

INTRODUCTION TO ENGINEERING DESIGN

Engineering Design, at its simplest, is problem solving that depends upon the application of Physics, Mathematics and the other sciences. Aesthetics and societal considerations may also play an important role in the design development process. The following will help you understand and define design problems and develop design solutions. A visualization of the design process (Figure 1.0) can be found at the end the document.

DEVELOPING DESIGN CRITERIA

The design process begins with developing design criteria. There are a number of factors that must be considered and the Design Trinity – Familiarization, Functionality, and Testing – must be consulted at every stage of the design process. The design team must take into account the following:

1. **Client Needs:** The design team must interpret client needs. Often, the client will not know exactly what they need and will turn to the design team to propose solutions.
2. **User Needs:** The needs of the end user should be considered along with client needs. The end user of the design and the context in which the design will be used are important consideration during the whole of the design process.
3. **Design Context:** The design team must determine the context in which the design will be used and identify any DFX (Design for X) constraints.
4. **Project Criteria:** Cost, scheduling, manpower, et cetera should be considered. These details help ensure that the design solution will remain within the scope of the project.

Client needs often suggest what the **Functionality** the design should be, but in this initial stage of the Design Process **Familiarization** and **Testing** should be conducted to help further refine **Functionality**. The design team should **Familiarize** themselves with all details of the design context, taking into account any DFX constraints. **Testing** can be included by addressing preliminary concerns such as potential materials. Additionally, the design team should **Test** the assumptions of the client in relation to user needs, design context and the limitations of project criteria. This information will help the design team to begin re-defining **Functionality** towards a workable design solution.

REFINING FUNCTIONALITY

The first trip around the Design Trinity will help the design team to establish some basic functional requirements. From this point the design team can begin formulating some potential design solutions to meet the needs of **Functionality**. There are a number of tools that can help the design team focus and perfect design solutions, and **Familiarization**, **Functionality** and **Testing** remain central concerns. The following design review tools will help the design team to direct design choices and define functionality.

It is important to remember that at any time during the design process the design team is free to re-evaluate the decisions they have made and make changes to them. The following tools will help the design team identify potential problems early on, allowing them to address them before they become major issues.

1. A **Prioritization Matrix** (in this tool box) can help the design team weight the relative importance of design criteria, allowing them to focus and agree on important design decisions. Further **Familiarization** should be conducted to ensure that all design criteria are properly weighted and not in conflict with the design context or any societal, socio-economic, or geographic issues etc.
2. An **Evaluation Matrix** (in this tool box) can help the design team determine which design options have the greatest potential to meet the established design criteria. This will help to further define the **Functionality**. **Familiarization** should again verify the appropriateness of the design options.
3. The **Design Criteria Checklist** (in this tool box) allows the design team to ensure that all design criteria are valid and accurate and appropriately address the client and user needs.
4. **Failure Modes and Effects Analysis** (in this tool box) can help the design team identify potential design problems before they become costly mistakes. The specific details of **Familiarization** and **Functionality** must be considered when conducting FMEA. The results of FMEA requires **Testing** of specific parts, components, materials etc.

TESTING DESIGN CRITERIA

The information the design team gathers while moving through the Design Trinity helps them to establish a list of design criteria. Design criteria address all aspects of the design problem from what it must look like to appeal to the end user to what the budget will allow for, and from gear ratios to system controls. Before the design team moves on to testing design options, they should have a list of criteria the design, or its component parts, will fulfill. The list of design criteria does not need to be exhaustive, but it should indicate the direction of the solution path.

Design criteria must be tested. Testing must prove that the criteria will be fulfilled by the proposed design solution. Should testing fail to verify design criteria, another design solution must be found. This will often require that the design team cycle back to the earlier stages of the design process.

TESTING DESIGN OPTIONS

Having been through the Design Trinity twice already and established and tested design criteria, the design team should have a clear idea of the functional requirements of the design problem before they begin any focused component, mechanism, or part testing. Individual components, mechanisms, and parts must be tested individually before any large scale testing of the complete design is attempted. The design team may find it useful to prioritize the components, testing those which impact the rest of the design first.

Testing Design Options will result in one of two outcomes:

1. Testing verifies that the component fulfills the functional requirements.

2. Testing indicates that the component does not meet with functional requirements. **If testing verifies** the component the design team should consult the information acquired during **Familiarization** and verify the appropriateness of the component. The **Functionality** should also be verified to ensure that the component is fully compliant with all details of the design problem. Even though the part has been verified by testing, if new information indicates that the part does not comply, the design team must alter the component, or the whole of the design if necessary, looping back to the initial stages of the design process. If the design team does not find any problems, other components can then be tested.

If testing does not verify the component, the design team must cycle through the Design Trinity to identify the source of the problem and how to proceed.

1. **Familiarize** with the results of the test and perform necessary analysis. What aspect of the component failed? Is this failure likely to occur in other parts? Perform FMEA and re-define **Functionality** as necessary, verifying any changes to functionality with **Familiarization** and **Testing**.
2. How will the **Functionality** be affected by the failure of the part? What is the impact to the other components? Does **Functionality** need to be re-defined? The design team may want to re-consider other design options.
3. **Test** other primary components of the design option.
 - a. Do they fulfill the functional requirements? If yes, should the component that failed be modified?
 - b. If the testing of other components does not produce favorable results, is there another design option that will fulfill the design problem?
4. **Modify component/design option.** When all components of the Design Trinity have been considered the design team can modify parts and design decisions to correct the failed component.

The design team should continue in this manner until all components have been tested ensuring that all part modifications are verified by Familiarization, Functionality, and Testing. When all components are verified, the whole device should be tested. Again, any problems that result from testing the device should be approached via the Design Trinity according the procedure outlined above for component testing.

ARRIVING AT A DESIGN SOLUTION

By cycling through the Design Trinity, the design team will arrive at a workable design solution. Although it may require multiple trips through Familiarization, Functionality and Testing, these steps will lead to a successful design solution.

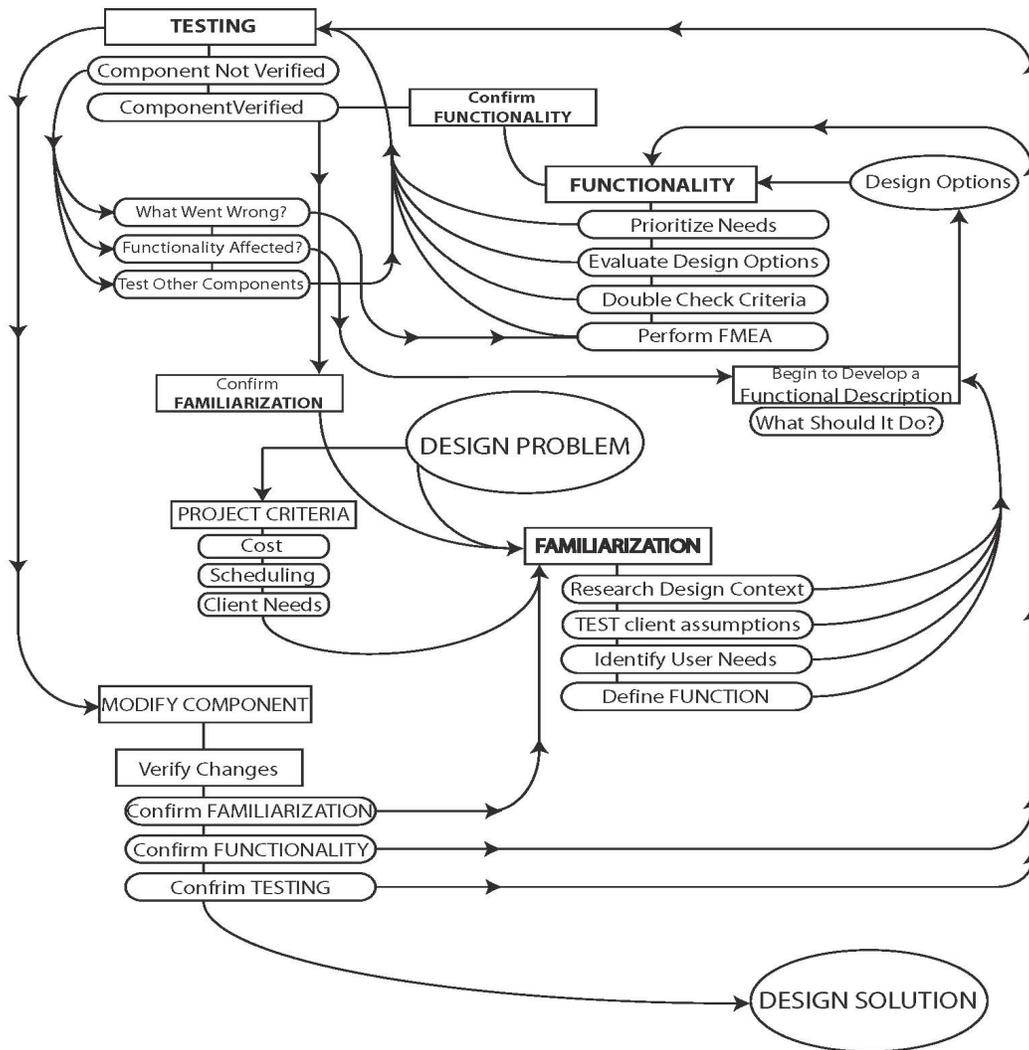


Figure 1.0 – How to approach design problems