CHAPTER 23: FINAL REPORTS

Chapter outline

- Planning a final report
- Structure and content of a final report
  - Cover and binding
  - Title page
  - Front matter
    - Table of contents
    - List of figures
    - List of tables
  - Executive summary
  - Body
  - References
  - Appendices
- Writing style for a formal report

This chapter explains how to write a final report about a design. You will write this kind of report at the end of each quarter of EDC. The goal is to persuade the client (and others in the client's organization) that a proposed design solves the problem in a way that fulfills the major stakeholder needs. It must also include whatever information is necessary for your client to proceed with the project, particularly a discussion of limitations of the design concept.

23.1 PLANNING A FINAL REPORT

To understand how to plan a final report, let's look at how one team considers content in relation to audience, purpose, and tone (see discussion of "communication square" in Chapter 17). The project was to design a new library for a local elementary school.

- Audience: Our clients—the school principal and parents and teachers on the library planning board— are knowledgeable about school libraries, so we need to anticipate their questions about, and objec-

tions to, our design features. It's also possible the principal will show the report to building contractors, so we need to present drawings with detailed measurements and specifications (especially in the appendices).

- Purpose: To explain all aspects of our design, how it satisfies all client and user requirements, and its basis in solid research. After reading the report, readers should understand our design and be convinced to move forward with it.
- Content: Detailed explanation of our design and its rationale, supported by our research.
- Tone: Businesslike and straightforward. We should avoid engineering jargon. Also, although we are trying to "sell" our design, we shouldn't make the report sound like a sales pitch; all statements need to be to the point and well supported by facts, research, and testing.

23.2 STRUCTURE AND CONTENT OF A FINAL REPORT

Many companies, organizations, and classes furnish style and report guidelines that writers must follow. In EDC, your final report should include the following elements:

1. Cover and binding
2. Title page
3. Front matter: Table of Contents, List of Figures, and List of Tables
4. Executive Summary
5. Body (text of the report, divided into key sections)
6. References
7. Appendices

23.2.1 Cover and binding

To look professional, your report should have a cover and binding (preferably spiral, but Velo is acceptable). Ask your instructors what type of binding they prefer. Any of the copy shops near campus will be able to bind your report.

23.2.2 Title page

The title page should include:

1. Full title of report

2. Names of team members in alphabetical order, and team and section number
3. Date of document (the final presentation date)
4. Name of the organization for which the team works (Northwestern University, Engineering Design and Communication) and the names of your instructors
5. Name of the client and the client's organization
6. Professional-looking, easy-to-read fonts and basic colors. (Avoid fancy fonts and colors.)

23.2.3 Front matter

The "front matter" of a report refers to those pages that follow the title page and are numbered in italics (see the Note on numbering below). These usually include a Table of Contents, List of Figures, and a List of Tables. Some organizations require an abstract instead of an Executive Summary.

Note on numbering pages

Formal reports typically include two sets of page numbers. Pages in the front matter —Table of Contents, List of Figures, List of Tables—are numbered consecutively in lower case Roman numerals. The title page is not numbered, but the Table of Contents usually is ii. All page numbers—Roman and Arabic—are typically centered at the bottom of the page.

Regular page numbering, using Arabic numerals, begins after the front matter, typically starting with the Executive Summary.

Pages in appendices continue the numbering sequence from the body of the text.

Table of Contents

In order of appearance, the Table of Contents comes first. It lists the headings and subheadings of the document and the page number on which each begins. Subheadings should be indented. Make sure the headings and subheadings in the body of the document are the same as those in the Table of Contents.

The Table of Contents also contains a list of all appendices. List each appendix separately, along with the page number on which it begins. Each appendix should have a letter and title (for instance, Appendix A: Design Specification).

To punctuate a Table of Contents, place a series of periods, called "leaders," between the heading and the page number. The page number should extend to the right-hand margin.

See Appendix I for a sample Table of Contents

List of Figures

If your document contains more than five figures, put a List of Figures after the Table of Contents. Figures include illustrations, sketches, photographs, graphs, charts, and maps. The list should contain the figure number, the figure title, and the page number on which the figure appears.

NOTE: Consecutively number the figures throughout the report using Arabic numerals (Figure 1, Figure 2).

See Appendix I for a sample List of Figures.

List of Tables

If your document contains more than five tables, put a List of Tables after the List of Figures. If there is no List of Figures, put it after the Table of Contents. The list should include the table number, the table title, and the page number on which the table is found.

NOTE: Consecutively number the tables throughout the report using Arabic numerals (Table 1, Table 2).

See Appendix I for a sample List of Tables.

23.2.4 Executive summary

An executive summary encapsulates in one page the main points of the report so that executives and managers can read it quickly to make administrative and budgeting decisions without reading all of the detail in the body of the report. An executive summary typically contains:

1. A title that labels it an executive summary
2. A brief statement of the problem that led to the project (one or two sentences)
3. A brief statement of the purpose and scope of the project (one or two sentences). NOTE: If the project was funded by an outside grant, indicate that in this part of the executive summary.
4. A brief description of the methodology used to develop the design: interviews, user testing, performance testing, etc. (one or two sentences). Avoid mentioning steps that are common to all design projects, such as brainstorming, design reviews, and analysis of competitive products. Instead, focus on the steps that distinguish your project from others, such as your specific methods of testing mockups and obtaining information from experts.

5. A summary of the design and its benefits. This is the most important part of the executive summary and should describe the design's major features and benefits. You may briefly describe each feature and concisely state the major benefits of the design. Alternatively, you may describe the major requirements and explain how the key features fulfill each of them. You may present this summary as a table or in short paragraphs. You may also include a photo or drawing of your design.
6. If applicable, a brief statement (one or two sentences) of significant limitations of the design

The executive summary should be written after you write the rest of the report so that you know exactly what to include and can even borrow sentences and perhaps a figure from the report.

The executive summary appears after the table of contents (or list of figures and list of tables, if they are included), and should be written to stand on its own so it can be read independently of the report. It is NOT an introduction and therefore should not contain statements such as, "as the report will explain" or "see Appendix 4 for more detail." (Similarly, the report should be written so that it can be read independently of the executive summary; the report will need a separate introduction.)

Those who read an executive summary may not be experts in your engineering field, so you should write it in clear, relatively non-technical language.

Appendix J contains examples of executive summaries from two EDC final reports.

23.2.5 Body (text of the report)

The body of the report presents the design problem and your solution in a way that persuades the client that the design meets all stakeholder needs. The body of the report starts on the page following the executive summary and usually consists of the following parts. Naturally, the report should appropriately reflect the project, so if your project does not lend itself to this structure, talk to your instructors about alternative ways of organizing the report.

- Introduction that summarizes the problem and the report's purpose
- Major users and requirements
- Design concept
- Rationale
- Limitations
- Conclusion

Each of these sections is described below.

Introduction

The introduction briefly summarizes the problem and solution, states the purpose of the report, and lists its main sections. If the client is not the only person in the organization who will read the report, then you may need to explain the problem in greater detail. Write the introduction as if it will be the first thing readers read; do not assume they have read the executive summary.

See Appendix K for examples of effective introductions.

Users and requirements

This section explains the major users and requirements, and how you determined that meeting the requirements was essential to the success of the design. It isn't necessary to detail each stakeholder group and need because the complete list is contained in your project definition. For that detail, you can refer readers to the appropriate appendix.

Design concept

This is the heart of your report, the section that will be of greatest interest to your readers. That is why you describe your design and explain how it works rather than giving readers a narrative about the design process you followed to get to this point. Below are guidelines for explaining your design clearly. NOTE: Your prototype is not, in most cases, identical to your design; it illustrates key features and functions of the design. In writing this section, therefore, describe your design concept, not just your prototype. Use pictures of the prototype only to illustrate the design.

1. Begin with an overview of the design. Explain the design's overall appearance or main function (what is it? A device? A plan? A system?), list its major features, and briefly describe how it works. Use one or more illustrations. End with a brief paragraph listing the sections that will follow.
2. Present design subsystems and features using words, numbers, and pictures. The sections that follow the overview should combine verbal descriptions and illustrations of each feature. When describing features, include weight, dimensions, and other numerical specifications where appropriate to show readers that you have been attentive, as engineers, to the finer details of the design.
3. Organize the subsystems and features logically. The order in which you present them may be from most to least important; in the order in which the user interacts with them; from top to bottom or vice versa; etc.

Design rationale

In this section, you persuade readers that your design is based on sound research and will indeed solve the problem. Again, avoid a chronological dis-

cussion of the process you followed. Instead, organize the discussion around the major decisions you made: general approach, key features, materials, etc. Support those decisions using the results from your research and testing.

Here is an example from a team working on a project to design a low-cost solar water heater to be built and installed during the construction of homes in the Dominican Republic (Millea, Nieman, Suszko & Wroblewski, 2003). To support its general approach of using thermosiphon heating, the team drew on its email correspondence with an expert on solar energy and research from an authoritative manual on solar heater design:

Example 23.1: Supporting the design approach with authoritative research

> Thermosiphon heating, upon which our system is based, has been shown to be ideal in meeting the requirements our design must satisfy: simplicity, reliability, and adaptability. In email correspondence with us, John Harrison, senior research analyst for the Florida Solar Energy Center, wrote, "[T]hermosiphon heaters would be perfect for that area [Dominican Republic]. Actually, thermosiphons are by far the most common systems outside of the US. A thermosiphon system is simple, reliable, and can be made of materials that are perhaps locally available" (2003). In *How to Build a Solar Water Heater*, D.A. Sinson, a McGill University engineering professor, states, "The unit described [thermosiphon] has been designed to incorporate low cost materials generally available, even in relatively remote parts of the world" (1965). Those who build the system do not need special training or expertise; it can be built by inexperienced volunteers and can be adapted to the environment where it is needed most.

In the following example, the team draws on performance testing results to support its decision to combine black rubber hose with an acrylic-roofed box to heat water quickly:

Example 23.2: Supporting design features with performance test results

> A major advantage of the device is its efficiency in heating water quickly. Our tests on heating devices showed that on a partly cloudy 60 F day, a simple black rubber hose can heat water from 62 to 116 in two hours (See Appendix F: Test Results, Phase 1). The heating effectiveness of the hose greatly increased when it was placed in the design's acrylic-roofed box; water temperature rose from 61 to 132 in two hours. Based on linear models, the system would heat water to just over 150 F when the air temperature is 110 F (See Appendix G: Test Results, Phase 2).

The next example draws on results from both user and performance testing to support the choice of a particular feature. The project was to design an appara-

tus to allow individuals with limited wrist and hand strength, due to spinal cord injury, to drink directly from a variety of beverage containers.

Example 23.3: Supporting design features with user and performance test results

> Container Strap: The beverage rests inside of the container strap. A rubber pad and foam insulation covered with Dycem® securely hold the beverage container in place after the container strap is tightened with a D-ring. User testing revealed that users were able to operate the D-ring easily (see Appendix E). Dycem®—a non-slip, non-adhesive material—has been used with great success at the Rehabilitation Institute of Chicago for its clients who have difficulty gripping objects. Performance testing demonstrated that the strap can securely hold up to 20 lbs and has a surface area large enough to hold an Arizona Iced Tea® can, which is quite large, securely (see Appendix F).

Design limitations

As stated in Chapter 10, "Concluding Conceptual Design," few EDC projects culminate in a fully functional product. More commonly, they offer a prototype and detailed drawings. Teams do not have time to test the functionality of all the features to be sure the design will work as expected. Moreover, the design may not address all the requirements. As responsible engineers, you should, therefore, make clear to your readers what the design's limitations are and how they might be addressed.

See Appendix L for an example of how one team discussed the limitations of their design.

Conclusion

The body of your report should conclude by summarizing how your design meets the requirements, as in the following example (Millea, et al., 2003).

Example 23.4: Effective summary of design features in relation to requirements (1)

> To summarize, our design meets the key needs of families who will use the system and volunteers who will install it. The design uses a combination of:
>
> - a commercial-grade rubber hose capable of transporting water up to 180 F
> - PVC-coated copper piping that transports water at temperatures up to 180 F without significant heat loss
> - a 3/8" acrylic sheet that uses the greenhouse effect to heat water

> Families also need a system that is safe. Our anti-scald valve prevents injury from burns. Finally, families need a design that's simple to maintain and fix. Our water heater fills the bill because it uses no pumps, batteries, or electricity.
>
> Volunteers want a simple system that does not require rigid building specifications or hard-to-find materials. Unskilled volunteer carpenters can easily construct this system for under $820 in a matter of hours.

References

Your report must include a complete list of references of all the books, articles, websites, and interviews you've used to explain your problem and your rationale. This list appears at the end of the body of the report, but before the appendices. See Chapter 25 for more detail on documenting sources. NOTE: If the project was funded by an outside grant, indicate that above the list of references.

Appendices

Most reports require appendices that support or supplement information in the body of the document. They are useful for the following kinds of information, which some readers will want to examine in detail. For example, if your client wants to build your design, he will refer not only to your instructions but to the Bill of Materials to find vendor names and materials needed. If he wants to have more work done on the design, he may need to see what performance testing you have done and decide whether more testing is needed.

Useful kinds of appendices:

- Project definition: This is generally the first appendix. Its major purpose is to show that your design adequately addresses the requirements and specifications. Use it to double-check that your design DOES actually meet all requirements and specifications. Your design and project definition must be complementary.
- User observation results
- User testing results
- Performance testing results
- Expert interview results
- Background research (e.g., analysis of competitive products)
- Bill of Materials
- Instructions for building the prototype

Do NOT use an appendix as a dumping ground for everything you did on the project. You are writing for a real audience, whose time and attention are limited. You are not trying to impress your client or professors with bulk. There-

fore, include only the material your readers might find useful in understanding and validating your design process, or in implementing your design. You do not, for example, need to include class work, such as your list of brainstormed ideas.

Conversely, be careful not to bury important supporting data and illustrations in the appendix; these belong in the body of the report—because most readers won't read the appendices (and the body of the report should make a persuasive argument on its own). When determining where to put information, assume readers will not refer to the appendix the first time they read the document.

Inexperienced writers often have no idea how frustrating it can be to readers if reports are poorly organized, incomplete, or incorrectly numbered. Below are some guidelines for structuring and organizing appendices.

- Put only one kind of information in each appendix so readers can find information easily.
- Arrange appendices in the order in which you refer to them in the text. Label them sequentially: Appendix A, Appendix B, etc. Begin each appendix on a new page and give it a descriptive heading: Appendix C: Summary of User Test Results.
- Refer to each appendix at least once in the body of the text.
- Consecutively number the pages of the appendices, continuing the pagination from the body of the document.
- List the title and beginning page number of each appendix in the Table of Contents.
- Begin each appendix with a brief introduction explaining what the information means and how you obtained it. For example, the introduction to an appendix that presents a table summarizing the results of your user testing should explain what the table is, how the test was conducted, and what the headings and numerical values mean. An appendix must stand on its own, meaning readers must be able to understand its purpose and results without referring to the body of the report.

While it is tedious and time-consuming to order and label all of your appendices properly, the effort is worth it. Poorly handled appendices greatly undercut a report's credibility.

23.3 WRITING STYLE FOR A FINAL REPORT

A good design report is written in a professional style so that all of its ideas are clear and unambiguous and the report itself underscores your argument by being attractive and correct in all its detail. Naturally, if you have an inadequate design that fails to meet your design requirements or can't be justified

by research and testing, then no amount of good writing and pretty pictures will turn your material into a good report. But the opposite isn't true. If you have a good design that you can't adequately explain or justify, your client won't understand it; and if you submit a report that has interesting content but contains grammatical errors or typos, your client will begin to doubt your reasoning and question your attention to detail.

To write a good report, follow the guidelines for page design, visual communication, documentation, and revising for clarity and conciseness in the rest of this book (see especially chapters 6, 20, 21, 24, and 25).

23.4 REFERENCES

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