How to Write a Design Report

Summary

A design report is the written record of the project and generally is the only record that lives once the design team disbands at the end of the project. The report has three sections. The first section describes the problem that was being solved and provides the background to the design. The second section describes the design and the third section evaluates how well the design worked by comparing its performance to the design requirements. The report starts with a short executive summary that contains a synopsis of the three sections. The body of the report is relatively short. Appendices to the report contain supporting information with the details needed by a reader who wishes to fully understand the design. While this document describes the general content and organization of a design report, some of the specifics (section headings, length, and format) may be determined by your project client.

Before You Begin

Some basics that you need to understand before starting to write a design report.

Definition: A design report documents the solution to a unique problem.

Purpose: To communicate the solution to a problem.

Audience: Anyone who has to implement your design, understand your design, or reference your design to solve their own problem. Typically, this is the project client. While the client may be familiar with the project, the report is still written as though the client is new to the project because that is the best way to tell the whole story.

A design report is different than a lab report that you might be familiar with. A lab report describes an experiment and its conclusions and has four main parts: Introduction, Methods, Results and Discussion. The major difference between design and lab reports is that design reports do not include a methods section (other than when describing the evaluation plan.) When performing an experiment, the method that you use to obtain an answer must be presented for someone else to validate the results. For example, when testing the emissivity of a material, the difference between using a thermopile and using an energy balance will affect the results. The absence of a methods section in your design report may be disconcerting because you might have spent up to half the semester considering different concepts before choosing one, but ultimately you won't write about that process. The audience only cares about what you came up with and not how you got there. A design report is not a history ("first we tried this and that did not work so then we tried this and finally we got to this"), but instead is results oriented. If you find you are writing about your concept selection process in the main body of your design report, you are writing too much.

Organizing a Design Report

A friend comes to you with a problem. "I haven't been sleeping at night," he says. You decide to help out. Upon further study you find that he hasn't slept on a box spring for three months, has a persistent backache and has been on a 90-ounces-of-coffee-a-day diet since his last heat transfer midterm.

Committed to your friend's well-being, you take the appropriate action. You find a box-spring on Craigslist for free. You suggest the use of caffeine-free tea after 6 pm and recommend that he play Bach softly as he falls asleep to drown out the sound of late-night buses. Your friend thanks you for the best night's sleep he's had in a while.

Word spreads and it isn't long before someone comes to you and says, "A friend of mine is having trouble sleeping at night."

What do you tell them? Do you say, "Easy, get a box spring and play Bach!?" If you did that, they would be confused. This is how you would answer.

> "My friend Tim was having problems sleeping at night. He had three problems. He had an unsupportive mattress, he was drinking WAY too much coffee, and there are noisy buses passing by his window every night."

The person would then ask you, "what was the solution?" and you would say

> "I got him a new mattress, got him hooked on caffeine-free tea, and had him play music to block out the background noise."

If you stopped there, you would most certainly be asked one more question, "did it work?" Therefore, you would continue

> "After we made those changes, Tim slept great for almost three weeks. He told me everything was back to normal, and what's better, he's become a huge classical music fan. The only drawback was getting the mattress for free off of craigslist. Next time I'd pay a little money for one that was less dirty."

This problem is not an engineering design problem, but the way in which it is documented is identical. Proper documentation includes three parts: problem definition, design description, and evaluation. All three are required to communicate your solution.

The figure below shows the basic organization of any design report and should be the model for any report that you write. The following sections provide more detail about the content for each part.
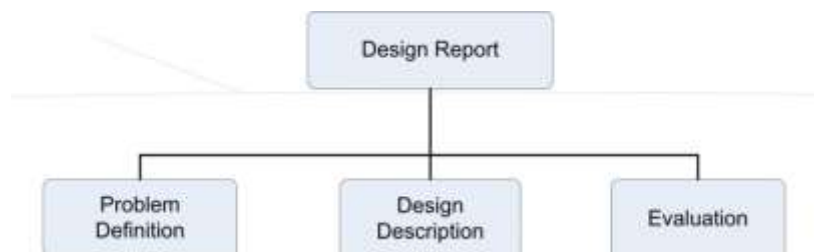
Problem Definition

In this part you describe the problem you set out to solve. You provide sufficient detail so someone can both understand why the problem is significant and how it has been solved in the past. Your problem is further detailed by providing key design requirements that the solution must meet.

The problem definition section should have the following subsections using the suggested labels for each subsection:

Problem Scope   A short paragraph explicitly stating the problem to be solved.

Technical Review   This section describes why the problem is important. It is a long section providing background information of the problem. It contains a state-of-the-art technical review that brings the reader up to speed to the current state of the field which you are working in. Chances are that the reader is not an expert in the field, as you are. Even if the reader is an expert, he or she will appreciate a comprehensive review of the field.

The review has two parts. The first part is a more detailed background to the field. For example, if you are developing a medical device, the background would be a tutorial on the medical condition being treated by the device. The second part describes the prior art relevant to the problem, which means all of the existing technology and methods relevant to the problem, including the ways the problem is dealt with now. The review can include commercial products, academic journal articles and theses, and patents.

The technical review will likely have many citations to the source of the information with citations listed in the Reference section. Citations and references should follow ASME, IEEE or APA style.

Design Requirements   Here, you describe the most important, measureable design requirements that drove your solution to the problem. Generally, there are about five requirements that are at the core of the design. Additional requirements are described in an appendix. At the beginning of this section, describe the source of the requirements. Typically requirements come through researching customer needs or in some cases the detailed requirements are provided to the designer from the client.

The design requirements are a central element to the design report and must be concrete, measurable criteria which can be tested. They should be based on a customer need. For example, "supports 80 lbs" and "has an emissivity greater than 0.8" are concrete, testable requirements. "Looks nice," "comfortable," and "low cost" are user needs and not design requirements. Refine them to measurable criteria, like "aesthetically rated above average on a 5 point Likert scale" or "can be held for 5 minutes without fatiguing the average user's hand," Or "parts cost less than $20 in lots of 100." Provide numeric values for all requirements. Numeric values can be binary for requirements that are best expressed in true/false form. The reason for having numeric values is that then it is easy to determine whether the design meets the requirements when the design is evaluated.

It is helpful to present the key requirements, typically no more than six, in a table. The table would include the design requirement, importance, units, marginal value and ideal value. For each entry, text describing the requirement, its source and why it is important should be in report body.

One last thing to consider when setting design requirements is that they must be tested by you. If you do not (or cannot) test a requirement using a virtual prototype (computer model) or physical prototype, then that requirement cannot be on your list of core design requirements. For example, do not use the design requirement, "can withstand a half-mile drop test," unless you are going to either make an analytical model or empirically test out of a C-130.

For examples of problem definition sections, read a U.S. patent. A well written patent generally has an excellent description of the problem to be solved, the prior art and why the prior art does not adequately solve the problem.

Design Description

In this part you describe what your solution is and how it works. You must describe your design in sufficient detail that the reader understands exactly what you did. This section is high technical because it dives down into the weeds of your design, but also must have a high-level overview so that the reader does not get lost.

The design description section should have the following subsections using the suggested labels for each subsection:

Overview   In a few paragraphs, summarize your design at a high level. First describe what your design does and then how it works. If appropriate, you can describe a scenario for its use. Include an overview line drawing (hand or CAD) but no photographs. The reason is that it is much easier to understand a design by viewing a line drawing than by viewing a photograph because the line drawing is limited to showing only the most important elements. This is why patents only have drawings and no photographs.

Detailed Description   This section dives down into the details of your design. Use subsections to guide the reader through this section as it will be long and complex. Start the section with a block diagram that shows the major functions or layout of the design, then use subsections to drill down into each block. For example, your design may have mechanical, electronic and software components. After describing this at a top level, use a subsection to describe each in detail. Use additional block diagrams as needed. For example, a section on software would likely include a flowchart or state diagram to help the reader understand what the code does. Do not include complete code listing, electronic schematics or CAD working drawings in this section as that would be too deep a level of detail. The place for those documents is in the appendices.

Use   In this section, describe how your design is used. For example, if your design is a surgical instrument, describe how the surgeon uses the instrument during a procedure. If your design is new coffee cup, describe how the consumer will use the cup. If your design is a process, describe how the process will be used. The purpose of this section is to provide the reader with a clear picture of what the design does. Generally, this section is short.

The design description part will be the longest part in the body of your report. For examples, again look at a well-written U.S. patent. In particular, notice how a patent describes a design by referring to one or more figures where key parts are annotated with numbers.

Evaluation

In this part you describe how you have verified that your solution works. You do this by evaluating your design against the requirements you outlined in the problem definition section. It is not enough to provide a solution to a problem; you must also demonstrate that it works. Evaluation could be through experimental testing of a physical prototype, through testing of a virtual prototype (computer model and simulation) or by analysis and hand calculations. For example, you might confirm that your design weight meets the requirement by using the mass analysis in Creo or SolidWorks to calculate the weight of the CAD model. Or, you could put your physical prototype on a scale. To confirm the required natural frequency of a cantilever beam you could calculate it by hand using the formula from a textbook.

The evaluation section is also where you describe any physical prototypes that you constructed. It may seem odd to you that physical prototypes would not be part of the design description section, but that is because the purpose of building a prototype is to determine if the design works.

Finally, the evaluation section is where you summarize the strengths and weaknesses of your design and describe recommendations for future work.

The evaluation section should have the following subsections using the suggested labels for each subsection:

> **Overview**   In this section, you provide an overview of your approach and an overview of the test plan for evaluating the design. Here is where you state whether the approach was by experimental testing of a prototype, computer simulation, hand calculations, user testing or a combination of these methods.

> In a new paragraph, include a summary table of the key design requirements from the problem statement section. A suggested structure for the table is that column one states the requirement, column two has the target value and column 3 has test method used to evaluate the requirement. The details come later in the evaluation section, so keep this summary short.

> **Prototype**   Here is where you introduce and describe the prototype. The description is top-level and includes the purpose and objective for building the prototype, what the prototype does and an overview of its key features. If appropriate, include a photograph. Reserve the detailed description of the prototype for an appendix. This is also the section where you present the computer model if you created a virtual prototype that you tested through simulation.

> **Testing and Results**   For each design requirement, create a subsection that describes how the requirement was evaluated. Use a lab report format, meaning that for each requirement, provide an introduction that describes the requirement and why it is relevant, methods that describes how the requirement was tested, results that presents what you found, and discussion that interprets the results, including whether the target value for the requirement was met. You might consider making the section headings (introduction, methods, results, discussion) explicit. Think of it as a mini-lab report because you won't have enough space to provide all of the

details. You may want to include a line drawing (generally better than a photo) of any experimental setup and apparatus that you used for testing. The full description of the evaluation test will be in an appendix. Remember that evaluation methods are not restricted to laboratory experiments. They can be a computer simulation, hand analysis, or a user survey. You can include a description of additional tests that should be performed either in this section or in the Next Steps section, wherever it fits best. This section is written in past tense because the tests were in the past.

Assessment   This is the brutally honest section where you assess the strengths and weaknesses of your design. Be enthusiastic, but candid. Do not oversell or undersell your solution. The assessment should be based on your evaluation, because presumably, a design that meets the requirements is a good design. However, the results often are different than what you expected, things are learned along the way and there is never enough time to perfect the solution. (Recommendation: avoid using "we ran out of time" as a theme in this section or anywhere in the report.)

Next Steps   In this section, state how the project should move ahead. Imagine that you are the project advisor. How should the company use the design? What areas need additional work? Who should do the work? Because one of your goals was to add value to the sponsor, a well thought out hand-off plan is critical for ensuring that the project. Remember that your design team is likely to disband at the end of the project so it doesn't make sense to assign to you the additional work.

Front Matter

The three main parts of the report have been described. In addition, there are parts of the report that precede the main section, and are described here.

Title Page   The front page has the project title, the names of the design team, the name of the client, the date and one graphic that best illustrates the design solution. The project title should be descriptive and generally is not the internal project name used by the team.

Executive Summary   The executive summary distills your entire report onto a single page and is for the busy reader who does not have the time to read the whole report. It contains a succinct synopsis of the problem definition, the design description and the evaluation. It is recommended that you use those headings in the executive summary to make sure that the summary touches all three points. That's what separates a summary from an introduction. The executive summary is placed right after the title page and before the table of contents, and should be limited to one page. Use passive voice in the executive summary. ("The objective of this project was to," rather than "our objective was," or "we developed a.")

Table of Contents   If the report is more than 10 pages, include a table of contents. Do not include a table of figures.

Back Matter

These are the sections that come after the evaluation part of the report

References   The references section has the list of references cited in the report. Use ASME, IEEE or APA style. (If you don't know what that means, look it up.) Citations are easier if you use a citation manager such as Zotero, RefWorks or EndNote. If you are at the University of Minnesota, the university library has excellent tutorials on using and formatting citations and using a citation manager.

Appendices   Appendices come at the back of the report and are not part of the main body. Appendices for a design report contain additional detail about the design that would not fit into the main body because of page limits or because including the detail would distract the reader from understanding the design. Content for the appendices could include patent search results, working drawings, schematics, computer code, rejected concepts, bill of materials, front pages of key data sheets, laboratory reports from the evaluation and so on. Your client will likely have specific requests for what to include in the appendices. While the appendices may be lengthy, do not go overboard. It makes no sense to include 100 pages of computer code. Instead, refer the reader to an electronic file.

Writing Style

First and foremost, be a good writer. The way to become a good writer is to do lots of writing and lots of reading. The best way to determine the writing style for a design report is to read professional reports. You might want to ask your project advisor if they have examples that could be shared with the team. Here are a few tips on style.

Voice   The report can be written in either passive ("a concept was selected") or active ("we selected a concept") voice. Pick whichever sounds more natural and be consistent.

Tense   Use past tense to describe what you did or found out. For example, "We built and tested a prototype." Use present tense to describe things that were known before your project. For example, "Squirrels are warm-blooded."

Self-Supporting   The main body of your report (without the appendices) should provide enough information to be understood and should not reference outside sources for information that is required for understanding what you did. An even more challenging bar is that your executive summary be self-supporting and that a reader can understand what you accomplished at a top level just by reading the executive summary.

Writing Level   Technical writing must communicate information clearly, effectively and succinctly. The language must not be excessive or complex and any company-specific jargon must be defined. Typically you write at an 8th grade level. This does not mean that you are dumbing down your engineering, but rather means that you are sticking to plain writing. Engineering writing is also fact-based, so be sure to back up any assertions you make using credible sources.

Separating Ideas   Divide your information up into small, manageable chunks and use headings to categorize the information so people can easily find it. Include only one idea in each

paragraph and state that idea in the first sentence. It's OK if the resulting paragraph is short. People would rather read several small blocks of text than one big block.

Figures, Tables and Equations   Technical reports almost always have figures, tables and equations. Use a profession style for captions, referencing figures and equations and for equation placement and punctuation. The best way is to follow the format and style that you find in one of your engineering textbooks. For example, pay close attention to the caption format (Plain? Italic? Centered? "Fig. 1" or "Figure 1"), how a figure is referenced in the body ("Figure 1"? "Fig. 1?"), how equation variables are described and so on.

Format

Your client may have requirements for the report format. If not, use 1 inch margins, single spacing, blank line between paragraphs, and serif or sans-serif font at 10 or 11 (preferred) point. Number the pages and provide a header or footer with sufficient information to orient the reader in the report. Headings should be appropriately formatted so that the reader knows where they are. Don't go overboard with fancy headings and if you chose to number headings, no more than three levels deep. (That is, stop at 3.1.2, no 3.1.2.1.).

The main body has continuous page numbers (title page through references.) Each appendix should reset the page numbers, for example, Appendix A starts on page A-1 and Appendix B on B-1.

The length of your report will often be dictated by who gave the assignment. If no length requirements are given. The main body of the report (the three main sections: problem definition, design description, evaluation) should be no longer than 25 pages. A comprehensive report is at least 20 pages. Of that length, no more than about 25% should be occupied with figures and tables. The purpose of the length limit is to keep your writing focused and concise. There are no length limits to the appendices, but keep things reasonable.

Review

Here, in one place, is the structure and sections of a design report

Section	Content
Title page	Key info and one illustration
Executive Summary	One-page summary of the project
Table of Contents	

Problem Definition
    Problem Scope
    Technical Review
    Design Requirements
	Introduces and defines the problem

Design Description
    Overview
    Detailed Description
    Use
	Describes the design

Evaluation
    Overview
    Prototype
    Testing and Results
        Subsection for each requirement
    Assessment
    Next Steps
	Evaluates the design

References	List of references used and cited
Appendices	All of the backup information