand why later engineering decisions are reasonable and necessary.

Help readers understand:

- what problem exists,
- why it matters,
- what constraints shape possible solutions,
- and what engineering challenges the project must address.

Prepare audiences to interpret later:

- design choices,
- tradeoffs,
- specifications,
- feasibility discussions,
- and recommendations.

Topic Sentence Example:

- “Roadside debris removal creates a recurring safety and efficiency problem because workers must operate near traffic while managing unpredictable debris conditions.”

Takeaway Sentence Example:

- “This context establishes why the project must address both worker exposure and field efficiency rather than treating debris collection as a simple capacity problem.”

REPORT SECTIONS

PROBLEM UNDERSTANDING (with Product Functions Subsection)

Key Audiences
Device Client,
Engineering Superiors

Primary User Tasks

- Understand the engineering situation, stakeholder needs, constraints, and design priorities that define the problem space.
- Evaluate whether the team has appropriately interpreted the problem (what the design must accomplish) before generating or selecting solutions.
- Understand what criteria (including limitations) will later be used to justify design decisions.

Common Design Tools
HoQ, Specification Sheet, Function Tree

Argument Tendency
Indirect (Context-Building)

2110 Sections	Capstone Sections
Problem Understanding	Existing Products / Prior Art
	Codes & Standards
	Customer Requirements & Engineering Specifications

Typical Arrangement
Engineering Situation → Stakeholder Needs → Constraints / Requirements → Design Priorities / Problem Framing

This section establishes how the team interprets the engineering challenge and defines what successful design performance should accomplish. Its justifies the team's understanding and what criteria should govern later design decisions.

- Clearly define the engineering problem or opportunity **(problem statement)**.
- Establish why the problem matters to users, clients, or broader engineering contexts.
- Identify important user or stakeholder needs.
- Introduce major engineering constraints such as safety, manufacturability, usability, cost, operational limitations (rules), or deployment requirements (rules).
- Explain how stakeholder priorities influence **design strategy**.

Topic Sentence Example:

- "Current roadside debris removal practices create safety and operational challenges that require a system to improve worker protection while maintaining practical field usability."

Takeaway Sentence Example:

- "Customer priorities, environmental constraints, and feasibility considerations require a design strategy that prioritizes portability and operational safety."

PRODUCT FUNCTIONS SUBSECTION
Typical Arrangement
Required System Behaviors → Functional Decomposition → Operational Priorities & Constraints

This subsection defines the product functions or system behaviors the design must accomplish ***independent*** of any specific implementation approach.

- Use functional decomposition tools to clarify how stakeholder needs translate into required engineering actions, subsystem responsibilities, and operational goals.
- Establish measurable engineering requirements or success criteria when appropriate; use design tools as evidence.

Topic Sentence Example

- "The central design problem is not only collecting debris, but enabling operators to collect it safely, quickly, and consistently under roadside operating constraints."

Takeaway Sentence Example

- "Defining the problem this way makes portability, operator protection, and deployment speed the governing criteria for concept generation and evaluation."

REPORT SECTIONS

EXISTING PRODUCTS/ PRIOR ART

Key Audiences
Sponsors,P lawyers,
Marketing,
Investors

Primary User Tasks

- Understand the current state of existing solutions, technologies, and engineering approaches relevant to the project for later comparison.
- Evaluate whether the team understands the broader design space before pursuing a proposed solution.
- Identify infringement liabilities, gaps, limitations, opportunities, and differentiators that justify the project's design direction.
- Determine possible novelty.

Common Design Tools
N/A

Argument Tendency
Indirect

Typical Arrangement
Existing Solutions → Observed Strengths & Limitations → Engineering Gaps / Opportunities → Design Direction Implications

This section establishes how the project relates to the broader engineering and market landscape: what solutions already exist, what approaches have already been attempted, what constraints shape the current design space, and why additional engineering work is still necessary.

- Discuss relevant patents.
- Identify relevant existing products, systems, technologies, or engineering approaches.
- Analyze important strengths, limitations, and tradeoffs within existing approaches.
- Compare competing approaches when appropriate.
- Identify engineering gaps in the market, unmet needs, or opportunities for improvement.
- Establish how prior art influences:
    - freedom to operate,
    - project constraints,
    - feasibility considerations,
    - stakeholder expectations,
    - or design priorities.

Topic Sentence Example:

- "Existing roadside collection systems tend to solve the capacity problem more effectively than the portability problem, leaving a gap for compact systems designed for constrained maintenance environments."

Takeaway Sentence Example:

- "This gap positions portability and rapid deployment as technical differentiators the proposed design must preserve during later development."

REPORT SECTIONS

CODES & STANDARDS

Key Audiences
Marketing,
Governmental Entities

Primary User Tasks
- Understand what external technical, safety, legal, manufacturing, or industry constraints govern the project.
- Evaluate whether the proposed design direction appropriately accounts for compliance, health and safety, and professional engineering expectations.
- Understand how standards influence engineering requirements, feasibility, risk, and validation.
- Evaluate the Interoperability with other devices, systems. etc.

Common Design Tools
FMEA

Argument Tendency
Indirect to Direct

Typical Arrangement
Relevant Standards / Constraints → Engineering Implications → Design Requirements → Compliance Strategy

This section establishes the external requirements and professional constraints that shape the engineering design space.
- Identify relevant standards and regulatory requirements (see next page).
- Explain why specific standards apply to the project.
- Clarify how standards influence:
  - engineering requirements,
  - material selection,
  - manufacturability,
  - usability,
  - testing procedures,
  - tolerances,
  - safety considerations,
  - or operational constraints.
- Establish how compliance requirements shape the feasible design space. *(Move to direct style.)*
- Identify situations where standards create important engineering tradeoffs or limitations.
- Explain how the team intends to evaluate or validate compliance.

Help readers understand:
- what constraints are externally imposed,
- how those constraints influence engineering decisions,
- and how the design strategy remains feasible within those requirements.

Topic Sentence Example:
- “Compliance with OSHA safety requirements and roadway visibility standards significantly constrains the deployment and operational design of the proposed debris collection system.”

Takeaway Sentence Example:
- “These compliance requirements establish the need for waterproof housing, low-voltage electrical systems, and repeatable validation testing to ensure safe long-term wearable device operation.”

REPORT SECTIONS

CODES & STANDARDS CONTINUED

Identifying and Understanding Standards

A code is often legally adopted by a government or authority. A standard is often a consensus technical document, but it can become legally required if referenced by a regulation, contract, or adopted code.

Search by engineering function, not just by product name

Bad search:
- Robot arm code

Better search:
- collaborative robot safety standard ISO 10218
- steel tension test ASTM E8
- engineering drawing GD&T ASME Y14.5
- electrical enclosure safety NFPA 70 NEC

You are designing…	**Look for…**	**Common sources**
Mechanical parts, pressure vessels, piping, drawings	Mechanical/design standards	ASME, ASTM, ISO, ANSI
Electrical/electronics systems	Electrical/electronics standards	IEEE, IEC, NFPA/NEC
Buildings, labs, fire safety, accessibility	Building/fire codes	ICC, NFPA, local jurisdiction
Materials and testing	Material/test standards	ASTM, ISO, SAE
Professional conduct	Ethics codes	NSPE or relevant professional society

System element	**Risk/failure mode**	**Relevant code/standard**	**Why applicable**	**Evidence (in “How Validated” section in Spec sheet)**
Battery pack	Fire/thermal runaway	UL/NFPA/IEC candidate	Energy storage safety	Test report/design calc
Frame	Structural failure	ASTM/ASME/ISO candidate	Material/load design	FEA + physical test
User interface	Misuse	ANSI/ISO candidate	Human factors/safety	User test

REPORT SECTIONS

CUSTOMER REQUIREMENTS & ENGINEERING SPECIFICATIONS

Key Audiences
Mfg. Engineers,
Marketing,
Future Teams

Primary User Tasks
- Understand what the design must accomplish and *how success will be measured*.
- Evaluate if relevant stakeholder needs have been appropriately translated into *measurable engineering criteria*.
- Understand what requirements and specifications will later justify features, tolerances, concept selection, testing, validation, and recommendations.
- Evaluate new needs with past specifications.

Common Design Tools
(HoQ), Engineering Specifications Sheets, Function Trees

Argument Tendency
Indirect to Direct

Typical Arrangement
Stakeholder Needs → Engineering Requirements → Measurable Specifications → Design Priorities & Tradeoffs

This section establishes how stakeholder or customer needs are translated into measurable engineering expectations. Engineers must interpret these needs and transform them into measurable specifications, performance targets, testing criteria, operational constraints, and validation requirements.
- Identify important stakeholder or customer needs.
- Explain how those needs influence engineering priorities.
- Translate qualitative expectations into measurable engineering criteria.
- Establish target values, tolerances, operational thresholds, or performance requirements.
- Explain how specifications were informed by standards, benchmarking, testing, prior products, stakeholder input, or operational constraints.
- Clarify which requirements are highest priority and why. *(Move to direct style.)*
- Identify situations where requirements create important engineering tradeoffs.
- Establish how requirements will later support concept evaluation, testing, validation, and final recommendations.

Help readers understand:
- what successful performance means,
- what constraints shape the design space,
- and what criteria will later justify engineering decisions.

Topic Sentence Example:
- “Customer feedback and operational constraints established reliability, battery life, and ease of maintenance as the primary engineering priorities for the wearable monitoring device.”

Takeaway Sentence Example:
- “Because portability and setup efficiency emerged as dominant stakeholder priorities, future concepts will be evaluated according to their ability to balance lightweight construction, deployment stability, and manufacturability.”

REPORT SECTIONS

MARKET RESEARCH / POTENTIAL IMPACT

Key Audiences
Sponsor, Marketing, Investor

Primary User Tasks
- Understand the broader relevance, applicability, and potential value of the proposed engineering work.
- Evaluate whether the project addresses a meaningful need, opportunity, or market gap that justifies funding.
- Understand how the proposed design may create operational, economic, social, environmental, or user-centered impact.

Common Design Tools
N/A

Argument Tendency
Direct

Typical Arrangement
Existing Need / Opportunity → Market or User Analysis → Gaps / Limitations → Potential Impact & Design Opportunity

This section establishes why the project matters beyond the immediate technical design challenge by demonstrating that a meaningful need or opportunity exists, that the proposed work addresses a real problem, and that the design may create value for users, organizations, industries, or communities.
- Describe market research plans such as customer surveys, focus groups, gathering market information from studies, the internet, experts, etc.
- Summarize important trends, unmet needs, or limitations within existing solutions or workflows.
- Identify how current products may fail to sufficiently address customer requirements (e.g., usability, safety, affordability, etc.).
- Identify the relevant market (sizing), user group (demographics), go-to-market strategy, number of potential procedures/uses per year (with references),
- Information on and comparison with current competitive products/procedures, target market sales price, with a brief justification.
- Discuss operational environment or stakeholder context.
- Establish why the project may provide meaningful engineering, organizational, or societal value.
- Discuss potential:
    - economic impact,
    - user impact,
    - workflow improvements,
    - safety improvements,
    - sustainability considerations,
    - or implementation opportunities.
- Clarify what differentiates the proposed design direction from existing alternatives.

Topic Sentence Example:
- “Maintenance agencies have a practical incentive to adopt debris collection tools that reduce worker exposure without requiring major changes to staffing, training, or vehicle operations.”

Takeaway Sentence Example:
- “The design’s potential value therefore depends not only on technical performance, but on whether it can be implemented within existing maintenance workflows.”

REPORT SECTIONS

CONCEPTUAL DESIGN

Key Audiences
Device Client, Engineering Superiors

Primary User Tasks
- Understand the range of concepts explored during early-stage design development.
- Evaluate how the team generated, compared, refined, and selected concepts.
- Understand why the proposed conceptual direction appears most appropriate given the project's requirements, constraints, and priorities.

Common Design Tools
HoQ, Function Trees, Morphological Charts, Sketches / CAD Concepts, Evaluation Matrices

Argument Tendency
Indirect (Derived from Deliberation)

2110 Sections	Capstone Sections
Conceptual Design	Design Ideation
	Concept Selection & Justification

Typical Arrangement
Design Goals & Constraints → Concept Generation → Concept Comparison → Selected Design Direction & Justification

This section establishes how the team explored possible solutions and **justified** an initial design direction. This section synthesizes design ideation, concept exploration, feasibility discussion, and concept selection justification together to demonstrate how the team moved from problem understanding toward an initial design strategy.

- Explain how the team generated or explored multiple design concepts.
- Identify important design goals, constraints, or stakeholder priorities guiding concept development.
- Use design tools to visualize:
  - functionality,
  - subsystem relationships,
  - alternative approaches,
  - or concept combinations.
- Compare concepts using:
  - evaluation matrices,
  - trade studies,
  - feasibility analysis,
  - benchmarking,
  - or engineering reasoning.
- Identify important tradeoffs influencing concept selection.
- Explain why certain concepts were refined, combined, deprioritized, or eliminated.

Topic Sentence Example:
- "Conceptual design translated the project's functional requirements into alternative system architectures for collecting, containing, and deploying the device in roadside conditions."

Takeaway Sentence Example:
- "This early design work narrowed the project toward architectures that could satisfy collection performance without making deployment or maintenance impractical."

REPORT SECTIONS

DESIGN CONCEPT IDEATION

Key Audiences
Marketing, Future Team

Primary User Tasks
- Understand how the team explored the design space before selecting a direction.
- Evaluate whether concept generation (including functions) appropriately responded to stakeholder needs, engineering specifications, and project constraints.
- Understand the range of possible approaches considered during early-stage design development for possible future augmentation.

Common Design Tools
Function Trees, Morphological Charts, Brainstorming Documentation, Sketches / CAD Concepts, HoQ, Subsystem Decomposition

Argument Tendency
Indirect (Derived from Deliberation)

Typical Arrangement
Design Goals & Constraints → Design Space Exploration → Concept Generation → Preliminary Evaluation & Emerging Design Directions

This section establishes how the team systemically explored possible approaches before committing to a final conceptual direction.
- Explain what was done to explore the design space, both strategically and generatively.
- Specifically communicate the value of each discussed embodiment relative to the goals of the identified design strategy.
- Identify the major stakeholder needs, engineering specifications, operational constraints, or functional requirements that guided ideation.
- Use design tools to visualize:
  - subsystem relationships,
  - functional decomposition,
  - alternative mechanisms,
  - architecture variations,
  - or concept combinations.
- Demonstrate exploration of multiple possible approaches rather than early fixation on a single solution.
- Explain how constraints influenced feasibility, manufacturability, deployment, usability, safety, scalability, or maintenance considerations.
- Identify promising conceptual directions and important emerging tradeoffs.

Help readers understand:
- how the team approached the design space,
- what alternatives were considered,
- what constraints shaped ideation,
- and what engineering opportunities or limitations began to emerge.

Topic Sentence Example:
- “Ideation deliberately expanded the design space by generating multiple collection, containment, and deployment approaches before the team committed to a preferred architecture.”

Takeaway Sentence Example:
- “Because high-capacity approaches repeatedly increased deployment complexity, ideation shifted attention toward simpler modular architectures with stronger field-use potential.”

REPORT SECTIONS

CONCEPT SELECTION & JUSTIFICATION

Key Audiences
Sponsor/Clients, Future Team

Primary User Tasks
- Understand why the selected concept was chosen over competing alternatives.
- Evaluate whether the concept selection process appropriately balanced stakeholder needs, engineering specifications, feasibility considerations, and project constraints.
- Understand the engineering reasoning and evidence supporting the proposed design direction.

Common Design Tools
Function Trees, Morphological Charts, Sketches / CAD Concepts, HoQ, Concept Evaluation Matrices, Pugh Matrices

Argument Tendency
Indirect (Evidence Centered)

Typical Arrangement
Evaluation Criteria & Constraints → Concept Comparison → Tradeoff Analysis → Selected Concept & Justification

This section establishes how the team moved from exploratory ideation toward a defensible engineering decision by using evaluation, comparison, tradeoff interpretation, and decision justification.
- Identify the evaluation criteria used to compare concepts.
- Explain how stakeholder priorities, engineering specifications, and operational constraints shaped concept evaluation.
- Compare competing concepts using:
  - evaluation matrices,
  - feasibility analysis,
  - benchmarking,
  - modeling,
  - or testing evidence.
- Clearly identify important tradeoffs between concepts.
- Explain why certain concepts were refined, combined, deprioritized, or eliminated.
- Justify the selected concept using evidence connected relevant considerations such as feasibility, manufacturability, safety, scalability, etc.

Help readers understand:
- why the selected concept appears strongest (criteria used),
- what tradeoffs were evaluated and accepted,
- what limitations remain,
- and how the concept best satisfies the project goals and constraints.

Topic Sentence Example:
- “Subsequent prototyping and feasibility evaluations confirmed that simplified mechanical architectures offered stronger long-term reliability, manufacturability, and maintenance performance than more complex automated alternatives.”

Takeaway Sentence Example:
- “Because simplified mechanical architectures consistently provided the strongest balance between reliability, manufacturability, maintenance accessibility, and deployment efficiency, continued development will focus on modular subsystem refinement and validation.”

REPORT SECTIONS

INDUSTRIAL DESIGN

Key Audiences
Sponsor/Clients, Mfg. Engineers, Marketing

Primary User Tasks

- Understand how the design's physical form, user interaction, aesthetics, ergonomics, and usability support the project's engineering goals.
- Evaluate if the product's appearance, interface, and user experience respond to stakeholder needs, operational constraints, and implementation environments.
- Understand how industrial design decisions influence usability, manufacturability, accessibility, safety, maintenance, branding, or user adoption.

Common Design Tools
Industrial Design Sketches, CAD Renderings, User Personas, User Journey Mapping

Argument Tendency
Indirect

Typical Arrangement
User & Operational Needs → Form & Interaction Goals → Industrial Design Decisions → Usability & Implementation Implications

This section establishes how the product's physical form and user interaction strategy support the broader engineering goals of the project by considering stakeholder needs, operational environments, user interaction constraints, manufacturing limitations, and implementation goals.

- Explain the intended user experience and operational interaction goals.
- Identify important ergonomic, accessibility, usability, or deployment considerations.
- Describe how industrial design decisions support: safety, visibility, maintenance, portability, comfort, manufacturability, or operational efficiency.
- Use visual representations to communicate: product form, interface layout, user interaction, component accessibility, or deployment configuration.
- Explain how aesthetics, form factors, or interaction strategies influence user trust, clarity, adoption, or workflow integration.
- Identify tradeoffs between appearance, manufacturability, durability, maintenance accessibility, or operational constraints.

Help readers understand:

- why the product is designed to look and function the way it does,
- how users are expected to interact with it,
- and how industrial design decisions support broader engineering goals.

Topic Sentence Example:

- "Industrial design development focused on improving operator visibility, ergonomic accessibility, and deployment clarity while maintaining manufacturable subsystem integration."

Takeaway Sentence Example:

- "These industrial design refinements support a manufacturable and user-centered product architecture in which enclosure geometry, interface visibility, and subsystem accessibility are prioritized to improve long-term usability and maintenance performance."

REPORT SECTIONS

FABRICATION, TESTING, AND VALIDATION PLAN

Key Audiences
Device Client,
Engineering Superiors

Primary User Tasks
- Understand how the team intends to evaluate whether the design works.
- Evaluate what evidence demonstrates feasibility or performance.
- Understand whether the proposed fabrication and validation strategy supports trustworthy engineering conclusions.

Common Design Tools
Gantt Chart,
Figures of Fabrication

Argument Tendency
Indirect → Direct

2110 Sections	Capstone Sections
Fabrication, Testing, and Validation Plan	Detailed Technical Analyses, Experimentation, and Performance Prediction
	Mockup & Prototyping

Typical Arrangement
Engineering Requirements & Risks → Fabrication Strategy → Testing Methods & Metrics → Validation Criteria → Performance Evaluation Plan

This section establishes how the team intends to evaluate if the proposed design satisfies the project's engineering requirements, operational constraints, and stakeholder needs. It must explain why specific testing strategies, validation methods, and evaluation criteria appropriately support engineering decision-making. Identify the major engineering requirements, risks, uncertainties, or performance concerns that motivate testing and validation efforts.

- Describe the fabrication approach and explain how fabrication decisions support feasibility, manufacturability, subsystem integration, testing access, iteration, and deployment goals.
- Explain what prototypes, mockups, subsystems, or experimental setups were fabricated and why.
- Describe the testing procedures, evaluation methods, or experimental approaches that will be used to assess system performance.
- Identify and justify the metrics, specifications, operational thresholds, or success criteria that testing will evaluate.
- Clarify testing scope: how it connects to earlier stakeholder needs, engineering specifications, design priorities, or concept selection decisions.
- Explain how validation evidence supports design refinement, feasibility conclusions, subsystem modifications, or final recommendations.
- Identify important testing limitations, assumptions, uncertainties, or risks when relevant.

Although fabrication, testing, and validation processes are iterative and nonlinear, communication must prioritize clarity, organization, and **decision traceability**. Avoid simply documenting events chronologically, and organize information around meaningful engineering questions, evaluation criteria, major findings, and resulting design decisions.

Topic Sentence Example:
- "Fabrication and validation planning focused on developing a modular prototype and testing strategy capable of evaluating deployment stability, collection efficiency, and operator usability under representative field conditions."

Takeaway Sentence Example:
- "Validation testing will evaluate whether the fabricated prototype satisfies the project's deployment stability, operator safety, and usability requirements with sufficient reliability to justify continued refinement and implementation."

REPORT SECTIONS

DETAILED TECHNICAL ANALYSES, EXPERIMENTATION, AND PERFORMANCE PREDICTION

Key Audiences
Sponsor/Clients, Future Teams

Primary User Tasks

- Evaluate design's (team's) technical credibility.
- Understand whether the proposed design appears technically feasible.
- Evaluate what evidence supports the project's engineering claims.
- Understand how performance was evaluated and what uncertainties or risks remain.
- Evaluate whether the results justify continued development, implementation, or refinement.

Common Design Tools
CAD Simulations

Argument Tendency
More Direct (Makes Case for Evidence Interpretation)

Typical Arrangement
Engineering Requirements & Risks → Analytical / Experimental Methods → Key Findings & Performance Evidence → Interpretation & Design Implications

This section establishes the technical feasibility and predicted performance of the proposed design by using engineering analysis, experimentation, modeling, simulation, and evidence-based evaluation to substantiate that the design can reasonably satisfy the project's requirements and operational constraints.

- Clearly identify the engineering questions, uncertainties, risks, or performance concerns motivating the analyses or experiments.
- Explain what analyses, simulations, calculations, models, experiments, or evaluation methods were performed and why they were appropriate for the project.
- Use evidence to evaluate functionality, performance, feasibility, subsystem behavior, safety, manufacturability, durability, efficiency, or operational reliability.
- Use figures, tables, graphs, simulations, calculations, and experimental results as evidence to support engineering interpretation rather than simply displaying technical output.
- Explain how the results informed design refinement and modifications, material selection, tradeoff evaluation, risk reduction, or implementation decisions.
- Identify important assumptions, limitations, uncertainties, sensitivities, or testing constraints when relevant.
- Clarify whether results validate performance expectations, reveal unresolved concerns, identify failure risks, or motivate additional refinement/testing.

While technical analyses and experimentation are iterative and highly complex, communication should prioritize interpretability and decision usefulness. Organize analyses around meaningful engineering questions, performance concerns, and design implications rather than presenting information chronologically.

Topic Sentence Example:

- "Finite element analysis, subsystem testing, and performance modeling were conducted to evaluate whether the proposed collection system could satisfy the project's structural durability, deployment stability, and operational efficiency requirements under representative field conditions."

Takeaway Sentence Example:

- "Results suggest the proposed design can satisfy the project's primary structural, operational, and deployment requirements while identifying subsystem vibration and long-term durability as areas requiring additional refinement."

REPORT SECTIONS

MOCKUP & PROTOTYPING

Key Audiences
Sponsor/Clients, Investor, Future Teams

Primary User Tasks
- Understand what engineering uncertainties motivated prototyping.
- Evaluate what was learned from iterative testing and refinement.
- Understand how mockups and prototypes were used to evaluate feasibility and reduce risk.
- Evaluate how prototype evidence informed subsequent design decisions.

Common Design Tools
Mockups, CAD Models & Renderings

Argument Tendency
Indirect → Direct (Evidence-Guided Refinement)

Typical Arrangement
Engineering Uncertainties & Risks → Prototype Purpose → Prototype Evaluation & Findings → Design Implications & Refinement

This section establishes how mockups and prototypes were used to investigate engineering uncertainties, evaluate design feasibility, reduce implementation risks, and inform subsequent design decisions.
- Clearly identify the engineering questions, uncertainties, assumptions, or risks motivating prototype development.
- Explain the purpose of each mockup or prototype and what engineering behaviors, subsystems, interactions, or constraints it was intended to evaluate.
- Distinguish between different prototype goals when appropriate, such as evaluating functionality, subsystem integration, ergonomics, manufacturability, deployment, structural behavior, usability, proof-of-concept, or operational feasibility.
- Describe how prototypes were fabricated, configured, or tested when relevant to interpreting results.
- Present the most important observations, performance outcomes, limitations, or lessons learned from prototyping activities.
- Explain how prototype findings informed design refinement, subsystem modification, material selection, geometry changes, manufacturing considerations, risk reduction, or later testing strategies.
- Identify important prototype limitations, unresolved uncertainties, or areas requiring additional refinement when relevant.
- Organize and prioritize the engineering purpose of each prototype, the evidence gathered, and the resulting design implications.

Topic Sentence Example:
- “Mockups and subsystem prototypes were used to test assumptions about operator interaction, deployment sequence, manufacturability, and subsystem accessibility before full integration.”

Takeaway Sentence Example:
- “Prototype evaluations revealed that simplified subsystem interfaces and modular deployment mechanisms significantly improved manufacturability and operational reliability, motivating continued refinement of the modular system architecture.”

FROM DESIGN DIRECTION TO DESIGN RESOLUTION

As projects mature engineering communication increasingly shifts toward helping audiences understand the proposed system itself as an integrated engineering solution.

This is the place where the report stops talking primarily about engineering decisions and starts communicating the integrated engineering system itself.

At this stage, readers are no longer asking only:

- Why was this direction selected?

They are increasingly asking:

- What exactly is the design?
- How does it work?
- How do the subsystems interact?
- What has been resolved?
- What remains uncertain?
- How implementation-ready is the project?

Because of this shift, design communication often becomes:

- more concrete,
- more system-oriented,
- more implementation-aware,
- and more technically specific as projects mature.

DESIGN COMMUNICATION EVOLVES WITH DESIGN MATURITY

Although different courses may use different section names, these sections often serve the same broader communicative purpose: **helping audiences understand the proposed engineering system as a coherent, integrated design solution.** For example:

Earlier-Stage Design Reports (e.g., 2110)	**Later-Stage Design Reports (e.g., Capstone)**
Design Overview	Final Design
Earlier-stage reports often emphasize: • overall system architecture, • intended functionality, • subsystem relationships, • operational behavior, • and evolving design direction. At this stage, some engineering decisions may still be iterative or partially unresolved. Communication should still remain clear and organized while honestly representing the project's current level of design maturity.	Later-stage reports often place greater emphasis on: • finalized embodiment decisions, • subsystem integration, • manufacturability, • implementation details, • operational readiness, • and demonstrated performance alignment. These sections increasingly help audiences evaluate if the design appears sufficiently refined for fabrication, deployment, commercialization, testing, or continued development.

Both sections synthesize previously created understandings to explain:

- the proposed system architecture,
- subsystem relationships,
- operational behavior,
- and how the design responds to stakeholder needs and engineering constraints.

However, the level of detail, refinement, and implementation specificity often changes as engineering uncertainty decreases and the project becomes more resolved.

ENGINEERING COMMUNICATION PROGRESSES ALONGSIDE ENGINEERING DECISION-MAKING

Across design reports, communication often evolves from:

- framing engineering uncertainty,
- toward communicating integrated engineering resolution.

This progression helps audiences move from understanding the problem and design space to understanding the proposed engineering system itself.

REPORT SECTIONS

DESIGN OVERVIEW
FINAL DESIGN

Key Audiences
Device Client,
Engineering Superiors,
IMfg. Engineers, IP lawyers, Marketing, Investors,
Future Teams,

Primary User Task
- Understand the current state of the proposed system as an integrated engineering solution.
- Understand how the system operates and integrates for possible replication.
- Understand how the design responds to stakeholder needs and engineering requirements.
- Evaluate what level of implementation maturity the project has reached.
- Evaluate whether the proposed system appears coherent, feasible (time & costs), and appropriately resolved.

Common Design Tools
CAD Assemblies & Renderings, Exploded Views, System Architecture Diagrams, Block Diagrams, Wiring / Control Schematics, Bills of Materials, Interface Diagrams, Assembly Diagrams

Argument Tendency
More Direct / Self-Integrative

Typical Arrangement
System Purpose & Design Priorities → Overall Architecture → Subsystem Operation & Integration → Key Design Features & Implementation Considerations → Overall Design Implications

This section establishes how the proposed engineering system is organized, how it functions, and how the integrated design responds to the project's stakeholder needs, engineering requirements, operational constraints, and broader design goals.
- Clearly identify the purpose of the proposed system and its primary operational goals.
- Introduce the overall system architecture and explain how major subsystems, components, or assemblies interact.
- Explain how the design performs its intended functions and supports stakeholder or operational needs.
- Describe important subsystem relationships, workflows, material choices, control strategies, interfaces, or operational sequences when relevant.
- For systems involving electronics, automation, sensing, or controls, explain how sensors, control logic, feedback systems, user inputs, and system responses support overall system operation and engineering goals.
- Use visual representations to help readers efficiently interpret the design.
- Identify important implementation considerations such as manufacturability, assembly, maintenance accessibility, portability, safety, scalability, usability, or subsystem integration.
- Include drawings and a detailed Bill of Materials when needed to communicate the finalized design configuration, including vendors, part numbers, and prices when available.
- Explain how earlier specifications, analyses, prototyping activities, validation efforts, or industrial design decisions influenced the current system configuration.
- Clarify important remaining limitations, unresolved concerns, or future refinement areas when appropriate.

Engineers should help readers efficiently build a mental model of the system rather than overwhelming them with isolated technical details or chronologically describing design evolution.

Topic Sentence Example:
- "The proposed debris collection system integrates modular collection, containment, and deployment subsystems designed to improve roadside operator safety while maintaining rapid deployment and manufacturable field operation."

Takeaway Sentence Example:
- "The resulting system configuration shows how the project's earlier requirements were embodied in specific subsystem relationships, interfaces, and implementation choices."

FROM PROTOTYPE REALIZATION TO MANUFACTURING FEASIBILITY

Engineering communication increasingly expands beyond:
"Can the system function?"
toward questions such as:

- Can the system be manufactured reliably?
- Can it be assembled efficiently?
- Can production scale realistically?
- What manufacturing constraints influence the design?
- How do tolerances, materials, quality control, and production economics shape implementation feasibility?

Because of this shift, implementation-focused communication often evolves from discussing:

- prototype realization and operational performance

toward discussing:

- specific materials and dimensions,
- production strategy,
- assembly planning,
- quality requirements,
- scalability,
- and manufacturing feasibility.

IMPLEMENTATION COMMUNICATION EVOLVES WITH DESIGN MATURITY
Although these sections may appear related, they often serve different engineering communication purposes as projects mature. For example:

Earlier-Stage Design Reports (e.g., 2110)	**Later-Stage Design Reports (e.g., Capstone)**
Final Fabrication (with Performance Results)	Manufacturing
Earlier-stage implementation sections often focus on: • what was fabricated, • how the system performed, • what implementation challenges emerged, • and what operational lessons were learned through fabrication, testing, deployment, or competition use.	Later-stage manufacturing sections increasingly focus on: • how the design could be reliably produced, • assembled, • quality-controlled, • scaled, • and economically implemented under realistic manufacturing constraints.
Fabrication-Oriented Communication Fabrication-oriented sections often emphasize: • prototype construction, • subsystem integration, • implementation challenges, • operational testing, • deployment observations, • and performance outcomes. This helps audiences evaluate whether the proposed system appears operationally feasible and how real-world implementation informed later refinement.	**Manufacturing-Oriented Communication** Manufacturing-oriented sections increasingly emphasize: • production methods, • material-process relationships, • assembly strategies, • tolerance requirements, • quality control, • scalability, • packaging/storage considerations, • supplier constraints, • and production cost feasibility. This help audiences evaluate whether the design could be produced reliably, repeatedly, safely, and economically at realistic production scales.

As engineering projects mature, implementation communication increasingly helps audiences evaluate not only: whether the system works, but also: whether the system can realistically and responsibly be produced, deployed, maintained, and sustained.

REPORT SECTIONS

FINAL FABRICATION (WITH PERFORMANCE RESULTS)

Key Audiences
Device Client,
Engineering Superiors

Primary User Task
- Understand how fabrication and implementation activities revealed information about system behavior, subsystem integration, operational feasibility, and design performance.
- Evaluate what operational strengths or weaknesses emerged.
- Understand what performance results suggest about future refinement or implementation feasibility.

Common Design Tools
N/A

Argument Tendency
Final Fabrication
More Direct / Implementation-Centered

Performance Results
Direct / Evidence-Argued

Typical Arrangement
Final System Realization → Fabrication & Integration Decisions → Implementation Challenges → Final System Configuration

This section establishes how the system was physically realized and integrated into the final implementation by explaining the biggest influences on the system.
- Synthesize the most important ways the fully fabricated system responded to stakeholder needs, engineering specifications, operational constraints, environmental conditions, usability concerns, and competition requirements.
- Identify known limitations or remaining concerns.

Topic Sentence Example:
- “The system integrated modular collection, sensing, and deployment subsystems designed to improve operational reliability and operator usability under competition conditions.”

Takeaway Sentence Example:
- “The use of compliant mechanisms improved rigidity and compactness over previous pneumatic design iterations.”

PERFORMANCE RESULTS
Typical Arrangement
Performance Goals & Evaluation Criteria → Competition Results → Results Interpretation → Implications & Remaining Limitations

This subsection explains how the system performed under competition conditions and subsequent conclusions.
- Clearly identify the operational goals, performance metrics, or evaluation criteria used to assess the system.
- Explicitly correlate performance of subsystems to validation outcomes (such as competition scores).
- Explain how sensing reliability, feedback behavior, controls responsiveness, or user interaction influenced performance.
- Explain how performance results supported or challenged expectations, revealed limitations, identified implementation concerns, or motivated future refinement opportunities.

Topic Sentence Example:
- “The system met the project’s deployment and usability goals during operational evaluation while signaling subsystem durability as a remaining limitation.”

Takeaway Sentence Example:
- “Results demonstrate the current design is operationally viable for short-term deployment, but refinement for repeated-use reliability is needed.”

REPORT SECTIONS

MANUFACTURING

Key Audiences
Sponsors, Mfg. Engineers, Investors, Future Teams,

Primary User Task
- Understand how the design could be fabricated and assembled at the level of replication.
- Evaluate whether the proposed manufacturing approach is realistic and worth costs.
- Understand how production methods influence design and material choices.
- Understand how to fabricate the solution including what quality, tolerance, cost, or scalability concerns remain.
- Evaluate whether the design appears manufacturable under realistic implementation conditions.

Common Design Tools
Bills of Materials, Exploded Views, Part Drawings

Argument Tendency
Indirect → Direct (Evidence-Guided Refinement)

Typical Arrangement
Manufacturing Requirements & Production Context → Fabrication / Assembly Processes → Material and Design Implications → Quality, Tolerance, Cost, and Scalability Considerations

This section establishes how the design could be manufactured, assembled, inspected, scaled, and produced under realistic engineering constraints that influence whether the design can be reliably and repeatably fabricated.
- Clearly identify the manufacturing context relevant to the design, such as prototype production, limited-batch production, mass production, custom fabrication, or specialized manufacturing.
- Describe the fabrication and assembly processes required to produce the design.
- Explain how manufacturing processes influenced design decisions, such as material selection, geometry, tolerances, part consolidation, fastener choices, surface finishes, assembly sequence, subsystem access, maintenance, packaging, storage, or production cost.
- Discuss any special production methods, tooling needs, machining processes, additive manufacturing methods, joining techniques, finishing processes, or inspection requirements.
- Identify important quality requirements, allowable tolerances, repeatability concerns, or production risks.
- Explain how manufacturing constraints affect feasibility, cost, scalability, reliability, safety, or long-term implementation.
- Provide production cost analysis or cost estimates when possible, especially when cost affects feasibility, adoption, or commercialization.

Avoid using this section to redescribe the design's purpose, functions, specifications, or performance results; only those when needed to explain a manufacturing decision.

Topic Sentence Example:
- "Manufacturing planning for the final debris collection system focuses on producing a durable, modular assembly using sheet-metal fabrication, welded support structures, and off-the-shelf hardware to balance production cost, repairability, and repeatable assembly."

Takeaway Sentence Example:
- "The proposed manufacturing approach supports reliable low-volume production by using accessible fabrication methods and modular assembly strategies, though tighter tolerance control and simplified part geometry would improve scalability for larger production volumes."

REPORT SECTIONS

SOCIETAL, ENVIRONMENTAL, & SUSTAINABILITY CONSIDERATIONS

Key Audiences
Sponsors, Mfg. Engineers, Investors, Governmental Entities, Future Teams

Primary User Task
- Understand who or what may be affected by the design and what broader consequences the design may create.
- Understand what tradeoffs shape responsible implementation.
- Understand how the design responds to societal, environmental, or sustainability concerns.
- Evaluate whether the team has considered the design's impact beyond immediate technical performance.

Common Design Tools
Stakeholder Analysis

Argument Tendency
Direct

Typical Arrangement
Relevant Stakeholders & Contexts → Potential Societal / Environmental Impacts → Sustainability Tradeoffs → Mitigation Strategies & Design Implications

This section establishes how the proposed design may affect people, communities, environments, systems, resources, and long-term implementation contexts beyond its immediate technical function. Rather than making broad claims that the design is "green," or "sustainable," this section should use specific evidence, stakeholder reasoning, and impact analysis to evaluate the design's likely benefits, risks, tradeoffs, and responsibilities.
- Clearly identify the societal, environmental, or sustainability contexts most relevant to the project.
- Discuss who may be affected, including users, clients, operators, maintainers, communities, vulnerable populations, supply-chain participants, or future stakeholders.
- Evaluate potential positive and negative impacts related to safety, accessibility, equity, labor conditions, environmental burden, energy use, material sourcing, waste generation, emissions, maintenance, end-of-life disposal, durability, repairability, cost, adoption, or unintended use.
- Explain how societal, environmental, or sustainability considerations influenced design decisions, material choices, manufacturing plans, operational procedures, maintenance strategies, or implementation recommendations.
- Identify tradeoffs, such as improved performance but increased material use, lower cost but reduced durability, increased automation but changed labor needs, etc.
- Use specific evidence such as Social Impact Assessment findings, life-cycle reasoning, material comparisons, energy estimates, emissions estimates, stakeholder analysis, safety or accessibility data, cost and maintenance estimates, repairability assessments, or disposal/recycling considerations to support claims about broader impact.
- Acknowledge limitations or uncertainties in the team's impact analysis when relevant.

Topic Sentence Example:
- "The proposed debris collection system offers meaningful worker-safety benefits by reducing direct exposure to roadside hazards, while its environmental sustainability depends on minimizing material waste, supporting repairability, and planning for component replacement over repeated field use."

Takeaway Sentence Example:
- "The design's broader value depends not only on reducing worker exposure to roadside hazards, but also on selecting weather-resistant materials, making high-wear components such as wheels, hinges, and debris-contact surfaces replaceable, and planning routine inspections after repeated field deployment."

REPORT SECTIONS

RISK ASSESSMENT, SAFETY, AND LIABILITY

Key Audiences
Sponsors,
Governmental Entities

Primary User Task

- Understand which risks are most important, how severe or likely those risks are, what mitigations reduce them, and what residual risks remain after mitigation.
- Understand who or what could be harmed.
- Evaluate how the team evaluated risk severity and likelihood.
- Understand what design or procedural choices reduce risk.
- Evaluate whether the design can be used, maintained, and deployed responsibly.

Common Design Tools
FMEA

Argument Tendency
Direct (High Transparency)

Typical Arrangement
Risk Context & Use Conditions → Hazard Identification → Risk Evaluation → Mitigation Measures → Design and Liability Implications

This section establishes how potential hazards, safety concerns, failure modes, and liability risks associated with the design's use, misuse, maintenance, deployment, and long-term operation was evaluated.

- Clearly identify the relevant use conditions, operating environments, users, maintainers, and foreseeable misuse scenarios.
- Identify potential risks associated with normal operation, user interaction, mechanical failure, electrical or controls failure, sensing errors, environmental exposure, assembly, maintenance, transport, storage, cleaning, misuse, or end-of-life handling.
- Use a formalized risk assessment approach, such as Failure Modes and Effects Analysis, risk matrix, hazard analysis, safety checklist, fault tree, or severity/probability ranking.
- Explain the severity, likelihood, detectability, or priority level of major risks.
- Prescribe ranked mitigation measures such as guards, interlocks, fail-safe behavior, emergency stops, warnings, labels, procedures, material changes, geometry changes, redundancy, inspection intervals, maintenance requirements, training, or operating limits.
- Discuss how risk, safety, or liability concerns influenced the final design, including changes to geometry, controls, materials, interfaces, tolerances, documentation, testing, or user instructions.
- Acknowledge residual risks that remain after mitigation and explain how those risks should be managed.

Because safety and liability claims carry serious professional weight, engineers should avoid vague reassurance such as "the design is safe." Connect specific hazards to specific mitigations, evidence, assumptions, standards, and residual-risk judgments.

Topic Sentence Example:

- "Risk assessment of the debris collection system identified roadside operator exposure, wheel-lock failure, pinch points near the folding frame, and debris ejection from the collection bin as the primary safety and liability concerns during deployment and repeated field use."

Takeaway Sentence Example:

- "The final design reduces these risks through reflective visibility panels, locking caster assemblies, guarded hinge points, and a lidded debris-retention bin, but safe implementation still depends on routine pre-use inspection and operator training for roadside deployment."

REPORT SECTIONS

PATENT CLAIMS & CONSIDERATIONS

Key Audiences
IP Lawyers, Investors

Primary User Task
- Understand specific technical features, combinations, mechanisms, methods, or system behaviors that distinguish the design from existing approaches.
- Evaluate aspects of the design may be novel.
- Evaluate what technical features could support potential patent claims.
- Evaluate whether the design has plausible commercialization value.
- Understand what barriers or next steps would affect real-world adoption.

Common Design Tools
CAD Assemblies & Renderings, Exploded Views, System Architecture Diagrams, Wiring / Control Schematics, as necessary for reference

Argument Tendency
Direct Direct (Strategic-Differentiation Argument)

Typical Arrangement
Potentially Novel Design Features → Relationship to Prior Art → Patent Claim Logic → Commercialization Opportunities & Barriers → Strategic Implications

This section establishes what aspects of the design may be novel, protectable, commercially valuable, or strategically important by explaining how the proposed design differs from existing products or prior art, which features may support potential patent claims, and what opportunities or barriers could affect commercialization.
- Clearly identify the design features or system elements that may be novel or commercially valuable.
- Connect potential patent claims to specific technical features, such as mechanisms, subsystem arrangements, control strategies, sensing methods, material/process combinations, user interaction features, manufacturing approaches, safety features, or integrated system architectures.
- Explain how these features differ from existing products, patents, or prior art discussed earlier in the report.
- Distinguish between broad invention-level claims and narrower implementation-specific claims when appropriate.
- Discuss commercialization considerations such as target users or customers, market need, production cost, manufacturing scalability, regulatory barriers, safety/liability concerns, maintenance requirements, adoption barriers, intellectual property ownership, licensing potential, competitive advantage, or next steps for product development.
- Explain how patentability and commercialization considerations influence design decisions, refinement priorities, manufacturing plans, or future development.
- Acknowledge uncertainty appropriately by demonstrating thoughtful reasoning about novelty, differentiation, and potential value.

Strong writing in this section connects specific design features to prior art, market needs, implementation constraints, and appropriately qualified commercial possibilities.

Topic Sentence Example:
- "The debris collection system supports patent claims around its modular folding frame, replaceable debris-retention cartridge, and sensor-assisted deployment indicator, which together differentiate the design from existing roadside collection tools that prioritize either large-capacity collection or manual portability but rarely both."

Takeaway Sentence Example:
- "These features suggest that the design's strongest commercialization opportunity lies in low-volume municipal and contractor use cases where improved worker safety, rapid deployment, and field repairability provide clearer value than maximum collection capacity alone."

REPORT SECTIONS

CONCLUSIONS & FUTURE WORK

Key Audiences
Device Client,
Engineering Superiors,
Marketing,
Investors,
Future Teams

Primary User Task
- Understand the project's overall engineering significance: what was learned, what has been demonstrated, what remains uncertain, and what next steps are justified.
- Understand project milestones.
- Understand engineering conclusions are justified.
- Understand what limitations still shape the design.
- Evaluate which future work should be prioritized and how the project should move forward.

Common Design Tools
N/A

Argument Tendency
Direct (Team's Judgment)

Typical Arrangement
Major Design Outcome → Evidence-Supported Conclusions → Remaining Limitations or Uncertainties → Future Work / Recommended Next Steps

This section establishes the major engineering conclusions that can be drawn and identifies what work should follow. *These conclusions may focus on what the prototype, testing, or competition performance revealed about the design's feasibility rather than claiming that the system is fully resolved or implementation-ready.* Synthesize the report's most important findings, explain what the evidence suggests about the design's feasibility or effectiveness, and recommend future work based on remaining limitations, risks, or unresolved questions.
- Clearly summarize the project's major accomplishment or final design outcome.
- State the most important engineering conclusions supported by the report's evidence, such as conclusions about feasibility, performance, usability, safety, manufacturability, sustainability, cost, reliability, scalability, or implementation readiness.
- Connect conclusions to evidence from earlier sections, including analysis, testing, prototyping, fabrication, performance/competition results, market research, risk assessment, or manufacturing planning.
- Identify important limitations, unresolved concerns, assumptions, or remaining uncertainties.
- Explain what future work, design iteration, or additional validation should address and why those next steps matter.
- Distinguish between minor refinements, prototype improvements, additional testing needs, and major future development work.
- Recommend next steps such as additional testing, design refinement, expanded validation, durability evaluation, manufacturing optimization, user testing, regulatory review, cost reduction, safety mitigation, controls improvement, sensing calibration, environmental assessment, or commercialization planning.

Strong conclusions specify what kind of success was demonstrated, what evidence supports that judgment, what limitations remain, and what next action is most important.

Topic Sentence Example:
- "The final debris collection system demonstrates that a modular, manually deployable design can improve roadside cleanup efficiency and operator accessibility while remaining feasible for low-volume fabrication and short-term field use."

Takeaway Sentence Example:
- "Future work should prioritize repeated-use durability testing and debris-retention refinement to determine whether the system can maintain reliable performance under extended deployment conditions."

COMMON ADDITIONAL REQUIREMENTS

Some design reports include **additional front matter, sections or appendices** that support accountability, documentation, citation, and project transparency. These sections may not always carry the main design argument, but they help readers verify the report's completeness, trace evidence, understand team responsibilities, and locate supporting information. These requirements should be handled carefully because they influence the report's credibility and usability.

NOMENCLATURE / GLOSSARY

When those terms appear frequently, use a nomenclature or glossary section to reduce cognitive load.

A useful rule: If readers need to repeatedly interpret symbols, variables, acronyms, or project-specific terms to understand the report, define them clearly before they become obstacles. Use nomenclature and glossary sections when symbols, variables, acronyms, or specialized terms would otherwise slow reader comprehension.

TEAM MEMBER CONTRIBUTIONS

This section documents each team member's specific responsibilities and individual contributions. It should help instructors, sponsors, and future teams understand how major project work was distributed across design, analysis, fabrication, testing, documentation, project management, and presentation preparation.

Avoid vague contribution statements such as "everyone helped with everything." Instead, identify meaningful responsibilities and deliverables.

2110 requires contribution statements at multiple project stages or report chapters. In those cases, each statement should document who contributed to the relevant design work, analysis, fabrication, testing, writing, editing, and project coordination for that stage.

In projects with potential intellectual property implications, contribution statements may also help clarify who contributed to specific inventive features, design decisions, analyses, prototypes, or implementation strategies.

REFERENCES / CITATIONS

References should support specific engineering claims, design decisions, background information, prior art comparisons, standards, methods, data, or market research. A reference list should not function as a disconnected bibliography.

Only include sources that are explicitly cited in the report. When students use information from a source, they should make clear how that source supports the engineering discussion.
Use citations to support:

- background context,
- existing products or prior art,
- standards and regulations,
- market research,
- material properties,
- equations or methods,
- benchmark data,
- supplier or cost information,
- safety guidance,
- environmental or sustainability claims.

COMMON ADDITIONAL REQUIREMENTS

APPENDICES
Each appendix should be clearly labeled, organized by topic, and explicitly referenced in the main text. Use appendices for:

- detailed calculations,
- extended raw data,
- supplemental testing procedures,
- long tables,
- additional concept sketches,
- detailed CAD documentation,
- supporting standards information,
- extended market research,
- backup analysis

If readers need the information to follow the design argument, place it in the main body. If readers need it to verify or inspect supporting details, place it in an appendix.

BUDGET APPENDIX
When required, the *budget* appendix documents how project funds were spent. It should be accurate, transparent, and easy to inspect. A budget appendix should help sponsors, instructors, or future teams evaluate whether funds were used responsibly and what costs should be expected if the project continues. A strong budget appendix usually includes:

- item names,
- quantities,
- vendors,
- unit costs,
- total costs,
- dates purchased,
- project category,
- remaining funds,
- and notes explaining unusual expenses or substitutions.

Tables are usually the clearest format.

COMMON 2110 DESIGN TOOLS AND REQUIRED ARTIFACTS
For ME 2110 reports, required tools such as the House of Quality, specification sheet, function tree, morphological chart, concept evaluation matrix, performance data tables, and Bill of Materials should be treated as evidence, not attachments. When these tools appear in the appendix, the main body should still interpret their most important implications for the design.

In ME 2110, appendices require:

- House of Quality
- Specification Sheet
- Function Tree
- Morphological Chart
- Concept Evaluation Matrix
- Performance Data through Sprint 1
- Performance Data through Sprint 2
- Performance Data through Sprint 3
- Contributions Statements through Chapters 1–3
- Bill of Materials
- Additional Figures

PART III: TECHNICAL COMMUNICATION BASICS

Engineering communication depends not only on strong reasoning and effective organization, but also on consistent technical conventions that improve readability, professionalism, accessibility, and usability.

Formatting, paragraph structure, figure conventions, citation practices, quantitative phrasing, file organization, and accessibility standards may appear small individually, but together they strongly influence how efficiently audiences can process information and how professionally engineering work is perceived. These conventions help:

- reduce unnecessary cognitive load,
- support consistency across teams,
- improve document navigation,
- minimize ambiguity,
- and make technical information easier to inspect, reuse, and evaluate.

Importantly, these conventions are not arbitrary rules or aesthetic preferences. Many exist because they support practical engineering needs:

- quick review under time constraints,
- collaboration across teams,
- traceability,
- accessibility,
- quality control,
- and long-term documentation usability.

At the same time, communication conventions should not override engineering judgment. Engineers are expected to apply standards thoughtfully and adapt them when necessary to better support audience understanding or communication goals.

This section introduces foundational technical communication practices commonly used across engineering contexts. These principles are broadly transferable across reports, presentations, documentation, and collaborative engineering work.

The purpose of these conventions is not merely correctness. Their purpose is to help engineering information remain clear, usable, trustworthy, and actionable.

IMPERSONAL VERSUS PERSONAL

When professionals read reports, they typically want to extract key information quickly to inform decision-making. A more direct and concise writing style that prioritizes technical details and results can better serve this purpose. Personal pronouns likely divert attention away from the critical content.

The use of personal pronouns or explicit references to the team can occupy important positions within a sentence, roles that could otherwise be dedicated to conveying technical information or data.

Consider these revisions of a sentence from a conceptual design section:

NOT ACCEPTABLE

The team determined which subsystem to select for further development by prototyping four collection

Subject Verb Direct Object Object of the Preposition

subsystem designs using cardboard and testing them in a scaled environment.

Sentence above prioritizes the **team**, and regulates the most actionable information to a less important position. We often call this “burying the lede.”

BETTER

By prototyping four collection subsytem designs using cardboard and testing them in a scaled

Prepositional Phrase

environment, the team determined which subsystem to select for further development.

Subject

Verb Direct Object Object of the Preposition

The emphasis, here, is on the design **process**, making it more accessible to an audience interested in the specific actions taken.

BEST

To determine which design to select for further development, four collection subsystem designs

Prepositional Phrase Subject

are prototyped out of cardboard and tested in a scaled environment.

Verb Object of the Preposition

The sentence emphasizes the **expected outcome** of the process - a design to put resources (time, materials, testing) to - which is likely of interest to clients who are concerned with testing validation.

COMMON WRITING STRUCTURE FOR DIRECT ARGUMENTS

Thesis is the main claim of the writing with its supporting reasons (2-4).

- X is recommended because 1 and 2.

Paragraph/sub-section 1 would be devoted to arguing for reason 1.
Paragraph/sub-section 2 would be devoted to arguing for reason 2.

Each paragraph is expected to have a topic sentence, evidence, and commentary. The expected structure is as follows:

- Topic Sentence - Reason 1 is acceptable because of generalized (qualitatively stated) evidence.
- Evidence - Quantitively stated technical evidence that supports reason 1.
- Commentary - Your analysis of the evidence that explains exactly how the given evidence supports reason 1.
- Commentary - Repeat as much as needed (generally twice as long as stating the evidence).
- More Evidence - Most reasons selected for reports have more than one piece of evidence; give another.
- Commentary - Analyze your evidence to support your reasons.
- Commentary - Clarify your analysis so that it cannot be misunderstood.
- Take Away - Clarify how both pieces of evidence demonstrate reason 1 and therefore support your thesis (main claim).

DESIGN ENGINEERING EXAMPLE W/ COMMON PARAGRAPH STRUCTURE

Topic Sentence	The design was successful because it maximized accuracy of the torpedo payload delivery task and minimized time necessary to retrieve sailor-themed items.
Evidence	The payload mechanism achieved a 100% loading success rate across 10 trials, with an average loading time of 3.2 seconds per torpedo.
Commentary	This high success rate demonstrates the reliability of the alignment and actuation system, which used a trigger linkage to ensure consistent delivery into the target receptacles. A mechanical trigger ensures precise alignment without relying on electronic timers, which use a non-variable actuation time, and more reliable than sensors, which can result in false positives in the chaotic competition environment.
Evidence	The egress system consistently cleared the blast zone in less than the 12 seconds allotted, with 8 out of 10 trials clearing the specified distance in under 8 seconds.
Commentary	This performance is improved due a unique focus on minimizing the mass of the deployed subsystem and ensuring exact constraint of linear motion components. Due to the low mass and properly-constrained motion of our extended subsystems, the retraction functionality required much less torque in order to move reliably. As a result, a100mm diameter line retraction spool was used which resulted in at least a 3x increase in retraction speed as compared to most competitors, who typically used a 20-30mm diameter spool for similar mechanisms.
Take Away	Together, these results show that the chosen design addressed the two top-rated customer requirements of precision and speed, validating our strategic focus.

ANOTHER DESIGN ENGINEERING EXAMPLE W/ COMMON PARAGRAPH STRUCTURE

Topic Sentence
State the reason and its relevance to the thesis.

Evidence
Provide data, calculations, design tools, or industry standards that support the reason.

Commentary
Analyze the evidence and explain how it supports the reason.

Evidence
Include a second piece of evidence to strengthen the argument.

Commentary
Analyze the second piece of evidence and clarify its significance.

Take Away
Summarize how the evidence supports the reason and, by extension, the thesis.

The threaded nose piece was designed to allow easy assembly and disassembly while maintaining a secure connection to the main body, ensuring both functionality and user convenience.The threads were modeled with a diameter of 0.875 inches and a pitch of 9 threads per inch, as shown in the CAD drawings (Figure 4). This design choice was based on the need for a secure fit that could withstand handling without loosening. The threaded connection provides a robust mechanical interface, preventing the nose piece from detaching unintentionally during use. This is particularly important for a desktop ornament, which may be moved or adjusted frequently. Additionally, the threads allow the nose piece to be removed easily, enabling access to the small storage compartment inside the rocket. This dual functionality enhances the design's practicality and user appeal. During assembly testing in Solidworks, the threads were verified using collision and screw mates, which confirmed that the design would function as intended under normal conditions. However, the 3D-printed prototype revealed threading issues due to manufacturing tolerances. Future iterations could explore alternative mechanisms, such as a tongue-and-groove design, to improve manufacturability. While the threaded nose piece design successfully balanced functionality and user convenience in theory, the challenges encountered during prototyping underscore the need to account for manufacturing limitations in interlocking features, which will inform future designs to ensure both performance and manufacturability.

COMMON WRITING STRUCTURE

In some cases, deviating from a standard may be appropriate if it improves clarity or usability for the client. Engineers are responsible for making and justifying these choices.

ACTIONABLE WRITING & TOPIC SENTENCES

The first sentence of the paragraph should be actionable for the audience. It needs to let them know what point, data, or analysis in this paragraph actually matters. As an engineer, it's your job to interpret findings and inform and guide. decision-makers

Topic sentences are the first sentence of their paragraphs; the purpose of the sentence is to clarify what the purpose of the paragraph is; what the main point the paragraph presents and how it relates to the report's goals.

Common issues with topic sentences include the ones that set the paragraph up for:

Hedging
- ”The mechanism's speed proves that it may be better than current market competitor's designs for automated vacuum cleaners.”

Vagueness
- “From observation in Figure 1, it is apparent that the volume is important.“
- “A subsystem was built that could do all the tasks while being safe for users.”

Listing
- “This section will provide the choice of materials for the construction of the bridge.”
- “The data was segmented by temperature. ”
- “The target distance was calculated for each trial.”

Instead, **topic sentences should set the paragraph up to argue, explain, or justify throughout the rest of the paragraph.**

Claims that Need to be Argued
- “The Shark Rocket design is the best option because it balances functionality, manufacturability, and user convenience.”

Claims that Need Explanation
- “A two pronged rotation mechanism is sufficient for facilitating ice cube movement while also reducing the frequency of ice cubes getting jammed inside the system.”

Claims that Need Justification
- “The use of fillets ensures that the shelled design is both functional and manufacturable for a plastic extrusion method.”

Topic sentences demystify the point for readers, making writer's recommendations and reasons seem more intuitive. Effective topic sentences decrease the audience's cognitive load because they clarify what they main point is.

Non-Actionable Topic Sentences
"A lot of successful ideas were developed that helped the design work well. Specifically, the torpedo subsystem was a strength of the design and worked perfectly."
"The mechanism consistently got out of the way in time, meeting design requirements."
"As shown in Figure 4, it was a good design concept which was built correctly."

Even in complicated contexts, engineers must turn uncertainty into direction.

- **Less actionable:** "The behavior could be due to thermal effects or control instability."
- **More actionable:** "Because the observed response is most sensitive to temperature variation, we recommend targeted thermal characterization before refining the material selection."

Actionable writing generally avoid chronological structure. An effective strategy for avoiding chronological writing is to ensure your **topic sentences** are justification-focused and **not** chronology-focused.

Chronological	**Argumentative**
"First, we..."	"The primary constraint was..."
"Then we..."	"X motivated evaluation of three key concepts..."
"After that..."	"The data clearly shows that X meets the intersection of requirements from A and B."
"The next thing we did was..."	"To validate this decision, X test was conducted..."
"Finally..."	"In conclusion, the recommended path forward is..."

QUALITATIVE & QUANTITATIVE ARGUMENTATION

Both qualitative and quantitative argumentation are appropriate in engineering communications. Often communications need a mix of both.

QUALITATIVE	QUANTITATIVE	MIXED
Interpretation-based, descriptive, or relating to language.	Numbers-based, countable, or measurable.	Numbers or measurable data with contextual, qualitative words.
Simplifies complex concepts with context.	Offers precision, clarity, and demonstrates technical acumen.	Both; but longer and may add unnecessary/inappropriate content.
“The thickness of the cantilever beam element was increased to improve stiffness.”	"The thickness of the cantilevered element was increased to 8mm, doubling the stiffness."	“The prototype fractured once weight was applied at the end of the cantilever, so the thickness of the element was increased to 8mm, doubling the stiffness.”

- Qualitative phrasing helps us understand values in relationship to other things, but in an imprecise way.
- Quantitative phrasing gives us a high-level of precision.

Often, both are needed so that the measurable data can be categorized and understood in the audience’s mind.

Often qualitative phrasing is used first and then clarified with quantitative data. For example, a **topic sentence might use qualitative phrasing** to give context to a finding that will be quantified in the following sentences.

Some qualitative language is never appropriate or very risky in engineering reports, such as: “extensive testing,” “detailed evaluation,” “optimal,” and more.

The key here is to balance actionability and trustworthiness: use qualitative phrasing that is useful for the reader and include quantitative engineering metrics to support your claims.

PRECISION, NOTATION, AND RELEVANCE

Small technical choices—symbols, units, numerical expressions, and levels of detail—signal to readers how carefully engineers think about their work. These choices should reduce reader effort, not increase it.

USE NOTATION YOUR READER EXPECTS

- Use standard technical symbols and formatting (e.g., ±, superscripts, subscripts) rather than substitutes such as +/-or caret notation (^).
- These conventions are not cosmetic; they reduce cognitive translation and signal professional precision.

Ask: Does my notation allow the reader to interpret values immediately, without mental conversion?

USE SCIENTIFIC NOTATION PURPOSEFULLY

- Scientific notation is most useful for expressing very large or very small values or for emphasizing order of magnitude.
- When it does not improve clarity or concision, prefer unit scaling (e.g., 44.1 kN) or standard numerical expression (e.g., 44,100 N).

Ask: Does this numerical form clarify scale for my reader—or does it simply apply a convention without benefit?

FILTER TECHNICAL DETAIL BASED ON AUDIENCE RELEVANCE

- Include procedural or setup details that help the reader evaluate the validity, reliability, or interpretation of results.
- Omit details that document activity but do not support understanding (e.g., internal wiring paths or DAQ port numbers, unless relevant to the claim).

Ask: Does this detail help my reader judge my conclusions—or does it merely show what I did?

KEY TAKEAWAY

Precision in notation, numerical expression, and detail selection supports trustworthiness by signaling care and competence, and intuitiveness by minimizing unnecessary cognitive load. These decisions should always be guided by the reader’s needs.

Reader Benefit	**Example**
Reduces translation	\`±\`, superscripts
Clarifies scale	\`44.1 kN\`
Filters relevance	Setup constraints, not wiring paths

EXPORTING FIGURES

Keep the usability of your figure in mind as you export and prepare for annotations. This will be especially true if your figure will be used in different formats (screen and printed) and genres (reports and presentations). **Excel-generated figures are not permitted**.

NOT ACCEPTABLE

SCREENSHOT

Windows key, Shift, S or Command, Shift, 4

Screenshots are limited by the resolution of your display. Taking a screenshot may result in lower quality, especially if the graph needs to be enlarged later. Dedicated exporting tools allow you to choose the resolution and file format, ensuring the highest quality output. This is crucial for maintaining clarity, especially when the graph needs to be resized or printed.

ACCEPTABLE

PNG

Portable Network Graphic

These supports both raster and transparent images while maintains good image quality, suitable for complex graphics or images with gradients. However, they are still written in pixels and have fixed resolution, so **resizing can result in loss of quality**. They are also larger file sizes compared to SVG and limited editability compared to vector formats.

BEST

SVG

Scalable Vector Graphic

SVG is a vector format, which means that the graphics are defined mathematically rather than as a grid of pixels. This makes SVG images **infinitely scalable without losing quality**. Whether the figure is displayed on a small screen or projected onto a large presentation screen, it maintains sharpness and clarity. SVG is resolution-independent, meaning that it looks the same regardless of the screen or print resolution.

To insert an SVG in Word, you must be using Word's Desktop Application.

INTEGRATING FIGURES IN WORD

1

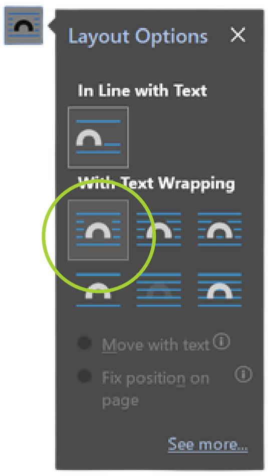
INSERT VISUAL

1.1. Open your Microsoft Word document.
1.2. Go to the location in your document where you want to insert the visual.
1.3. Click on the “Insert” tab in the Word toolbar.
1.4. Select “Pictures” to insert an image from your computer.
1.5. Navigate to the image file you want to insert on your computer.
1.6. Once you’ve selected the image, click the “Insert” button. The image will be placed in your document.

2

TEXT WRAP VISUAL

2.1. Click on the inserted visual to select it.
2.2. Go to the “Format” tab in the Word toolbar.
2.3. In the “Arrange” group, you'll find options for positioning and aligning the visual.
2.4. Click on “Wrap Text” and choose the text wrapping option “Square.”
2.5. You can now drag the visual to the desired location within your document. It should seamlessly integrate with the surrounding text.



3

ADD CAPTION

3.1. Right click on the visual.
3.2. Select “Insert Caption.”
3.3. Type in the caption of your visual.
3.4 Change font to Roboto 10, black, no italics.

VISUAL PLACEMENT

PLACEMENT

Placing figures close to their significance allows the reader to make informed decisions by easily referencing visual data in relation to the supporting content. This proximity facilitates a quicker and clearer understanding of the significance of the figures. **When considering placement, prioritize how large the figure needs to be to be easily visible (intuitive).**

Placement is <u>often determined by the size the figure needs to be to legibly display the data.</u> If the figure must be a size that does not allow for placement beside its relevant text, then put the figure at the end of the paragraph. Otherwise, decide on its placement based on the following.

After

- Used to summarize or reinforce the findings or information presented in the text.
- After the reader has absorbed the textual content, they can refer to the visual as a concise visual summary or illustration of the key points discussed.
- Particularly useful for reinforcing the main takeaways from the text.
- **Detriment**: If the reader encounters the text without the visual context, they may not fully grasp the significance of the information until they reach the visual.

Beside

- Used when you want the reader to be able to refer to the visual and the accompanying text simultaneously while reading.
- Allows for a direct and constant comparison between what is described in the text and what is shown in the visual, enhancing the reader's understanding of the subject matter.
- This approach is often used for complex visuals or when it's essential for the reader to correlate specific details in the text with elements in the visual.
- **Detriment**: Can disrupt the flow of the text if not integrated seamlessly and may require careful formatting to ensure alignment and readability.
    - <u>**If the figure becomes too small to be intuitively usable/visible, do not use beside placement.**</u>

In the Appendix

- Used when you want to provide the reader with more detailed and relevant reference materials. May be used if the recipient of the deliverable requests that all figures and tables are put into an appendix.
- Allows for an extended reference beyond the text or presentation. Uninterrupted figures and tables make comparing similar datasets or designs easier for the audience.
- This approach is often used when a figure or table is highly detailed beyond what is needed to support the text or remains large in order to be understandable.
- **Detriment**: Can disrupt the readers train of thought when flipping back and forth between the text and reference material, decreasing overall understanding.

Below is a diagrammed example of expected figure formatting.
Credit to Fall 2025: Dylan Burkey, Lena Nguyen, Aaron Qu, Albert Liu.

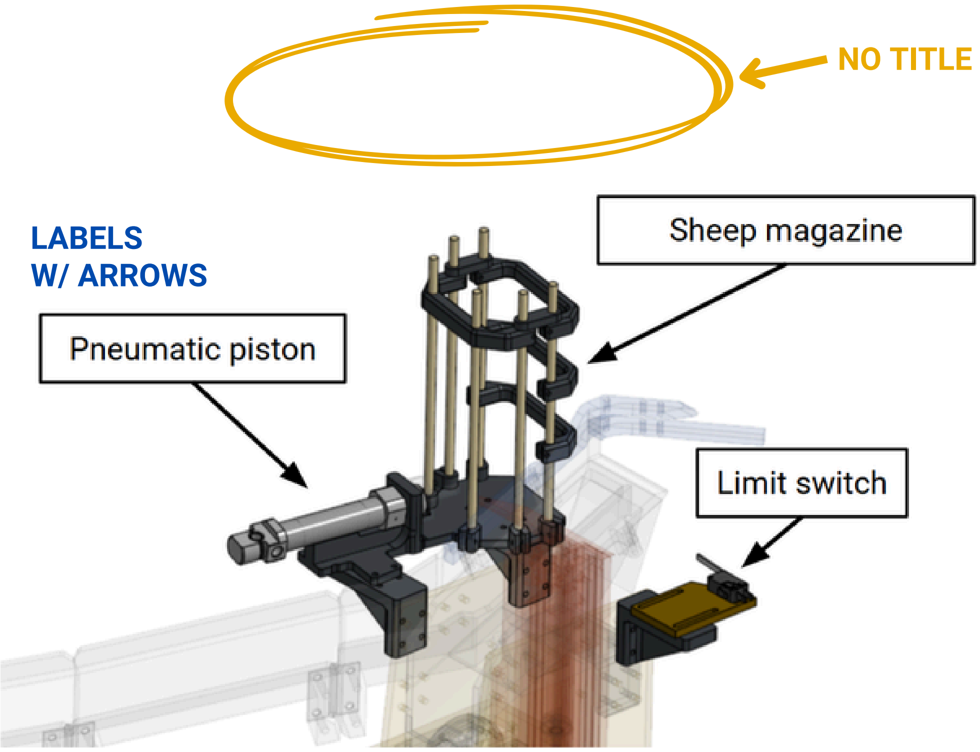


Figure 8: Isolated detailed view of the sheep depositing subsystem.

CAPTION

REFERRING TO FIGURES

In addition to placing figures in the body of the report or in the appendix, you should directly refer to your figures and call attention to their information that is most usable for making decisions. Doing this requires more than merely stating “see figure”; instead, make the value of your figures intuitive by explicitly telling the reader what to look at in the figure.

Non-Intuitive Integration ✕	As seen in Figure 1, ...
Intuitive Integration ✓	The orange shaded area of Figure 1 designates ...
	The rightmost column in Table 2 shows distance of [x] in order from shortest to longest.
	The visual peak (circled in Figure 3) represents ...
	The cross section view of the latest tested subsystem in Figure 4 highlights...

Note each figure or table has a callout or the text points the audience to a specific aspect of the figure or table. This confirms with the audience at least twice what information is pertinent, rather than relying on their memory from the text or their ability to draw conclusions from the figure.

Figures document data (evidence); therefore, it is unusual to refer to them in the topic sentence because, in typical paragraph structure, sentences on evidence come after claims (which are made in the topic sentence).

REMINDER

TS *(TOPIC SENTENCE) →* ***E*** *(EVIDENCE) →* ***C*** *(COMMENTARY) →* ***C*** *(COMMENTARY) →* ***E*** *(EVIDENCE) →* ***C*** *(COMMENTARY) →* ***C*** *(COMMENTARY) →* ***TA*** *(TAKEAWAY)*

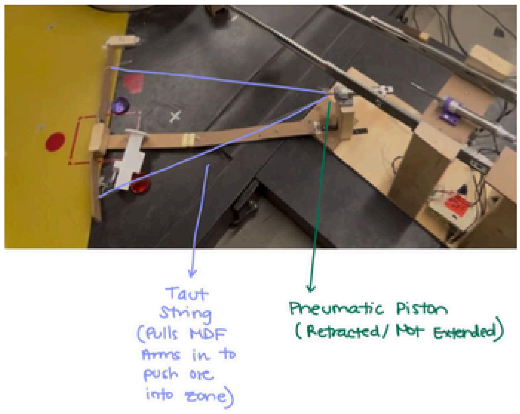
DESIGNING IMAGES

When creating technical figures, such as images and CAD views, for client audiences, it's important to follow practices that support quick understanding of the engineering commentary. Best practices include:

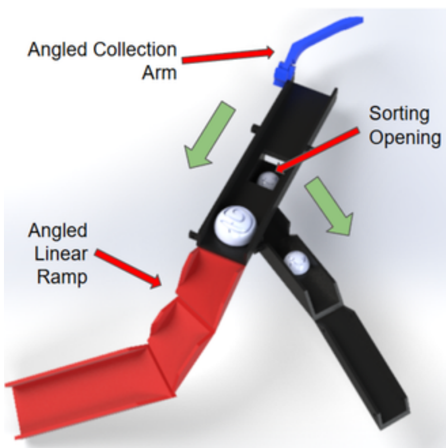
1. **Appropriate Cropping and Background:**
    - Zoom in to what you want the audience to see without removing supporting information. Crop distractions from the background.
    - Note distractions when taking staged images, like messy workspaces. Take the time to select a better background.
2. **Effective Lighting:**
    - Adjusting lighting in the room or on the CAD software so the resulting image is legible.
    - Note components that are similar colors making them hard to distinguish in darker lighting.
3. **Intentionally Aligned Annotations:**
    - Select a theme to align with the supporting commentary and use this to determine what annotations are appropriate for the image.
    - Example guiding questions to help determine a theme:
        - Is this image showing dimensions?
        - Is it highlighting how subsystems come together? Is it subsystem detail?
        - Is it calling out failure during testing?
    - ***Over-labelling does not lead to more understanding.***
4. **Use Arrows for Movement or Direction**
    - Highlight system or interaction movement with arrows.
    - Distinguish arrows for labeling and arrows for movement or direction.
5. **Use of Color:**
    - **Test for accessibility to ensure meaning is still correctly represented in grayscale.**
    - Employ a consistent color scheme that is visually appealing and aids in distinguishing different elements.
    - Consider using color strategically to highlight key areas.
6. **Simplicity:**
    - Keep the figure design simple and uncluttered to avoid overwhelming the client with unnecessary details.
    - Focus on presenting the most relevant information that aligns with the client's needs.

NOT ACCEPTABLE

BETTER



BEST



DESIGNING IMAGES

Below are examples of pictures that are not acceptable, better, and best with descriptions explaining why they are in these categories.

<table>
<tr>
<td>

NOT ACCEPTABLE

</td>
<td>

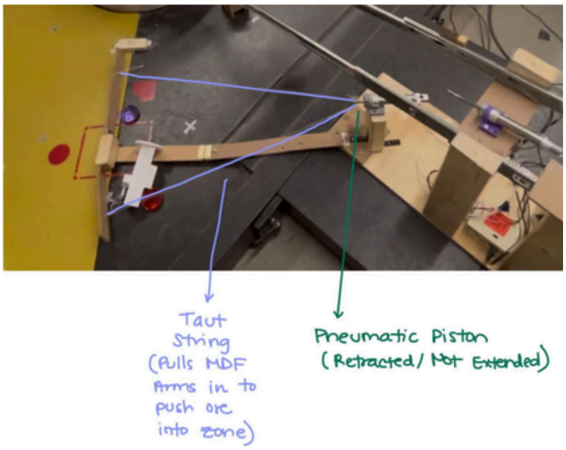
REASONING

- Con: Improper cropping
- Con: Poor lighting
- Con: No annotations or highlighting

In addition to the quality of the figure, it’s unclear why the figures are provided and what the takeaway could be.

</td>
</tr>
<tr>
<td>

BETTER



</td>
<td>

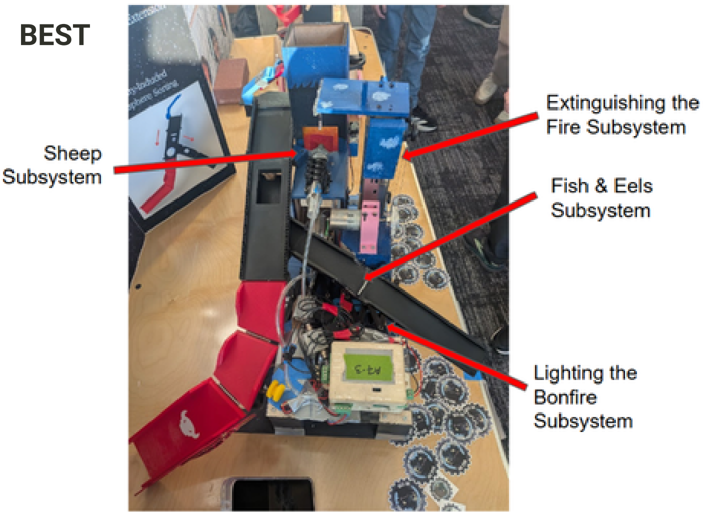
REASONING

- Pro: Thematic annotations
- Pro: Clear arrows/use of color
- Con: No highlighting
- Con: Improve cropping

Annotations support the takeaway, however, the cropping makes it difficult to the see the described detail. Highlighting, a cleaner background, and tighter cropping would aid clarity.

</td>
</tr>
<tr>
<td>

BEST



</td>
<td>

REASONING

- Thematic annotations relevant to the communication task (labeling subsysystems)
- Clear arrows
- Simplicity
- Con: Cluttered background

Subsystem labels appropriately communciate how functional subsystems are integrated into a larger system.

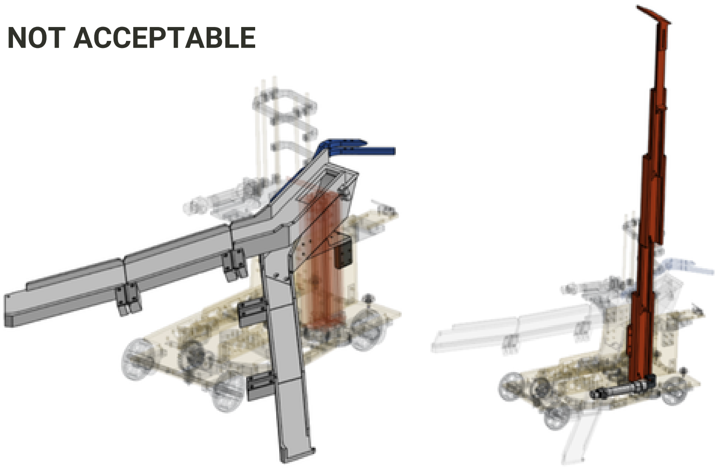
</td>
</tr>
</table>

Images courtesy of Nisha Detchprohm and Fall 2025: Dylan Burkey, Lena Nguyen, Aaron Qu, Albert Liu. Image in ‘Better’ category is cropped from a slide to reduce detail and fit example category.

DESIGNING IMAGES

Below are examples of CAD that are not acceptable, better, and best with descriptions explaining why they are in these categories.

NOT ACCEPTABLE

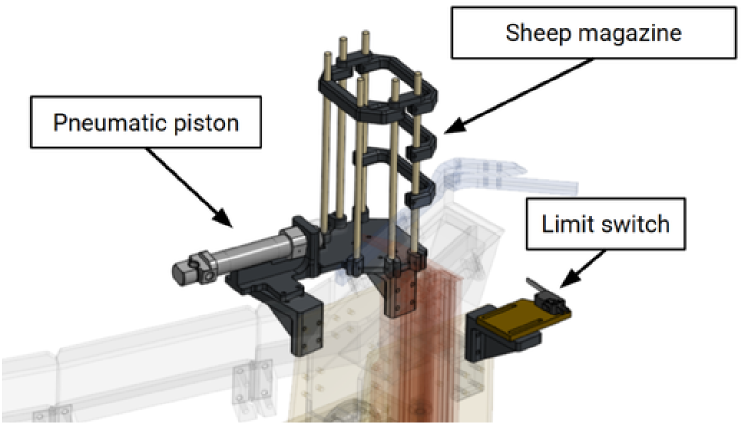


REASONING

- Con: No annotations or highlighting
- Pro: Good lighting
- Pro: Clear background, no distracting shadows

Even though the figures are clean, it's unclear why the figures are provided and what the takeaway for each subsystem could be.

BETTER

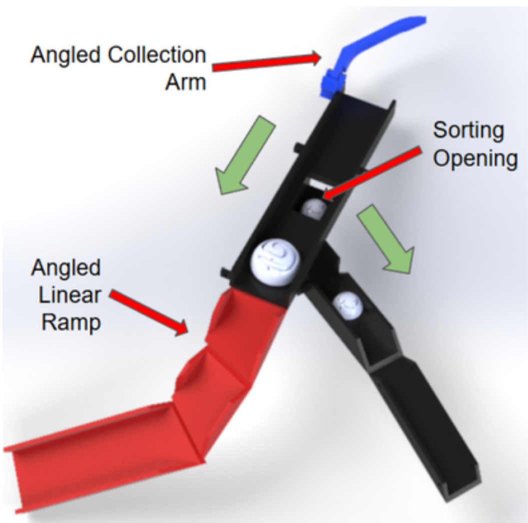


REASONING

- Pro: Thematic annotations
  - Con: Use of jargon
- Pro: Clear arrows
- Con: Not color-coded
- Pro: Good cropping

Labels are relevant to functionality of subsystem, but would be better if they referred to engineering functions. Components are similar colors, making them difficult to distinguish.

BEST



REASONING

- Pro: Thematic annotations
- Pro: Clear arrows, use of color
- Pro: View selection and cropping
- Pro: Simplicity

Figure clearly shows functionality with movement arrows. The lighting, view, and cropping support ease of understanding. Components are color coded to aid in identification.

Images courtesy of Fall 2025: Dylan Barkley, Lena Nguyen, Aaron Qu, Albert Liu and Dr. Denis Dorozhkin. Examples in the 'not acceptable' category are cropped to reduce detail.

DESIGNING TABLES

When creating technical figures, such as tables, for client audiences, it's important to follow practices that enhance **intuitiveness** and **usability**. Best practices include:

1. **Clean Up and Well-Format Text:**
    a. Type out data. Allows for adjustability between modes and legibility.
2. **Clear Direction of Data:**
    - Select a primary direction of main data and secondary direction of subsets within the main data.
        - Ex. U.S. Audiences read from left to right. Put the dependent or changing variables as the column and the independent variables as the rows.
        - Ex: Columns are completion rates per subsystem, rows are trials.
    - Stick with the selected directions throughout to avoid confusion.
    - Ensure that units of measurement are explicitly stated to avoid any ambiguity.
3. **Legends and Keys:**
    - Include legends or keys to explain symbols, colors, or patterns used in the figure.
    - Place legends in a location that doesn't obstruct the view of the main data.
4. **Distinguish Headers and Data:**
    - **Font Size, Bolding, or Different Font:**
        - Select a maximum of two fonts or sizes. Determine what font style is the header, sub-header, main data, call outs, etc.
            - This is plenty for technical writing and makes deliverables cohesive and polished.
        - Sans serif fonts are better for on-screen reading, serif fonts are better for print.
    - **Use of Color:**
        - Consider using color strategically to highlight shading or callouts key data points or trends.
        - Ensure that the shading is subtle enough not to overwhelm the data.
5. **Simplicity:**
    - Keep the figure design simple and uncluttered to avoid overwhelming the client with unnecessary details.
    - Focus on presenting the most relevant information that aligns with the client's needs.

NOT ACCEPTABLE

	Subsystem A	Subsystem B	Subsystem C	Total Average
Trial 1	4%	12%	3%	6.3%
Trial 2	12%	18%	3%	11%
Trial 3	20%	15%	2%	12.3%

BETTER

	Subsystem Success Rates (%)			Total Average (%)
	A	**B**	**C**	
Trial 1	4	12	3	6.3
Trial 2	12	18	3	11
Trial 3	20	15	2	12.3

BEST

	Individual Subsystem Success Rates (%)			Overall Success Rate (%)
	A	**B**	**C**	**Total Average**
Trial 1	4	12	3	6.3
Trial 2	12	18	3	11
Trial 3	20	15	2	12.3

DESIGNING TABLES

Below are examples of tables that are not acceptable, better, and best with descriptions explaining why they are in these categories.

NOT ACCEPTABLE

	Subsyst em A	Subsy stem B	Subsy stem C	Total Average
Trial 1	4%	12%	3%	6.3%
Trial 2	12%	18%	3%	11%
Trial 3	20%	15%	2%	12.3%

REASONING

- Poor formatting
- No visual distinction
- Unclear direction of information

Information is in the table with units, however, there is no visual distinction and text is chopped up. It is unclear what the takeaway from the table is or where the audience should begin reading the information.

BETTER

	Subsystem Success Rates (%)			**Total Average (%)**
	A	**B**	**C**	
Trial 1	4	12	3	6.3
Trial 2	12	18	3	11
Trial 3	20	15	2	12.3

REASONING

- Baseline formatting
- Distinction of headers
- Some direction of information
- Use of highlighting

Grouping of headers with units in the headers makes table information more digestible. Bolding of column headers makes primary direction clear. Highlighting of two columns makes the data for the takeaway clear, but the takeaway itself is uncertain.

BEST

	Individual Subsystem Success Rates (%)			**Overall Success Rate (%)**
	A	**B**	**C**	**Total Average**
Trial 1	4	12	3	6.3
Trial 2	12 +	18	3	11 +
Trial 3	20	15	2	12.3

REASONING

- Improved formatting
- Distinction of headers
- Use of highlighting and arrows
- Simplicity

Header formatting is visually different from data. Header grouping adds clarity with corresponding headers; individual versus overall and A versus total.

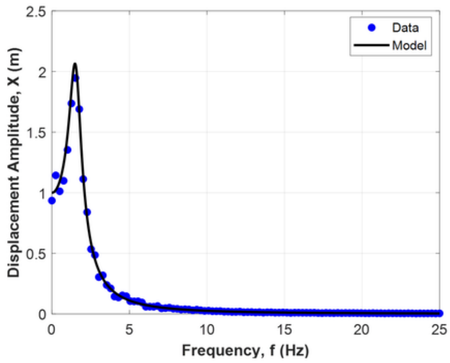
The highlighting with arrows clarify the takeaway as subsystem A's success directly influencing overall success.

DESIGNING TECHNICAL FIGURES

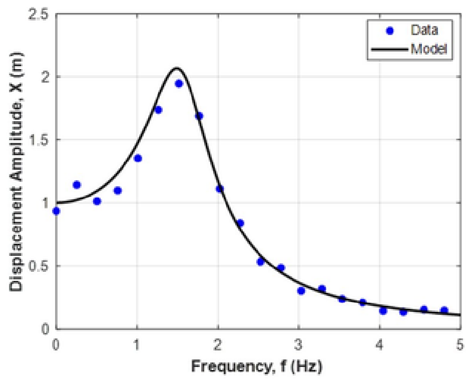
When creating technical figures, such as charts and graphs, for client audiences, it's important to follow practices that enhance **intuitiveness** and **usability**. Best practices include:

1. **Clear Annotations:**
    - Label axes, data points, and key features with clear and concise annotations.
    - Ensure that units of measurement are explicitly stated to avoid any ambiguity.
2. **Legends and Keys:**
    - Include legends or keys to explain symbols, colors, or patterns used in the figure.
    - Place legends in a location that doesn't obstruct the view of the main data.
3. **Appropriate Scaling:**
    - Choose appropriate scales for axes to ensure that the data is presented in a readable and meaningful way.
    - Avoid distorting the scale, as it can lead to misinterpretation (or misrepresentation) of the information.
4. **Use of Color:**
    - **Test for accessibility to ensure meaning is still correctly represented in grayscale.**
    - Employ a consistent color scheme that is visually appealing and aids in distinguishing different elements.
    - Consider using color strategically to highlight key data points or trends.
5. **Shading and Fill Patterns:**
    - Use shading or fill patterns to differentiate between areas or categories, especially in bar charts or maps.
    - Ensure that the shading is subtle enough not to overwhelm the data.
6. **Simplicity:**
    - Keep the figure design simple and uncluttered to avoid overwhelming the client with unnecessary details.
    - Focus on presenting the most relevant information that aligns with the client's needs.

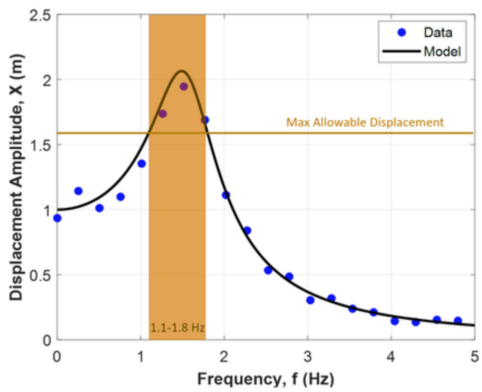
NOT ACCEPTABLE



BETTER



BEST

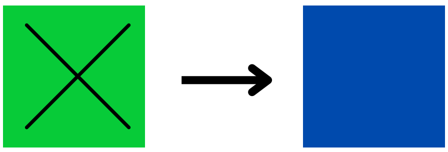


ACCESSIBLE FIGURES

Information designers often use blue and orange instead of green and red to annotate figures because blue and orange provide a more accessible and inclusive design for viewers, particularly those with color vision deficiencies.

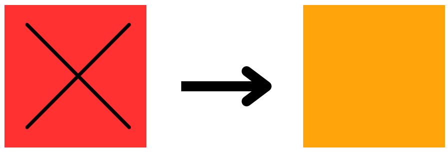
- The most common forms of color blindness, deuteranopia and protanopia (~1/12 men and ~1/200 women), affect the ability to distinguish between red and green.
- Blue and orange are distinct and easily distinguishable by most individuals with color vision deficiencies.
- Blue and orange create a strong contrast against each other and against most backgrounds. These colors are more distinct on the color spectrum and easier to differentiate.

BLUE = POSITIVE OR DESIRABLE



Blue as a stand-in for green, representing cool, calm, or favorable conditions.

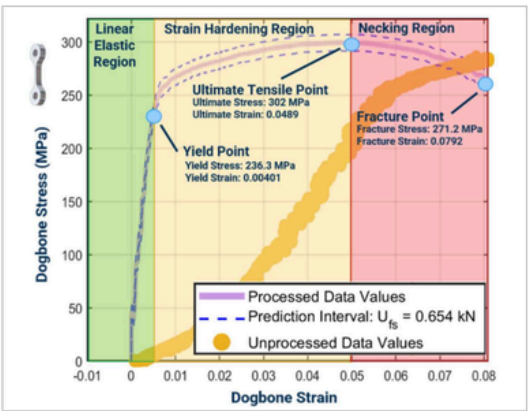
ORANGE = NEGATIVE OR UNDESIRABLE



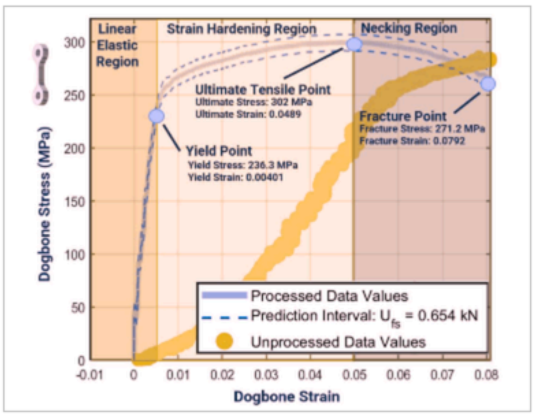
Orange as a substitute for red, representing warmth, warning, or critical conditions.

- *Success/Error Scenarios:* Replace green with blue for success and red with orange for error.
  - *Example*: Blue for "successful" and orange for an "unsuccessful" trial in a comparative trial visualization.
- *Positive/Negative Trends:* Use blue for gains and orange for losses in efficiency graphs.

ORIGINAL



***SIMULATED* DEUTERANOPIA**
(COMMON COLOR BLINDNESS)



You can check your figures but uploading them to online resources such as PILESTONE.

INFORMATION DESIGN

You already are an information designer.

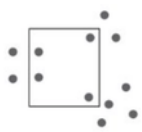
- As the person with access to the information, your communication controls your audience's experience of that information.
- To be effective, you need to purposefully design the audience's experience of that information to make it more likely that they will do want you want with that information.

<u>Communication design mirrors engineering design in it's efforts to lower cognitive load by playing into how people already respond to and interact with visual stimuli.</u>

Gestalt Principles of Visual Perception

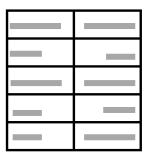
Proximity: Group related annotations close to each other. For example, place labels near the data points they describe. This helps users connect labels with specific elements in the figure.

Similarity: Use similar fonts, colors, or shapes for related annotations. This creates a visual association between elements and communicates their similarity or shared characteristics.



Closure: Enclose related information using shapes or lines. For instance, draw lines to connect labels to corresponding data points, forming a closed shape. This enhances the perception of connectedness.

Continuity: Arrange annotations in a continuous manner to guide the viewer's eye along a path or sequence. This is particularly useful when annotating time or trail-series data.



Common Fate: Align annotations that share a common purpose or relate to the same aspect of the figure. This reinforces the idea that these annotations belong together and serve a shared function.

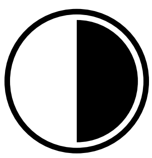
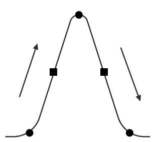


Figure-Ground: Ensure a clear contrast between the figure (main content) and annotations. Use different colors or shades to distinguish between the background and the annotated elements, improving overall visibility.



Connectedness: Use connecting lines or arrows to show relationships between annotations and corresponding elements in the figure. This reinforces the idea that certain elements are connected or dependent on each other.

FIGURE ANNOTATION SOFTWARE

CANVA

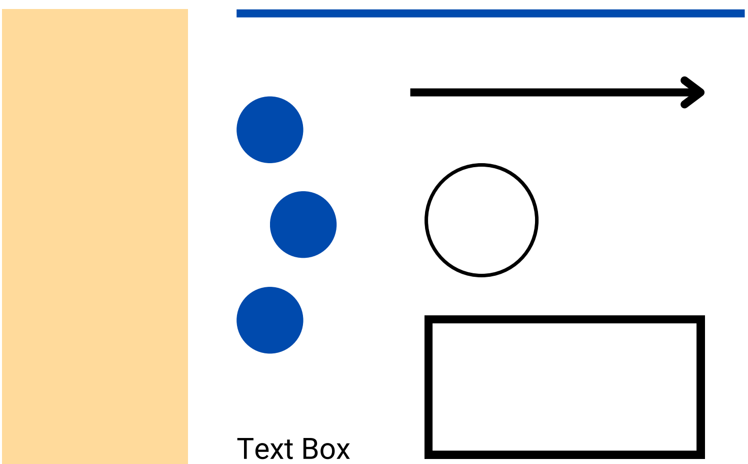
Canva provides a rich library of pre-designed elements, including icons, shapes, and text styles. This extensive collection allows users to easily add annotations, labels, and other graphical elements to their figures without the need for external design resources. It also allows for easy manipulation of layering and transparency.

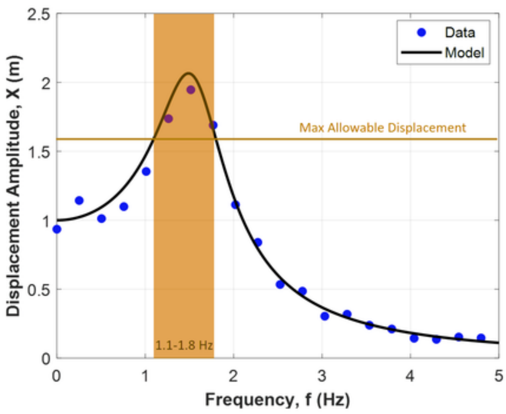
As an online tool, no app download is needed, and it facilitates collaboration among team members by allowing multiple users to work on a design simultaneously. This is useful for projects that involve input and feedback from different team members.

POWERPOINT

PowerPoint provides a range of text and drawing tools, allowing users to add annotations, labels, and other textual elements directly onto figures. This facilitates clear communication of key points within the figure.

PowerPoint enables users to layer and order elements, including figures and annotations. This is crucial for ensuring that annotations appear in the desired sequence and don't obstruct important parts of the figure. Users can customize the appearance of annotations by adjusting fonts, colors, sizes, and styles. This flexibility ensures that annotations align with the visual style of the figure and the overall presentation.





REPRESENTING UNITS

SPELL OUT

When referring to a unit without a value, spell out the word.

- The system was tested to determine its millivolts and hertz thresholds.

ABBREVIATION

Use the acronym when the unit is accompanied by a value (number).

- Testing resulted in sensor signal uncertainty of 1.7 mV (95.4% confidence) over range of sensor amplitudes from 0 to 2.26±0.1 V when tested at 500 Hz.

BRACKETS

Bracket the acronym when it follows a variable name (to avoid confusion).

- T_1 [K]

EQUATIONS

Report unit when defining variables in equations.

- $\dot{Q}_{12} = \sigma_{exp} \cdot A_1 \cdot F_{12} \cdot (T_1^4 - T_2^4)$ [1]
- Measure Power Transferred ($\dot{Q}_{12}$) [W] was determined from Equation 1, where σ_{exp} is the Experimentally Derived Stefan-Boltzmann Constant [$\frac{W}{m^2 \cdot K^4}$], r_1 is the Black-Body Aperture [m], F_{12} is the view factor [N/A], T_1 is the Black-Body Source Temperature [K], and T_2 is the Meter Temperature [K].

MATLAB CODE

Put units in the comment at the end of each defined variable, and include units in the variable names.

LISTS & TABLES

Lists should be integrated into paragraphs to provide context, interpretation, and a narrative flow to the information they present. By incorporating them into the text, the writer can guide readers on how to understand the information, highlight key points, and ensure that the information aligns with the overall purpose of the document.

This integration enhances the clarity and coherence of the content, helping readers understand the significance of the listed or tabulated information in the broader context of the text.

BULLETED LISTS

Use bulleted lists to emphasize key points, list items without a specific sequence For example, you'd use this list when you want to demonstrate:

- Equal or Egalitarian Nature
- Similarity
- No Implied Priority or Order

Lists should always be sandwiched between paragraphing that introduces the list and clarifies how the list should be understood or used.

Ultimately, the choice between bulleted and numbered lists depends on the specific content and the message you want to convey.

NUMBERED LISTS

Numbered lists should be used in specific circumstances. These include:

1. To convey a sequence.
2. To demonstrate priority or hierarchy.
3. To enhance quick reference to a particular listed point.

This list, for example, is numbered because the order of the listed material is from when it is most vital to use a numbered list to when it is more of a style preference.

Consistency within lists is crucial for maintaining clarity and readability in a document. **Lists can be presented as words or phrases, or as full sentences, but maintaining internal consistency within each list ensures a cohesive and organized presentation**. It is acceptable to use both types of lists within the same document.

TABLES

Step	Activity	Equipment	Parameters
1	Prepare blackbody device	Source, mounting fixture	N/A
2	Set up temperature control	Controller, thermocouples	Initial temperature: 300 K
3	Calibrate temperature sensors	Reference thermometer	Compare with reference
4	Establish experimental setup	Vacuum chamber, insulation	Low-pressure environment
5	Power on blackbody source	Power supply, control panel	Gradual power increase
6	Measure radiation spectrum	Spectrometer, data system	Record wavelength data
7	Vary temperature for observation	Temperature controller	Incremental adjustments
8	Capture thermal images	Infrared camera	Document temperature distribution
9	Analyze collected data	Data analysis software	Evaluate trends

Tables should appear at the end of the paragraph to their key relevance. They should be titled and captioned in the same style as figures with the exception of the title should be placed above the table (and left aligned).

Tables should use type-facing, alignment, and color to enhance the intuitiveness of the information while avoiding the over-production of visual stimuli. Use center-alignment sparingly if at all. When they are needed, make gridlines non-invasive.

COMMUNICATING WITH NUMBERS

IEEE STYLE RULES

- **Numbers 10 and Above:** Use Arabic numerals (e.g., "15 participants").
- **Numbers Below 10:** Typically spelled out (e.g., "three trials"), but exceptions exist for technical contexts, such as units of measure, percentages, and mathematical expressions (e.g., "3 mm," "5%").
- **Numbers in Titles:** Follow the same general rules as the body text.
- **Units and Symbols:** Always use numerals with units (e.g., "3 mA").

BEST PRACTICES FOR NUMBERS IN TECHNICAL REPORTS

1. Always Prioritize Clarity and Precision:
- Use Arabic numerals for all data, measurements, and calculations, regardless of size/quantity (e.g., “5 samples,” “3.14 cm”).
  - This practice avoids ambiguity and aligns with the expectations of technical readers.

2. Maintain Consistency:
- If your report includes a mixture of numbers, stick to a consistent format within the same context or section.
  - For example, in a results table, do not switch between “ten” and “10.”

3. Follow Industry Standards for Units:
- Always pair Arabic numerals with units of measurement, which should be abbreviated in standard format (e.g., “7 kg,” “15 ms”).
- Avoid spelling out numbers with units unless they are part of the narrative and do not indicate data (e.g., “The experiment lasted three hours” versus “3 hours”).

4. Use Numerals for Quantities, Dates, and Percentages:
- For technical contexts, always use numerals for quantities (e.g., “5 experiments”), percentages (e.g., “95%”), and dates (e.g., “July 4, 2024”).

5. Spell Out Numbers in Non-Technical Contexts:
- Use words for numbers in general text or **when they begin a sentence** (e.g., “Twenty participants were selected”).
  - Alternatively, rewrite the sentence to avoid starting with a numeral: “A total of 20 participants were selected.”

6. Group Similar Numbers:
- When multiple numbers appear in proximity and some are greater than 10 while others are not, use numerals for all to improve readability (e.g., “There were 7 groups with 15 members each”).

7. Tables, Figures, and Labels:
- Always use Arabic numerals in data presentations such as tables, graphs, and captions (e.g., “Table 3,” “Figure 2”).
- Label figures and tables numerically even if they contain textual descriptions.

8. Use Words for Approximate Values or General Contexts:
- When the exact value is not critical, you may spell out numbers to improve the flow of the text (e.g., “Approximately three dozen parts were tested”).

REFERENCES

In any cases where references are needed, use IEEE style.

IN-TEXT REFERENCES

In-text references should be cited in-line where they occur (not at the end of the sentence) by referring to its number in your reference list, the last name of the lead author, and applicable page number in square brackets. They should appear inside the punctuation when applicable.

EX.
[3, Lemma 2];

REFERENCE LIST

If references are made, a complete reference list should be included at the end of reports and labeled "References." These should be cited according to current IEEE style and numbered.

COMMONLY USED RESOURCES IN IEEE STYLE

Manuals/Software
J. K. Author (or Abbrev. Name of Co., City of Co. Abbrev. State, Country). Name of Manual/Handbook, x ed. (year). Accessed: Date. [Online]. Available: http://www.url.com

Book With Chapter Title
J. K. Author, "Title of chapter in the book," in *Title of Published Book*, X. Editor, Ed., City of Publisher, State (only U.S.), Country: Abbrev. of Publisher, year, ch. x, sec. x, pp. xxx–xxx.

Book With Editor(s)
J. K. Author, "Title of chapter in the book," in *Title of Published Book*, X. Editor, Ed., City of Publisher, State (only U.S.), Country: Abbrev. of Publisher, year, pp. xxx–xxx.

COMPLETE IEEE REFERENCE GUIDE LINK

CREATED BY THE WEBB COMMUNICATION PROGRAM

UNANSWERED QUESTIONS?

Defer to IEEE style regulations when this guide does not answer your questions.