Design for X

Dr Jane Marshall

Product Excellence using 6 Sigma Module

Objectives of the session

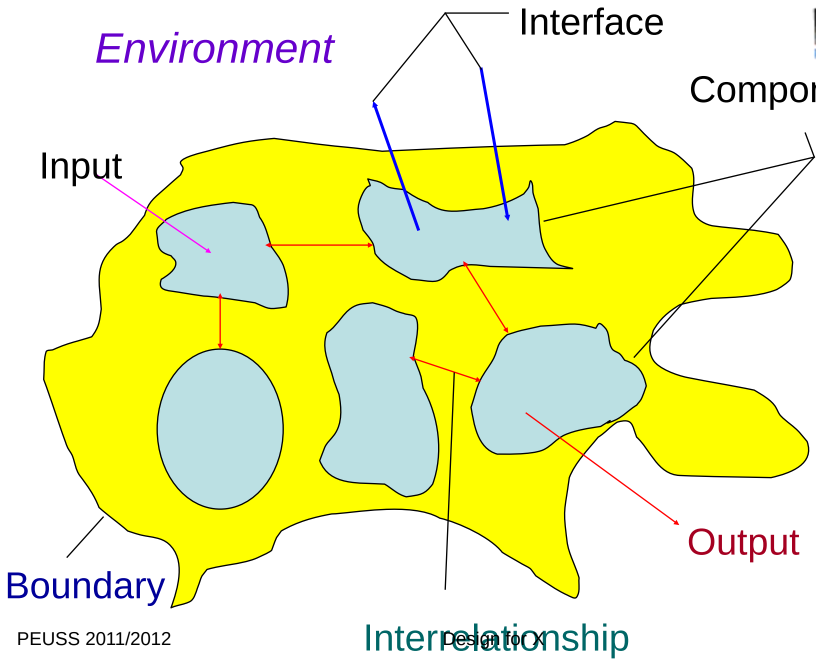
- Introduce Design for X
- Discuss Specific Design for X methods
- In-module project question

Design for X

- Concurrent engineering is a contemporary approach to DFSS.
- DFX techniques are part of detail design
- To improve:
  - life-cycle cost; quality, increased design flexibility, and increased efficiency and productivity
- Benefits include:
  - competitiveness measures, improved decision-making, and enhanced operational efficiency.
- “X” in DFX is made up of two parts: life-cycle processes *x* and performance measure (ability) (Huang 1996).
- Effective approach to implement concurrent engineering.
- System design

System design

- Systems and its characteristics
  - System is an interrelated set of components, with identifiable boundary, working together for some purpose
- A system has nine characteristics:
  - Components---------------------Subsystems
  - Interrelated components
  - A boundary
  - A purpose
  - An environment
  - Interfaces
  - Input
  - Output
  - Constraints



Environment

Interface

Components

Input

Output

Boundary

Interrelationship

System characteristics

- A component
    - an irreducible part or aggregation of parts that make up a system, also called a subsystem
- Interrelated components
    - Dependence of one subsystem on one or more subsystems
- Boundary
    - The line that marks the inside and outside of a system and that sets off the system form its environment

System characteristics

- Purpose
  - The overall goal or function of a system
- Environment
  - Everything external to a system that interacts with the system
- Interface
  - Point of contact where a system meets its environment or where subsystems meet each other.

System characteristics

- Constraint
  - A limit to what a system can accomplish
- Input
  - Whatever a system takes from its environment in order to fulfill its purpose
- Output
  - Whatever a system returns from its environment in order to fulfill its purpose

Logical and Physical system description

- Logical system description
  - Description of a system that focuses on the system function and purpose without regard to how the system will physically implemented
- Physical system description
  - Description of a system that focuses on the how the system will be materially constructed

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Important system concepts

- Decomposition
- Modularity
- Coupling
- Cohesion

Decomposition

Is the process of breaking down a system into smaller components in order to:

- Focus on one area at a time
- Concentrate one component pertinent to one group of users
- Build different components at independent times

Modularity and Coupling

- Modularity
  - Dividing a system up into chunks or modules of a relatively uniform size. To Simplify the redesign and rebuild process
- Coupling
  - The extent to which subsystems depend on each other.
  - Subsystem should be independent as possible. If one subsystem fails and other subsystem are highly dependent on it, then the other will either fail themselves or have problems functioning

Cohesion

- A cohesion is the extent to which a subsystem performs a single function.

Design for X tools

- Design for Manufacture and Assembly;
- Design for Reliability;
- Design for Maintainability;
- Design for Serviceability;
- Design for the Environment;
- Design for Life Cycle Cost;
- Etc.

Design for manufacture and assembly

- Consider during concept stage to reduce cost of redesign later
- Involvement of manufacturing engineers and supply chain management at concept phase
- Involve investigating waste
- Reducing number of standalone parts
- DFA time – identifies cost of assembly and efficiency
- Investigate alternatives through experimentation
- Error-proofing – poke-yoke

Design for Reliability

- Analyse load-strength relationship
- Design out inherent weaknesses
  - Analyse potential failure mechanisms and remove or accommodate
  - Analyse potential failure modes
  - past data
  - suppliers history
- Plan for reliability improvement
- Plan correct testing

What is Reliability?

- Quality over a period of time
- The ability of an item to perform a ‘*required function’* under ‘*stated conditions’* for a ‘*stated period of time’*.
- Reliability is an aspect of engineering uncertainty and therefore measured using probability

Why is reliability important?

- Costs of unreliability or unavailability
- Safety
- Competitiveness
- Examples:
  - Airline costs
  - Automotive reputation
  - Military equipment availability

Why do products fail?

- Design inherently incapable
- Item overstressed
- Variation
- Wear-out
- Specification, design or coding errors
- Noise
- Interaction

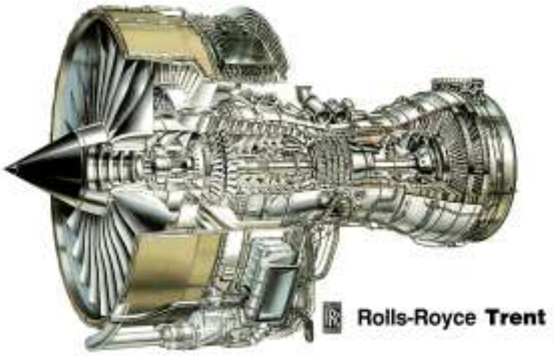
Load and strength

- Load - Key Characteristic of interest in environment
  - Temperature / Pressure
  - Vibration / Humidity
- Strength - Key characteristic of interest in manufactured product
  - Tensile Strength
  - Current Rating
  - Propagation Delay

Requirements & Environment - Engine Controls

- Typical Civil Engine environment
  - Temperature extremes
    - operating -55 to 100
    - non-operating -65 to 125
  - Vibration extremes
    - low frequency <5g
    - general 20g
    - blade passing 50g
  - Typical environment
    - much more benign
- Service requirements
  - Life 25 yrs 100,000 hrs operating
  - Reliability 30,000 hours MTBF (33 failures/million hrs)

FADEC Reliability Requirements



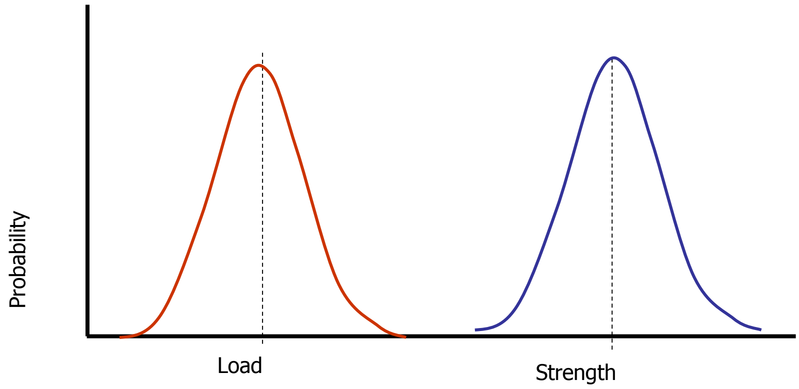
In a Safety Critical Harsh Environment Application

Load and strength

Generally failures occur if

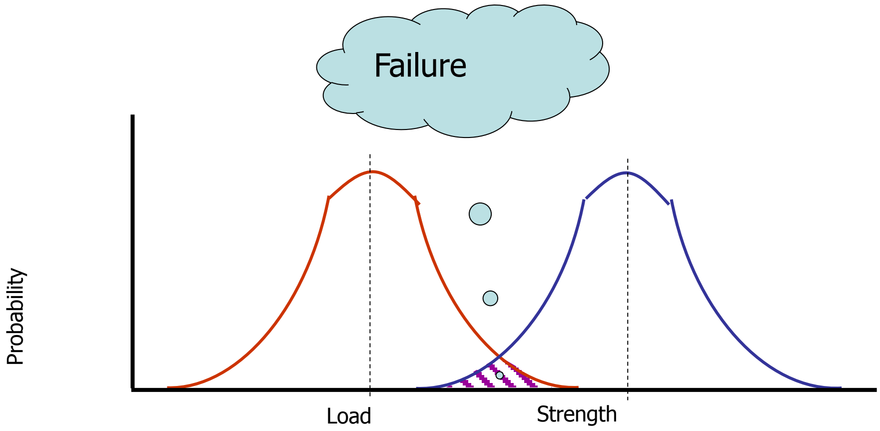
Load *exceeds* Strength

Load and strength

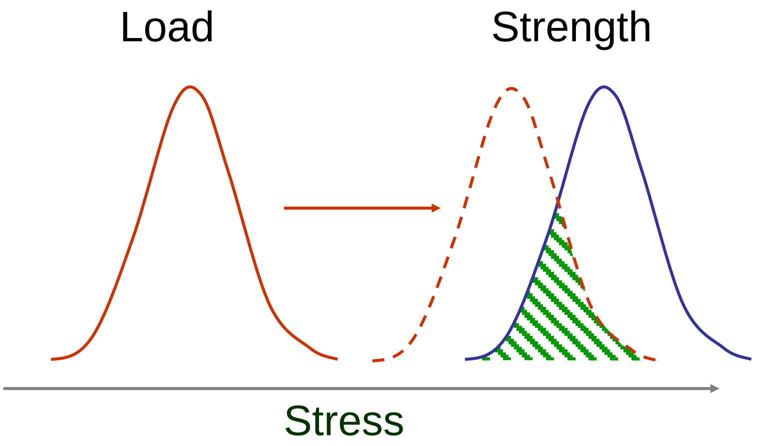


No overlap of distributed values ….. No failures

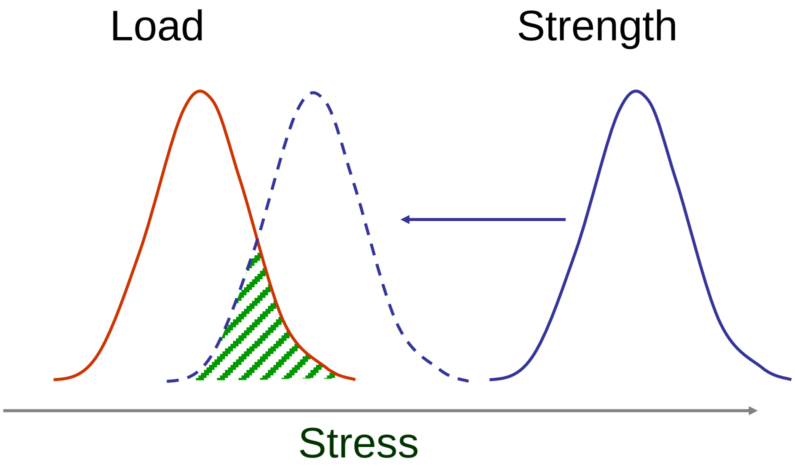
Load and strength



Over-stress



Wear-out

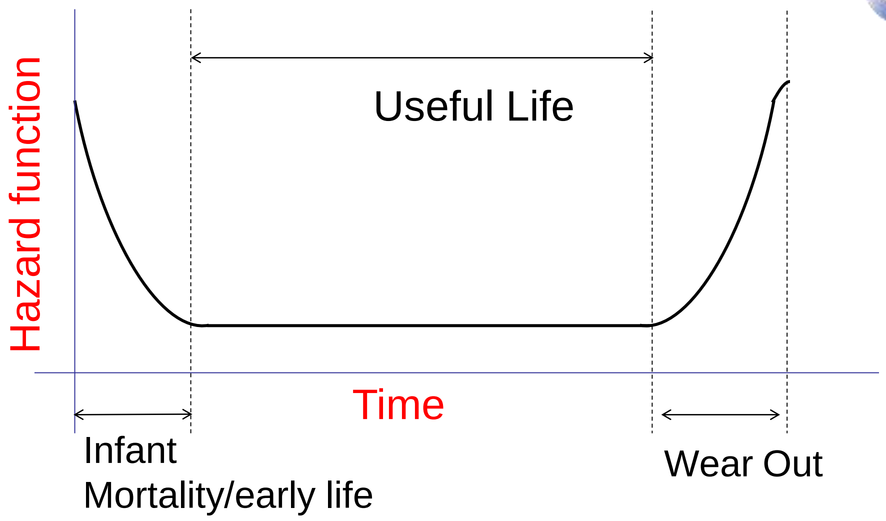


Design for Reliability

Aim to maximise reliability during service life by:

- Measurement & control of manufacturing quality / screening
- Optimized design & build process to improve intrinsic reliability
- Assure no systematic faults present in product
- Provide sufficient margin to meet life requirements

Early - life



Useful Life

Hazard function

Time

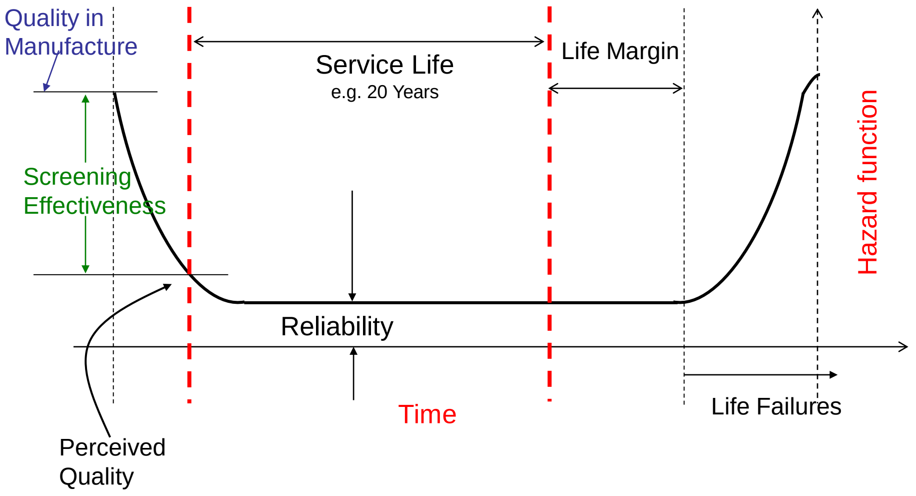
Infant
Mortality/early life

Wear Out

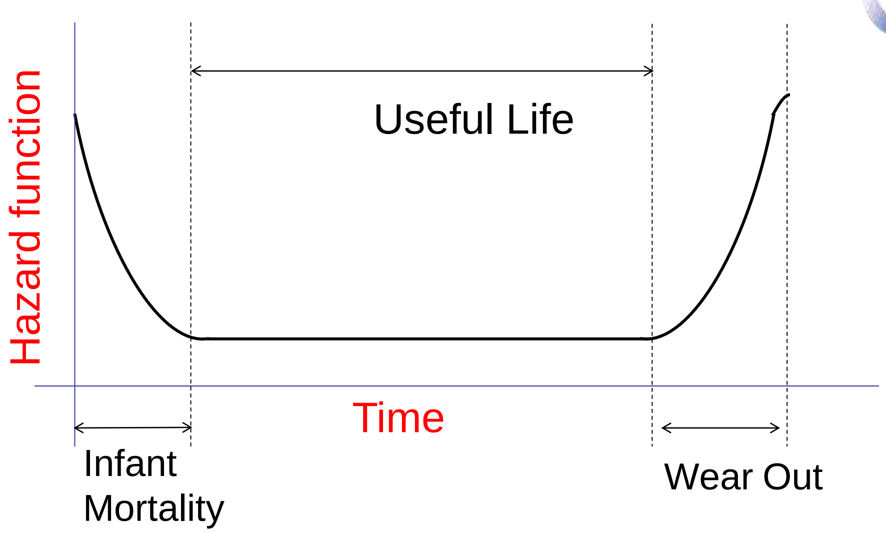
Early Life Failures – Environmental Stress Screening

- Sometimes called burn-in – electronic components
- Stresses that cause defective production items which pass other tests to fail
- Normally 100% test but can be done for batches
- HASS – high combined stresses
  - – Test time shorter than ESS
  - – Cheaper

Early-life failures



Useful- life



Useful- life

- Characterised by failures occurring randomly over time
- Due to non-systematic, minor anomalous process variations, for example:
  - Marginal design / tolerance build-up
  - Random periods of reduced manufacturing process control
  - Component part batch problems
  - Maintenance induced failure

Minimising failures during useful life

- Learning *(and using)* lessons from current products
  - Determine those factors that have a significant effect on product reliability by analysing in-service with manufacturing data.
  - Root Cause analysis of service issues enables generic process improvements in design and manufacture

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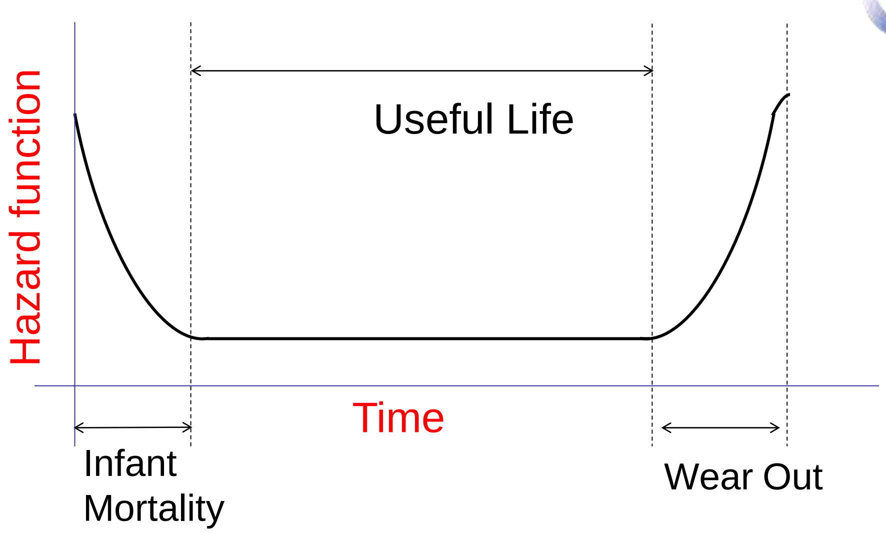
Wear-out



Wear-out

- Characterised by failure mechanisms broadly repeated across a product type, often following a similar period of use.
- Due to systematic weak links in design / manufacture.
  - Processes that consistently stress product during Manufacture
  - Design / Selection of inappropriate parts or function
  - Incompatibility between design and manufacturing capability
- Not necessarily an ‘end of life’ issue
  - Could occur at any point during product life

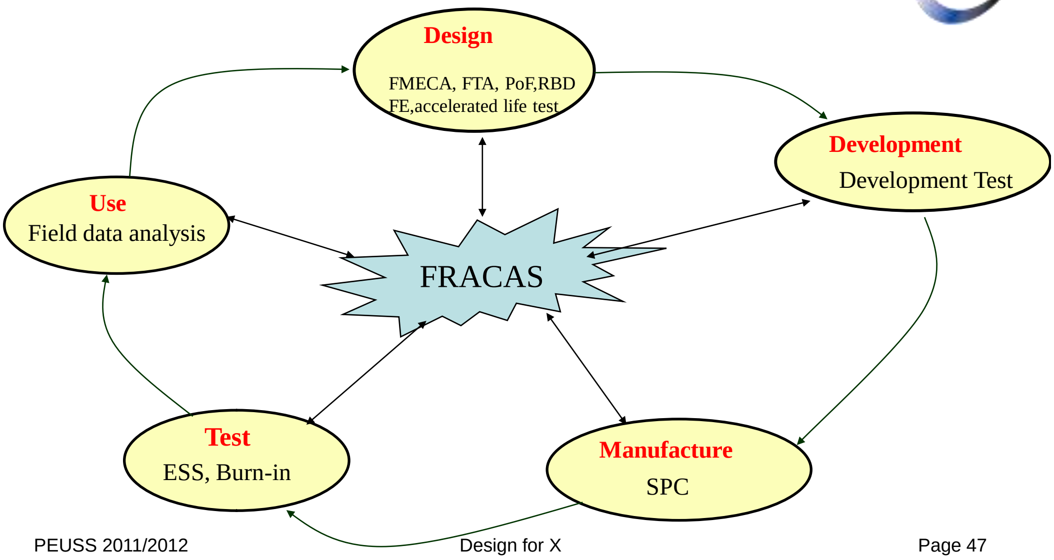
Wear-out - solutions

- How can systematic problems be detected prior to use ?
  - Physics of Failure (PoF) analysis,
  - Finite Element Analysis,
  - Design Of Experiments,
  - Reliability Enhancement Testing (RET)

Design for Reliability

- Design for useful life
- Design out inherent weaknesses using tools such as:
  - FMECA
  - Fault tree analysis (FTA)
  - Physics of Failure
  - ESS
  - Finite element analysis
  - Development Testing
  - Data analysis

Product life cycle



Design

FMECA, FTA, PoF,RBD
FE,accelerated life test

Development

Development Test

Use

Field data analysis

FRACAS

Test

ESS, Burn-in

Manufacture

SPC

Design for maintainability

- To minimise:
  - The downtime for maintenance,
  - user and technician maintenance time,
  - personnel injury resulting from maintenance tasks,
  - cost resulting from maintainability features, and
  - logistics requirements for replacement parts, backup units, and personnel
- Maintenance actions can be preventive, corrective, or recycle and overhaul

Design for serviceability

- Ability to diagnose, remove, replace, replenish, or repair any component or subassembly to original specifications with relative ease
- Poor serviceability produces warranty costs, customer dissatisfaction, and lost sales and market share due to loss loyalty
- Have serviceability personnel involved in the early stages, as they are considered a customer segment.

Design for the environment

- Addresses environmental concerns as well as post-production transport, consumption, maintenance, and repair
- The aim is to minimize environmental impact, including strategic level of policy decision-making and design development
- DFE usually comes with added initial cost, causing an increment of total life cost
- Economic evaluation is required both for maximum economic benefit and to estimate what the expected financial savings (or losses) will be

Design for life-cycle cost

- Real cost of the design
- Includes the associated costs of defects, litigations, buybacks, distributions support, warranty, and the implementation cost of all employed DFX methods
- *Activity-based cost* (ABC)* is a method for estimating life-cycle design cost
- ABC assumes that the design, whether a product, a service, or a process, *consumes activities.*
- ABC objective is to identify activities in the design life, and then assign reliable cost drivers and consumption intensities to the activities

In-module assignment

- Watch the video
- Identify the main causes of the crash and characterise the faults – choose categories such as human factors, system design, reliability, maintenance etc.
- Investigate which DFX (one or more) is the most appropriate to prevent the faults
- Which tools for a given DFX would be most appropriate for preventing such faults.
- This work will be done in groups and the marks for the assignment will be given on the presentation given at the end of the week.