

1

**2001**

LSS Green Belt  
Training  
initiated

2

**2003**

LSS Black Belt  
Training  
initiated

3

**2007**

Master Black  
Belt initiated

4

**2013**

Business Value  
Analyst  
launched and  
included in MBB  
competencies

5

**2014**

DFSS Black Belt  
launched for in-  
company  
programs

6

**2020**

Business  
Analytics  
Expert, ECIL,  
Design  
Thinking, PM  
Champion  
launched



benchmark  
Inspiring Minds, Facilitating Excellence

6ix sigma

DFSS Black Belt  
August 2020 V2.0

# Program Outline

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Introduction

**Block 1 - D** – MGPP,  
VOC, Kano, QFD, 9  
Windows, CIs and  
KCs, DFSS Scorecard

**Block 2 - M** – Function  
Analysis, Function  
Tree, P diagram, Block  
Diagram

**Block 3 - A** - Concept  
generation and  
selection, Failure Mode  
Avoidance

**Block 4 - D** - Product  
Design - DRA,  
DFMEA, Design  
Records, linking Specs  
and MSA with SPC

**Block 5 - D** - Process  
Design – PFD-PFMEA-  
Control Plan

**Block 6 - D** -  
Experimentation and  
Reliability – DOE and  
RSM, Taguchi methods

**Block 7 - D** - Design  
advancement using  
Simulations

**Block 8 - V** - Product  
and Process Validation  
methods

# Block 2 – Measure

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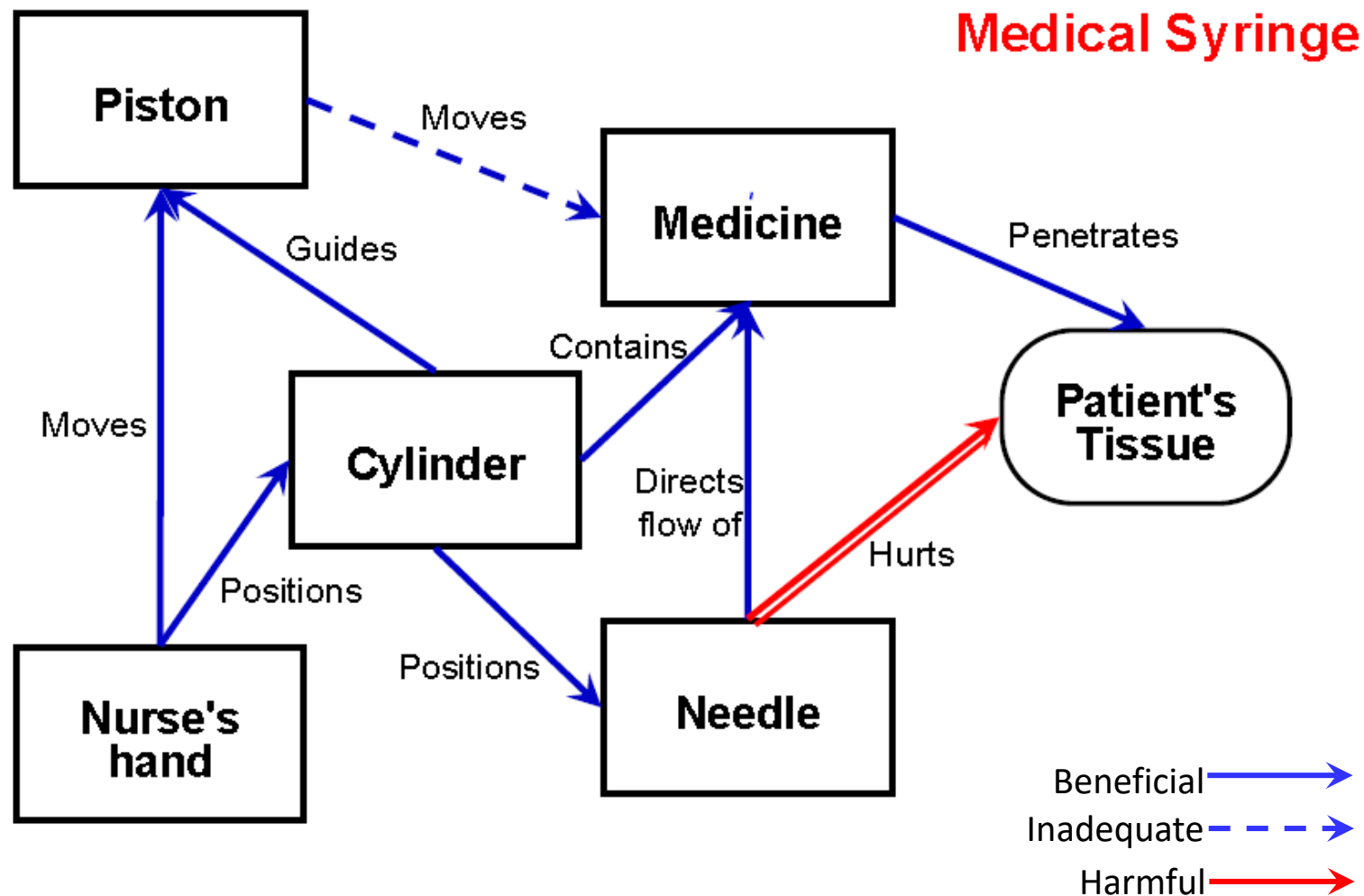
Function  
Analysis

Function Tree

P Diagram

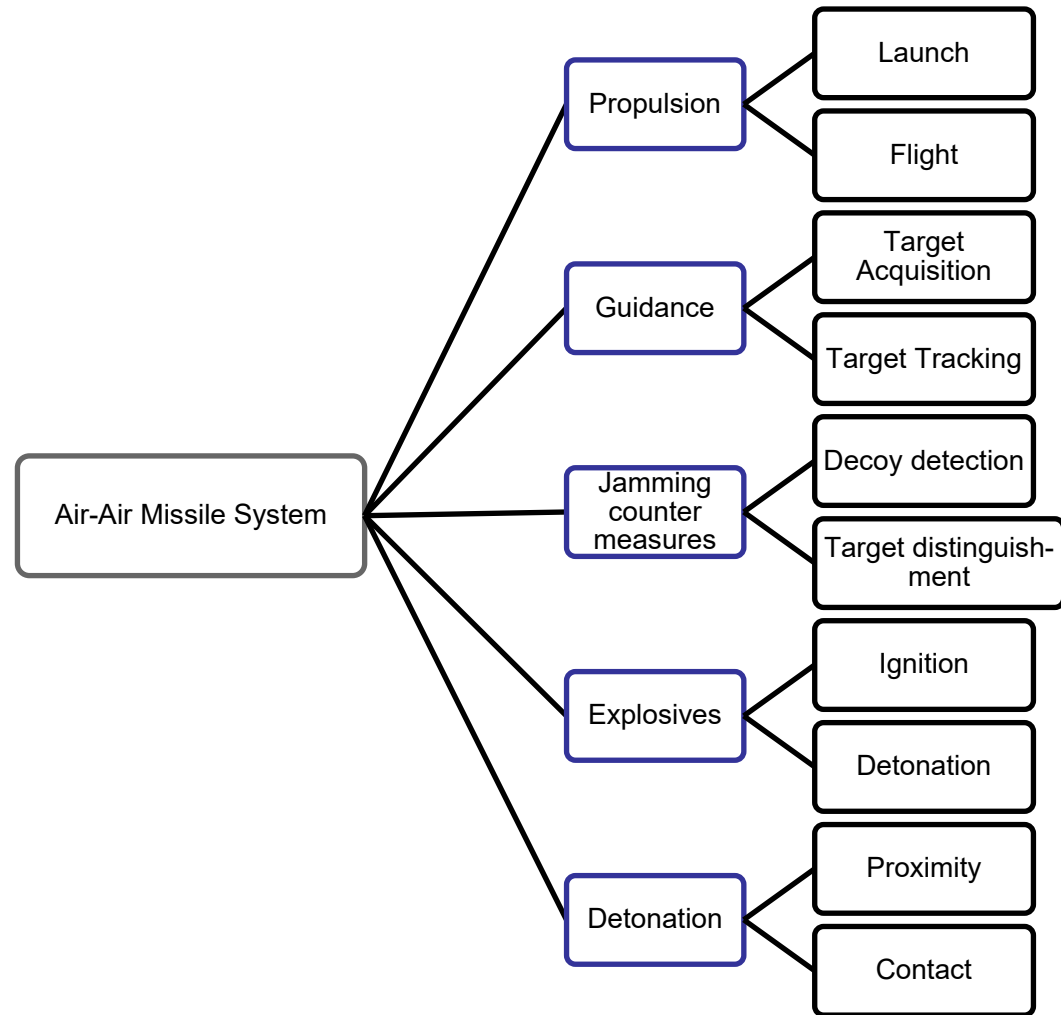
Block  
Diagram

# Functional Analysis Diagram Example

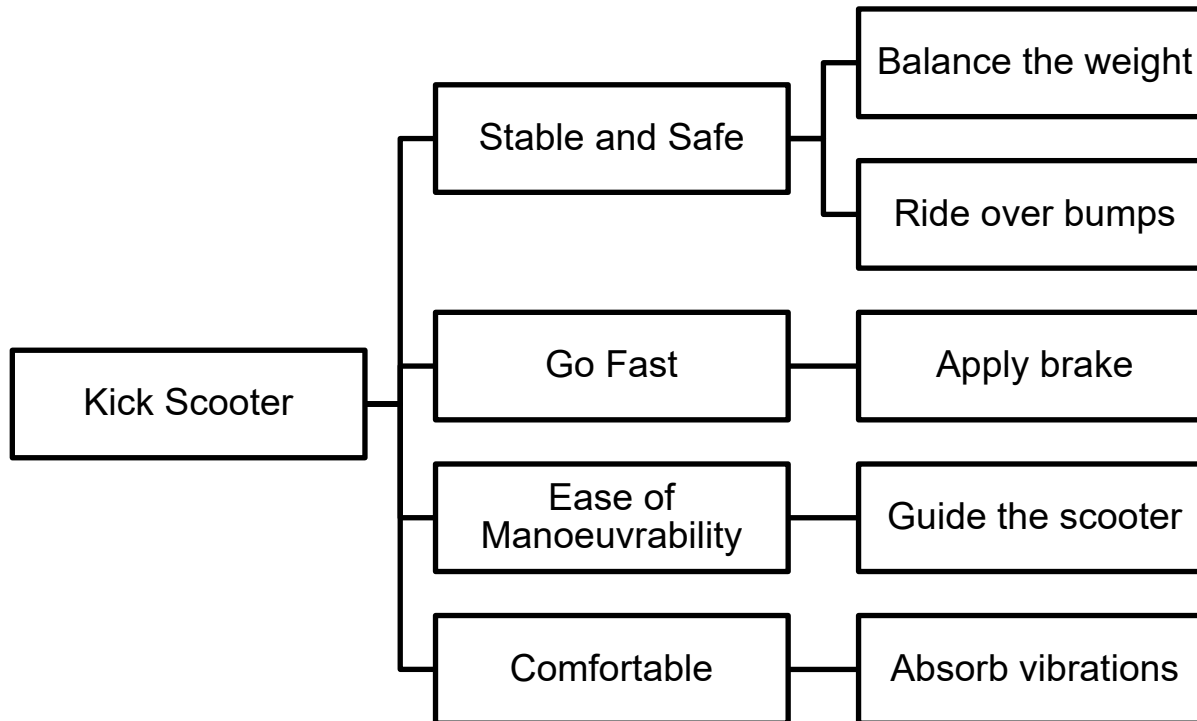


# Function Tree

Function tree helps create a preliminary listing of functions and their hierarchy



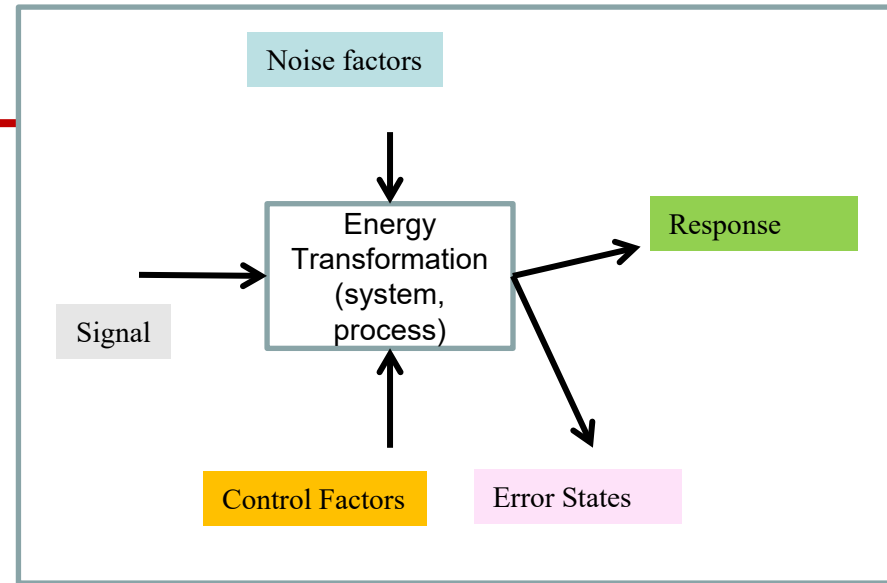
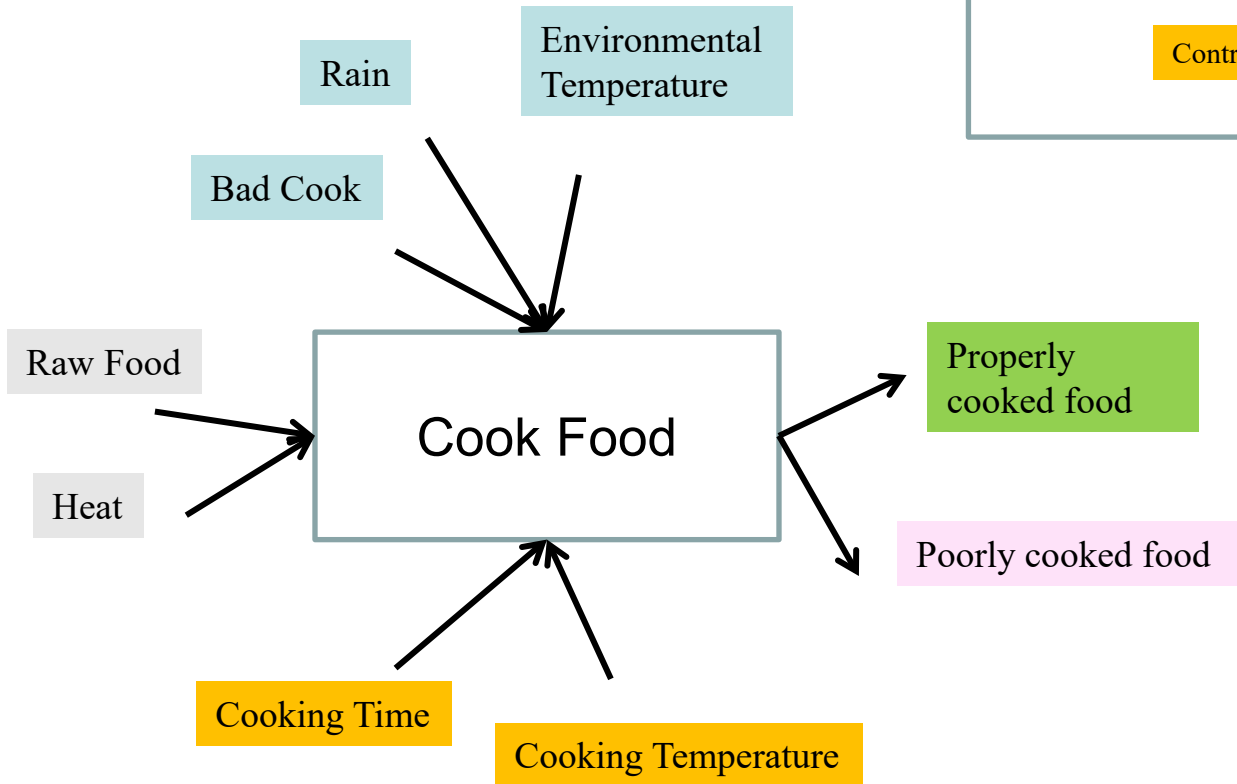
# Function Tree



An example function tree is shown here

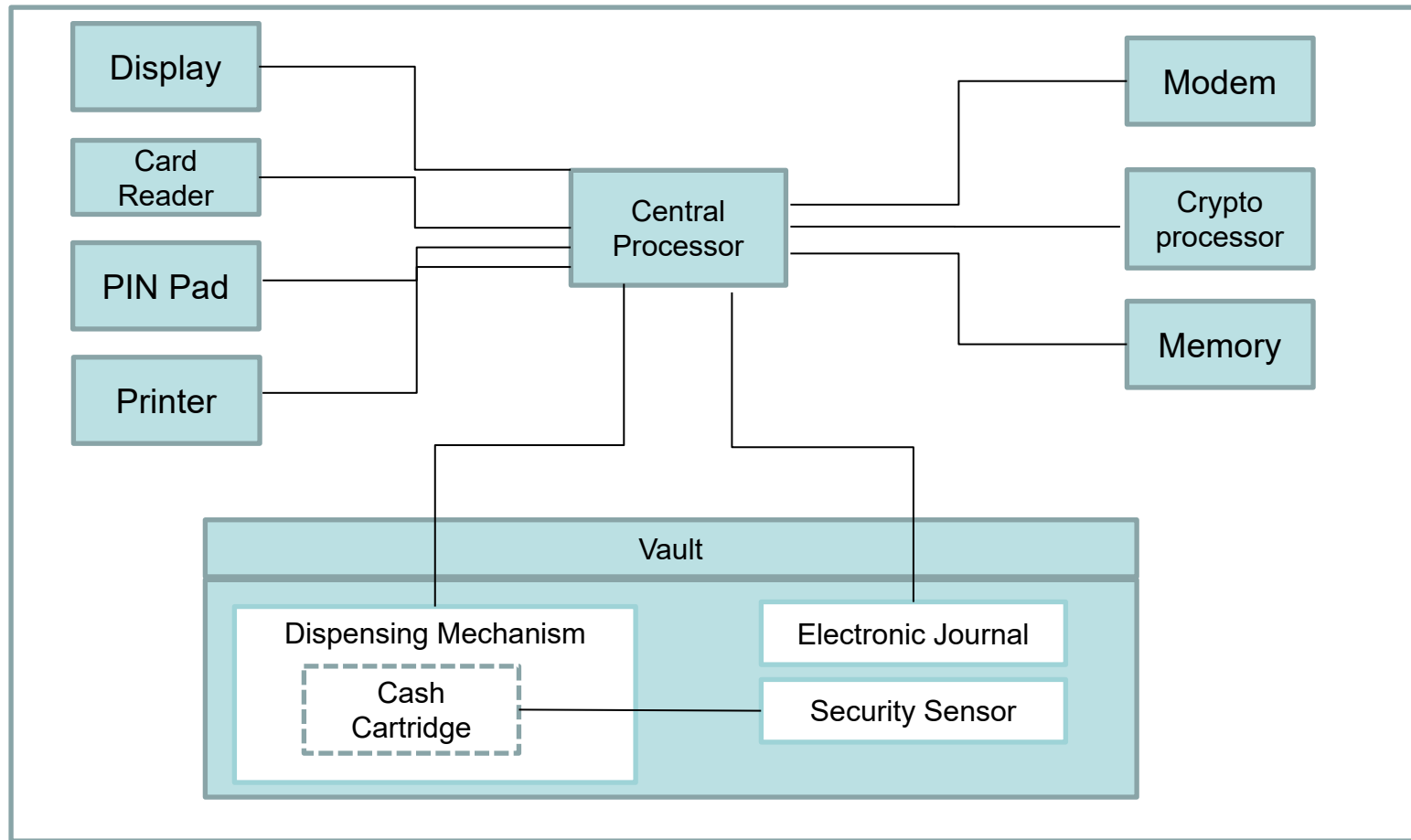
Is it possible that two design teams create different hierarchies although they are presented with the same first level expectations?

# Parameter (P) Diagram



# Boundary (Block) Diagram

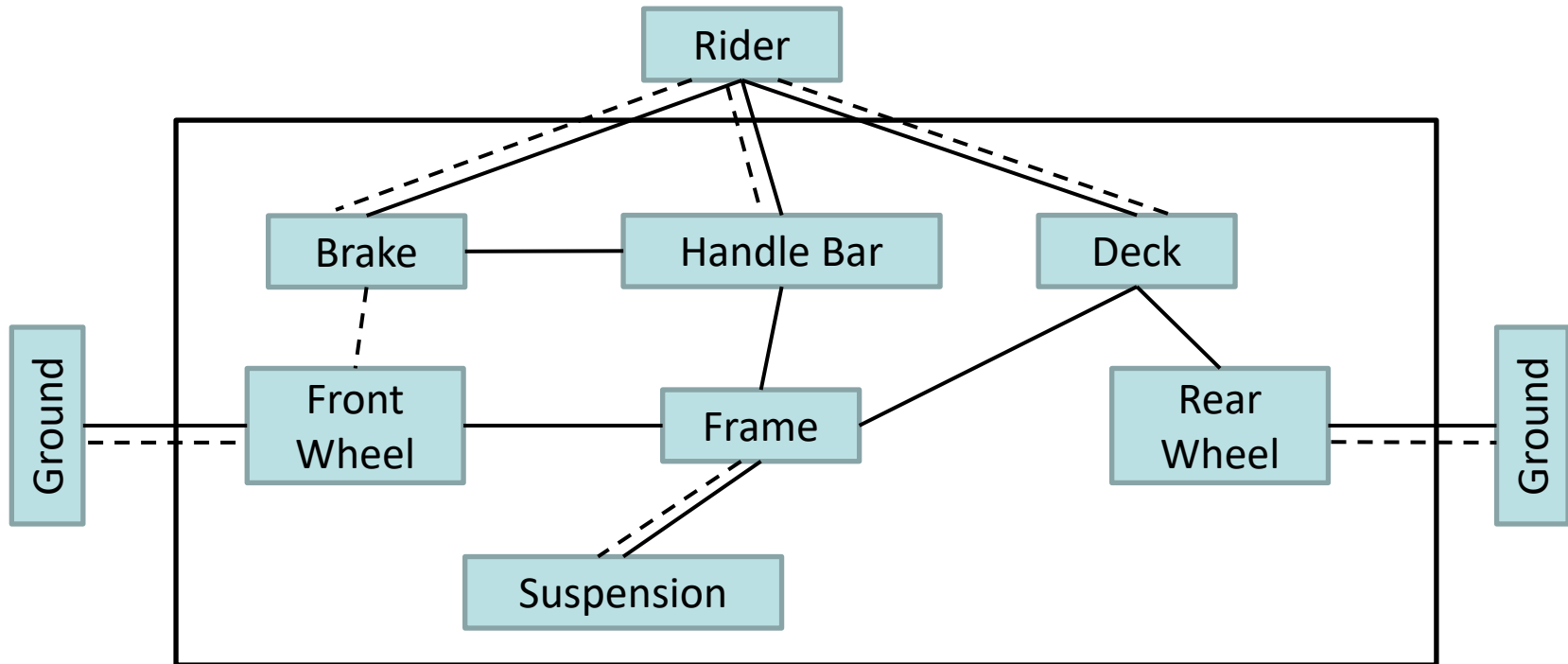
## Example





# Agreed Block Diagram (Product Design)

## Kick Scooter



Physical Connection  
Energy Transfer

# Team Exercise

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- Think of a new process being designed in your organization.
- Prepare one of the following for it –
  - Function Analysis Diagram
  - Function Tree
  - P Diagram
  - Block Diagram



# Block 3 – Analyze

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Concept  
Generation and  
Concept  
Selection

Failure Mode  
Avoidance

# 1. Refine Functional Requirements Definition

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## Items To Avoid When Refining Functional Requirements (FRs)

Attribute description like binary (0-1) requirements

- Instead: use ratio scale requirements with defined measurement systems & unit of measurement

Statements of solution ("Design is made of x...")

- Instead: "Design fulfils x..."

Auxiliary verbs like "must" or "have to"

- Instead: "Design needs to be..."

Intangible concepts ("tasty")

- Instead: use concrete terms ("add more sugar")

Statements in a non-positive form ("Design does not ...")

- Instead: "Design performs x..."

Abstract words such as "reliable" and "durable"

- Instead: "design withstands x environmental conditions..."

FRs should be  
defined in a  
solution neutral  
environment

## 2. Establish function structure

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### Depth Of Sub Functions

- Theoretically, you can keep dividing into sub-functions until they cannot be sub-divided further – this is not practical
- Sub-functions need to be identified to an appropriate level based on needs of project
- All top level function structures can be combined into one overall design function structure.
- If structure Tree is already available, try to extend to the lowest Actionable sub functions !!

# 3. Search for design solution

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Once Function Structure has been established, design parameters (solutions) to those sub-functions must be developed.

Remember that sub-functions may be further decomposed to form a refined hierarchy

When looking for design parameters ask “How can I fulfil this sub-function?”

- How can I *multiply force*?
- How can I *cut fingernail*?
- How can I *enter data*?
- How can I *reduce friction*?

# 3. Search for design solution

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Developing Design Concepts:

Once you have mapped your customer requirements (CTQs) to product functions you need to generate as many alternate concepts as possible. These concepts in turn will satisfy customer needs.

Later in the process you will narrow down, build on, and combine these ideas into a single solution.

But now you need to generate as many ideas as possible by using:

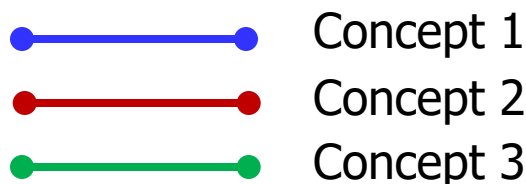
- Morphological Matrix
- Creativity Tools
- Benchmarking
- Triz
- Brain storming

# 3. Search for design solution

## Creativity Tool: Morphological matrix

A Morphological Matrix is a way to show all functions and corresponding possible design solutions

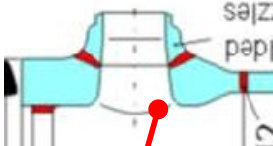
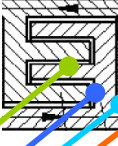
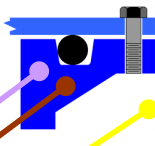
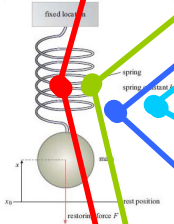
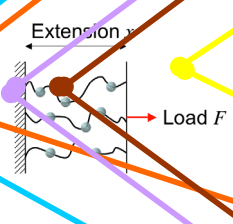
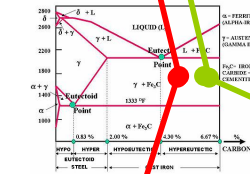
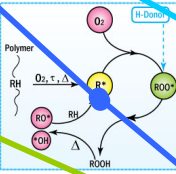

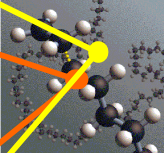

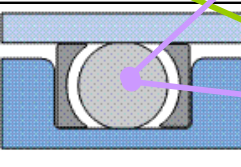
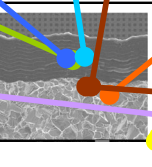

	Function	Solution			
		Alternative 1	Alternative 2	Alternative 3	Alternative N
1	Function 1	Solution 1	Solution 2	Solution 3	Solution N
2	Function 2	Solution 1	Solution 2	Solution 3	Solution N
3	Function 3	Solution 1	Solution 2	Solution 3	Solution N
4	Function 4	Solution 1	Solution 2	Solution 3	Solution N
N	Function 5	Solution 1	Solution 2	Solution 3	Solution N





# 3. Search for design solution

## Creativity Tool: Morphological matrix

Work Both way →						
↓	Functions		Design Solution1	Design Solution2	Design Solution3	Design Solution4
	Seal Gaps/clearances		welding			
	Retain Sealing force		Use spring			
	Remain stable in oil		Use Metals/steel			
	Resist extrusion thru gaps		Strong Welding Material			

# 3. Search for design solution

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## Creativity / Invention Myths

- What Picture Do You Have in Your Mind of How Creativity, Invention or Innovation Occurs?
- Can Creativity/Invention Occur in a Team Environment?
- What are the Aids to Creativity/Invention in Your Business?
- What are the Barriers to Creativity/Invention in Your Business?

# 3. Search for design solution

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## Obstacles for Creative thoughts

Staying in our box

Not challenging existing paradigms

Not challenging assumptions

Fear of being wrong

Early childhood and school experiences

The search for the “right” answer

Focusing on logical thought

Judging ideas before they are formed

Psychological inertia

Look out for killer phrases that start with “That’s a good idea, but...”

It’s against company policy

It’s not practical

It’s not necessary

We don’t have the resources

It will cost too much

We’ve never done it that way

Our customers (or vendors) won’t like it

It needs more study

It’s not part of your job

Let’s make a survey first

Let’s sit on it for a while

That’s not our problem

The boss won’t go for it

The old timers won’t use it

It’s too hard to administer

Why hasn’t someone else suggested it before?

Let’s form a committee

We should wait until the economy improves

Who else has tried it?

Is it best practice?

# 3. Search for design solution

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**Concept Generation** is the creation of numerous ideas that potentially meet Requirements and Specifications.

The context provided by Quantitative Performance Targets (*Requirements and Specifications*) is essential to guide the creation of and provide 'Scope' boundaries for ideas.

The process starts with a thorough understanding of **what** the Function is. The challenge is to create many different design approaches for **how** the Function can be performed.

This transition from **what** to **how** is huge.

The amount of information added during conceptual design is enormous.

Draw Morph Matrix to show different solution variants

# 3. Search for design solution

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## Principles of Concept Generation

- Concept Generation is a very creative process.
- Creativity Methods and Tools offer enormous value.
- **Place an absolute embargo on Selection of Concepts until Generation of Concepts is completely exhausted.**
- Pugh cites McGrath's ideas concerning effectiveness of individuals and groups in generating and evaluating ideas.

- **“Concepts are often best generated by individuals”.**
- **“Concept Selection and Enhancement is often best performed in groups.”**

**Reference:** J. E. McGrath, *Groups: Interaction and Performance*, Prentice Hall, Englewood Cliffs, New Jersey, 1984.

**Reference:** Stuart Pugh, *Total Design: Integrated Methods for Successful Product Engineering*, Addison-Wesley Publishing Company, Workingham, England, 1991, p 71.

# 3. Search for design solution

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## Three Cycles of Concept Generation

Experience and research suggest that Concept Generation is best performed in three cycles:

1. Groups — Gathering information and developing shared purpose
2. Individuals — Creating ideas
3. Groups — Combining, enhancing, improving, refining ideas

“Clearly no group can as an entity create ideas.  
Only individuals can do this.  
A group of individuals, may, however, stimulate one another in  
the creation of ideas.”

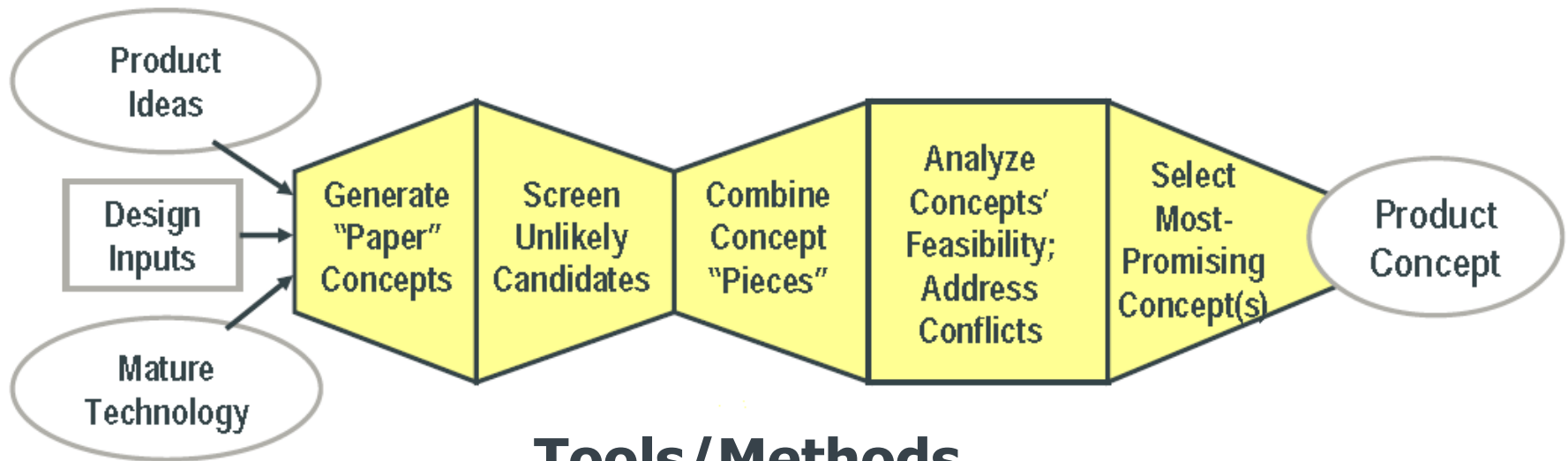
Estill I. Green, VP Bell Labs

**Reference:** James Martin, *System Engineering Guidebook: A Process for Developing Systems and Products*, CRC Press, Boca Raton, 1996, p 257.

# 3. Search for design solution

Concept Generation Path:

Variation on the “Open/Narrow/Close” Decision-Making Process:



## Tools/Methods

Function Analysis	Pughs concept selection	Function/Concept matrix	Prototyping	Pughs concept selection
Creativity methods			Rapid Application Development	Prioritization Matrix
Benchmarking			TRIZ	

# 3. Search for design solution

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## Tools for Concept Generation

- Brainstorming
- Challenge assumptions
- Solution mapping
- Mind-mapping
- Random word
- Idea box
- Twenty questions
- Candid comments
- Musical chairs
- Building on ideas

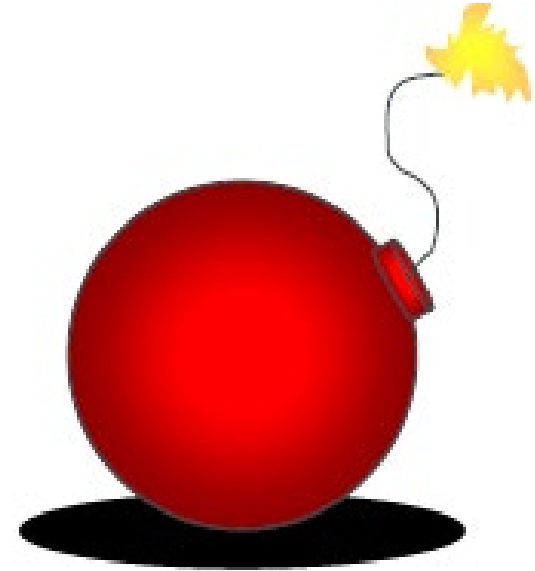


# 3. Search for design solution

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## Challenge Assumptions

Everyone brings assumptions to the problem-solving table. Such assumptions can reflect what we know or, as is often the case, what we think we know.



- Challenging conventional assumptions about your problem can help you turn obstacles into opportunities
- Work to escape the self-imposed constraints that traditional assumptions often create

### 3. Search for design solution

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Idea Box: The Idea Box helps you generate concepts for different functions or attributes of your design:

Improve Design for Order Placement System				
S.No	Database	User Platform	Language	Connectivity
1	DB-2	Unix	COBOL	Peer Network
2	Oracle	Windows PC	Fortran	Network Server
3	Ms-Access	Apple PC	C++	Telephone Modem
4	Object	Server Kiosk	Java	Wireless Modem
5	HTML	VT-100	NetFusion	Secure Data Link

# 3. Search for design solution

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Twenty Questions: Useful to “tear apart” an existing process or service and challenge all current assumptions prior to developing the next generation:

	What?	Where?	When?	Who?	How?
Current Method	What happens?	Where is it done?	When is it done?	Who does it?	How is it done?
Reason	Why do it?	Why do it there?	Why do it then?	Why them?	Why do it this way?
Better way	Can we do something else?	Can we do it somewhere else?	Can we do it some other time?	Can somebody else do it?	Can we do it some other way?

New ideas:

What should we do?

Where should it be done?

When should it be done?

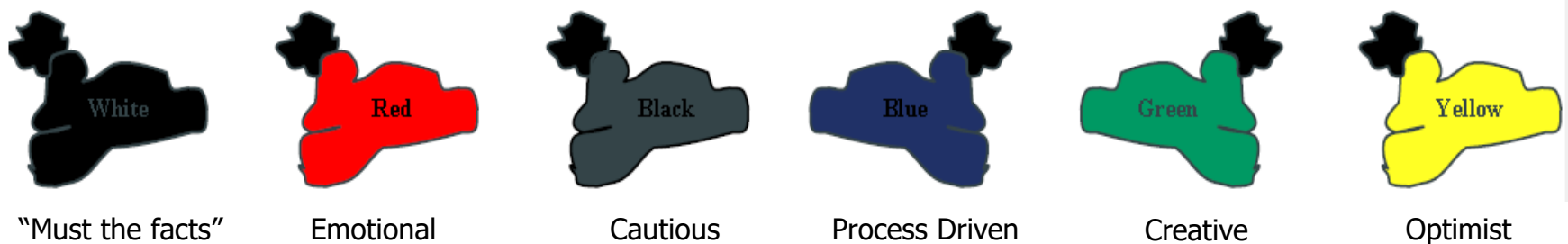
Who should do it?

How should it be done?

# 3. Search for design solution

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Six Thinking hats Technique: Another tool that may help the team reach a good decision on the best concept is the Six Thinking Hats Technique.



## How to Use the Six Hats Technique

- A thinker puts on or takes off one of the hats
- A facilitator asks a thinker to put on or take off one of the hats
- All thinkers put on one hat for a period of time
- Each thinker is assigned a different hat to wear for a period of time
- All thinkers wear hats they do not "normally" wear

### 3. Search for design solution

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## Exercise: Generate Concepts

Objective

Use one of the creativity methods to generate concepts

Deliverable

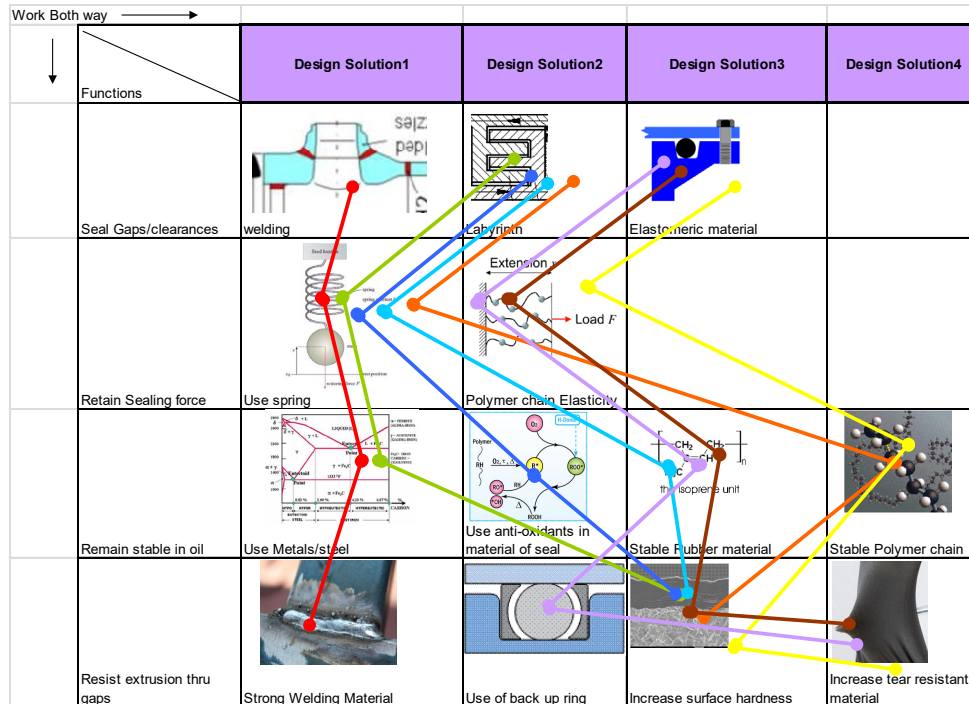
Alternative Concepts & a summary of lessons learned

Instructions

1. Select 2 – 3 Key Functions for which design concepts are required.
2. Generate design concepts for these functions, employing one of the methods described on the previous pages.
3. Critique the application of the new creativity technique employed.

# 4. Combine the design solutions to tangible structures

## Creativity Tool: Morphological matrix



Weld the joints



Metal Labyrinths



Hardened Rubber Labyrinths



Oil resistant Hardened Rubber Labyrinths



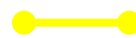
Oil resistant Hardened Polymer Labyrinths



Oil resistant Hardened Rubber Seal with Back up



Oil & Tear resistant Hardened Rubber Seal



Oil & Tear resistant Hardened Polymer Seal

# 5. Select suitable feasible structures

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## Preliminary Evaluation of Physical Structures

Some concepts will be technically impossible or too costly to implement

- Cost constraints
- Spatial constraints
- Part/process mating problems
- Environmental issues
- Geometric compatibility
- Safety factors
- Environmental factors
- Other design constraints

CAREFUL: You don't want to throw out concepts prematurely. **If in doubt, leave in.**

Theoretical  Practical

## 6. Firm into solution variants

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Objective:

- To assure that the design Solutions selected in the physical structures are **weakness free**
- Move towards Ideality



# Block 3 – Analyze

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Concept  
Generation and  
Concept  
Selection

Failure Mode  
Avoidance

# Failure Mode Avoidance (FMA)

## Understanding Taxonomy of Failure Modes

### What is it?

A structured approach used to identify detect all failure modes in the early design phases helping Design Engineers to successfully fill out FMEA documents from top to bottom. Helps select the right design that will fail the least.

### Taxonomy of Failures

- No Function
- Partial Function
- Degraded Function
- Intermittent Function
- Unintended Function

Failure Mode	Failure Cause	Failure Type
No light from bulb	Filament burnt	No Function
Insufficient light from Bulb	Drop in voltage	Partial Function
Car starts slowly but engine races	Clutch slippage due to worn out clutch disk	Degraded Function
The bike's light dipper does not work each time	Contact failure due to dimensional design error.	Intermittent Function
Air bag deployed without collision	EMI emission	Unintended Function

# Failure Mode Avoidance – Team Exercise

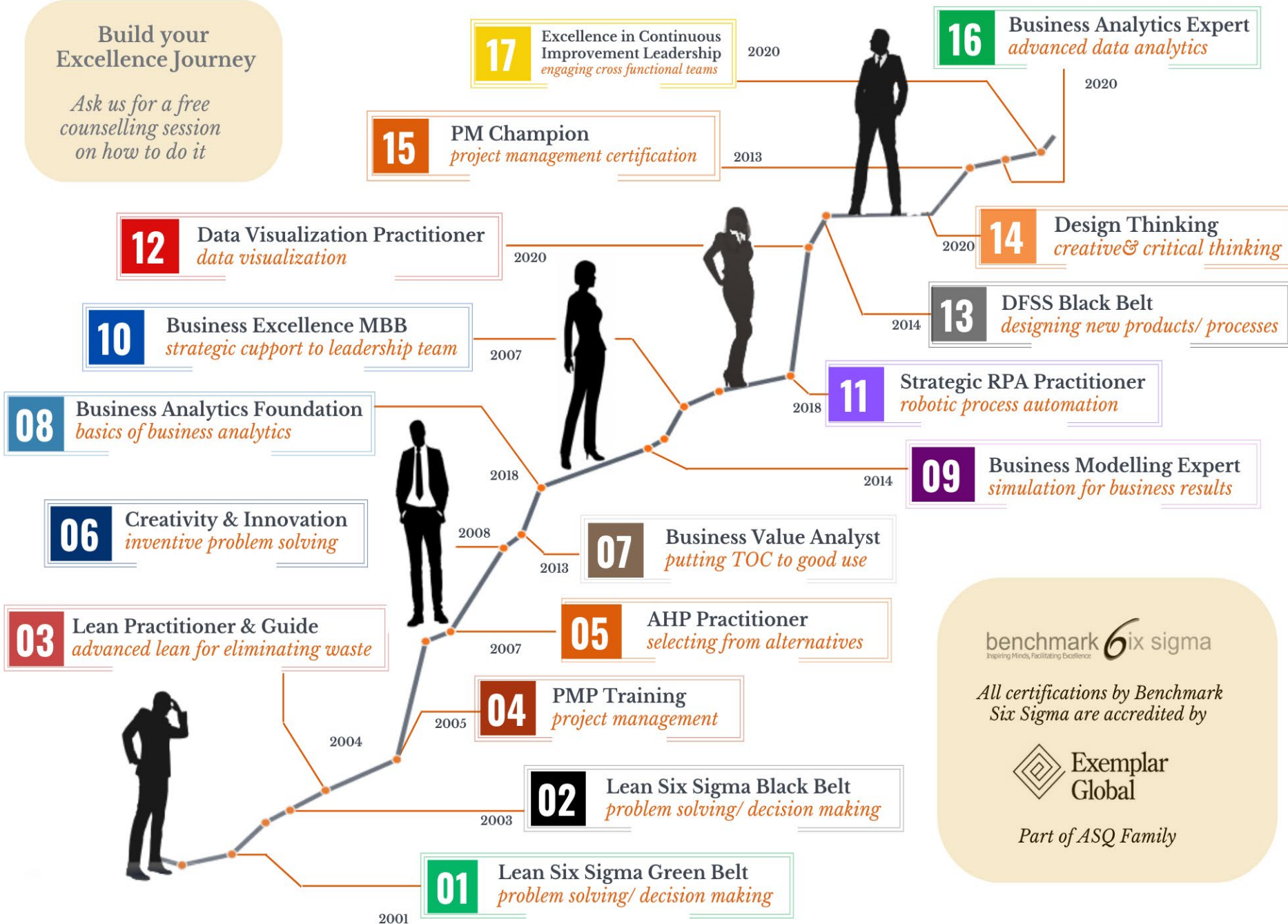
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- Select a service element for which you are considering a design sequence.
- Carry out FMA for the element and submit your result.



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