Avoiding Failure in Design

A guide to utilising FMA to catch problems before they happen.

When it comes to designing and launching space vehicles, airplanes, and cars, product failure of any kind is simply not an option.

Over the past 50 years, the automotive, aerospace, and manufacturing industries have developed front-end design processes that reduce failures and R&D costs whilst improving product quality.

Locus has developed expertise that leverages these Failure Mode Avoidance (FMA) techniques and applies them to product design, though the tools and techniques are not limited to the product design space.

This type of systematic thinking is applicable in any innovation space: process design, software design, attribute improvement, etc.

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Failure Mode Avoidance in the NPD Landscape

Increase quality, save time, and reduce R&D costs; it's a win-win-win situation

Throughout the product development process, there are on average five engineering changes per part[1]. The average cost of an engineering change is estimated at $50k[2] (resource cost, manufacturing costs, tooling changes, etc.)

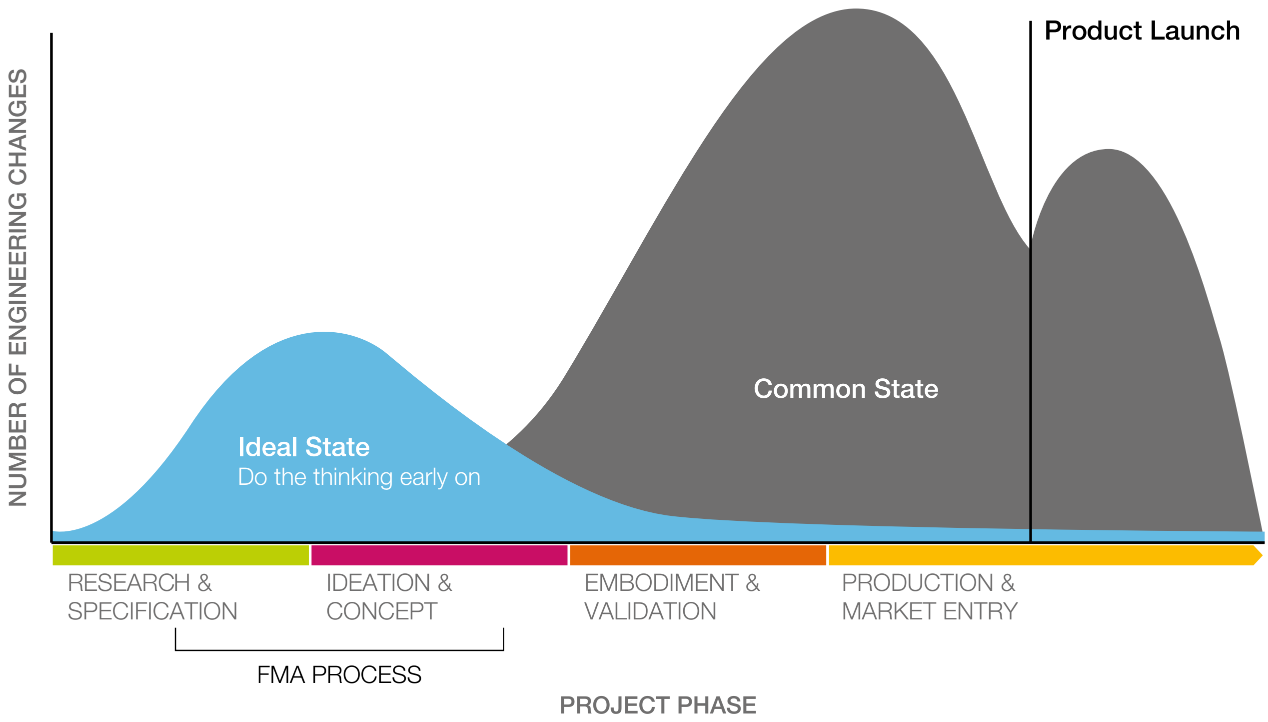
This generally happens because most designers dive straight into the physical design domain. Issues and failures only become apparent during a test and validation phase just prior to product launch. Then more changes occur just after launch to perfect and finalise the product.

At its worst, you get into the realm of product recalls.

Our FMA tools avoid this by doing the thinking upfront; before money is spent on physical design and on prototyping. We scrutinise any design with a fine-tooth comb, drilling down into its functionality and assessing noise factors which could derail its functioning.

We then embed mitigation and controls into the initial design, reducing the number of prototype phases. By the time the product launches you can be sure that it is transparent to a whole host of noise factors.

The FMA Landscape[3]

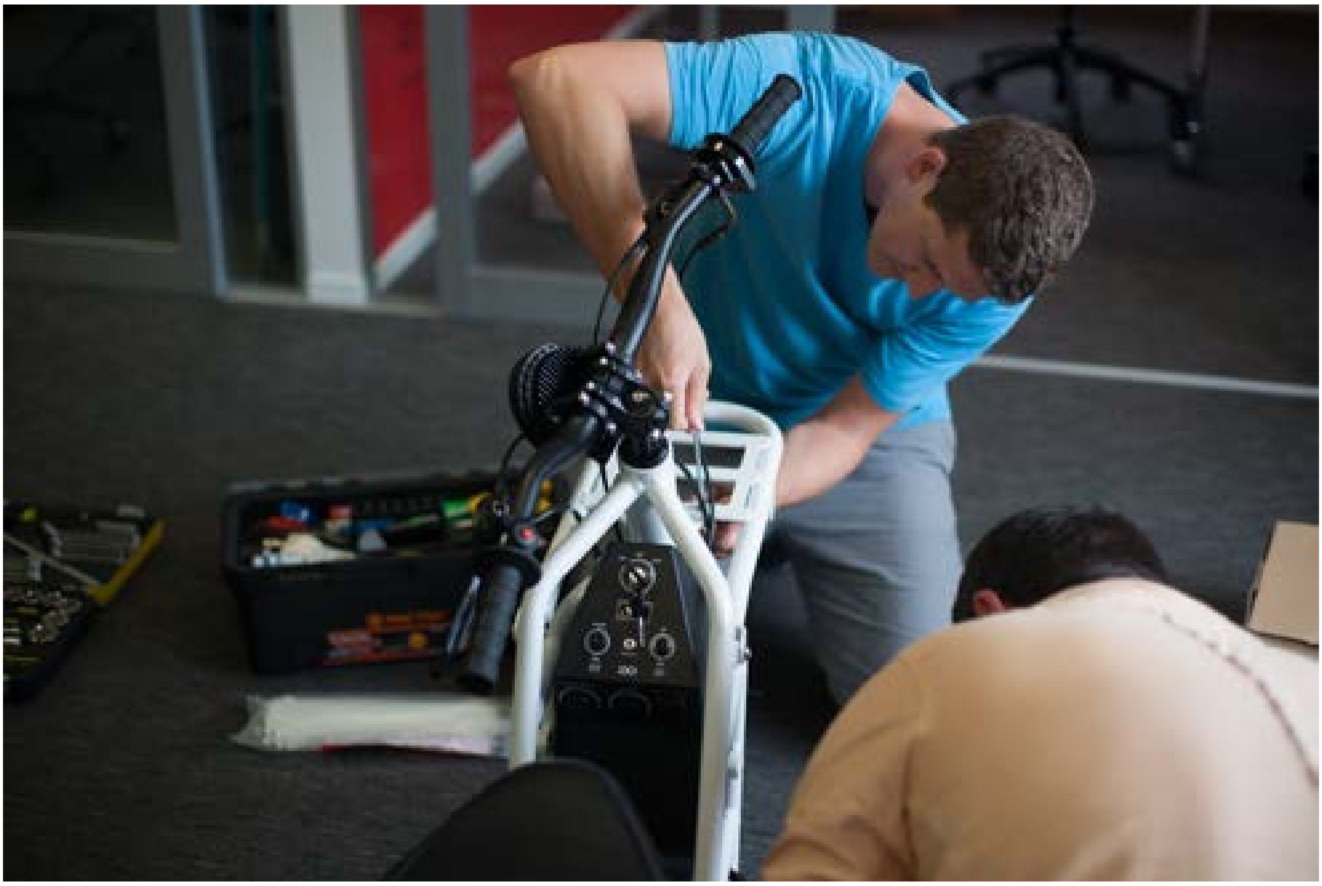


Sources:

[1] Cash, P.A.: Right first time production releases. MSc thesis, University of Bradford (2003)

[2] Wasmer A., et al.: An industry approach to shared, cross-organizational engineering change handling – The road towards standards for product data processing. Computer-Aided Design (2010)

[3] Rutter, B.G, et al.: Systems Engineering Excellence Through Design: An Integrated Approach Based on Failure Mode Avoidance

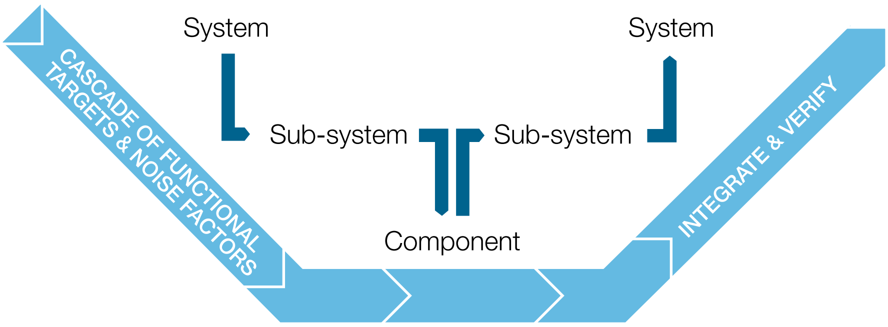


A structured framework

A suite of tools and techniques have been developed to help you apply the FMA process to your product or process.

Our FMA approach is underpinned by a functional requirements cascade. We ask, "What does your product/process need to do, and how does that cascade into the functionality of the sub-systems and components that make up the product?"

This means we apply and validate our tools at a total system level, at sub-system level, and also at the nuts and bolts (component) level. It works the same whether you are in the process design space, manufacturing, or production planning space.



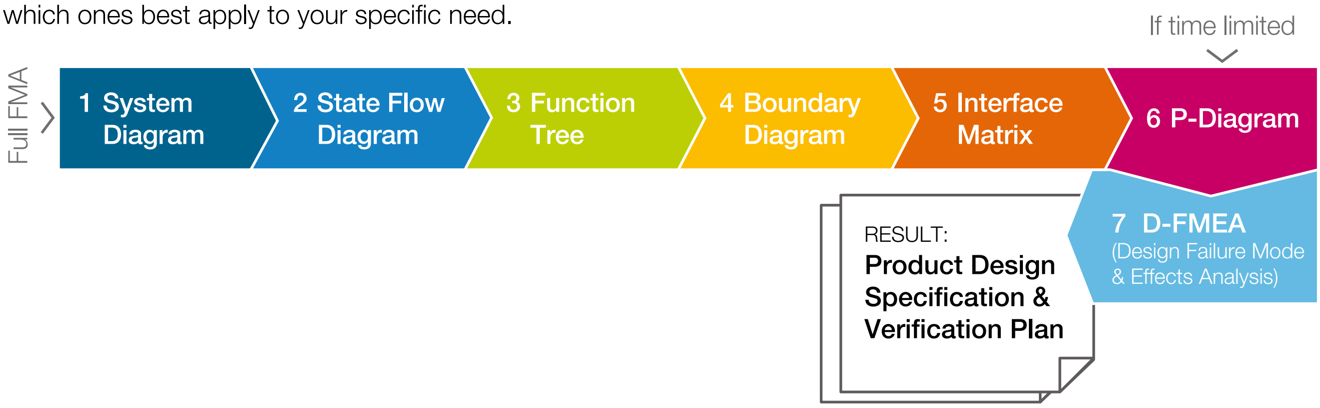
The Tool Kit

Before we dive into the design work, we need to utilise the tools to answer the most key design question:

“How can I make sure my product performs well under all conditions?”

In the full FMA process, the information from one tool will flow into the next, as shows in the Process Flow diagram below. Each tool will then feed the information used in the D-FMEA. The beauty of FMA is that the tools are modular; this means we can pick and choose which ones best apply to your specific need.

We understand that not everyone has the time or budget and that resources are finite. In most cases a parameter diagram and FMEA can get you to where you need to be.

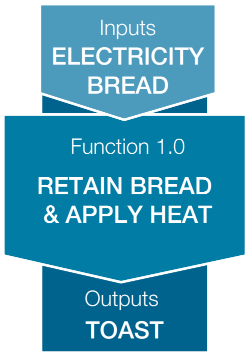


The Tools Explained

In order to better understand each diagram in the FMA process, we will use the example of turning bread into toast. While this may seem like a simple output, the processes that go into the transformation of bread to toast can be broken down into detail to ensure the perfect outcome.

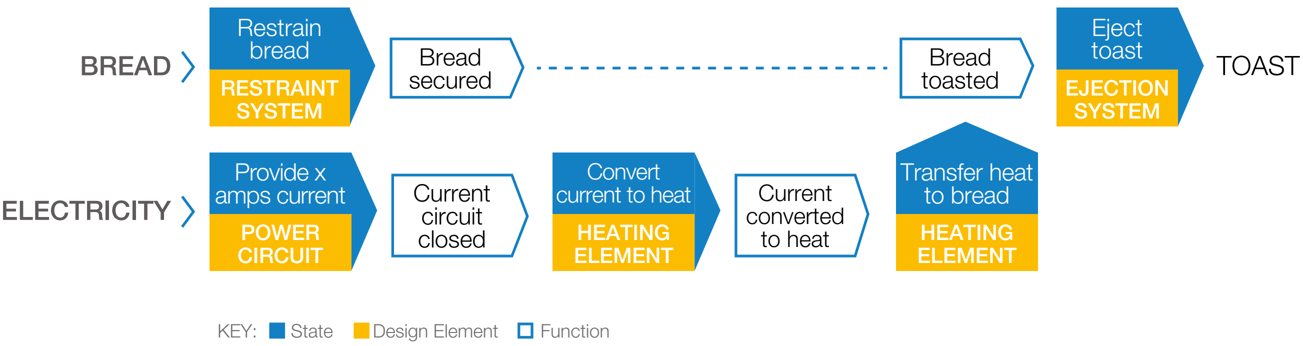
1 System Diagram

An overview of the system in terms of inputs, outputs and system functions: What goes in (inputs), how they’re transformed (functions), and what comes out (outputs).



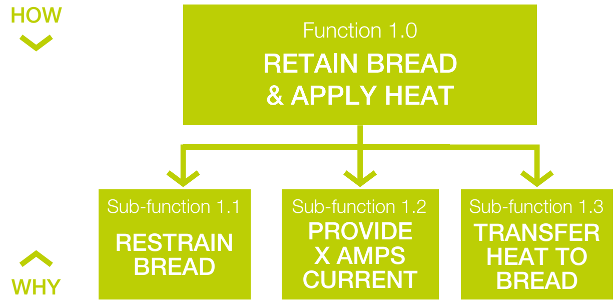
2 State Flow

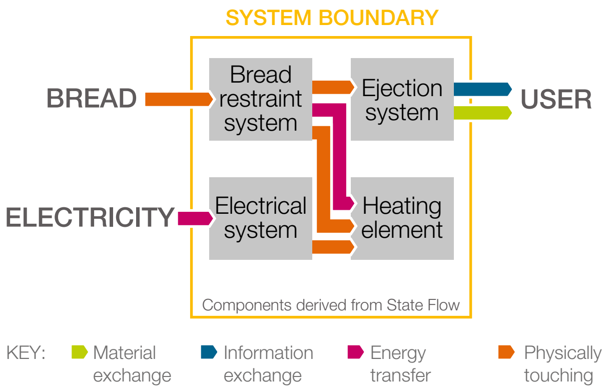
The state flow breaks down the inputs and tracks their various states as they are transformed or transferred into outputs. It also identifies the design elements that perform those transformations. This is where we start to identify the whats and hows of the system’s internal workings.



3 Function Tree

The function tree takes the high-level information from the state flow and further defines each function using a how and why structure. In one direction, the team can think about and document precisely how the product functions, and in the other direction, derive why certain actions are taken to achieve the functions. Each aspect of the second level on the function tree is to be cascaded into further function trees – eventually down to component level. This gives each function a range of sub-functions that can then be assessed for their potential to fail.





4 Boundary Diagram

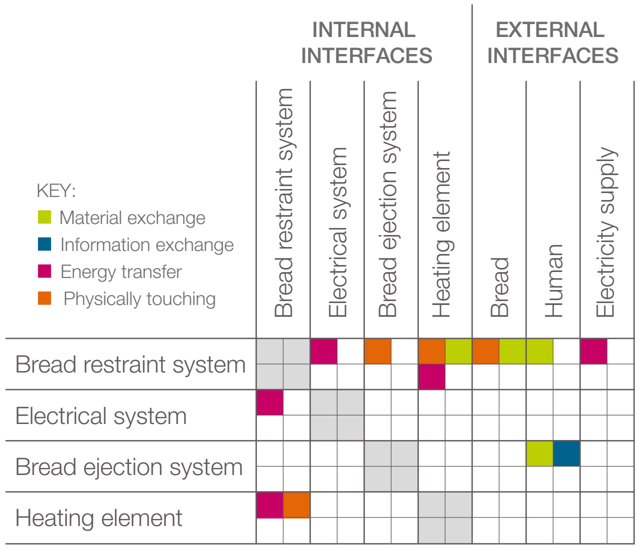
The boundary diagram identifies which aspects of the system fall within the system's domain of responsibility and those that fall outside of it (i.e. managed by processes external to the system). The boundary diagram also identifies the relationships between the sub-systems in terms of energy, material, and information exchanges. From here, we start to see how we must engineer and manage critical interfaces for the system to function properly.

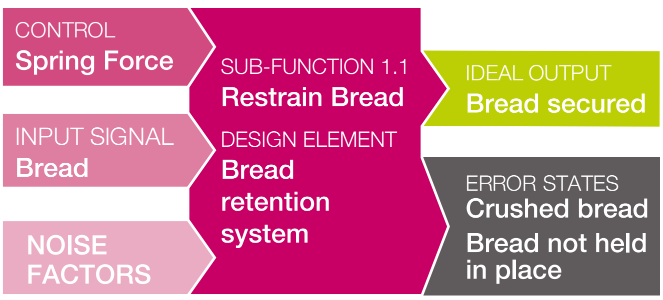
5 Interface Matrix

A summary of all the exchanges/interfaces internal and external to the system. We do this by further categorising the exchanges using the P.I.E.M matrix: Physical, Information, Energy or Material exchange. This is done in conjunction with the boundary diagram and Interface Function Management tools.

Interface Function Management

Drilling down a bit further, this table plays a major part in identifying potential failure modes and their causes. It is a detailed analysis of all the interfaces as defined in terms of P.I.E.M. We now look at each of the interfaces and identify how they must be managed for the system to function as intended.



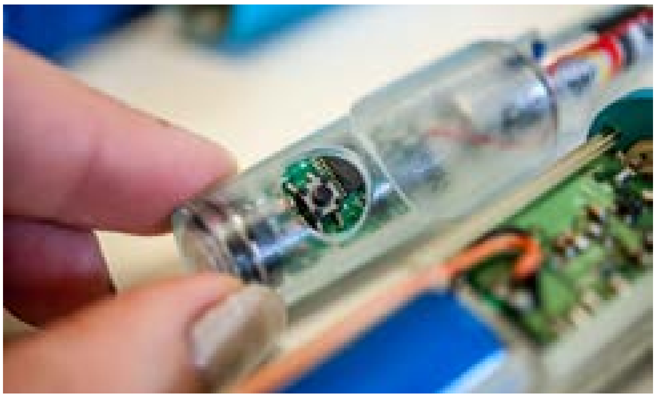


Noise factors include:

- Piece to Piece: **Spring rate**
- Change over time: **Fatigue**
- Customer / duty cycle: **Replacement**
- External environment: **Humidity causing rust**
- System interaction: **Heat interferes with spring rate**

6 Parameter Diagram

We take a step back to get a macro view of each of the high-level functions and investigate additional global factors which might lead to failure modes. It incorporates global factors such as customer usage and environmental effects. This complements the Interface Function Management tool, which takes more of a granular view of the interfaces.



“When applied properly, the outcome is a robust design that goes a very long way towards getting a product right first time.”

All this leads to…

7 **Failure Mode Effects and Analysis (FMEA)**

The FMEA is a synthesis of the insights generated from the previous tools, prior to starting physical design work. It is used to assess how the system might potentially fail and proposes actions such as design, process, and control to eliminate or reduce those failures, starting with the highest priority ones.

FMEA is a tool used to assess how a system, function, attribute or process might potentially fail. It then proposes actions to eliminate or reduce those failures. FMEA is conducted prior to actual design work and then updated with data from testing, validation and customer feedback.

FMEA's can be applied at the system design level, sub-systems, component design, process design, manufacturing, or production planning.

FMEA also documents current knowledge and actions about the risks of failures, for use in continuous improvement. When applied properly, the outcome is a robust design that goes a very long way towards getting a product right first time – and high customer satisfaction.

Lastly, the FMEA process evidences the level of systematic thought which has gone into a product for type approval certification. The international standard for FMEA is SAE J1739.

FMA mindset

Before any process, product, or function is designed, undertake a series of thoughts and rankings to create a risk priority to implement new controls that reduce or eliminate failure.

These might be:

THINK:

How might it fail to achieve its ideal function?

What are the potential effects of that failure

What mechanisms could cause such a failure?

Do I have any controls in place to detect this failure?

Do I have any controls in place to mitigate this failure?

RANK:

How severe is the failure for the customer?

What is the likelihood of such a failure occurring?

What is the likelihood of my controls detecting this failure?

RANK:

Create a Risk Priority Number

ACTION:

Implement new controls to reduce or eliminate failure.

Then, validate those controls.

In conclusion

Our Failure Mode Avoidance thinking produces products and process that come very close to the magical 'right-first-time' mark. It is proven and it works.

Each year, hundreds of satellites are successfully launched into space, thousands of flights take off and land safely, and cars cover mile after mile. This is because their functional robustness is underpinned by FMA. Locus puts your design under the same Failure Mode Avoidance lens to get the best result the first time.

Change is the only constant

Developing a new product or service and taking it to market is one of the most difficult things you can do. There are a lot of variables and things are constantly changing. We have developed processes that recognise this and work with it, not against it.

The first principle of innovation: change is the only constant

Creating a culture that rewards dynamic thinking and embraces the likely event of change will deliver benefits for your company. It is important to celebrate the concrete milestones alongside a team's flexibility and embracing a plan that can change with opportunity. This document reinforces what we believe are the four tenets of innovation:

Research

Pursue knowledge, to drive understanding and insight.

Structure

Create a structure to support your activity that is capable of change.

Culture

Encourage a culture that rewards dynamic behaviour and thinking.

Creativity

Often has the solutions to change so encourage it in your workplace.

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We believe in the power of research to explore, learn, discover, and create.

Our cross-functional design team uses research to deliver insights, develop products, and improve the outcomes of innovation in business.

We are a product development and innovation company that works with you to deliver world class products to market.

Curious about how we can help you and your business? Get in touch.