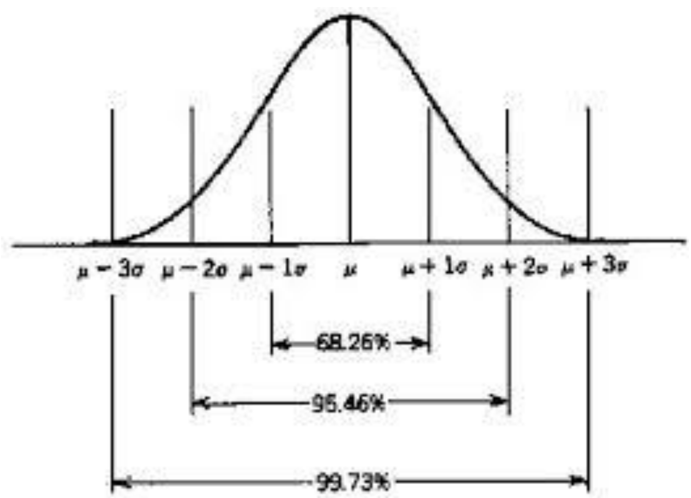
Design for X

ENGR 2110

Standard Deviation

What does standard deviation really mean?



$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}$$

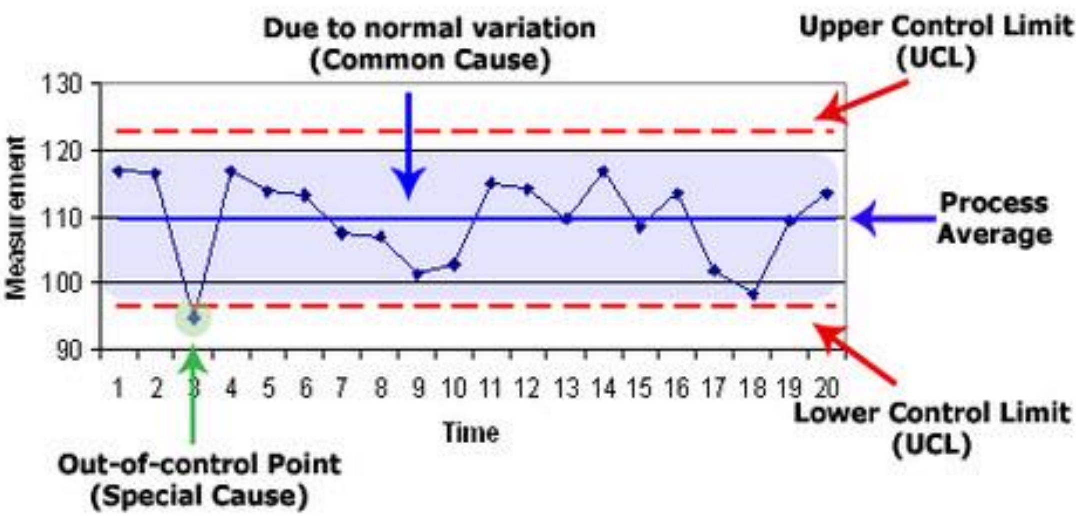
A measure of the average deviation from the mean and how spread out the data is!

Six Sigma

- Six Sigma quality is a term generally used to indicate that a process is well controlled (within process limits $\pm 3\sigma$ from the center line in a control chart, and requirements/tolerance limits $\pm 6\sigma$ from the center line).

Control Chart

- The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data.



DFSS/DFX

Design for Six Sigma (DFSS) is the methodology associated with the design of a process, product, or service, which results in Six Sigma output that satisfies both the external customer and internal business requirements.

Design for X (DFX) is a component of Design for Six Sigma (DFSS)

DFX Tools

- Design for Manufacture and Assembly;
- Design for Reliability;
- Design for Maintainability;
- Design for Serviceability;
- Design for the Environment;
- Design for Life Cycle Cost;
- and so on

DFMA

- Analyze each design parameter that can be identified as a part or subassembly for manual or automated manufacture

- Gradually reduce waste

DFA

- Identify
  - parts that can be eliminated
  - parts that may be trimmed or reduced
- Attack waste sources such as
  - Assembly directions that require unnecessary operations
  - Design Parameters with unnecessarily tight tolerances

Boothroyd-Dewhurst DFA methodology

(1) During operation of the product, does the part move relative to all other parts already assembled?

(2) Must the part be a different material than, or be isolated from, all other parts already assembled? Only fundamental reasons concerned with material properties are acceptable.

(3)Must the part be separate from all other parts already assembled because the necessary assembly or disassembly of other separate parts would otherwise be impossible?

DFA

- A “Yes” answer to any of these questions indicates the part must be separate (critical)
- Non-critical parts can theoretically be removed or physically coupled with other critical parts.
- Therefore, theoretically, the number of critical parts is the minimum number of separate parts of the design.

DFA

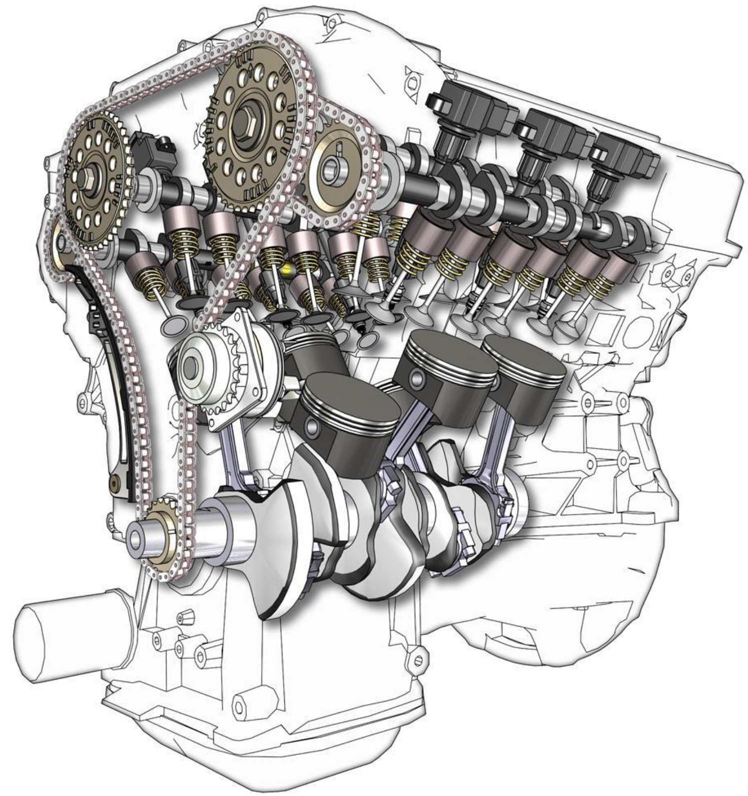
- Estimate assembly time
- Determine how it will be grasped, oriented and inserted into product
- Rating->standard times for ALL operations needed to assemble part

Additional Criteria

- Storing & Retrieval
- Handling
- Identifying, Picking-Up, Moving
- Positioning
  Orientating, Aligning
- Joining
- Adjusting
- Securing
- Inspecting

DFA criteria

- Standardization of assembly operations
- Use of existing assembly equipment and tools
- Use of standard assembly tools



Number of operations in overall assembly

• Favorable sequence (preassembly, parallel assembly)

Other DFA criteria

- Possibility of automation
- Freedom from possible assembly errors
- Avoidance of damage to components
- Avoidance of special training of the assembly staff
- Maintenance of safe working conditions
- Observance of ergonomic standards

When DFA applicable?

DFA is applicable to

– Products consisting of 20 -200 parts

– Mainly for mechanical parts (not electronic circuits)

– Dimensions lie between those of watches and cars

- No specialized knowledge of production means is needed
- Requires 1-2 days to perform for a product
- Often 30% improvement in the assembly cost
- Can be performed in the various stages in the design process and repeated

DFM

- Analyze the manufacture of the individual parts.
- Enable the DFSS team to weigh alternatives, assess manufacturing cost, and make trade-offs between physical coupling and increased manufacturing cost.
- The DFM approach provides experimental data for estimating cost of many processes.

DFR

- Reliability is the probability that a physical entity delivers its functional requirements (FRs) for an intended period under defined operating conditions. The time can be measured in several ways.

DFR Time

- Time can be measured by
  - Number of cycles
  - Time in service
  - Mileage or distance
- Assessment involves testing and analysis of
  - Strength (dynamic and static), environmental factors, improper usage by end user

DFR

- A reliable design should anticipate all that might go wrong. Two categories:
- Knowledge based-engineering
  - Designing products to bear applied loads or convert/transfer energy
- Variation control
  - Accounting for sources and effects of variation that can affect functional performance

DFR

DFR adapts the law of probability to predict failure and adopts:

1. Measures to reduce failure rates in the physical entity by employing design axioms and reliability science concurrently.
2. Techniques to calculate reliability of key parts and design ways to reduce or eliminate coupling and other design weaknesses.
3. *Derating*—using parts below the specified nominal values.
4. Design failure mode–effect and criticality analysis (FMECA), which is used to search for alternative ways to correct failures. A "failure" is the unplanned occurrence that prevents the system or component from meeting its functional requirements under the specified operating conditions.
5. Robustness practices by making the design insensitive to all uncontrollable sources of variation (noise factors).
6. Redundancy, where necessary, which calls for a parallel system to back up an important part or subsystem in case it fails.

DFR

- Minimizing damage from shipping, service, and repair
- Counteracting the environmental and degradation factors
- Reducing design complexity. (See El-Haik and Young 1999.)
- Maximizing the use of standard components
- Determining all root causes of defects, not symptoms, using DFMEA
- Controlling the significant and critical factors using SPC (statistical process control) where applicable
- Tracking all yield and defect rates from both in-house and external suppliers and
- developing strategies to address them

DFR Tools

- Hazard analysis
- Fault Tree Analysis
- Design Failure Mode and Effects Analysis (DFMEA)/Failure Mode Effects and Critical Analysis (FMECA)
- Fishbone Diagram

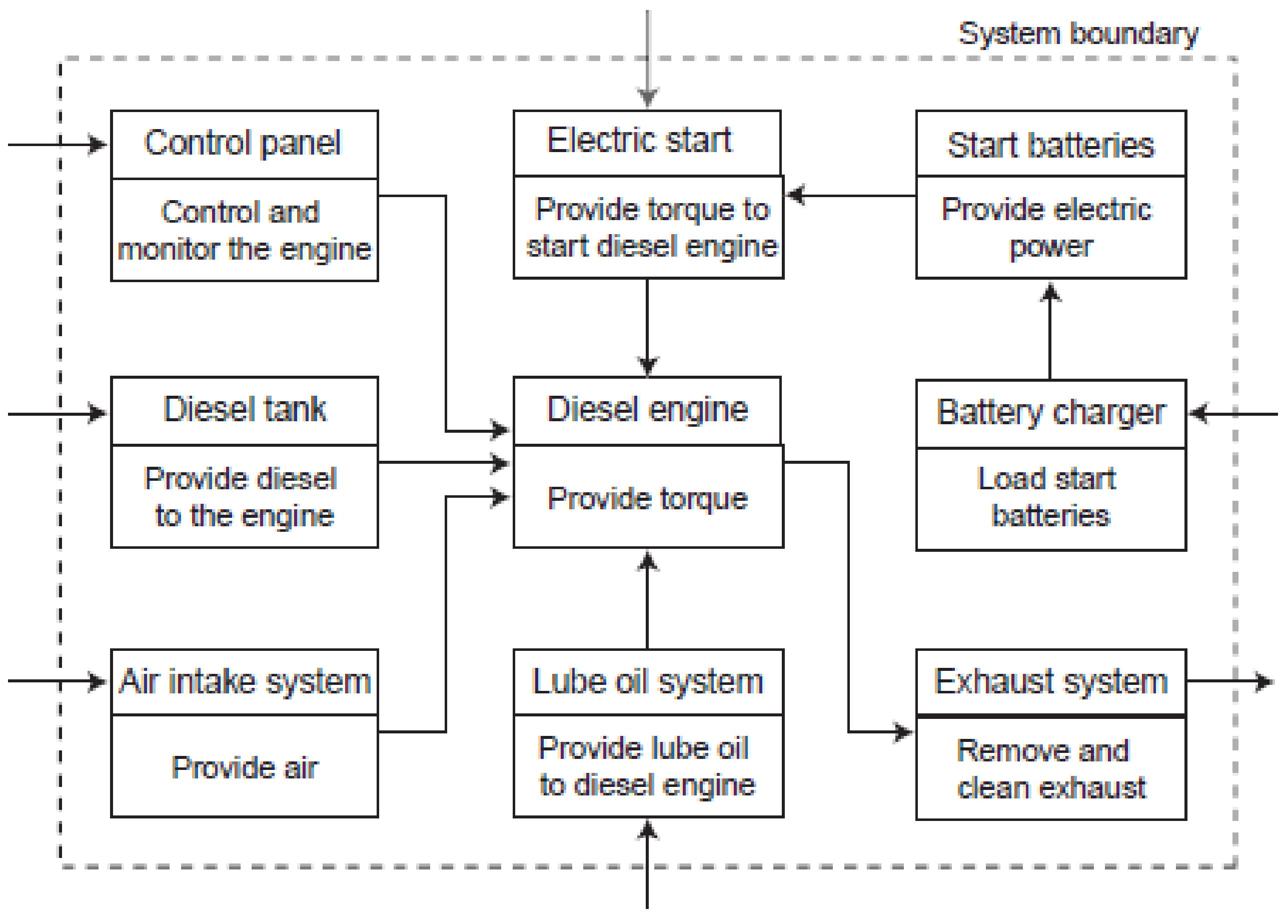
FMECA

- Define the system to be analyzed
  - (a) System boundaries (which parts should be included and which should not)
  - (b) Main system missions and functions (incl. functional requirements)
  - (c) Operational and environmental conditions to be considered
- Note: Interfaces that cross the design boundary should be included in the analysis

FMECA

- Collect available information that describes the system to be analyzed; including drawings, specifications, schematics, component lists, interface information, functional descriptions, and so on
- Collect information about previous and similar designs from internal and external sources; interviews with design personnel, operations and maintenance personnel, component suppliers, and so on

FMECA

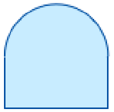

System boundary
Control panel
Control and monitor the engine
Electric start
Provide torque to start diesel engine
Start batteries
Provide electric power
Diesel tank
Provide diesel to the engine
Diesel engine
Provide torque
Battery charger
Load start batteries
Air intake system
Provide air
Lube oil system
Provide lube oil to diesel engine
Exhaust system
Remove and clean exhaust

FMECA

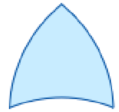
Description of unit			Description of failure			Effect of failure					
Ref. no	Function	Opera-tional mode	Failure mode	Failure cause or mechanism	Detection of failure	On the subsystem	On the system function	Failure rate	Severity ranking	Risk reducing measures	Comments
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

Rank	Description
1-2	Very high probability that the defect will be detected. Verification and/or controls will almost certainly detect the existence of a deficiency or defect.
3-4	High probability that the defect will be detected. Verification and/or controls have a good chance of detecting the existence of a deficiency/defect.
5-7	Moderate probability that the defect will be detected. Verification and/or controls are likely to detect the existence of a deficiency or defect.
8-9	Low probability that the defect will be detected. Verification and/or control not likely to detect the existence of a deficiency or defect.
10	Very low (or zero) probability that the defect will be detected. Verification and/or controls will not or cannot detect the existence of a deficiency/defect.

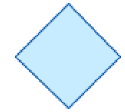
VISIT: http://www.weibull.com/hotwire/issue46/relbasics46.htm



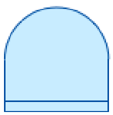
AND gate
The output event occurs if all input events occur.



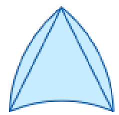
OR gate
The output event occurs if at least one of the input events occurs.



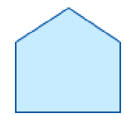
Undeveloped event
An event which is no further developed. It is a basic event that does not need further resolution.



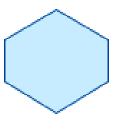
Priority AND gate
The output event occurs if all input events occur in a specific sequence.



XOR gate
The output event occurs if exactly one input event occurs.

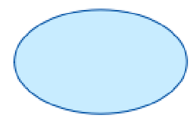


House event
An event that is normally expected to occur. In general, these events can be set to occur or not occur, i.e. they have a fixed probability of 0 or 1.



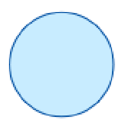
Inhibit gate
The input event occurs if all input events occur and an additional conditional event occurs.

Voting gate
The output event occurs if k or more of the input events occur.

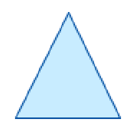


Conditional event
A specific condition or restriction that can apply to any gate.

Event

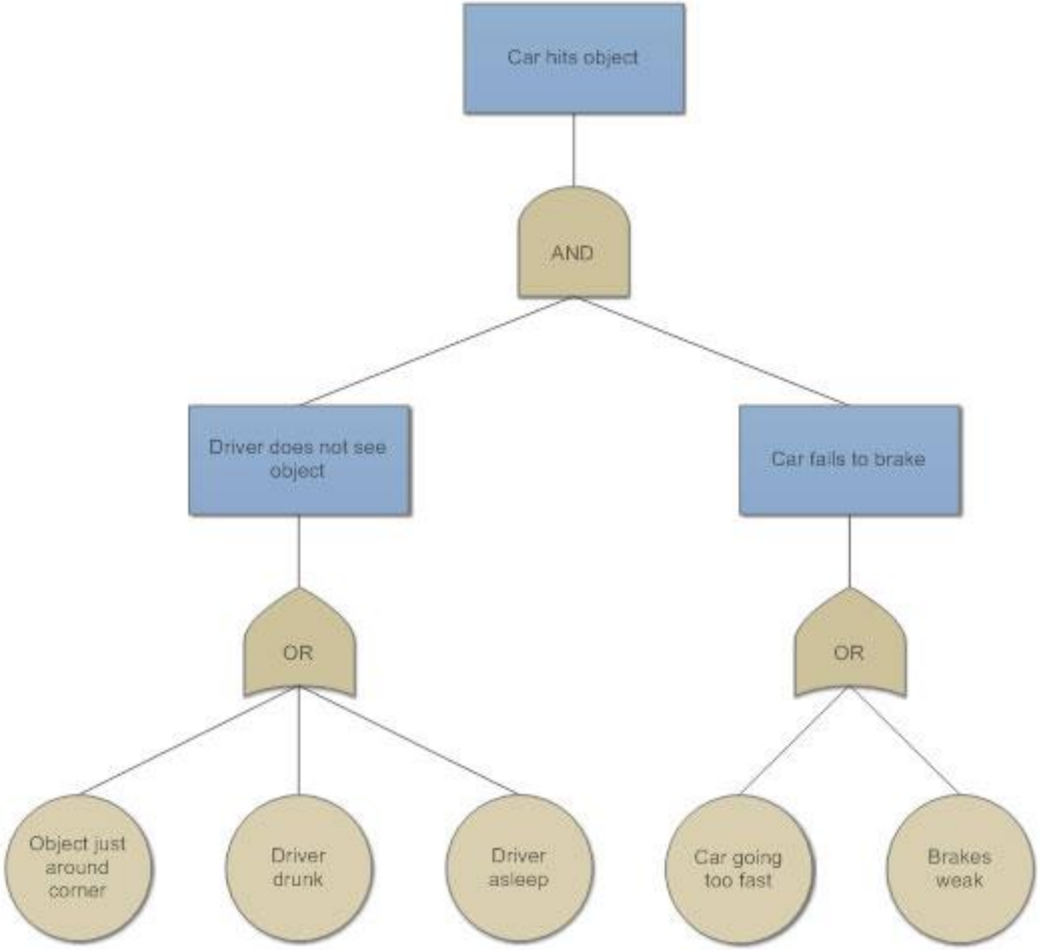


Basic event
A basic initiating fault (or failure event)



Transfer symbol
Indicates a transfer continuation to a sub tree.

Fault Tree Diagram



Fishbone Diagram