Research and Development Project Report Guide

Prof. Robert B. Darling

Dept. of Electrical and Computer Engineering, Box 352500
University of Washington
Seattle, Washington 98195-2500 U.S.A.

Rev. 1 April 2, 2018
Rev. 2 March 31, 2019
Rev. 3 December 9, 2019

Introduction

Research and development (R&D) projects are efforts undertaken to sustain and grow businesses or other enterprises by systematically introducing new products and services to meet customer demands and markets. When the research is very basic in nature, the R&D effort is more scientific; whereas when the research is more applied, the R&D effort is more commercial. Unlike pure scientific research in which the end goal is deeper understanding or discovery of nature, R&D has the very specific goal of creating new products and services for markets that may be either existing or anticipated. Development, the "D" in R&D, refers to creativity and innovation, which when paired with the principles of scientific investigation, the "R", comprises a systematic method for introducing new solutions, techniques, products, methods, and services. It strives to improve upon random evolution and guesswork by asking strategically phrased questions whose answers can be experimentally determined and used to guide a more direct pathway to productive outcomes. Pure science deals with the wonder of discovery and understanding nature; engineering carries additionally the responsibility to put that knowledge to useful good; and R&D is the process by which that is carried out within sustainable enterprises.

Presenting the results of an R&D effort is just as important as carrying out the individual steps of the process. If the results are not made accessible to others, then the effort has been wasted, counteracting the original goal of more efficient product evolution. Each product design cycle begins with a premise, a hypothesis, or a leap of faith upon which any further refinement depends. Usually, that further refinement is quite expensive, so prudence demands verifying and validating the initial premise or hypothesis as soon as possible. All R&D efforts are ultimately to answer a question. Is this product concept technically feasible? Can this design be created using this technology? Is design A or design B the more reliable? How can the manufacturing cost be reduced? What design will best serve the customer's need? In short, an R&D report tells the story of how the R&D question was researched and answered.

An effective R&D report should include the following components:

1. Title Page
2. Team, Roles and Responsibilities
3. Product Requirements Document (PRD)
4. Realistic Constraints and Engineering Standards
5. System Requirements Document (SRD)
6. Project Schedule
7. Project Resources
8. Outline of Experiments
9. Trial Designs
10. Experimental Outcomes
11. Impact and Consequences
12. Conclusions and Recommendations

13. References, Acknowledgements, and Intellectual Property

Components of an R&D Report

1. Title Page

This should contain the title of the R&D project, the R&D team, the parent organization, the laboratory or design division, the address of the organization, who is sponsoring the project, the project number, and the date that the report was submitted. Organizational branding is often included here.

2. Team, Roles, and Responsibilities

The organization of the R&D team should be presented first. Typically one member serves as the project manager who organizes the meetings and activities, keeps track of deadlines and resources, and who assigns team members to various activities to keep the project on time and within budget. The project manager is usually the lead author of the R&D report. Other members of the team would typically offer specific skills for the key activities of the project, such as software, electronics, mechanicals, industrial design, or design research. The project manager often participates fully in other activities, but the most important role of the project manager is leading the team to success.

The project should be broken down so that the role and responsibilities of each team member are clear. Although the final report is the work of the team, each member of the team must take ownership and full responsibility for carrying out their assigned roles. It should be documented and made clear who did what, who sparked the key ideas, and who pulled the team through the difficult issues.

3. Product Requirements Document (PRD)

The premise of the R&D effort is summarized in a Product Requirements Document (PRD) which is an industry-standard method for explaining a new product concept. The PRD addresses both the business rationale and the technical feasibility of the product concept at a high level. A PRD can be as short as a single paragraph, or sometimes as long as ten pages, but it is written in non-technical plain English that can be understood by a lay person. The audience for a PRD would include business development, sales, marketing, and corporate strategy personnel, as well as external investors, financiers, and publicists. It can be considered the elevator pitch or the white paper which is first reviewed by management to decide whether to fund the R&D effort. In many cases it is the short proposal which initiated the R&D project. The product requirements document describes the use model for the product by answering the following questions:

1. What is the need for the product?
2. Where will it be used?

3. Who will use it?
4. How will it be used?
5. What will it be used with?

Illustrations and sketches are valuable additions to the PRD. They can readily convey concepts which might be difficult to accurately describe otherwise. All types of illustrations or sketches are acceptable. These can range from artistically detailed photo-realistic 3D computer graphics all the way to rough hand sketches drawn on the back of a napkin. Whatever the medium or level of artistry, the most important aspect is to convey the product concept clearly and engage the audience with its prospects. The objective of the PRD is to be crisp, concise, clear, and connecting. The value proposition must be clearly evident.

4. Realistic Constraints and Engineering Standards

After the lofty new product concept has been extolled by the PRD, it becomes time for a reality check. Any design must eventually fall within certain boundaries set by practical constraints which may be resource, economic, environmental, social, cultural, political, ethical, health, safety, welfare, manufacturability, standards, sustainability, or timeframe driven. An assessment of these realistic constraints establishes the envelope around the design space. While the universe may be ever expanding, the design sandbox in this case has some hard boundaries. Engineering is the art of finding solutions in the face of complicating factors and inconvenient limitations, and assessing these constraints up front is important to keep the team focused and appreciate the scope of the problem that lies ahead. Some of these constraints will be rigid and inflexible while others will be softer and negotiable. Often one constraint may trade off with another.

The realistic constraints on a project are usually developed in parallel with the project itself, not all at the beginning or all at the end. As more is learned about the project through the research, the constraints on the project will become increasingly revealed. Start with a simplified list of everything that comes to mind as a possible limitation, and as research and discussion progresses, the list can be continuously refined until the core constraints emerge at the end of the R&D effort. The final list of realistic constraints should be a vetted one, that is, each constraint should have been researched to find the true limitation value or nature, based on data or mandate, not hearsay, folklore or speculation. Each constraint should also be non-trivial and pertinent to the technical and business choices that it will help guide. For example, a pertinent constraint might be, "the electronic components must all be RoHS-2 and Pb-free compliant." A not-so-pertinent constraint might be, "there are only 24 hours in the day." Which is true, but not a decision-making factor.

Engineering standards are an important consideration of any R&D project. It is essential to identify early on which standards the design must comply with, and to what degree. Some may be required for proper regulatory approval, while others may be required to ensure compatibility with existing systems to which the design must interact. Many safety and performance requirements are also specified within published engineering standards. The requirements of specific standards are additional realistic constraints which must be considered in the early specification of the design and should be discussed in this section.

Many realistic constraints can be directly incorporated into the System Requirements Document (SRD), described next, but often many realistic constraints defy numerical quantitation and instead involve human perception, preferences, and attitudes. Those are the ones to include in this section and which should be described by words rather than numbers.

5. System Requirements Document (SRD)

The system requirements document (SRD) is a set of specifications written by engineers for engineers. The SRD contains the full technical specifications that drive a given design. After an SRD is composed, it is handed over to the engineering department to develop a solution which satisfies all of the requirements in the SRD. Composing the SRD normally requires consultation or planning with the engineering department to achieve a set of realistic specifications. The SRD is composed from a conceptual system architecture that has been proposed as a design solution to the premise put forth in the PRD. In many cases, the SRD requirements may prove to be too restrictive to allow for a cost-effective solution, and the SRD requirements may have to be loosened up. This is handled through various design reviews and depending upon the severity of the change, may require re-evaluation of the PRD.

System requirements documents are conventionally organized using a hierarchical 1.2.3.4 numbering scheme so that each requirement receives a unique identifying number that can be referred to later in design verification testing. A table format is also most commonly used with columns for requirement number, requirement parameter, test conditions, minimum value, nominal value, and maximum value. The SRD presents quantifiable and measureable limits for each parameter from which any proposed or prototyped design solution can be tested and evaluated. It becomes a check-list to insure that a given design meets all of the needed requirements. The manufacturer data sheets for various electronic and mechanical components are a good example of the format and organization of an SRD.

Some of the requirements commonly found in an SRD are listed below. These are each general categories which would be further subdivided into more specific items.

1. Functional Requirements
2. Size, Weight, and Cost Requirements
3. Mechanical Requirements
4. Power Requirements
5. Thermal Requirements
6. Communication and Interface Requirements
7. Control Requirements
8. Computation Requirements
9. Software and Firmware Requirements
10. Data Storage, Format, Security Requirements
11. Precision and Accuracy Requirements
12. User Interface Requirements

13. Test and Validation Requirements
14. Electromagnetic Compatibility Requirements
15. Safety Requirements
16. Standards Requirements
17. Regulatory Requirements
18. Environmental Requirements
19. Materials Requirements
20. Patient or Clinical Requirements

6. Project Schedule

Most simply, the project schedule should be presented as a Gantt chart with time increasing towards the right. Milestones and critical paths should be indicated. An initial project schedule is usually composed at the beginning of a project, but good project management will also use that schedule to track progress through the project. This is necessary to understand the impact of delays and reassignments of personnel and resources. Conventionally, the original planned schedule and the actual completed tasks are plotted on the same Gantt chart to illustrate where the delays and progress slips occurred. Good project management will also attach specific team members to each of the tasks to optimize the available talent and timing of the team.

7. Project Resources

The R&D team members are always the most important resource of the project, but there may be other limited resources which must be managed as the project is carried out. These usually include funding, working space in the office, shop, or laboratory, high value components, consultants and technicians outside of the team members, and machine and testing lab time. In addition to simple financial budgeting, resource planning involves securing access and priority to facilities and scheduling time and engagement level with personnel outside of the team. This section can be a simple list of what resources were used and managed within the project.

8. Outline of Experiments

The R&D report is the story of the experimental development of a design, and the outline of experiments is the action narrative of that story. This explains the methods and techniques that were used to create the design, and then how that design was evaluated. The plot of the story will vary depending upon what specific questions the R&D effort is trying to answer. If the R&D question was of the form "will this design architecture work as desired?", then only one functional design needs to be developed, prototyped, and tested. If the R&D question was of the form "what type of design will achieve the required performance?", then the several attempts may be needed before a successful one is attained. Each of those successive failures should be documented, along with the lessons learned leading up to the final design, which presumably does meet the requirements. If the R&D question was of the form "what is the best design to meet the requirements?", then usually more than one design will be developed, prototyped, and tested so that the different designs can be compared directly against each other and the winner chosen based upon the testing and evaluation results. Playing off two or more design concepts against each other is an often used and effective method for perturbing the design space and ensuring that all options are being considered in the product development cycle. Some organizations have even been known to commission two or more R&D efforts with the same charter, but not known to each other, just to see how similar the resulting final designs ended up.

Inevitably, problems within a given design will surface, and the R&D team must engineer modifications and revisions to address those. The emergence and solution of these problems should also be documented in the outline of experiments. Engineering development is an iterative process, and the outline of experiments tells the story of how those problem and solution iterations were carried out.

There are many options for how to organize this tale, but chronological is usually the easiest to describe and understand. A laboratory or design workbench logbook is a common format for this. If laboratory notebooks or journals are used, the outline of experiments can be constructed as simply a high-level summary of those.

9. Trial Designs

Each of the designs developed for the experiments should be fully documented to the extent that they were developed. This would include block diagrams, schematics, bill of materials, PCB and assembly drawings, mechanical drawings, and software and firmware listings, along with an explanation of how the design is intended to work. In many cases, the different experimental designs that are being evaluated may be small variations from one another. In such cases, only the differences between them need to be described, rather than creating a completely independent set of design documents for each.

In the PCB world, one given PCB layout may be populated in different ways to achieve different functions, performance levels, or optional features. PCBs which are assembled in different ways are known as variants. Variants are one very commonly used vehicle for evaluating different designs to answer the question "which works best?" and many eCAD design systems allow one schematic design to contain and switch between all of the constructed variants.

10. Experimental Outcomes

The experimental outcomes chronicle the evaluation and testing results that were performed within the R&D project. Most importantly, each design should be verified against the requirements listed in the SRD. If the SRD has been organized logically, it can readily be converted into a test report for each design that is being evaluated. Besides the reported numerical test results, commentary is usually added to explain or discuss any unexpected or anomalous results.

In industry, the V&V process refers to Verification and Validation of a design. Verification is simply whether the design meets all of the SRD requirements, which can be carried out as a checklist that covers all of the test measurements. Verification addresses the question "is the product being built right?" By contrast, validation addresses the question "is the right product being built?" Validating a design involves testing the product prototype with the customer to ensure that the value proposition is being delivered to meet the customer's real needs. Usually, verification happens in the lab, and validation happens in the field. The V&V process is often a lengthy, time consuming, and detail oriented affair, but many industries require a full pass V&V before any new design is released to manufacturing. The high cost of setting up a manufacturing line and investing in the sunk cost of NRE items requires a high level of diligence to ensure a successful product enters the market. If any V&V effort was carried out, then this should be detailed in the experimental outcomes.

11. Impact and Consequences

In the interests of efficiency and expediency, an R&D project team must focus on the scope of work and avoid the tendency to become distracted by tangential issues. A good project manager will keep the team focused and on track to completion. However, as the R&D project is carried out, numerous considerations will emerge which were not originally within the scope of the work. Many will wind up being truly inconsequential, but others will bear significance which cannot be ignored. Each person on the R&D team has a professional and ethical responsibility to remain fully aware of the impact and consequences of the work products that they are creating. Being responsible in this manner means looking beyond the scope of work and taking a broader view of the project and its longer term effects, both positive and negative.

Engineers control the future by virtue of designing it, and with that power comes the responsibility of exercising informed judgment. The design envelope for any given project offers an infinite number of solutions, and the choices made within that envelope affect not only the performance of the product and perhaps the company, but also the employees, the local economy, the environment both local and global, and the health, safety, and welfare of all those who may become linked to the project in even the most indirect ways. One might choose, for example, a design which absolutely minimizes cost so as to optimize corporate profits. But one could also choose a design which costs a little bit more, but which creates significantly less environmental impact caused by manufacturing waste products. This choice, and innumerable ones like it, lie in the hands of the design engineers who must exercise informed judgment to make those decisions. Professional and ethical responsibilities will dictate part of that decision making process, but the underlying basis for those decisions rests upon broad awareness of the impact and consequences of each design choice.

Each R&D project should provide some statement of its impact and consequences, both locally to the product design cycle and the corporate business plans, and globally to considerations within broader environmental, economic, and societal contexts. It is not necessary or desired to evangelize one personally held belief in favor of another, but rather, to identify those aspects of the R&D project which involved the consideration of professional and ethical responsibilities, and to explain the impact and consequences of the project outcomes within those contexts. It is a matter of exercising and documenting due diligence within the R&D process.

12. Conclusions and Recommendations

This is the point to circle back to the originating question: what was the purpose of this R&D effort? Has the R&D work answered the question which prompted it? Rarely is the answer to this a simple yes or no. More commonly, the R&D effort has revealed new questions that may require additional work to resolve. The conclusions and recommendations section is the place to discuss the unexpected outcomes and their impact on the technical and business decisions which will follow from the R&D effort. A successful R&D effort normally reveals tradeoffs in performance, features, cost, and consumer needs which can be used to build a more successful business plan for the new product. The best R&D reports quantify these tradeoffs with numbers that can be used in future business models.

The most common error in composing conclusions is to present only a summary of the project. A summary belongs in a summary section or abstract and does not address what is desired for conclusions. Conclusions are the result of deductive reasoning that is based upon an insightful review of the experimental outcomes. Conclusions should attempt to answer the more profound questions which prompted the R&D effort. Those conclusions should then lead to logical recommendations on the next steps in the path forward. Prospective, insightful recommendations are what guide the product development cycle forward, not retrospective perfunctory summaries. R&D work is expensive, and the results of the effort should add substantive value to the company funding it. Make certain that value shows up in the conclusions and recommendations.

13. References, Acknowledgements, and Intellectual Property

A good R&D report cites all of the references which were used in by the team. These include published articles from magazines, manufacturer's data sheets and application notes, copies of applicable standards (AAMI, ANSI, ASME, EIA, IEC, IEEE, ISO, NIST, etc.), and any compliance requirements from regulatory agencies (EPA, FCC, FDA, FTC, etc.). Any other sources of inspiration may also be included here. Since much of today's data comes from the internet, the applicable web hyperlinks should be included.

This section should also detail what parts of the design's intellectual property are intended to be protected by either patent, copyright, trademark, or trade secret. New designs must be careful to avoid patent infringement. If a certain patent of copyright is being licensed in order to produce the design, that should be noted with reference to the signed agreement between the parties. Intellectual property ownership and infringement is a thorny issue, and the best preparation is to lay out explicitly what is being claimed with reference to the supporting documents. Patent application numbers and provisional patent numbers are very useful to cite here.

It is also worth noting that the vast majority of new patentable and copyrighted material results from R&D efforts. This is where new designs are born, and documenting their development or discovery is essential in creating a solid patent application. Laboratory notebooks that detail the inventors and their date of success are especially important to preparing a patent application. The invention details do not need to be documented in the R&D report, but the report should indicate if any patent or copyright material resulted from the effort.