EPICS

Design Process Document

An Introduction to Design

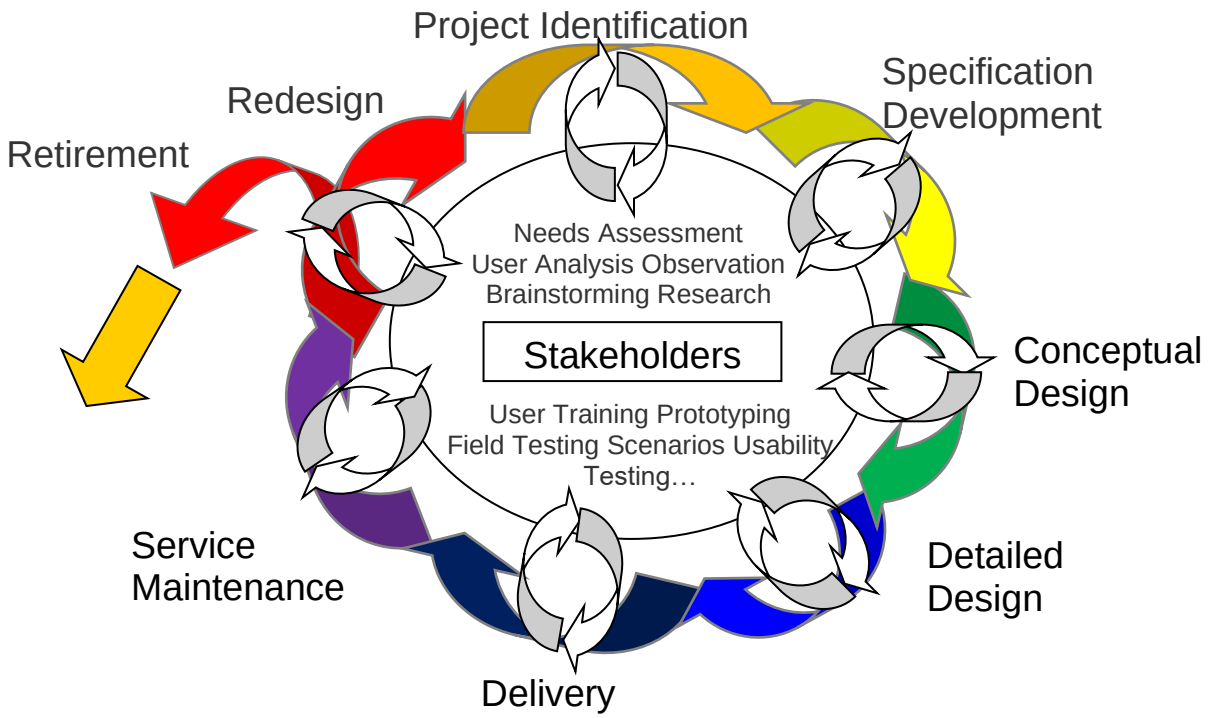
Contents

Overview

The EPICS design process is a series of steps that designers follow to solve problems and create products. There are many versions of design processes, but most versions follow a similar set of steps: Define the problem, set the specifications, propose conceptual solutions, choose the best solution, develop the solution into sufficient detail for fabrication, and finally build the solution. One of the key differences is that some of the design processes focus significantly more on the people involved in the design. These have been referred to as "human-centered" or "user-centered" design processes. The EPICS Design Process model is "human-centered" and will be used in the course to demonstrate and guide you through your project.

The EPICS Design Process consists of the following steps or phases:

- Project Identification
- Specification Development
- Conceptual Design
- Detailed Design
- Delivery
- Service and Maintenance
- (Retirement)



The EPICS Design Process model is not just a recipe for creating products or simply an exercise that you need to complete. The design process is the method through which the designer combines their technical knowledge, design experience, and research to develop a quality product. The success of your project depends on how well you complete each phase. The work of each phase will use the knowledge gained in the previous phases. While many

useful products can be made without using a formal process, following the steps of a design process will maximize the designers' probability of producing a successful and useful product.

As the team moves through the phases, sometimes you gain new knowledge about the requirements, constraints, users, context, usability, and/or capabilities of technologies being used that make it necessary to iterate or go back to a previous phase and complete it again. This is entirely normal, and students should not be discouraged. The design process is never linear and includes many iterations to arrive at a useful solution. Throughout these phases and iterations, the student designer should always engage their partners, instructors, and community users to ensure that they are working toward a useful final deliverable.

Project Identification Phase:

The first phase of the design process is Project Identification. The goal of the Project Identification phase is to understand the project partner's mission and the specific need that you will address. The knowledge that you learn from this phase should be recorded in Section 1 of the Design Document. The new team members must read the Project Identification section to understand the project.

During the Project Identification phase, you will work with your community partner to identify needs and opportunities that they would like the team to help address. Your project partner may have a clear idea of what they want your team to accomplish from the beginning, but often you will need to get to know them and understand their mission to identify potential projects. Your project partner may describe existing products that address some aspect of the need but have shortcomings that limit effectiveness, or they may describe a particular solution to the need. It is important to separate the need from the solution when conducting the needs assessment.

During this phase, the design team will establish the project scope. Project scope defines what is included in the project and specifies clearly what is not included. The project scope should be agreed upon between the design team and the project partner. It is helpful for team members to review the design document throughout the design process to prevent one of the most common problems in design projects, scope creep. It is natural for both the customer and designers to want to add features to the design as the progress inspires new ideas, and this unintentional expansion of the project scope is called scope creep. It is important, however, that any changes to the scope be deliberate, and that everyone understands and agrees to the impact of the changes, which may include an increase in the project budget, complexity, and time to delivery.

The following are some of the common tools and activities involved in the Project Identification phase. Your team may complete some or all of these, depending on the needs of your project.

Understand the Community Partner:

What is the mission of my project partner? Who are the clients that your project partner serves, and the challenges do these clients face? Are there stereotypes or prejudices associated with these clients? Are there differences in cultural understanding or behavior that affect the issue your project partner confronts or how the issue is framed? How do the following factors impact the project partner or the people they serve: socio-economic status, gender, race, ethnicity, and/or physical or cognitive disability?

How is my project partner organized? How is my project partner funded? What constraints does funding put on the organization? Are there regulations (city, county, state, federal, and/or professional) that dictate the behavior or guide the operation of your project partner?

Identify stakeholders and determine their needs: The project partner may not be the direct user of the project you are designing, but it is intended for the clients that they serve. It is important to understand all those people who might be involved in the project and gain an in-depth understanding of those users. You should identify who the users and beneficiaries are and what you know about them in general.

What are the high-level goals, objectives, and constraints that each stakeholder will contribute to the project? Will the final product be a production-quality version of the product, a report, process plan, or other?

Conduct a Needs Assessment: If the project partner's need is not clear, your team should complete a needs assessment. This typically involves visiting and observing your project partner discover opportunities to improve some aspects of the organization.

- What need of the organization could be addressed by your team?
- What product or processes are your project partner currently using, and what are the problems with the current approach that is motivating this project?
- What is the main goal of the project?
- How will addressing this need be important to your project partner?

Determine time constraints of the project: When will the project be started, and how long is it estimated to complete? Is a time frame required by the project partner for this project? Are there critical resources that could impact the timeline of the project?

Project Objective Statement: The results of all the above activities should be succinctly summarized in a Project Objective Statement. Both the Project Partner and Team should approve the Project Objective Statement as the overall guiding principle of the project.

Documenting Project Identification Activities: This section should include a concise statement that addresses such questions as:

- Why are you doing the project (i.e., what is the motivation or need for the project?)
- How does your project fit within the mission of the project partner and your team?
- Who is the project partner for this project?
- What is the overall mission of the project partner?
- Who will be affected by your project other than your customer?

- Who has a vital interest in the project's success?
    - Think beyond the end-user – Who has an interest in maintenance, storage, etc.?
- What is going to be the project results?
- When the project is finished, what will be left behind by your team?
- What functionality is in-scope and should be part of the project at this time?
- What functionality is out-of-scope and should not be included?
- What assumptions has your team made?

For more information, you may want to view this video tutorial:
https://tinyurl.com/EpicsProjectIdentification

Specification Development Phase:

Specifications are the performance goals for the project. The goal of the Specification Development phase is to understand what is needed by your community partner and to develop measurable criteria to use in evaluating design concepts. This is accomplished by understanding the context, stakeholders, requirements of the project, and why current solutions do not meet the project partner's needs.

There are several ways to gain both an understanding of the context, your stakeholders, and the task analysis. A common approach, which is also the most efficient, is to spend time with the users in the setting in which they will be using your project. If you are trying to develop a better device than one currently being used, try to observe them using the current device. This will give you a better understanding of what your users are capable of as well as better illustrate the issues you are trying to address with your project. Based on the observation, it is often helpful to develop a scenario, which describes the user and the product, and how they interact in the environment. The scenario can also be used to evaluate potential solutions. Another common way to gain insight into your users is to talk with your project partner. This can be done by a formal or informal interview. In most cases, they are dealing with your intended users daily and have a wealth of information to share. In addition, there are several other techniques for acquiring information about the stakeholders, the context, and the task, for example, literature review, user surveys, questionnaires, focus groups, ethnography, and role-playing.

The following set of tasks may help you develop appropriate specifications. The objective is not to just check off the task or answer the questions, but to use the tasks and questions to help you better understand the requirements of the project, how users and stakeholders will interact and be impacted by the project, the context in which the project will be utilized, and the measurable criteria which will be used to evaluate the project.

Understand and describe the Use Context:

How is the project going to be used? What are the physical dimensions of the space, the time allocated to the task, facilities available to support the project, etc.? What are other activities that are occurring during the same time? How often will the project be used? If it is not being used, where will the project be stored?

One key to understanding the user context is to understand the people who will be affected by the project, and how they will interact with it. Some tools to help understand these factors include:

> Create stakeholder profiles: Describe in more detail the various stakeholders that will be impacted by the project and how they will interact with the project. What are the expectations of the stakeholders? What actions can your stakeholders perform, what their level of understanding will be, and in what capacity will they be interacting with the project? It is important to consider all the stakeholders, including those who will be primary users, as well as those who will have to maintain it, service it, etc.
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> Develop user scenarios: How the user will interact with the project. The user interface is a key component of any design since this will be the only way someone will be able to make use of the project.

Compare to benchmark products (prior art): Do any existing products fulfill all the needs of the customer? If so, then that product should be discussed with the project partner to determine how to proceed.

Compile the list of Specifications and their metrics: Specifications are the values associated with the measurable evaluation criteria; that is, the values you are aiming to meet. For example, one of your criteria might be the access time for a database query. Your specification would then be the actual time you want that query to take. What quantifiable and measurable specifications will be used to evaluate designs?

Once you have determined what your project will need to do and how someone will use it, you will then need to find ways to evaluate distinctive design options. What you need to develop is a set of comprehensive, measurable criteria that can be used during the evaluation process. You should have criteria for each of the basic functions you have developed. Your criteria should also relate to the user requirements, the user analysis, and the constraints. You will also need to have specific criteria for the user interface.

Documenting Specification Development Activities: This section should include a concise statement that addresses such questions as:

- How is the project going to be used, and how could it be misused?
- What systems will the project interface with, and what are their requirements?
- What are the limitations of the space the project will reside in for use and storage
    - Consider the physical size, storage space, servers, ADA, or other standards.
- Who will maintain the project?
    - Consider site/application management, training, and access limitations.
- What are the environmental conditions?
    - Will the project be exposed to rain or sun?
    - Will the project be exposed to the public or children who may damage it?
    - What security issues need to be considered?
    - How durable does the project need to be?

- What are the social/societal factors that may affect the project?
- What are the technological limitations of the project?
- What other factors may be important for this context?

For more information, you may want to view this video tutorial:
https://tinyurl.com/EpicsSpecificationDevelopment

Conceptual Design Phase:

This phase should begin without preconceived ideas for the design of the product. The conceptual design phase spans from generating the first concepts to building prototypes to validation of the concept design. At the start of the phase, the goal is to generate as many workable solutions as possible and then evaluate the ideas to determine the best. Brainstorm a variety of approaches, evaluate the many different ideas, and then select the "best" one to move forward.

The following set of tasks or strategies may help you first explore and evaluate several concepts, then finally decide on the "best" concept for the project. The objective is not to just check off the task or answer the questions, but to use the tasks to better understand the benefits of the various solution strategies. It is possible that the specifications may be refined as knowledge is gained and a solution strategy is chosen. Some of the tasks could be undertaken several times (e.g., prototypes, proofs-of-concept) until a concept that can meet all the specifications is developed.

Concept Generation:

Now that you have a solid understanding of what your project will need to accomplish based on the specifications developed during the Specification Development phase and the Functional Decomposition, it is now time to start developing viable solutions that will meet those specifications. There are many tools and approaches to help the design team through the ideation of concepts. A few common approaches are outlined below, but if your team is struggling to generate promising concepts, try branching out to new techniques. What is critical is that you create a wide variety of concepts.

> Brainstorming: Brainstorming is one of the most common ways to generate ideas. When brainstorming, the key is to think of as many ideas as possible, no matter how strange or impractical they may seem. Each team member can suggest new, outside-the-box ideas, and the rest of the team can build upon them, remix them, or veer into unexplored directions. You should not reject any ideas at this point; simply keep a record of all the ideas that were generated.
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> Functional Decomposition: To perform a functional decomposition, determine the main function your project needs to perform. Break this function down into sub-functions. Continue this process until you reach the basic functionalities of the project. The key to a functional decomposition is that you only look at the *functionalities* required for the

project and not get caught thinking about ways to implement those functionalities. At this point, all you care about is what you need the project *to do*, not *how it will do it*. Once you break the project into basic functions, it can be easier to produce concepts to satisfy each function, freeing you from looking at the full system if that is causing the problem to feel overwhelming.

Benchmarking research: Another way to generate workable solutions, just as you did when developing the specifications, is to look at what others have already done. Looking at what has been done can show you how other people have tried to address the same problem and help you develop your approaches. Common ways to research prior artifacts are to do web searches, patent searches, talk to members of other EPICS teams, etc.

Low Fidelity Prototyping: Prototypes can be overly critical to communicating to your stakeholders your solution strategies as well as helping define an aspect of the design. You may be able to visualize what a potential solution will look like, but your customer may not. Having a "physical" model to show the customer and explain how the potential solution(s) will function will help when discussing the direction of the project with the customer. Furthermore, you may use multiple prototypes to demonstrate distinct aspects of the same project. It is important to get stakeholder feedback on your prototypes which can be used to develop and refine potential solution strategies.

A proof of concept or rapid prototype will allow you to test the feasibility of the potential solution, both in terms of the ease of implementation and its functionality. As with the prototype or mock-up, the key to developing a proof of concept is to get to a working model quickly. It does not have to be perfect if it adequately demonstrates how the potential solution would work in the final project.

Concept Convergence: Once you have several viable solutions, you may want to create a decision matrix to help choose between the different options available. A decision matrix is a systematic way to evaluate the possible alternatives in your design. The difficulty with a decision matrix is accurately determining the value of weighting and an objective rating of each criterion.

For a framework for decision matrixes, see: https://asq.org/quality-resources/decision-matrix

Concept Verification and Validation: Once you decide on one solution for the project you will need to verify and validate the design. In most cases, this will involve building a concept prototype and evaluating it against your requirements. Verification is the process of ensuring the Specifications are met, where Validation ensures that the User Needs are met. You may get part way into your design and test program and then realize that what you thought was the best option will not work after all. Do not limit yourself to this solution and try to force it to work. You can return to your list of concepts and begin again. You may have come across added information that you did not have before or developed new potential solutions. Redo your analysis of the potential solutions and move forward with the one that best fits the added

information you have. At this stage, you are not seeking 'final' Verification and Validation, but ensuring you are not wasting time on a concept that cannot ultimately meet the requirements.

Design Failure Mode Effect Analysis (dFMEA): A dFMEA should be initiated as soon as possible in the design process. The dFMEA should be considered as a living document and the team should review it several times during the product development. As the team adds detail to the design and additional knowledge of the product and specifications, this should be reflected in more detail and accuracy in the dFMEA.

dFMEA Resources: https://asq.org/quality-resources/fmea

Documenting Conceptual Design Activities: Below are several ways to document your work from the Conceptual Design phase:

Artifacts from the concept generation should be shown and described. This may include lists, descriptions, and sketches of the various ideas that were created. Include both your viable and nonviable ideas, with at least enough commentary that future team members can understand your thought process. Similarly, be sure to include sketches, photos, and/or videos of any prototypes, including a description of any details, analysis, and test results.

The means your team used to select the 'best' solution should be well documented, including what criteria were considered and how well each of your viable ideas fulfilled those criteria. The design matrix is one common way to consolidate all the different decisions you made about the design you have chosen. One of the best ways to organize your table is to list each of the specifications that your project will need to meet and list the solutions chosen to fulfill all those specifications. You should also have a column listing the overall reasons for choosing those solutions.

For more information, you may want to view this video tutorial:
https://tinyurl.com/EpicsConceptualDesign

Detailed Design Phase:

The goal of the Detailed Design Phase is to refine your concept prototype design to become a finished product. This may be a change in materials, manufacturing methods, or other features to improve function, durability, and aesthetics.

Bottom-Up Design: The concept design has demonstrated the overall functionality of the design. Now focus on each component and how the components interface with each other. For example, your concept design may have been a circuit built on a proto board that functioned properly. The final design may require a printed circuit board, an enclosure for the electronics, connectors for the power supply, etc. Each of the components can be developed separately but their design must consider how each component interfaces with the others. The main result of this step in the detailed design phase will be the diagrams, drawings, schematics, etc. needed to

construct the components and assembly of the project. Document the design of each of the components in design records.

Complete the Assembly: Complete fabrication, assembly, and testing of the interfaces between the completed components. At the end of this step, you should have a fully functioning product.

Risk Assessment: Risk assessment activities seek to minimize the probability that your deliverables could cause harm. The risk assessment should consider the users, the fabrication process, and the environment in which the project resides. The assessment should be done as a team, with every effort made to consider the failure modes from every stakeholder's perspective. This section should include a link or pasted image of any risk analysis or risk mitigation activities. One of the most common tools for risk analysis is the Failure Mode and Effect Analysis (FMEA). While it is recommended to begin risk assessment activities as early as possible in the design process, it is important to revisit the assessment and determine if any new risks have been identified before the project is delivered.

Final Verification and Validation Testing: Before the product can be delivered the product must be tested to verify that it meets all specifications and validate that it performs the function that fulfills the project partner's need. If it does not, the process iterates to examine the design.

Documenting Detailed Design Activities: Below are several ways to document your work from the Conceptual Design phase:

The artifacts created during Detailed Design vary more than in the previous phases and can be as diverse as the projects themselves. Your team's output may include drawings, prints, schematics, code, physical prototypes, Bills of Material, recommendations, manufacturing instructions, or any number of other viable products. In addition to the design artifacts, a final copy of the risk assessment and testing activities should be included in the Design Document.

For more information you may want to view this video tutorial:
https://tinyurl.com/EpicsDetailedDesign

Delivery Phase:

The goal of the Delivery Phase is to deliver the final product. This includes completing testing (functionality, usability, and reliability) and developing user manuals and training materials to support the delivery of the project.

Complete Usability and Reliability Testing: Final functionality, usability, and reliability testing should be completed to ensure that the design meets all the specifications.

Complete User and Training Manuals: The other key task in this phase is the development of user and training manuals. You need to provide a manual instructing all the stakeholders on how to use all the features of the project and provide routine maintenance. You should include

diagrams and pictures along with text explanations. Lists of steps are always helpful. You must have people unfamiliar with the project go through the manuals to determine if any portions require more clarification. In addition, an in-house repair guide may also be created to aid future teams in servicing and troubleshooting the product. File this manual with the project documentation

Complete Delivery Review: Before delivering the project to the project partner, you must go through a delivery review. It does not need to have taken place in the same semester as delivery. If possible, the delivery review takes place during the design reviews. Alternately a review could be conducted with the advisor, project partner, and other EPICS staff. You will present all the information on the functioning of the project and demonstrate the finished project.

Delivery Checklist: After you have completed the project and are ready to deliver it, you must first get the project partner's, your advisor's, and the EPICS administration's approval and complete the delivery checklist. This is needed to ensure that the project is safe and ready for being deployed to the community. To get the EPICS administration's approval, you will need to set up a meeting with the EPICS Academic Administrator, at which point you will demonstrate your completed project, and supporting documentation, and complete the Delivery Checklist (by team and advisor). The delivery checklist is a one-page document that EPICS requires to be completed for every project delivered. It ensures that everything is in order before placing the project out in the community. The form can be accessed at:
https://engineering.purdue.edu/EPICS/teams/team-documents/delivery-checklist

Service/Maintenance Phase:

Congratulations! Your project was delivered. However, it still requires ongoing evaluation and support from your team while it is in the field. Each semester your team should complete the following tasks and answer the associated questions to determine if the project should remain in the field or should be retired or redesigned.

Evaluate the performance of fielded project: How is the project performing? Does it still meet the needs of the project partner? Should the design continue to be deployed as-is, or is redesign or retirement required?
Determine resources required to support and maintain the project: Does the project require any fixes? Who on the team is prepared to provide service for the project is needed? Is additional training required?

Project Identification Phase: The goal is to identify a specific, compelling need to be addressed	
Common tasks	Conduct needs assessment (if need not already defined) Identify stakeholders (customer, users, person maintaining project, etc.) Define basic stakeholder requirements (objectives or goals of projects and constraints) Determine the time constraints of the project
Gate 1: Continue if have identified an appropriate EPICS project that meets a compelling need	
Specification Development Phase: The goal is to understand "what" is needed by understanding the context, stakeholders, requirements of the project, and why current solutions do not meet the need, and to develop measurable criteria in which design concepts can be evaluated.	
Common tasks	Understand and describe the context (current situation and environment) Create stakeholder profiles Create mock-ups and simple prototypes: quick, low-cost, multiple cycles incorporating feedback Develop a task analysis and define how users will interact with the project (user scenarios) Compare to benchmark products (prior art) Develop customer specifications and evaluation criteria; get project partner approval
Gate 2: Continue if the project partner and advisor agree that have identified the "right" need and if no existing commercial products meet design specifications.	
Conceptual Design Phase: The goal is to expand the design space to include as many solutions as possible. Evaluate different approaches and select the "best" one to move forward. Exploring "how".	
Common tasks	Conduct Functional Decomposition Brainstorm several viable solutions Create prototypes of multiple concepts, get feedback from users, refine specifications Evaluate the feasibility of potential solutions (proof-of-concept prototypes); select one to move forward *if it can meet all specifications* *Initiate dFMEA analysis*
Gate 3: Continue if the project partner and advisor agree that the solution space has been appropriately explored and the best solution has been chosen.	
Detailed Design Phase: The goal is to design a working prototype that meets functional specifications.	
Common tasks	Design/analysis/evaluation of project, sub-modules, and/or components (freeze interfaces) *Continue dFMEA analysis of product* Prototyping of project, sub-modules, and/or components *Performance and durability product testing against specifications.*
Gate 4: Continue if can demonstrate the feasibility of the solution (is there a working prototype?). Project Partner and advisor approval required.	
Delivery Phase: The goal is to refine the detailed design to produce a product that is ready to be delivered! In addition, the goal is to develop user manuals and training materials.	
Common tasks: Complete user manuals/training material Complete usability and reliability testing Complete delivery review	
Gate 5: Continue if Project Partner, Advisor, and EPICS Admin agree that the project is ready for delivery!	
Service/Maintenance Phase	
Common tasks: Evaluate the performance of the fielded project, *update dFMEA* Determine what resources are necessary to support and maintain the project	
Gate 6: Project Partner and Advisor approve continued fielding of project. If not, retire or redesign.	
Retirement or Redesign	