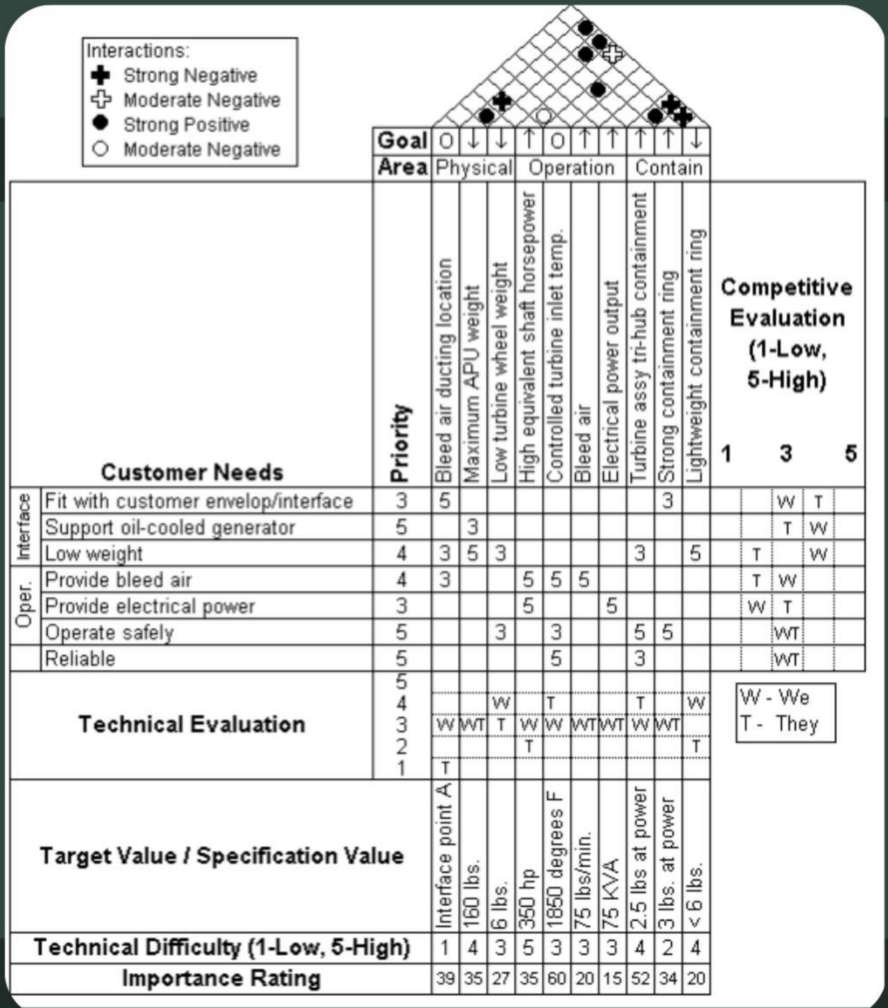


Interactions:
- Strong Negative
- Moderate Negative
- Strong Positive
- Moderate Negative

	Customer Needs	Priority	Bleed air ducting location	Maximum APU weight	Low turbine wheel weight	High equivalent shaft horsepower	Controlled turbine inlet temp.	Bleed air	Electrical power output	Turbine assy tri-hub containment	Strong containment ring	Lightweight containment ring	Competitive Evaluation (1-Low, 5-High) 1	2	3	4	5
	Goal		O	↓	↓	↑	O	↑	↑	↑	↑	↓					
	Area		Physical			Operation				Contain							
Interface	Fit with customer envelop/interface	3	5								3				W	T	
Interface	Support oil-cooled generator	5		3											T	W	
Interface	Low weight	4	3	5	3					3		5		T		W	
Oper.	Provide bleed air	4	3			5	5	5						T	W		
Oper.	Provide electrical power	3				5			5					W	T		
Oper.	Operate safely	5			3		3			5	5				WT		
	Reliable	5					5			3					WT		
	Technical Evaluation	5															
		4			W		T			T		W					
		3	W	WT	T	W	W	WT	WT	W	WT						
		2				T						T					
		1	T														
	Target Value / Specification Value		Interface point A	160 lbs.	6 lbs.	350 hp	1850 degrees F	75 lbs/min.	75 KVA	2.5 lbs at power	3 lbs. at power	< 6 lbs.					
	Technical Difficulty (1-Low, 5-High)		1	4	3	5	3	3	3	4	2	4					
	Importance Rating		39	35	27	35	60	20	15	52	34	20					

W - We
T - They

Quality Function Deployment (QFD)

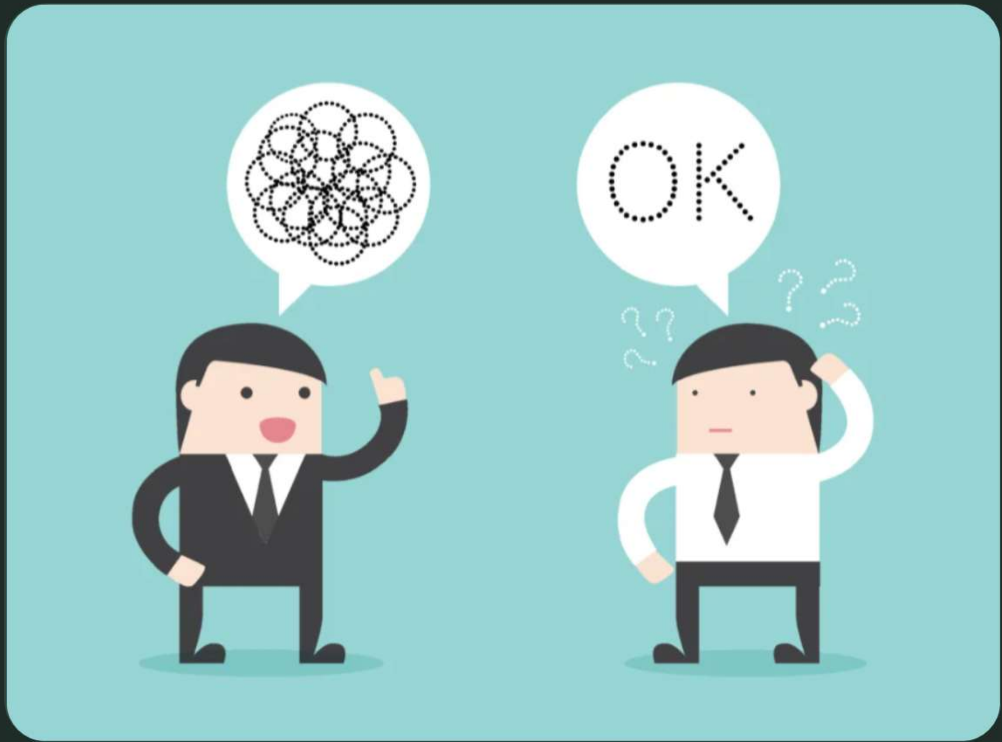
GROUP 1

What is the QFD Method?

Communication

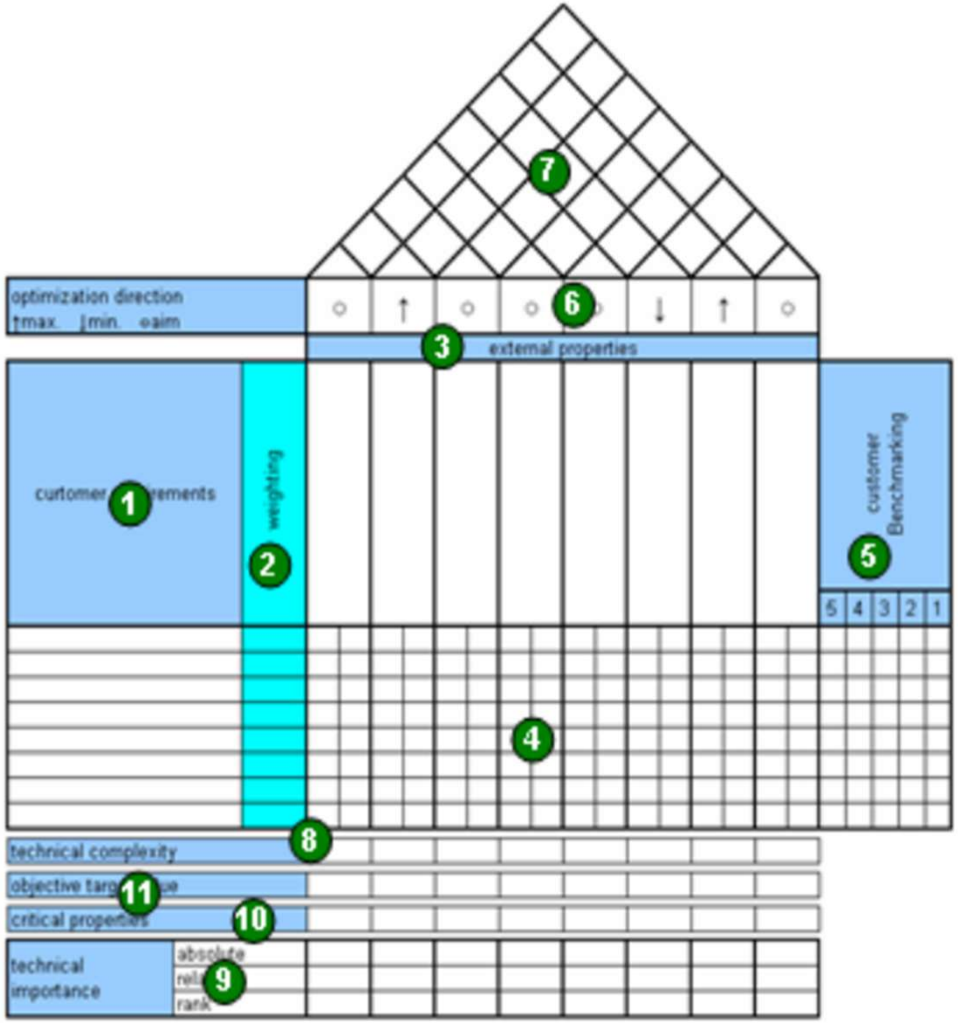
Customer needs --->

Technical requirements



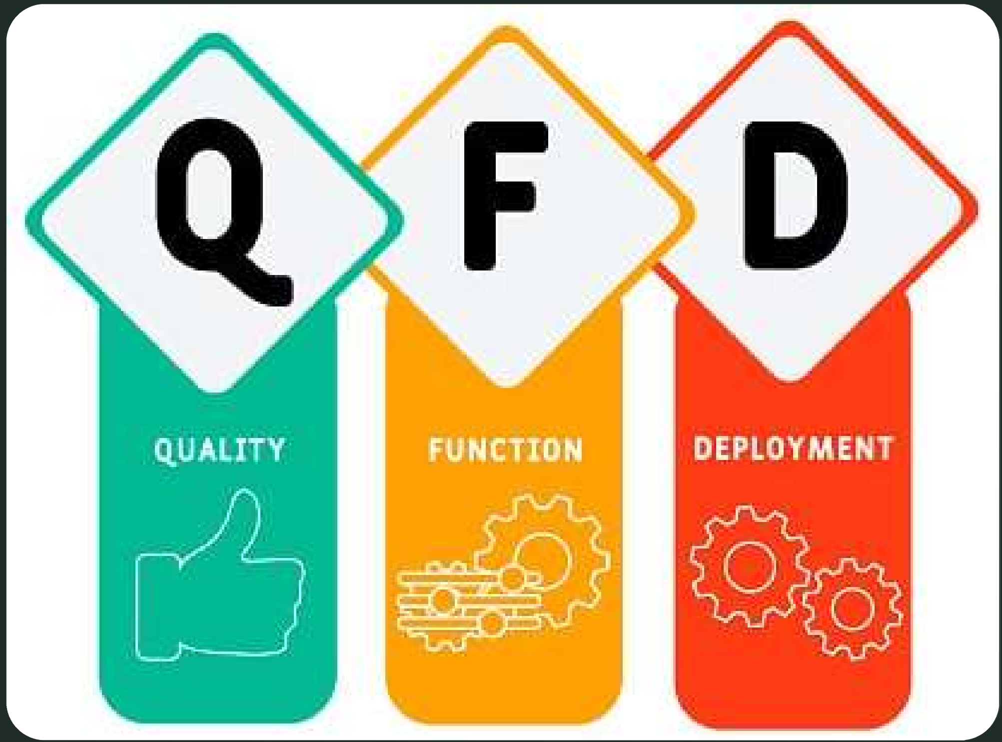
Steps to Use QFD

1. WHATs: Define Customer Requirements
2. HOWs: Identify Technical Requirements
3. Evaluate Relationships
4. Determine the correlation between HOWs
5. Calculate Importance Scores
6. Competitive Assessment (Optional)
7. Develop Technical Specifications and Targets
8. Deployment to Subsequent Levels



1. customer requirements
2. weigthing of requirements
3. external properties
4. quality, relation matrix
5. Customer benchmarking
6. optimization
7. correlation of the external properties
8. technical complexity
9. importance of external properties
10. critical properties
11. objektive target value

How is the QFD Method used?



How QFD is relevant in Reliability engineering

1. Align reliability Goals with customer expectations

2. Prioritise Critical Design parameters

3. Prevent over-engineering

QFD in Automotive Industry: Toyota Lexus LS400

Goal: Compete with Mercedes-Benz by delivering unmatched quality, reliability, and comfort

Method: Collected detailed VoC through surveys, interviews, and market studies

Mini House of Quality

Customer Needs	Acoustic insulation	Suspension system	Door sealing	Engine mount design	Benchmarking vs. Mercedes
Quiet cabin	🏠🏠🏠	🏠🏠	🏠🏠🏠	🏠🏠	Better
Smooth ride	🏠	🏠🏠🏠	🏠	🏠🏠🏠	Equal
Safe driving	🏠	🏠🏠	🏠	🏠🏠	Equal
Luxury feel	🏠🏠	🏠🏠	🏠	🏠🏠	Equal

Legend: Strong relationship 🏠🏠🏠 | Moderate relationship 🏠🏠 | Weak relationship 🏠

1980s Lexus LS400

Link to reliability:

- QFD helped to reduce design flaws before production
- Proactively addressed failure risks
- Resulted in a vehicle known for:
  - Long-term durability
  - Small amount of mechanical issues
  - High customer satisfaction

Outcome:

- The vehicle launched to worldwide praise
- Set new standards for luxury vehicle reliability
- Cited as a textbook case of successful QFD uses to this day.

Advantages and Disadvantages of QFD

Advantages

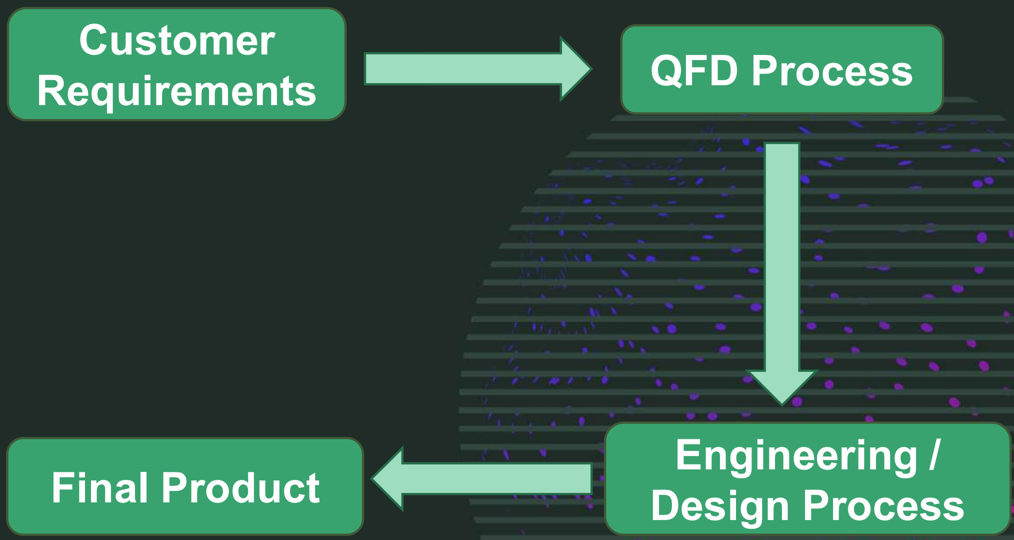
- Boosts product quality
- Organizes data systematically
- Improves customer satisfaction
- Shortens development time
- Reduces waste and startup costs
- Encourages teamwork and consensus
- Enhances competitive analysis

Disadvantages

- Complex and time-consuming
- Labor-intensive process
- Conflicts in team opinions
- Difficult for non-technical users
- Limited for fast-paced/less structured projects

Modern day use of QFD

- Wide use in companies that emphasize **customer-driven design** and **lean principles**. Main industries include:
  - Automotives
  - Electronics
  - Manufacturing
  - Healthcare



Real-world modern application of QFD

Toyota

Toyota still uses QFD for:

- Electric vehicle development (e.g., aligning customer demand for range, fast charging, eco-friendliness with engineering specs).
- Translating sustainability goals and priorities into product and process design.

Integration of QFD with Lean, Six Sigma & reliability-centered design

Lean

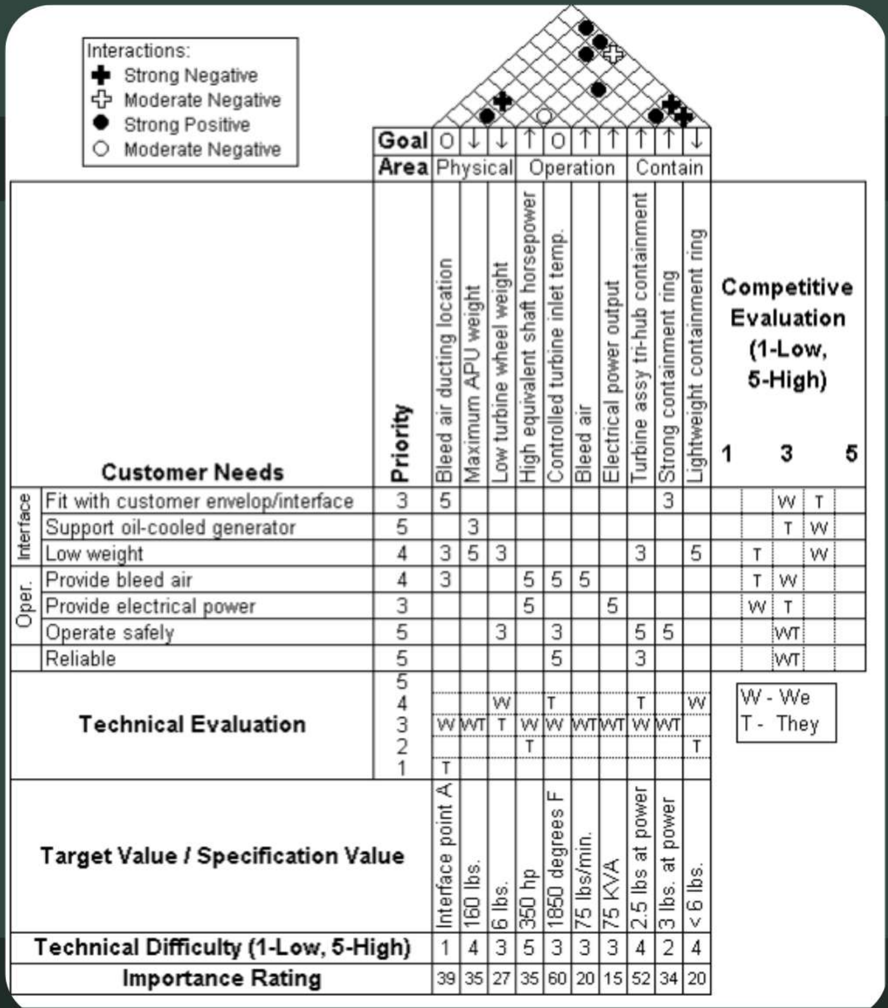
- **Purpose**: Eliminate waste and deliver customer value efficiently.
- **How QFD fits in**:
  - Identifies what customers truly value.
  - Prevents overproduction of unnecessary features (eliminating waste).
  - Aligns team efforts with high-priority customer needs (improving efficiency).

Six Sigma

- **Purpose**: Improve quality and reduce process variation.
- **How QFD fits in:**
  - Helps define CTQs (Critical to Quality elements).
  - Used in Define and Measure stages of DMAIC.
  - Translates customer voice into measurable quality targets.

Reliability-centered Design

- **Purpose**: Ensure products perform reliably under real-world conditions.
- **How QFD fits in:**
  - Prioritizes features related to durability, uptime, and fault tolerance.
  - Supports failure mode analysis and design-for-reliability processes.



Customer Needs		Priority	Bleed air ducting location	Maximum APU weight	Low turbine wheel weight	High equivalent shaft horsepower	Controlled turbine inlet temp.	Bleed air	Electrical power output	Turbine assy tri-hub containment	Strong containment ring	Lightweight containment ring	Competitive Evaluation (1-Low, 5-High) 1	2	3	4	5
	Goal		O	↓	↓	↑	O	↑	↑	↑	↑	↓					
	Area		Physical			Operation				Contain							
Interface	Fit with customer envelop/interface	3	5								3				W	T	
Interface	Support oil-cooled generator	5		3											T	W	
Interface	Low weight	4	3	5	3					3		5		T		W	
Oper.	Provide bleed air	4	3			5	5	5						T	W		
Oper.	Provide electrical power	3				5			5					W	T		
Oper.	Operate safely	5			3		3			5	5				WT		
Oper.	Reliable	5					5			3					WT		
Technical Evaluation		5															
		4			W		T			T		W					
		3	W	WT	T	W	W	WT	WT	W	WT						
		2				T						T					
		1	T														
Target Value / Specification Value			Interface point A	160 lbs.	6 lbs.	350 hp	1850 degrees F	75 lbs/min.	75 KVA	2.5 lbs at power	3 lbs. at power	< 6 lbs.					
Technical Difficulty (1-Low, 5-High)			1	4	3	5	3	3	3	4	2	4					
Importance Rating			39	35	27	35	60	20	15	52	34	20					

Thank you

Christine van der Merwe - 26455102

Sindy Long - 25936670

Aletta Gersbach - 25865714

George de Kock - 26347628

Francois Ackerman - 25862405

Shailin Pillay - 23604387

Q&A

Quality Function Deployment (QFD) in Reliability Engineering

Group 2

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Minya Geyser
Linda Lötter
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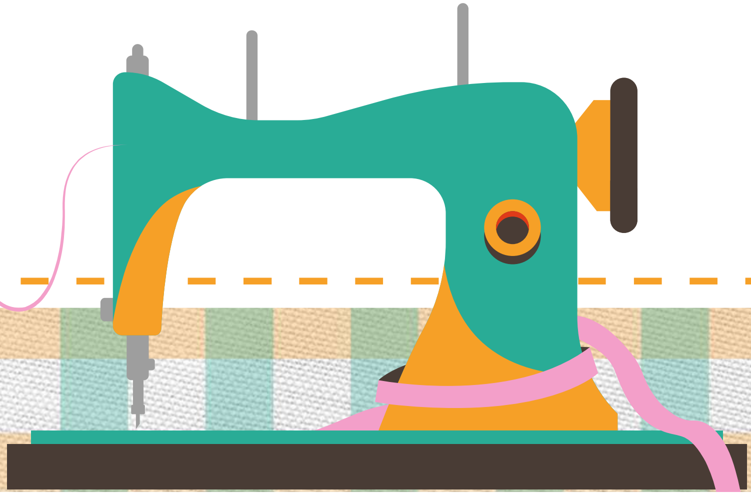
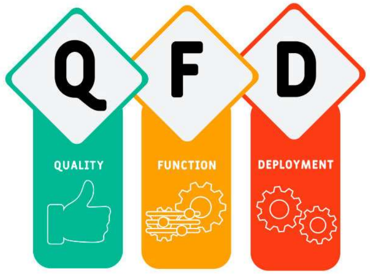


Introduction to QFD

"What if engineers could hear the customer's voice in every bolt, circuit, and button they design?"



Key Historical Highlights

-<u>**Origin**:</u> Developed in **Japan** in the late **1960s** under the **Total Quality Control** (TQC) movement.
-<u>**Pioneers**:</u> Influenced by Dr. Juran, Dr. Ishikawa, and Dr. Akao.
-<u>**Purpose:**</u> To develop a quality assurance method that would design customer satisfaction into a product before it was manufactured.
-<u>**Global Launch**:</u> Introduced to the **USA in 1983** and widely adopted in industries like automotive and electronics.
-<u>**Name Origin**:</u> The term **"House of Quality"** was made popular by **Toyota Auto Body**.

Presentation Agenda

- What is QFD
- How it works (House of Qualities)
- Practical Example (sewing machine)
- Relevance to Reliability engineering
- Benefits and limitations
- Key takeaways

Relevance Today:

QFD is widely used in **reliability engineering** to design products that are robust, meet user expectations, and reduce the risk of failure over time.

What is QFD?

"A way to take what customers want and turn it into product features and design decisions."
~ Yoji Akao (1990)

Key steps of QFD
1. Identifying the customer's requirements 2. Determining the technical requirements to meet those standards 3. Assessing the relationships between customer and technical requirements 4. Prioritizing the most important customer needs to guide design decisions

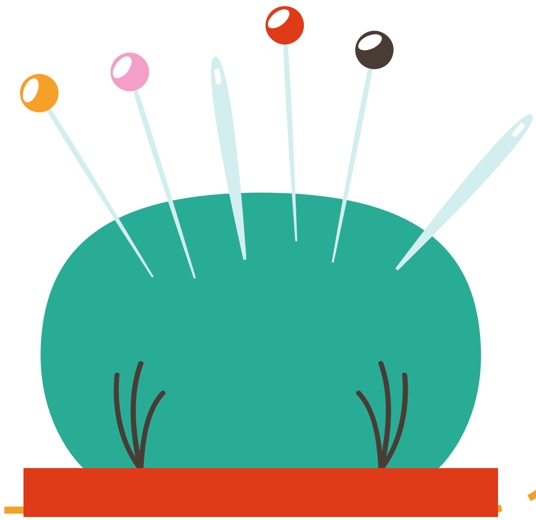
Aim of QFD
1. Ensure customer satisfaction 2. Ensure teams focus on most important features, reduce design mistakes, and build better-quality products

How Does QFD Work?

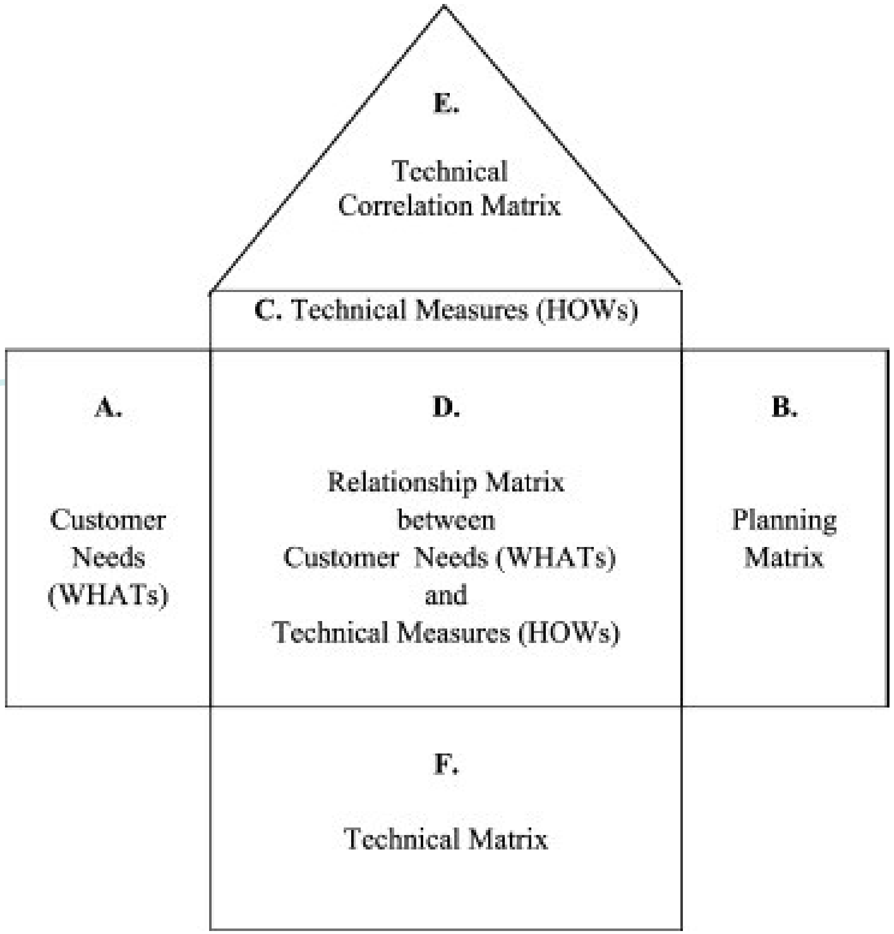
QFD is a Four-Phase Process

House Of Qualities → Parts Deployment → Process Planning → Production Planning

- Converting customer needs into design specifications
- Customer needs are all rated in order of importance
- Technical prioritization and how they relate to key customer needs.
- Cross-functional teamwork is promoted by QFD ensuring departmental collaboration.

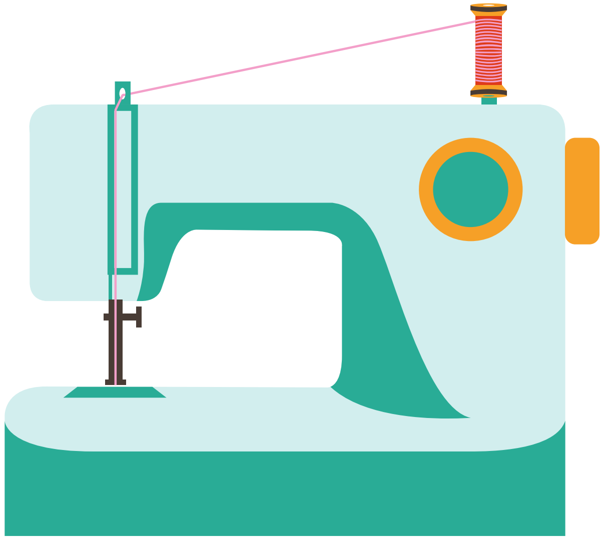


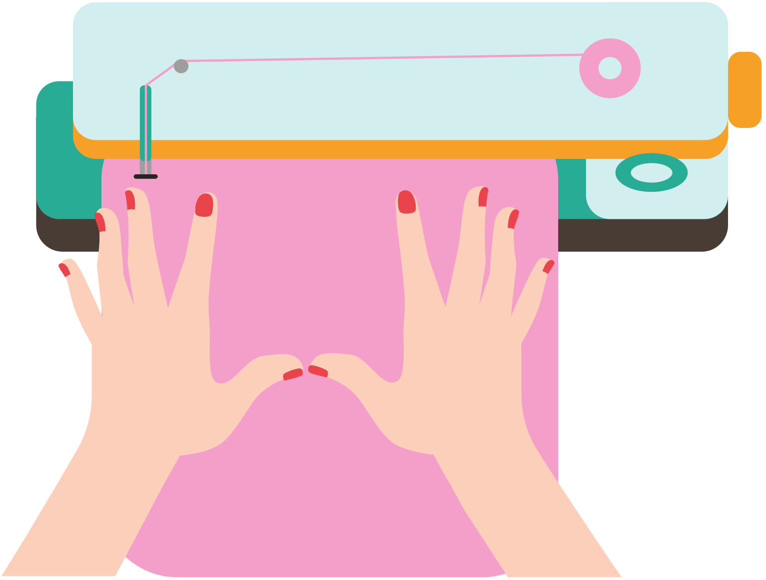
House Of Qualities



- Rows: Customer Requirements
- Columns: Technical Specifications
- Matrix: Shows relationship strength (strong/medium/weak)
- Roof: Shows interaction between technical features

QFD Example:
Sewing Machine





Customer Voice:
"What Do Sewists Really Want?"

Easy to thread

"I want to start projects quickly."

Importance: 5/10

Consistent Stitch Quality

"My stitches should look professional"

Importance: 9/10

Quiet operation

"I don't want to disturb my family."

Importance: 5/10

Durable construction

"This machine should last for years"

Importance: 8/10

House of Quality: Technical Translation

Customer Requirement	Technical Specification	Target Value	Relationship
Easy to thread	Threading guide clarity	3-step visual guide	●●● Strong
Consistent stitch quality	Tension control precision	±0.1mm variance	●●● Strong
Quiet operation	Noise level (dB)	<65 dB	●● Medium
Durable construction	Motor lifespan (hours)	5000+ hours	●●● Strong

Benefits & Limitations of QFD in Reliability

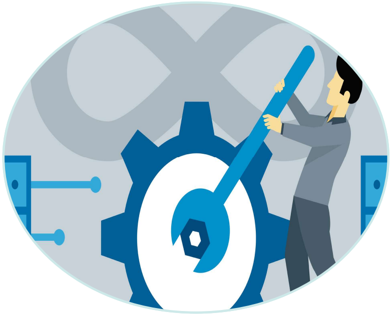
Benefits

- Focuses on customer satisfaction
- Reduces failure rates through systematic approach
- Aligns design with reliability goals
- Systematic documentation of decisions

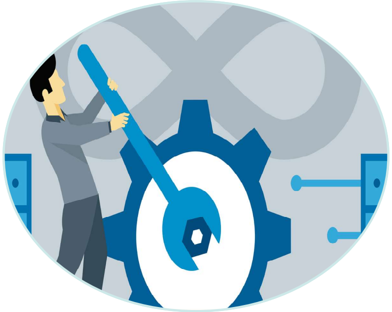
Limitations

- Time-consuming implementation process
- Requires accurate customer data collection
- Complex for large, multi-component systems

QFD prevents the common problem where engineers build what they think customers want rather than what customers actually need for reliability.



Key Takeaways:
QFD in Reliability Engineering



Rich History & Refinement:
QFD has a long history and has been continuously refined towards modern engineering requirements.

Quality-Focused, Realiability-Applicable:
While QFD is traditionally a quality tool, its applicability in guiding reliability engineering decisions is highly effective.

Encourages Holistic Design Approach:
QFD brings together different departments, allowing for better end products.

Customers' Needs guide Design Specification:
Vague customer needs are directly related to measurable technical design specifications with measurable metrics.

Guides Engineers:
Knowing which technical specifications are important to customers guides engineers, resource allocation and innovation.

Supports Continuous Improvement:
Allows adaption of new data, enabling continuous improvement to meeting customers' needs.

"What gets measured, gets managed." - *Peter Drucker*

FAILURE MODE AND EFFECTS ANALYSIS

Presented by Group 3

WHAT IS FMEA?

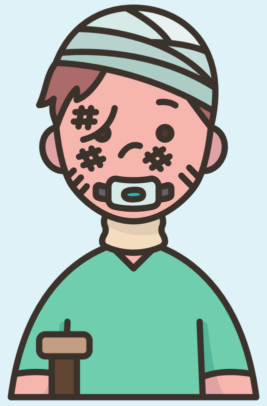
- **FMEA: A structured and systematic approach for identifying potential ways in which a system, process, or product might fail.**

- **GOAL: Prevent failures before they happen (proactively).**

- **Prioritize risks by evaluating:**
  - **Failure Modes (how something might fail)**
  - **Effects (what happens when it fails)**
  - **Causes and Controls**

Cause

Failure Mode



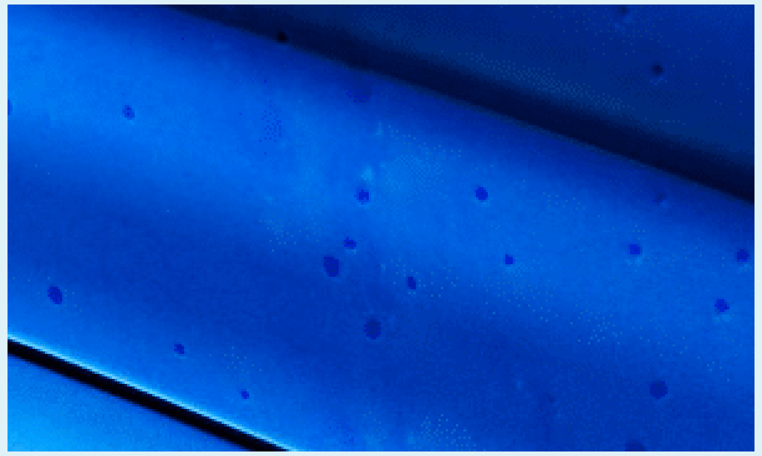
Effect

STEPS IN FMEA

1. **Define Scope: Choose system/process to analyze; form cross-functional team**
2. **List Failure Modes: Brainstorm ways each component/process can fail**
3. **Identify Effects: What happens if that failure occurs? How does it impact the system or customer?**
4. **Identify Causes & Controls: Why might the failure happen? What safeguards are in place?**
5. **Assign Severity (S): How serious is the effect? (Scale 1–10)**
6. **Assign Occurrence (O): How likely is it to happen? (Scale 1–10)**
7. **Assign Detection (D): How likely will current controls detect it before impact? (Scale 1–10)**
8. **Calculate RPN: RPN = S × O × D**
9. **Prioritize & Act: Focus on high RPNs; implement corrective actions**
10. **Review & Update: Reassess after implementing actions or changes**

FMEA EXAMPLE: AUTOMOTIVE PAINT PROCESS

Process Step	Potential Failure Mode	Potential Failure Effects	Severity	Potential Causes	Occurance	Current Controls	Detection	RPN	Actions Recom-mended	Responsibility	Actions Taken	Occurance	Severity	Detection	RPN
Vehicle Painting	Dust particle contami-nates paint	Visible defect, unhappy customer, costly repaint	7	Insuffi-cient booth air filtration	3	Visual Inspec-tion	5	105	Replace filters/ Improve Filtration	Emp-loyee who is Resp.	Filters replaced, Run tests for contami-nation	1	7	5	35



BENEFITS AND LIMITATIONS

Benefits

- Improves safety and reliability
  - Identifies failures and their effects, allowing for a proactive resolution of issues.
- Prevents failures early in design
  - Analyzes components and functions before production, allowing issues to be corrected while changes are still cost effective.
- Focuses efforts where they matter most
  - Helps teams use limited resources efficiently by addressing the most critical risks first.
- Drives continuous improvement
  - FMEA evolves with real-world data, allowing teams to update risks and actions over time

Limitations

- Time Consuming
  - Requires detailed analysis of every process step and component
- Subjective Ratings
  - Scores depend on team judgement, which can vary and create inconsistencies.
- RPN can mislead without context
  - May undervalue serious issues if one rating is low, potentially obscurring critical risks
- Requires expert knowledge
  - Accurate analysis depends on experienced personnel with a deep undertstanding of the system
- Doesn’t handle multi-failure interaction well
  - Evaluates failures in isolation

FINAL THOUGHTS AND Q&A

THANK YOU

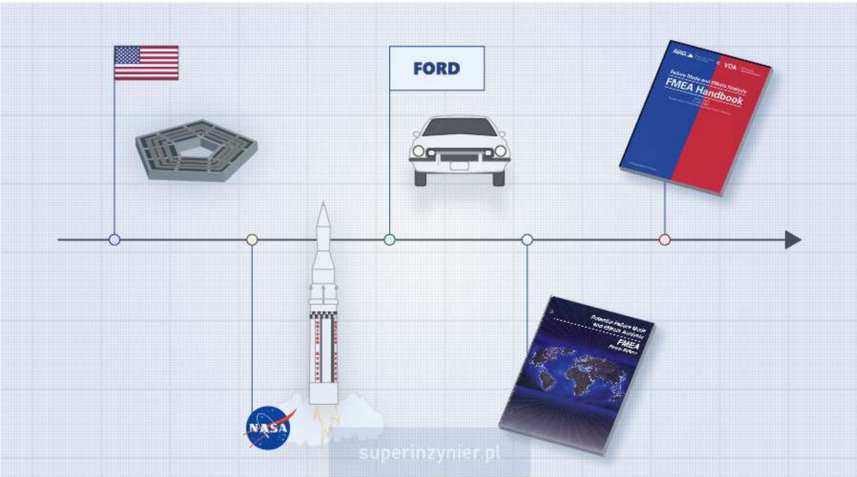
FMEA

QUALITY MANAGEMENT 444
GROUP 4

INTRODUCTION

Failure Modes and Effects Analysis (FMEA)

BRIEF HISTORY



- ORIGINATED IN 1940S WITH US MILITARY
- AIMED TO IMPROVE MISSION-CRITICAL SYSTEMS
- LATER ADOPTED BY NASA AND THEN BY THE AUTOMOTIVE INDUSTRY
- USED TODAY IN VARIOUS INDUSTRIES FOR PROACTIVE RISK ASSESSMENT AND QUALITY IMPROVEMENT

DFMEA & PFMEA

- DESIGN FAILURE MODES AND EFFECTS DESIGN
- PROACTIVE RISK ASSESSMENT TOOL
- USED IN PRODUCT DEVELOPMENT
- IDENTIFIES POTENTIAL FAILURE MODES WITHIN A PRODUCT'S DESIGN

- PROCESS FAILURE MODES AND EFFECTS DESIGN
- SYSTEMATIC METHOD
- USED TO IDENTIFY POTENTIAL FAILURES IN A MANUFACTURING PROCESS
- ANALYSES THE EFFECTS
- IMPLEMENTS PREVENTIVE ACTIONS

PURPOSE AND BENEFITS OF FMEA

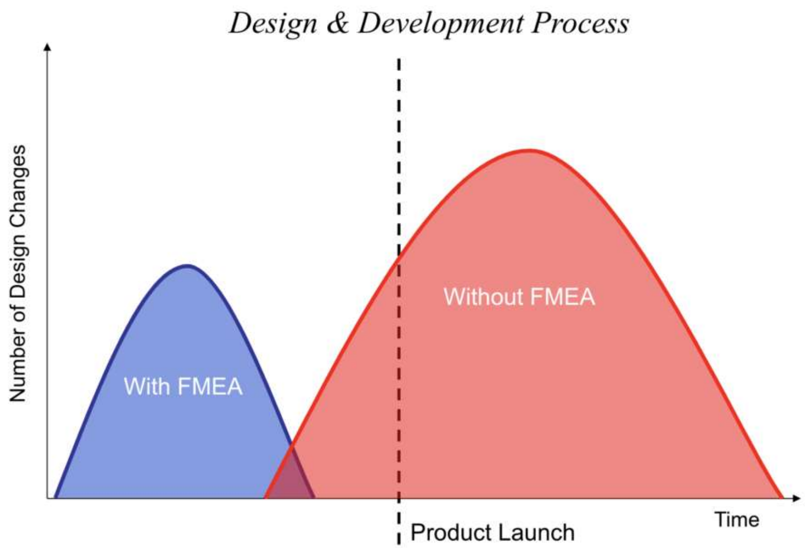
Why use FMEA?

- Prevents failures before they occur
- Improves reliability and product quality.
- Reduces need for late-stage fixes
- Encourages proactive risk assessment

REAL BUSINESS IMPACT OF FMEA

Ford Case Study highlights:

- Defects decrease to 0.2 parts per million
- Increase equipment uptime from 74% to 89%
- Eliminate customer complaints entirely



FMEA enables early detection and resolution of design risks, reducing cost and disruption.

Source: Jama Software, 2024. *Meeting Regulatory Compliance and Industry Standards with FMEA*. [online] Available at: https://www.jamasoftware.com/requirements-management-guide/meeting-regulatory-compliance-and-industry-standards/fmea/ [Accessed 28 Jul. 2025].

FMEA PROCESS

A way to identify the failures, effects and risks within a process or product, and then eliminate or reduce them.

* **Failure modes:** ways in which a product or process can fail. Each failure mode has a potential effect.

FMEA PROCESS

Evaluating the risk of failure

- Severity – The consequence of the failure should it occur.
- Occurrence – The probability or frequence of the failure occurring.
- Detection – The probability of the failure being detected before the impact of the failure is realised.

Assessing the risk priority number (RPN)

- To rank the need for corrective actions to eliminate or reduce the potential failure modes.

$$RPN = Severity \times Occurrence \times Detection$$

- Resulting RPN: A new RPN is calculated after corrective action was taken.

10 STEPS OF FMEA

Step 1 - Review the process or product.

Step 2 - Brainstorm potential failure modes.

Step 3 – List potential effects for each failure mode.

Failure Mode and Effects A

Process or Product: Product: Model X-1050 Fire Extinguisher
FMEA Team: Kevin M, Shane T, KC McG, Chase L, Tyler J
Team Leader: Kevin M.

FMEA Process

Line	Component and Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Cause(s) of Failure	Occurrence	Current Controls, Prevention
1	Hose; delivers extinguishing agent	Cracks					
2		Pinholes					
3		Blockages					
4	Canister; reservoir for extinguishing agent	Paint coverage uneven					
5		Canister dented					
6		Label not properly applied					
7	Charge gauge: determine remaining volume of agent	Inaccurate reading					
8		Broken crystal					
9	Valve mechanism; releases agent	Safety pin missing					
10		Handle jams					

Step 2: Partially completed FMEA Worksheet.
(Basics of FMEA, 2nd edition)

10 STEPS OF FMEA

Step 4 - Assign a severity ranking for each effect.

Step 5 - Assign an Occurrence Ranking for Each Failure Mode.

Step 6 - Assign a detection ranking for each failure mode and/or effect.

Table 8.2a (Generic) Design FMEA Severity Evaluation Criteria

Effect	Criteria: Severity of Effect on Product (Customer Effect)	Rank
Failure to Meet Safety and/or Regulatory Requirements	Potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulations without warning.	10
	Potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulations with warning.	9
Loss or Degradation of Primary Function	Loss of primary function (vehicle inoperable, does not affect safe vehicle operation).	8
	Degradation of primary function (vehicle operable, but at reduced level of performance).	7
Loss or Degradation of Secondary Function	Loss of primary function (vehicle inoperable, but comfort/ convenience functions inoperable).	6
	Degradation of primary function (vehicle inoperable, but comfort/ convenience functions at reduced level of performance).	5
Annoyance	Appearance or Audible Noise, vehicle operable, item does not conform and noticed by most customers (>75%).	4
	Appearance or Audible Noise, vehicle operable, item does not conform and noticed by many customers (50%).	3
	Appearance or Audible Noise, vehicle operable, item does not conform and noticed by discriminating customers (<25%).	2
No effect	No discernible effect.	1

Source: Reprinted from Potential Failure Mode and Effects Analysis, (FMEA 4th edition, 2008 Manual) with permission of DaimlerChrysler, Ford and GM Supplier Quality Requirements Task Force.

10 STEPS OF FMEA

Step 7- Calculate the RPN for each failure mode

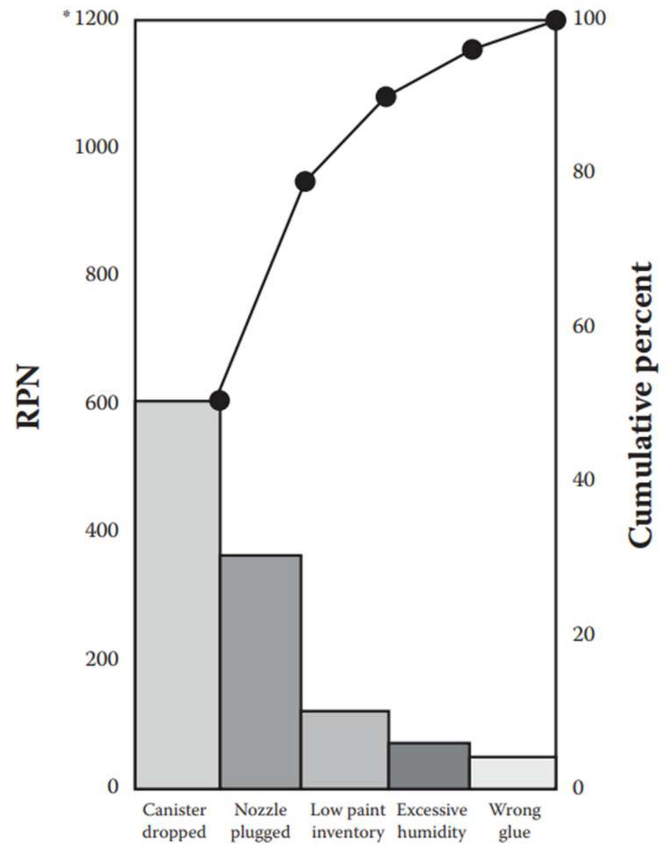
Step 8 - Prioritize the failure modes for action.

Step 9 - Take action to eliminate or reduce the high-risk failure modes.

Step 10 - Calculate the resulting RPN as the failure modes are reduced or eliminated.

Table 8.5 Specific Actions to Reduce Rankings

Severity	*Occurrence*	*Detection*
■ Personal protective equipment (e.g., hard hats or bump caps, side shields on safety glasses, full face protection, cut-proof gloves, long gloves) ■ Safety stops/emergency shut-offs	■ Increasing the Cpk through design of experiments and/or equipment modifications. ■ Focus on continuous improvement/ problem-solving teams. ■ Engaging mechanism	■ Statistical process control (to monitor the process and identify when the process is going out of control) ■ Ensure the measuring devices are accurate and regularly calibrated.



Step 8: Pareto diagram of rankings (Basics of FMEA, 2nd edition).

FMEA PROCESS

Failure Mode and Effects Analysis Worksheet

Process or Product: ______________________
FMEA Team: ______________________
Team Leader: ______________________

FMEA Number: ______
FMEA Date: (Original) ______
(Revised) ______
Page: 1 of 1

	FMEA Process												Action Results				
Line	Component and Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Potential Cause(s) of Failure	Occurrence	Current Controls, Prevention	Current Controls, Detection	Detection	RPN	Recommended Action	Responsibility and Target Completion Date	Action Taken	Severity	Occurrence	Detection	RPN
1																	
2																	
3																	
4																	
5																	
6																	

REAL-WORLD EXAMPLE

FMEA IN THE AUTOMOTIVE INDUSTRY

TOYOTA BRAKE PEDAL FAILURE (2009–2010)

- IN 2009–2010, TOYOTA FACED A MAJOR RELIABILITY CRISIS INVOLVING UNINTENDED ACCELERATION AND BRAKE SYSTEM FAILURES IN MILLIONS OF VEHICLES, INCLUDING THE TOYOTA CAMRY AND COROLLA.
- THE ISSUE WAS TRACED TO A **POTENTIAL FAILURE MODE IN THE BRAKE PEDAL ASSEMBLY**, WHERE CONDENSATION AND WEAR CAUSED **STICKING OR DELAYED RESPONSE** IN THE PEDAL MECHANISM.
- TOYOTA ENGINEERS CONDUCTED A FULL **DFMEA(DESIGN FMEA) ON THE BRAKE PEDAL SUBSYSTEM** TO UNDERSTAND THE FAILURE MODES, CAUSES, EFFECTS, AND PRIORITIES CORRECTIVE ACTIONS (KIM, 2011).

FMEA FINDINGS AND ACTIONS TAKEN

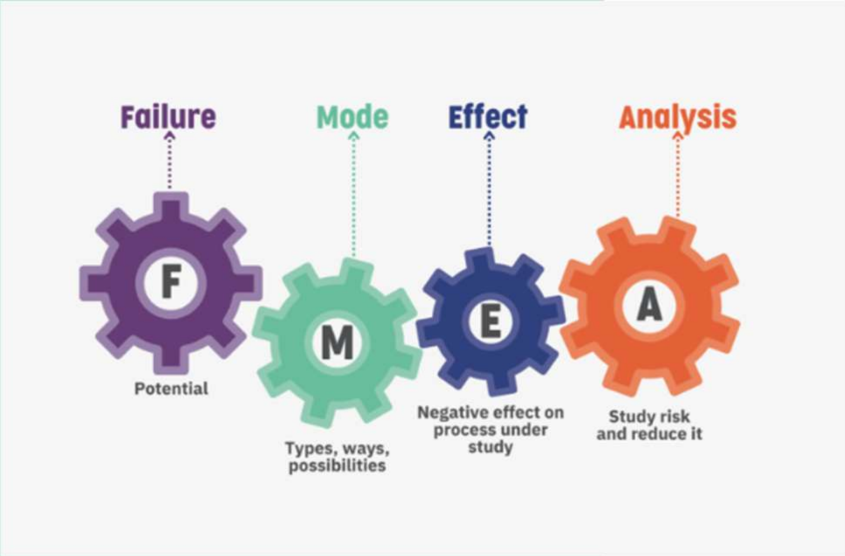
- FAILURE MODE: BRAKE PEDAL BECOMES SLOW TO RETURN OR STICKS IN DEPRESSED POSITION.
- EFFECT: DELAYED OR FAILED BRAKING RESPONSE – A MAJOR SAFETY RISK.
- CAUSE: CONDENSATION AND MATERIAL FATIGUE INSIDE THE PEDAL MECHANISM.
- SEVERITY RATING: HIGH (BRAKING FUNCTION CRITICAL TO SAFETY).
- TOYOTA REDESIGNED THE PEDAL MECHANISM USING MORE HEAT- AND MOISTURE-RESISTANT MATERIALS, MODIFIED THE GEOMETRY, AND INTRODUCED ADDITIONAL QUALITY CHECKS ON ALL BRAKE PEDALS (KIM, 2011).

RELIABILITY OUTCOME

- THE FMEA PROCESS HELPED TOYOTA REDUCE THE RISK OF RECURRENCE.
- THE SOLUTION LED TO **MASSIVE IMPROVEMENTS IN THE DETECTION AND PREVENTION** OF PEDAL-RELATED FAILURES.
- THIS CASE SHOWED HOW FMEA, EVEN WHEN APPLIED REACTIVELY, IS VITAL IN **PREVENTING FUTURE FAILURES AND PROTECTING BRAND REPUTATION.**

FMEA IN RELIABILITY ENGINEERING

Combining functionality and user-friendliness, we empower users to streamline operations and boost efficiency



PROACTIVE FAILURE MANAGEMENT

- ANTICIPATES FAILURE MODES BEFORE THEY HAPPEN.
- PRIORITIZE RISKS BASED ON SEVERITY, OCCURRENCE, AND DETECTION.
- ENABLES TARGETED MITIGATION PLANS.

BROADER RELIABILITY PROGRAMS

- Integrates with RCM & TPM.
- Drives design improvement and maintenance planning.
- Informs risk-based decision making.

PREVENTIVE MAINTENANCE

- FOCUSES ON AVOIDING FAILURES, NOT REACTING TO THEM.
- REDUCES DOWNTIME AND REPAIR COSTS.
- PROMOTES A CULTURE OF CONTINUOUS IMPROVEMENT.

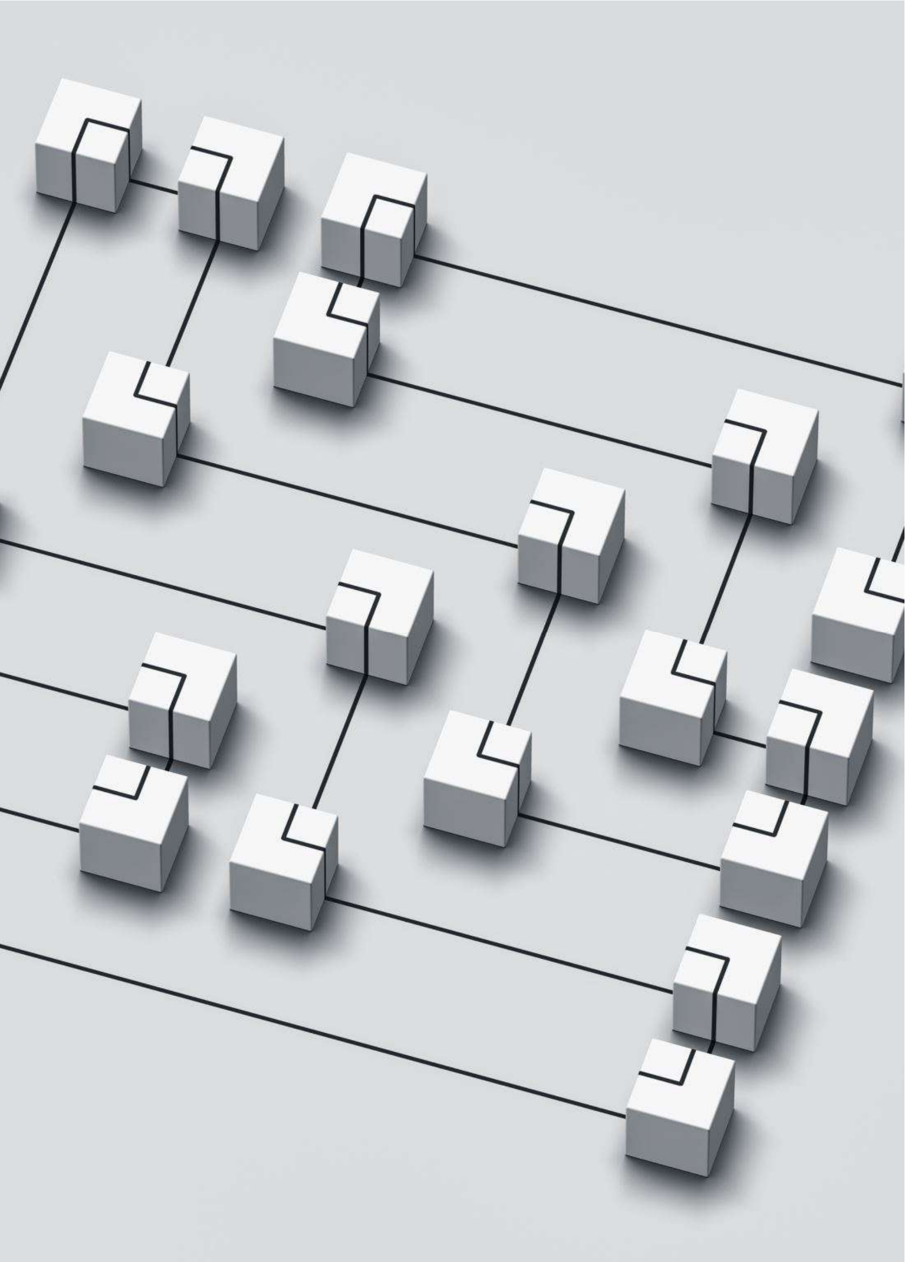
CONCLUSION AND SUMMARY

- Identify, prioritise and prevent failures
- Used across multiple industries
- Proactive rather than reactive

THANK YOU

Fault Tree Analysis

Group 5



What is Fault Tree Analysis?

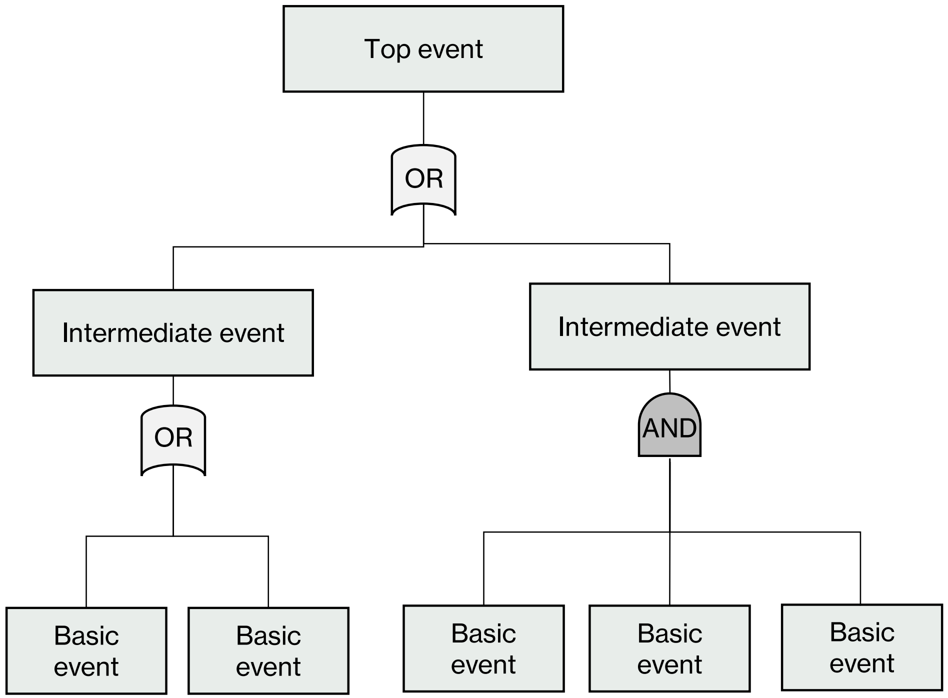
- Systematic and top-down analytical method
- Evaluates reliability and safety of complex systems by identifying potential failure modes and their root causes
- FTA uses a tree-like diagram structure that starts with an undesired top event (system failure) and works backward through logical gates (AND, OR) to identify all possible combinations of basic events that could lead to that failure.

Performing a Fault Tree Analysis

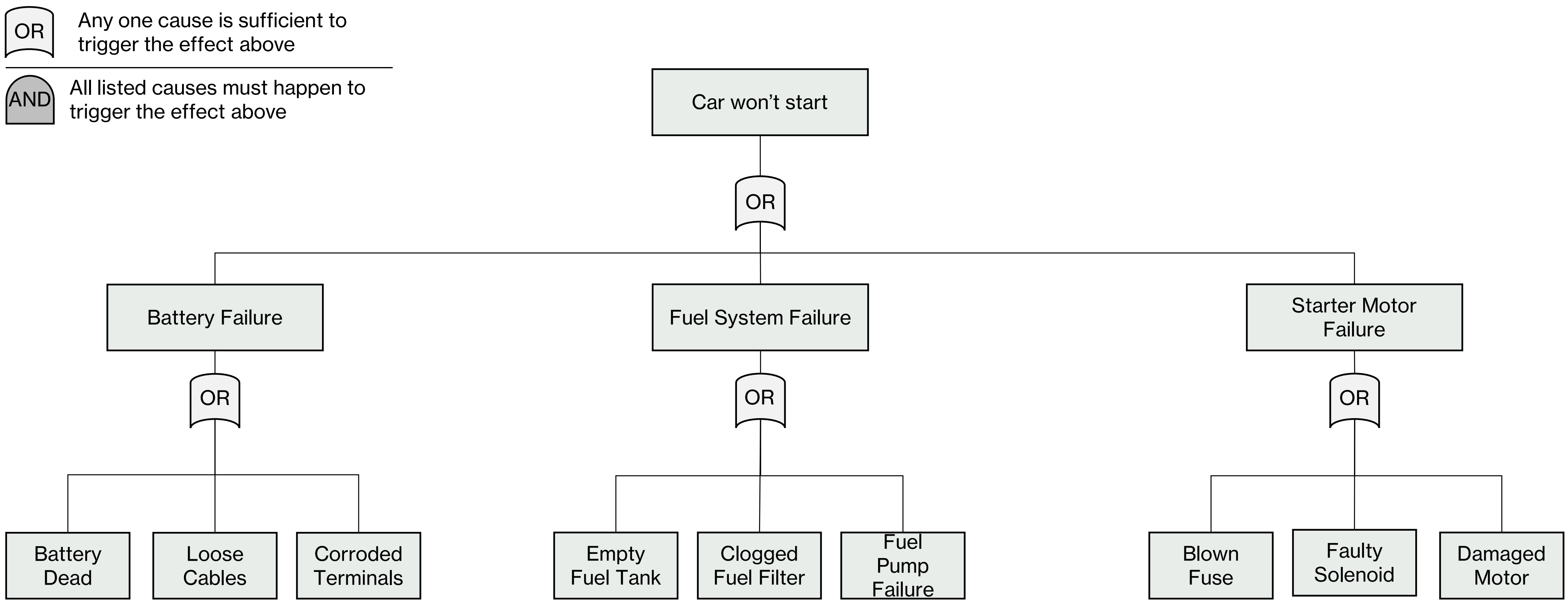
- Define the undesired event
- Identify contributing factors
- Construct the fault tree
- Analyze the fault tree

OR Any one cause is sufficient to trigger the effect above

AND All listed causes must happen to trigger the effect above



Using FTA to analyse why a car won’t start



Limitations of FTA

- Complexity for large systems
- Data dependency and reliability on analysts expertise
- Can only analyse **one** top event at a time
- Limited to identifying **technical** causes
- Limited guidance on corrective actions

Overcoming limitations of FTA

- Using software tools to facilitate FTA creation and analysis
- Applying dynamic FTA methodologies to model complex interactions
- Integrating FTA with other reliability analysis techniques
- Using expert judgment and other qualitative methods to supplement quantitative analysis
- Rigorous data collection and validation
- Regular review, update and continuous improvement

Effective application of FTA

Suitable systems:

1. Complex Engineered Systems
2. Hardware dominated systems
3. Systems where component failure rates are known and measurable
4. Systems with clear hierarchical structure
5. Safety critical Systems

Examples:

1. Railway and transportation
2. Aerospace systems
3. Nuclear industry

Less suitable systems:

1. Complex software applications
2. AI based systems
3. Processes heavily dependent on human judgement

Questions?

Prepared by group 6

Fault Tree Analysis (FTA)

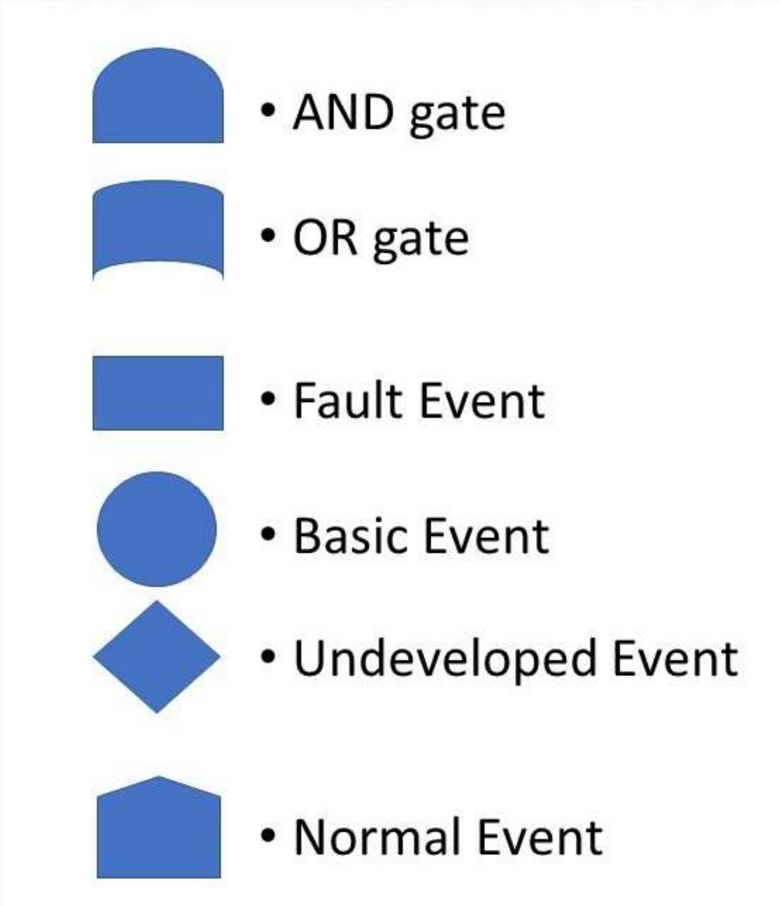
by Milan Dixon, Alicia Booyens, Megan Heppell, Susan Maree, Nicola Shakerley & Reghard Van Wyk

What is FTA?

- Top-down method to analyse system failures
- Identifies combinations of causes for one failure

Core Purpose: Understand and reduce the risk of failure

Basic Symbols



Gates:

AND →All the things must go wrong

OR → Only one thing needs to go wrong

Events:

Fault Event → A problem caused by other problems

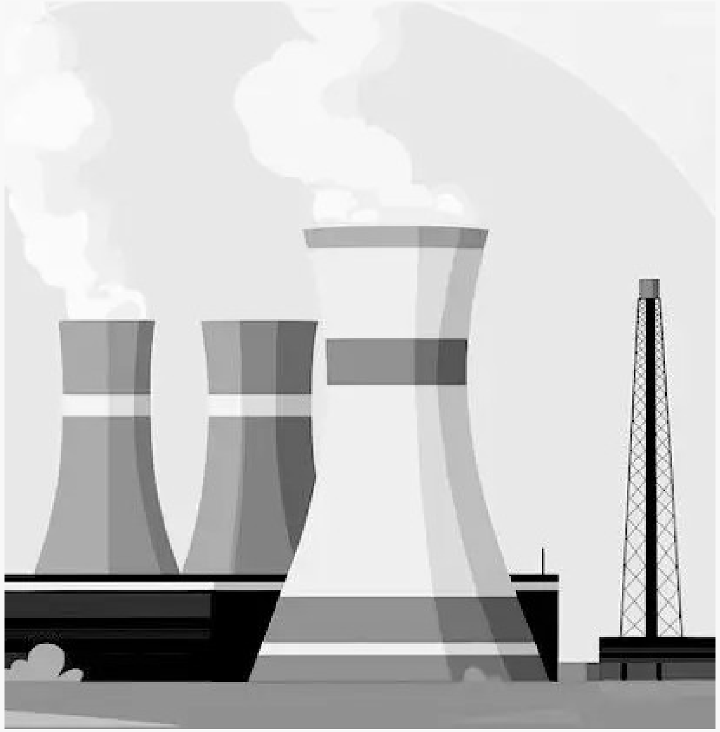
Basic Event →A known failure with a known cause

Undeveloped Event → Issue without enough information

Normal Event → A condition that exists, but isn't a failure

Why use FTA in Reliability Engineering?

- Identifies the root causes of system failures
- Quantifies the failure probability of top level events
- Highlights critical components and potential weak points
- Improves the design through preventative measures
- Supports risk assessment and decision-making



Benefits & Limitations

Benefits:

- Visual and logical.
- Encourages structured thinking.
- Can be quantitative or qualitative.

Limitations:

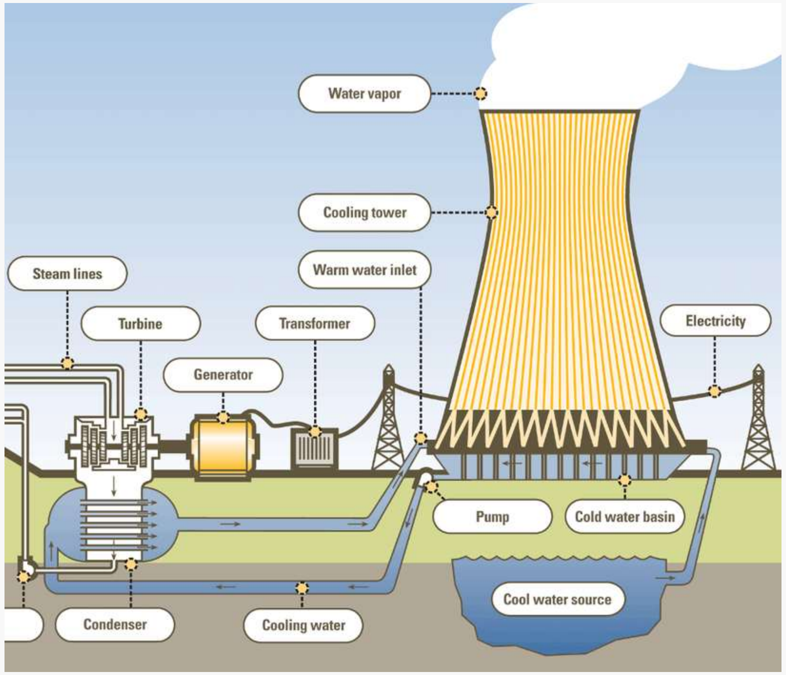
- Requires detailed system knowledge.
- Can be complex for large systems.
- Assumes independence of events (sometimes unrealistic).

Fault Tree Analysis Process Steps

.

1. **Defining the Top Event** – Identify and clearly state the main issue or failure to analyze.
2. **Understanding the System** – Gather detailed information on how the system works before the issue occurred
3. **Listing Potential Causes** – Identify and rank possible causes that could lead to the top event.
4. **Drawing the FTA Diagram** – Create a fault tree diagram linking causes with AND/OR gates.
5. **Gauge the Risk** – Assign probabilities to base events and analyze overall risk.
6. **Reducing the Risk** – Implement actions to lower the likelihood of the top event occurring.

Practical Example: Power Plant Cooling System



Key Components:

- Cooling Towers: Dissipate heat from the power plant
- Pumps: Circulate coolant
- Heat Exchangers: Transfer heat from the plant to the coolant
- Power Supply: Provides electricity to pumps and control systems
- Control System: Manages coolant flow and temperature regulation.

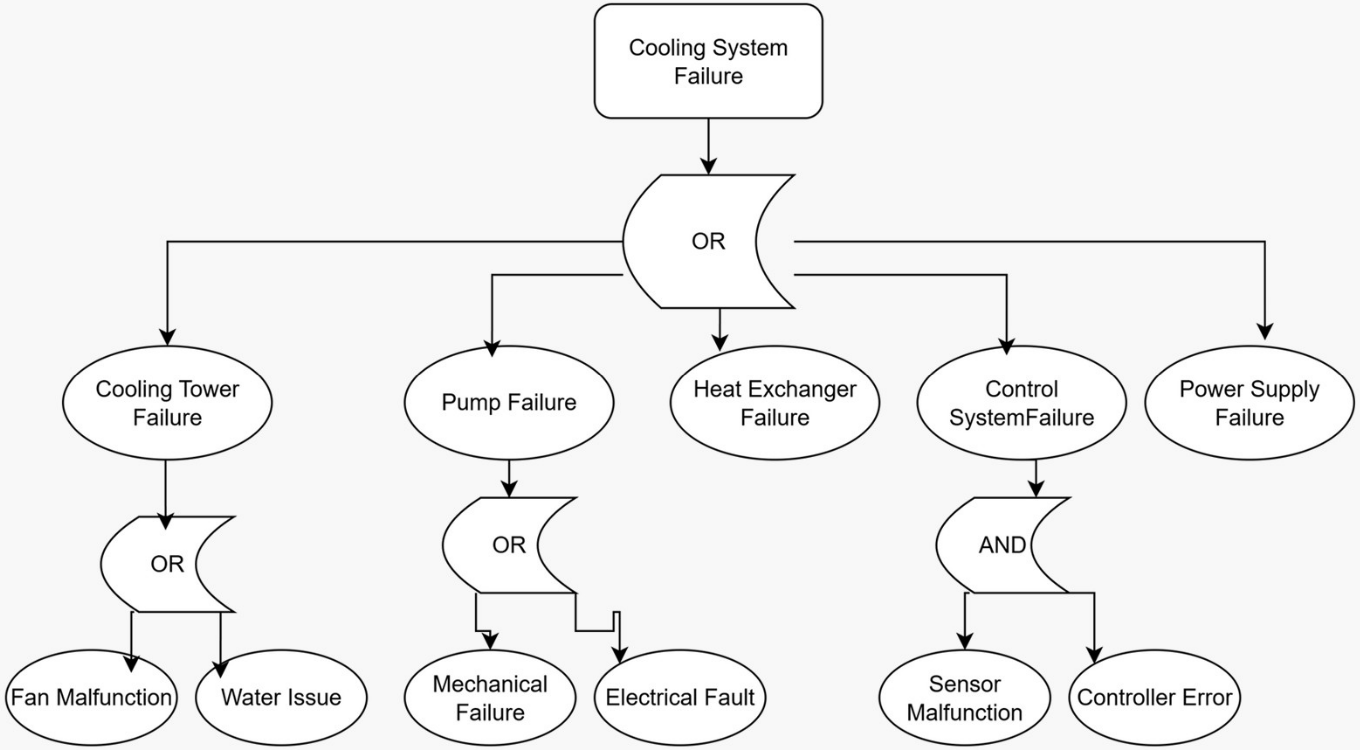
Fault Tree Analysis Process

1. **Determine Top Event**: Determine the undesired event, which is the Cooling System Failure.
2. **Identify Failure Modes**: List all possible failure modes that can lead to the top event
3. **Create the Fault Tree:** Use OR gates to indicate that any identified failure modes can cause the top event; break down each failure mode into more specific sub-events
4. **Review:** Ensure all possible failure modes are indicated

Potential Failures

- Cooling Tower
- Pump
- Heat Exchanger
- Power Supply
- Control System

FTA of Power Plant Cooling System



Thank you

HAZARD AND OPERABILITY STUDY

HAZOP

Hazard and Operability Study

WHAT IS IT?

- Structured, systematic qualitative technique for examining a process or operation
- Applied to process “nodes” to explore deviations from design intent

IMPORTANCE

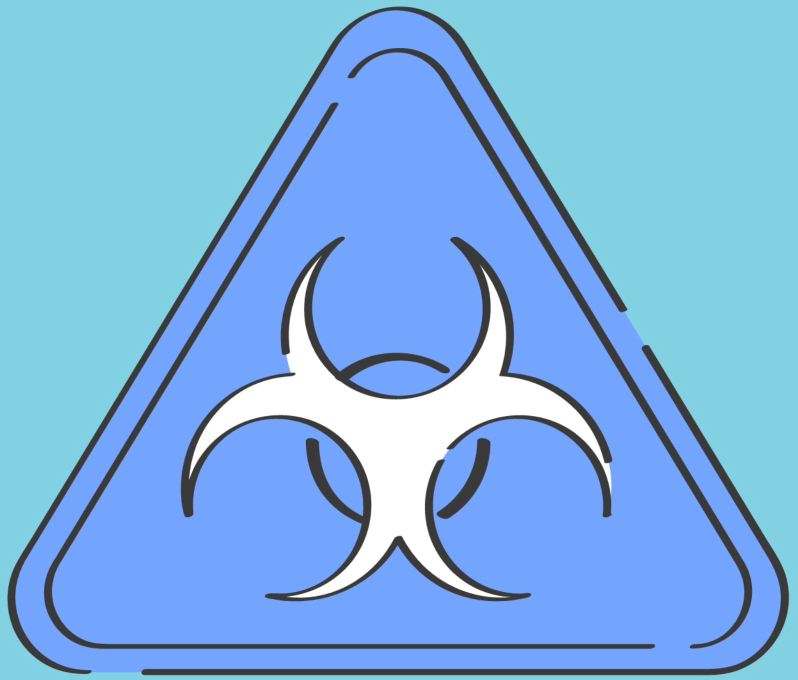
The primary objective of the HAZOP study is to identify and evaluate Health, Safety, and Environment (HSE) hazards caused by Process deviations/System failures/Human error

ORIGINS & EVOLUTION

Developed in the 1960s by Imperial Chemical Industries (ICI)

Formalised as HAZOP in the 1980s by Trevor Kletz

ICI later acquired by AkzoNobel (2008)



NOW WIDELY APPLIED IN:

- Oil & Gas industry
- Pharmaceuticals industry
- Power industry
- Software and Transport industries

ABOUT

- Standard method that is commonly used in the process industry
- Team-based method, requiring a group of experts working together to discuss all aspects in detail
- Team may vary depending on node being worked on

METHOD

ENSURES ALL POTENTIAL HAZARDS ARE SYSTEMATICALLY CONSIDERED

- HAZOP is based on P&ID drawings (Piping and Instrumentation Diagrams)
- P&IDs are created by process engineers during the design phase
- The HAZOP team uses P&IDs to analyse the process systematically
- Each part of the process is reviewed in detail, node by node
- Hazards are identified by pairing:

  Process parameters (e.g., pressure, flow, temperature)

  With guidewords (e.g., High, Low, No, More, Reverse)

RELIABILITY ENGINEERING

Ensuring systems function without failure

HAZOP

Identifies hazards that threaten system function

HOW IT FITS INTO RELIABILITY ENGINEERING

- Proactive hazard and failure identification
- Connecting safety and reliability
- Risk assessment and mitigation
- Informing Other Reliability Methodologies
- Application throughout the lifecycle

PRACTICAL EXAMPLES

CAUSE:

Lack of maintenance, inadequate training, and poor communication

CONSEQUENCE

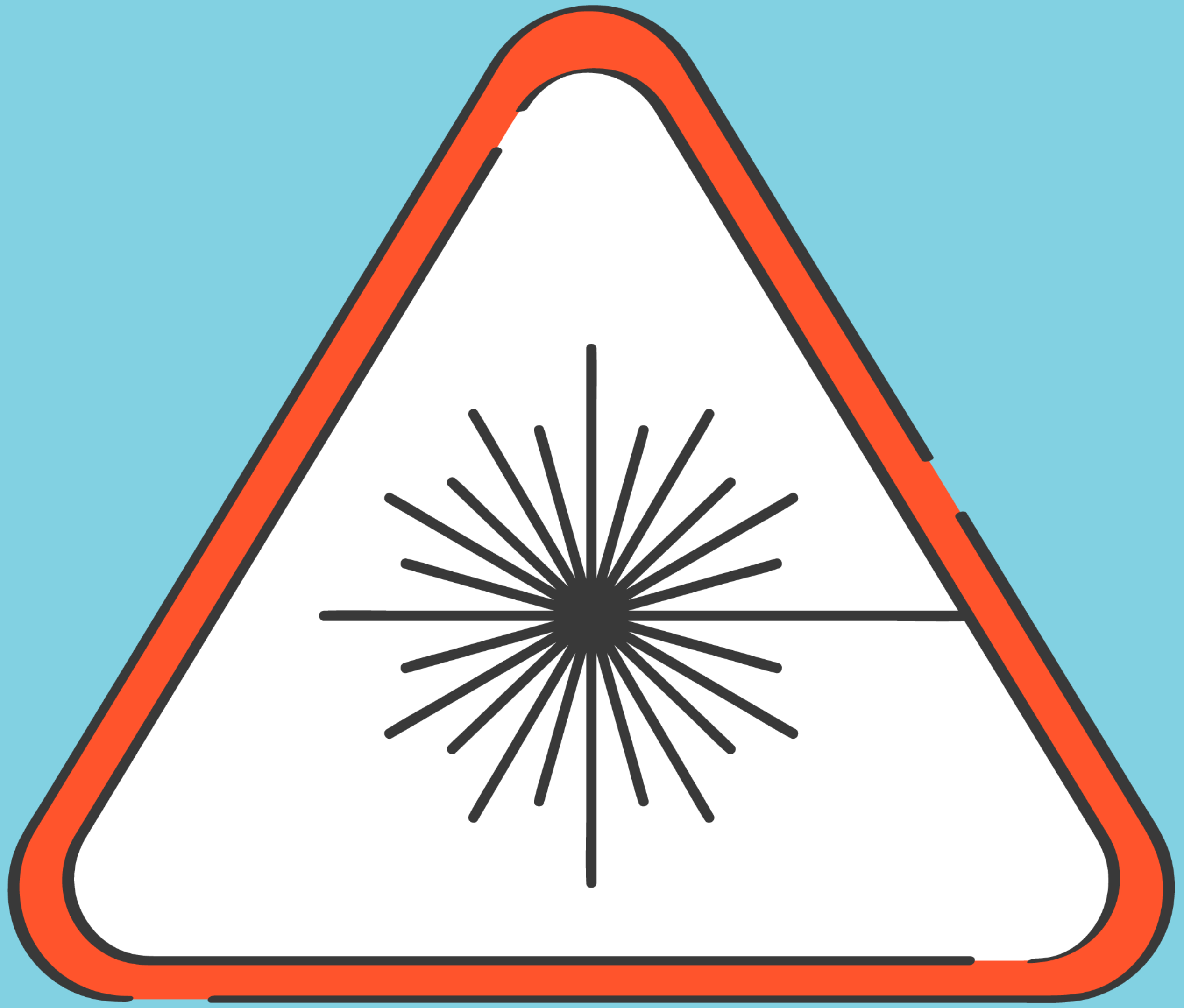
15 fatalities, 170 injuries, and significant property damage

LESSON LEARNED

The importance of process safety management and the need for effective communication and training

BP TEXAS CITY REFINERY EXPLOSION

OIL AND GAS INDUSTRY



DEEPWATER HORIZON OIL SPILL

OIL AND GAS INDUSTRY

CAUSE:

Equipment failure, poor decision-making, and inadequate safety measures

CONSEQUENCE

11 fatalities, significant environmental damage, and economic impact

LESSON LEARNED

The importance of risk assessments, effective safety measures, and emergency response planning

CHERNOBYL NUCLEAR DISASTER

NUCLEAR ENERGY INDUSTRY

CAUSE:

Design flaws, operator error, and inadequate safety culture

CONSEQUENCE

31 immediate fatalities and long-term health effects for thousands of people

LESSON LEARNED

The need for a strong safety culture, effective training, and thorough risk assessments

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Group 7

HAZOPS

HAZARD AND OPERABILITY STUDIES

WHAT IS HAZOPS?

- **HAZOPS = Hazard and Operability Studies**
- A **systematic technique** to identify potential **hazards** and **operability problems** in complex systems.
- Originated in the 1960s at **Imperial Chemical Industries (ICI).**
- Primarily used in **process safety, reliability engineering** and **risk management**.
- Applied to systems **like chemical plants, software** and **cybersecurity.**

WHY USE HAZOPS?

- **Main goal**: Identify deviations from design intent and assess associated risks.

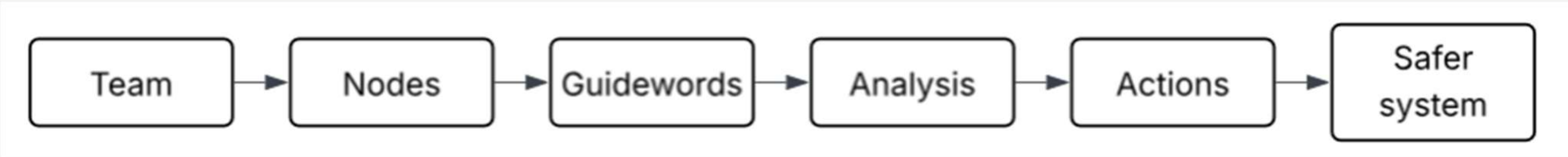
Used to:

- Uncover **hazards to people, environment and equipment.**
- Improve **operability** and **efficiency.**
- Enhance **Design for Reliability (DfR).**

- Helps organizations **proactively** prevent failures and meet **safety regulations** (e.g. OSHA, IEC 61882)

HAZOPS METHOD: STEP-BY-STEP

- 1. Form a multidisciplinary team (e.g. engineers, operators, safety experts).
- 2. Define scope & system nodes (based on Piping and Instrumentation Diagrams).
- 3. Apply guidewords to process parameters (e.g. No Flow, More Pressure).
- 4. Identify causes, consequences, safeguards.
- 5. Document findings & recommend actions.
- 6. Implement improvements & monitor



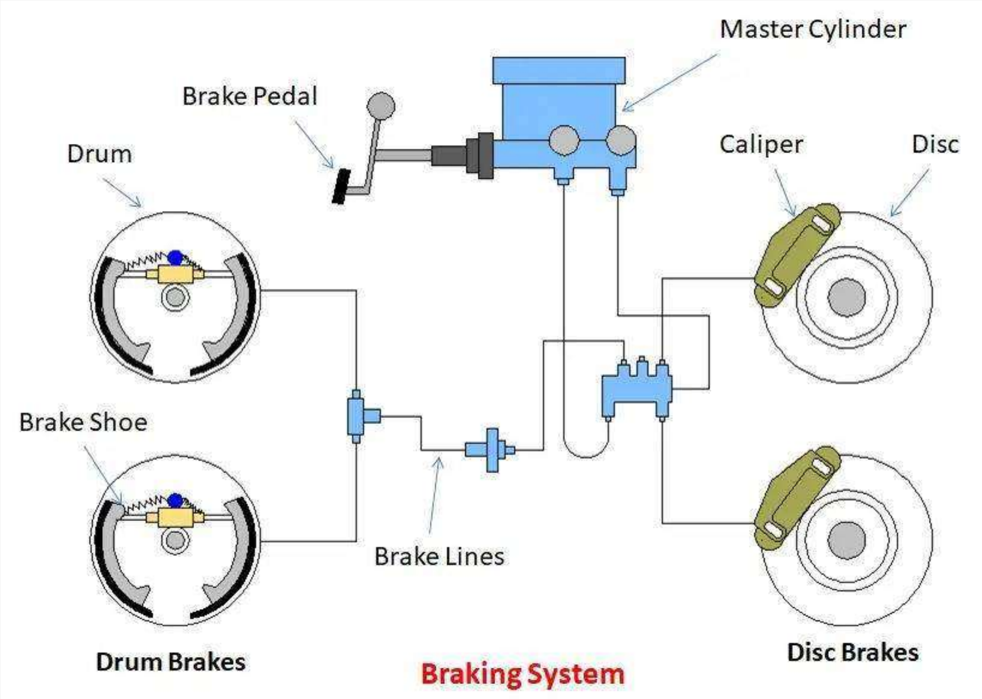
Lecture Hall

Node	Deviation	Cause	Consequence	Safeguard	Recommendation
Students	Lack of attendance	Rain and exam stress	Lecturer questions their career choice	Attendance register	Add a snack incentive

Lunch Room Coffee Machine

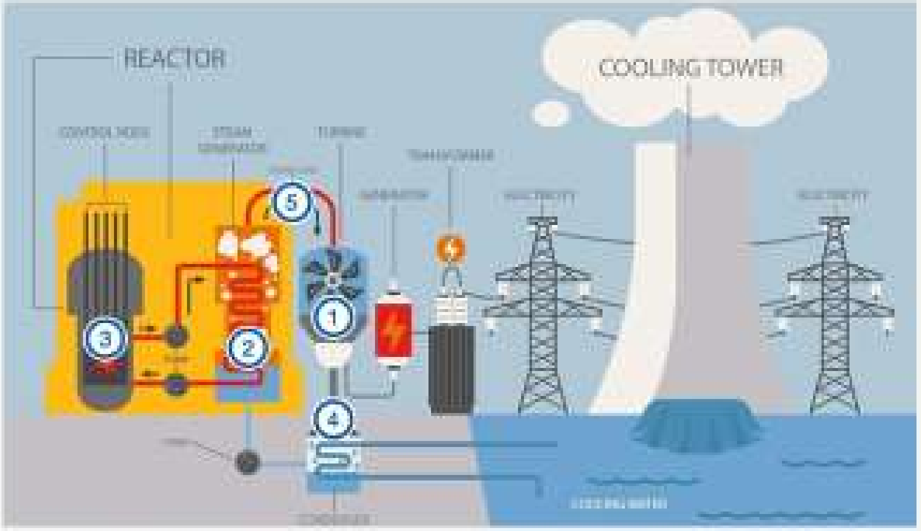
Node	Deviation	Cause	Consequence	Safeguard	Recommendation
Coffee Dispenser	No Coffee	Empty beans hopper	Sleepy and angry students	Staff refill routine	Add a low-beans alarm

Brake Line Assembly

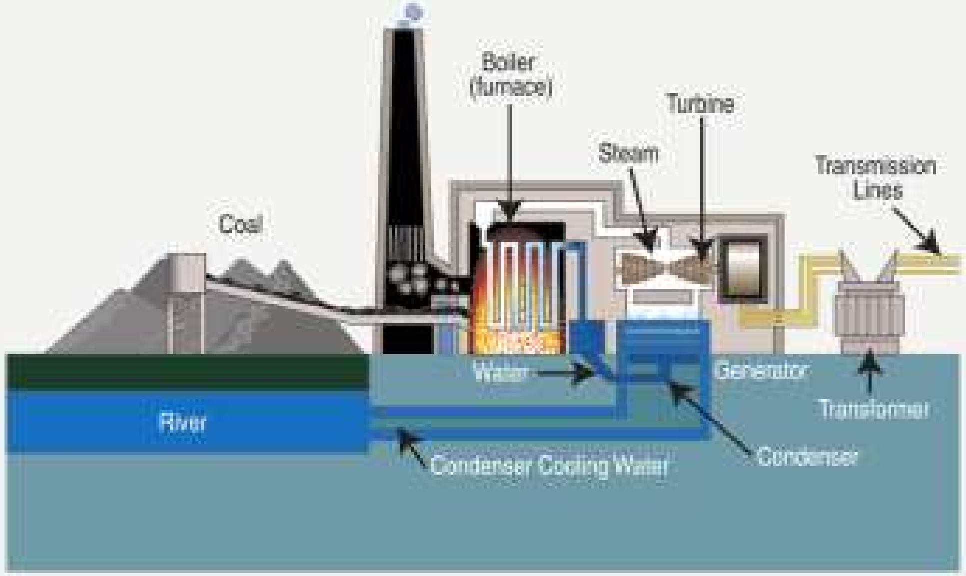


Node	Deviation	Cause	Consequence	Safeguard	Recommendation
Brake Line Assembly	Low Pressure	Air in line / fluid leak	Reduced braking performance	Pressure sensor	Add automatic leak detector before line install

HAZOPS in a Power Plant

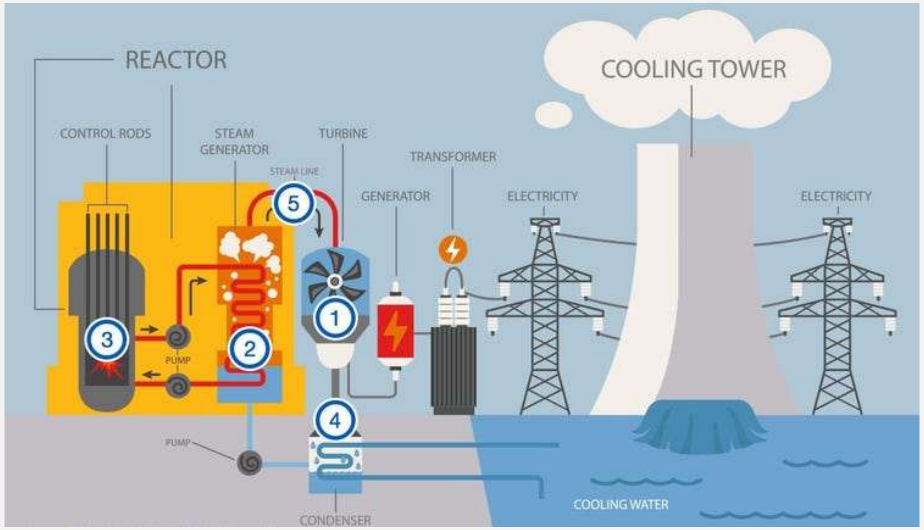


Nuclear



Coal

HAZOPS in a Power Plant



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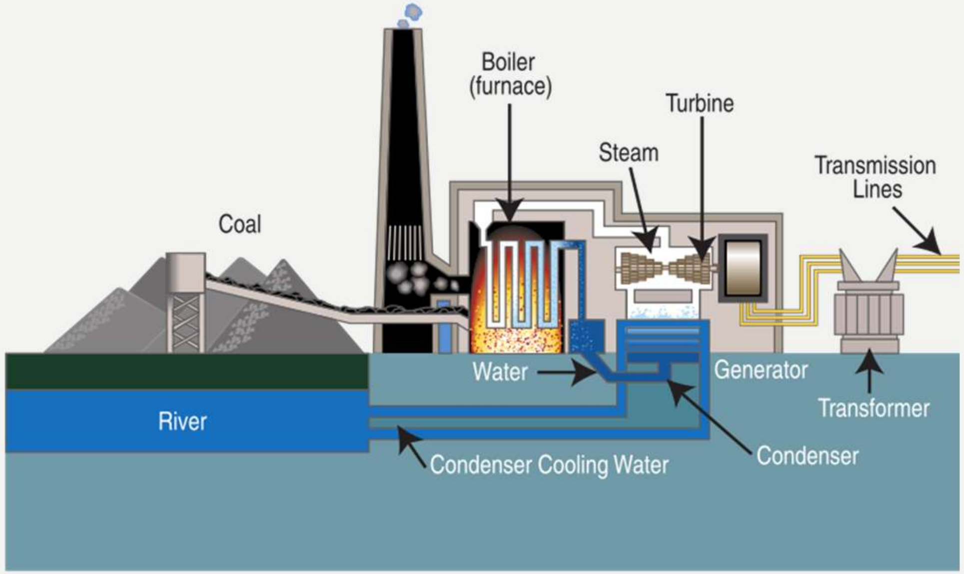
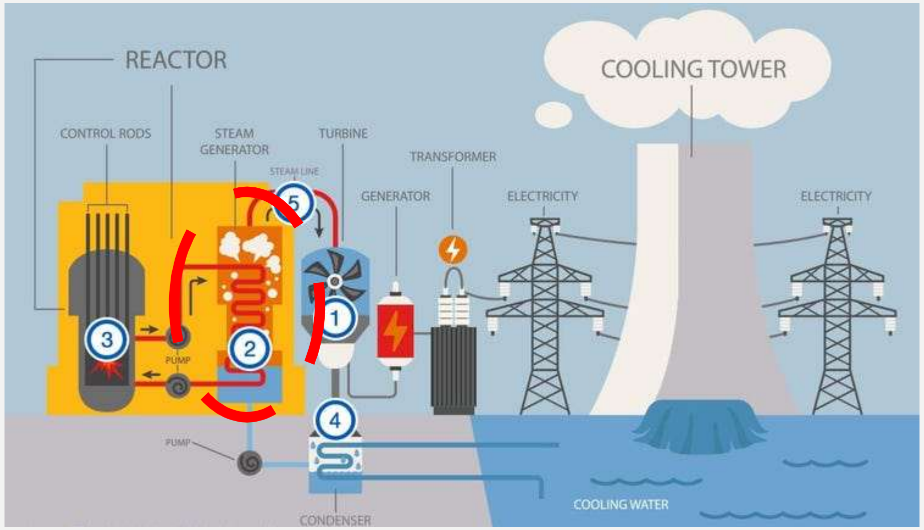


Coal

HAZOPS in a Power Plant



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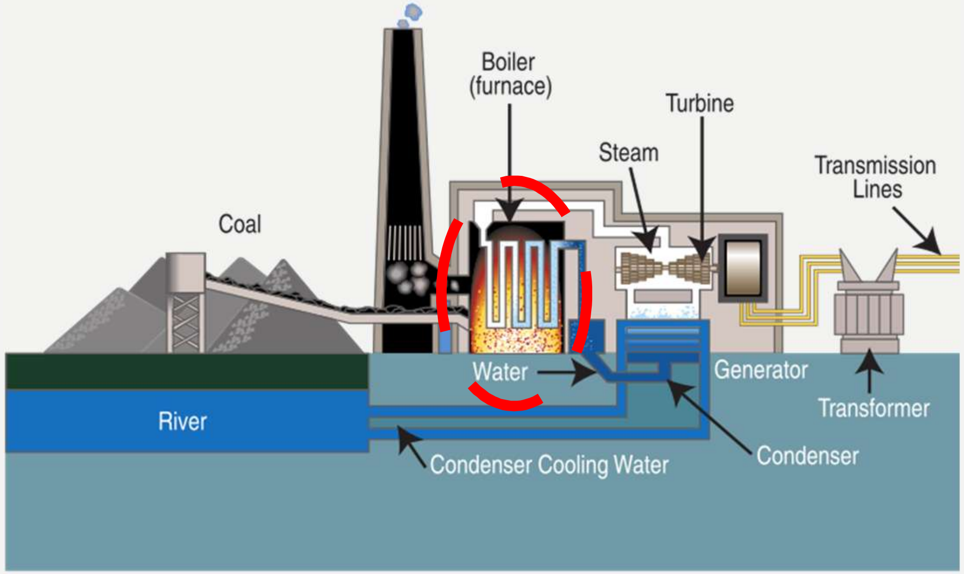
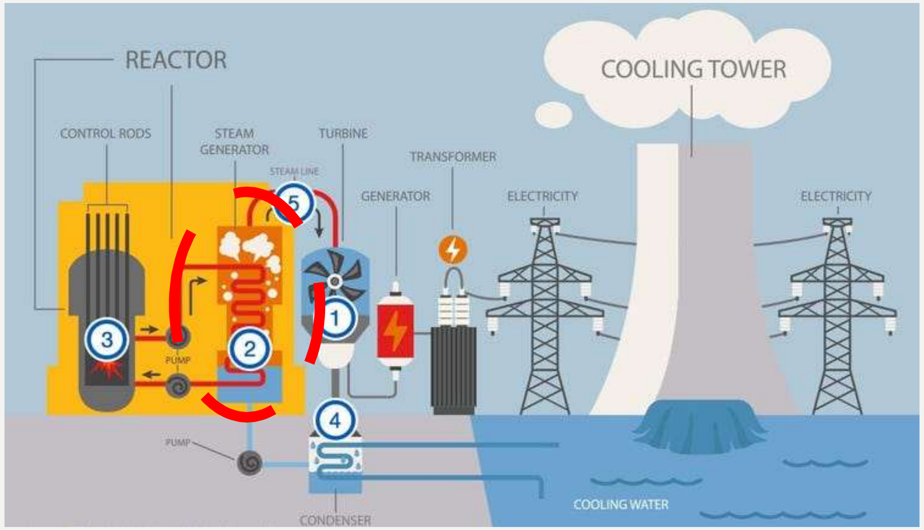


Coal

Lets focus on the boiler

HAZOPS in a Power Plant



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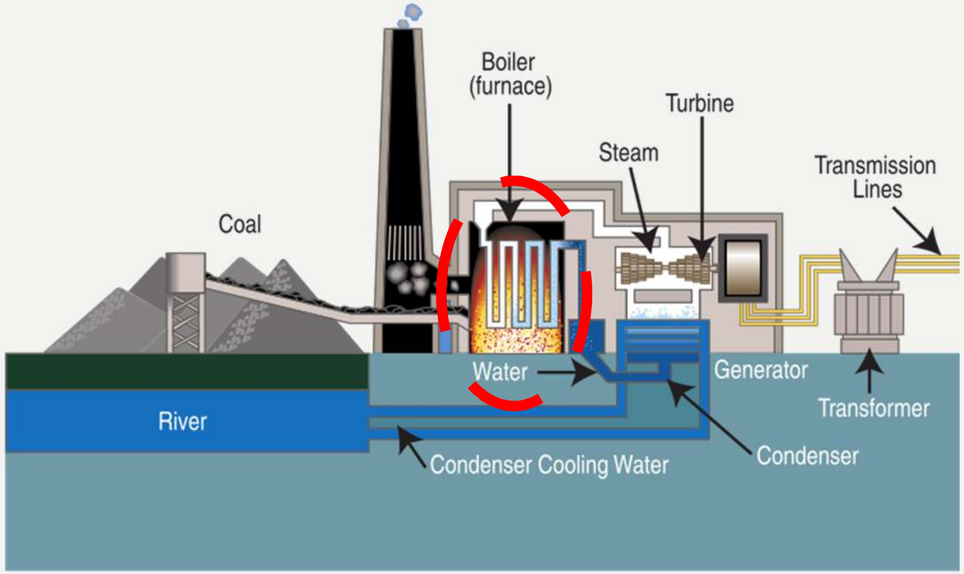
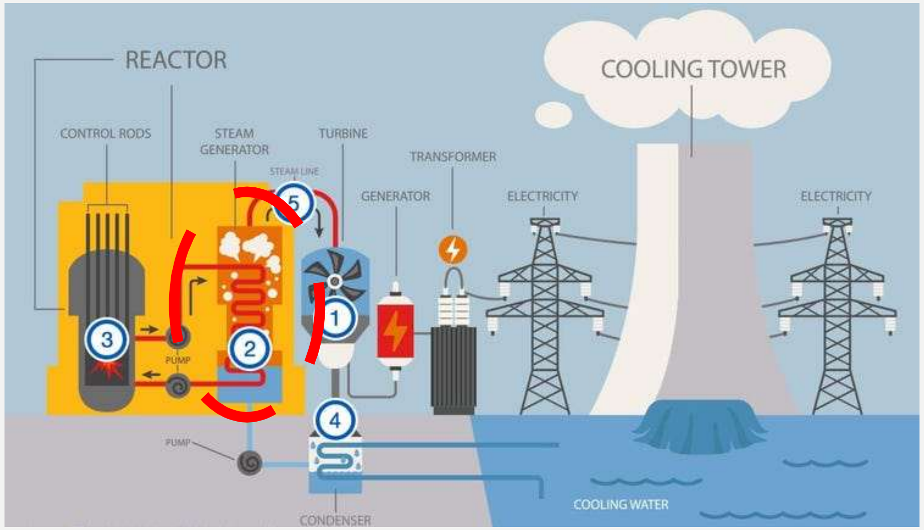


Coal

Node	Deviation	Causes	Consequence	Safeguard	Recommendation
Boiler	No Flow				

HAZOPS in a Power Plant



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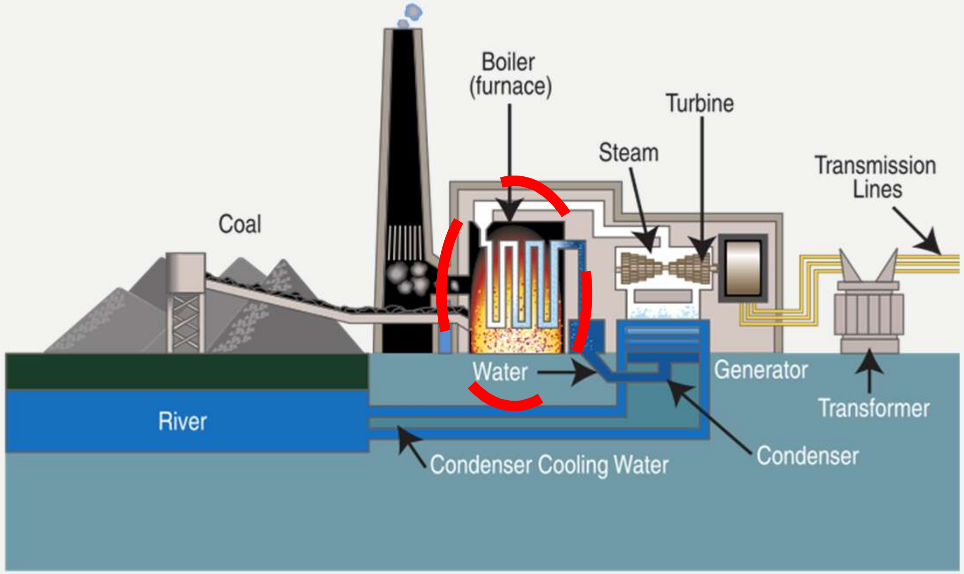
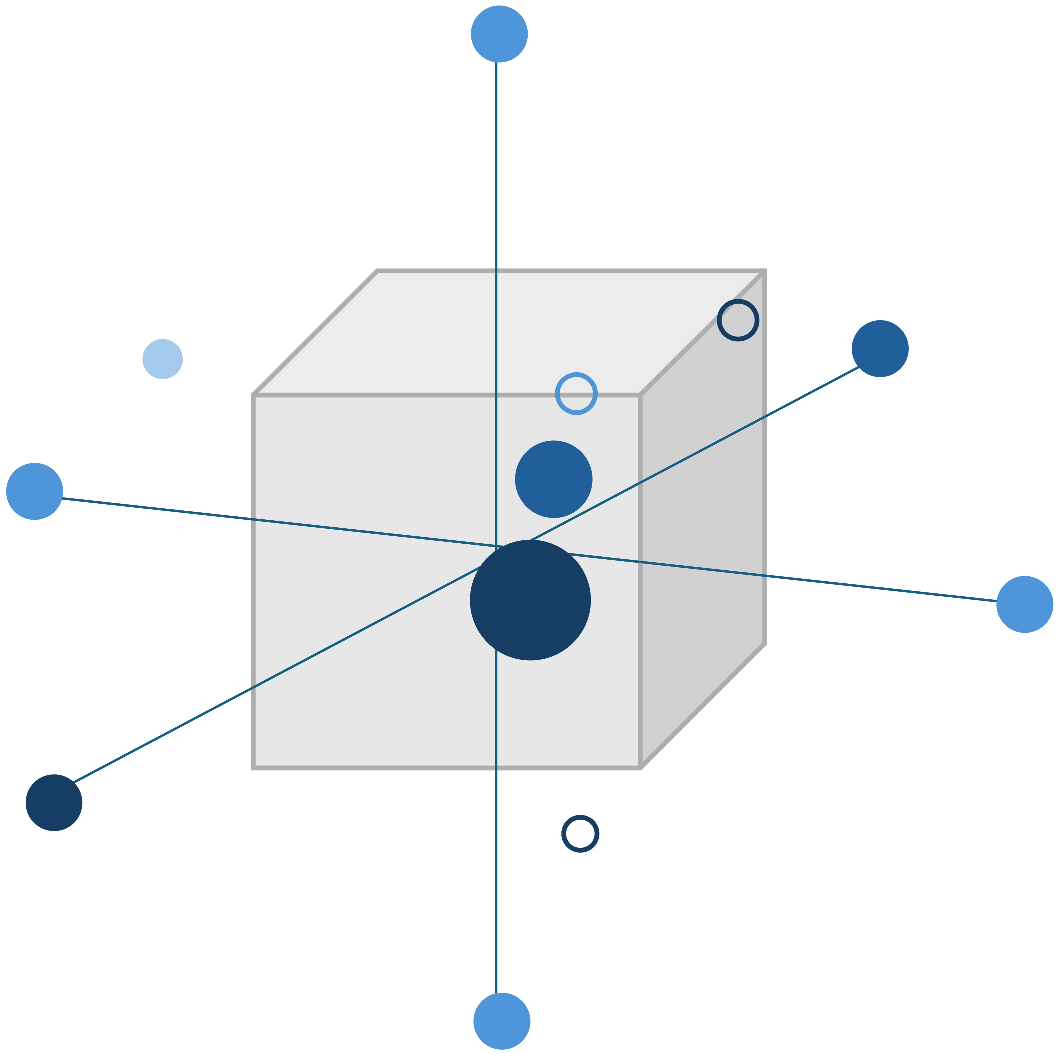


Coal

Node	Deviation	Causes	Consequences	Safeguards	Recommendation
Boiler	No Flow	-Faulty Sensors -Blocked Feedwater Valve -Feedwater Pump Failure -Loss of Power -Human Error	-Low Water Level -Overheating of Water Tubes -Risk of Tube Rupture or Boiler Explosion	-Level Alarms to Monitor Water Level -Automatic Trip/Shutdown -Backup Power -Manual Checks	-Install Level Alarms -Upgrade the Diagnostics Systems -Regular Calibration & Maintenance on Sensors/Pumps



Design of Experiments

By Group 9

What is DoE?

- Structured, statistical approach to test variables
- Tests multiple factors simultaneously
- Analyze the relationship between several input variable (factors) and output (response) variables
- Originated by R.A. Fisher in the 1920s
- Used to improve performance, quality, and reliability

Benefits and Limitations

Benefits:

- Saves time and cost
- Identifies key factors
- Detects interactions
- Improves design reliability

Limitations:

- Complex for many variables
- Requires careful planning
- Time-consuming and resource-intensive
- Not always feasible for real systems

Key Concepts

1

Factors:

Variables we change (e.g. temperature)

2

Levels:

Settings of each factor (e.g. 60º, 80º)

3

Response:

Outcome measured (e.g. MTBF, cost)

4

Types:

Full factorial, Fractional factorial, Taguchi, RSM

5

Error:

Systematic vs Random Error, Blocking and Randomisation

1

Factors:

Variables we change (e.g. temperature)

2

Levels:

Settings of each factor (e.g. 60º, 80º)

3

Response:

Outcome measured (e.g. MTBF, cost)

4

Types:

1. **Full Factorial Design:** all possible combinations of factors and levels.
2. **Fractional Factorial Design:** a subset of combinations. Reduces time and cost.
3. **Taguchi Method:** orthogonal arrays to efficiently study factor effects. Robust against variation.
4. **Response Surface Methodology (RSM):** used for modeling and optimization with complex relationships

5

Error:

Systematic vs Random Error, Blocking and Randomisation

1

Factors:

Variables we change (e.g. temperature)

2

Levels:

Settings of each factor (e.g. 60º, 80º)

3

Response:

Outcome measured (e.g. MTBF, cost)

4

Types:

Full factorial, Fractional factorial, Taguchi, RSM

5

Error:

Systematic error:

- Consistent bias
- Predictable
- e.g. broken thermometer

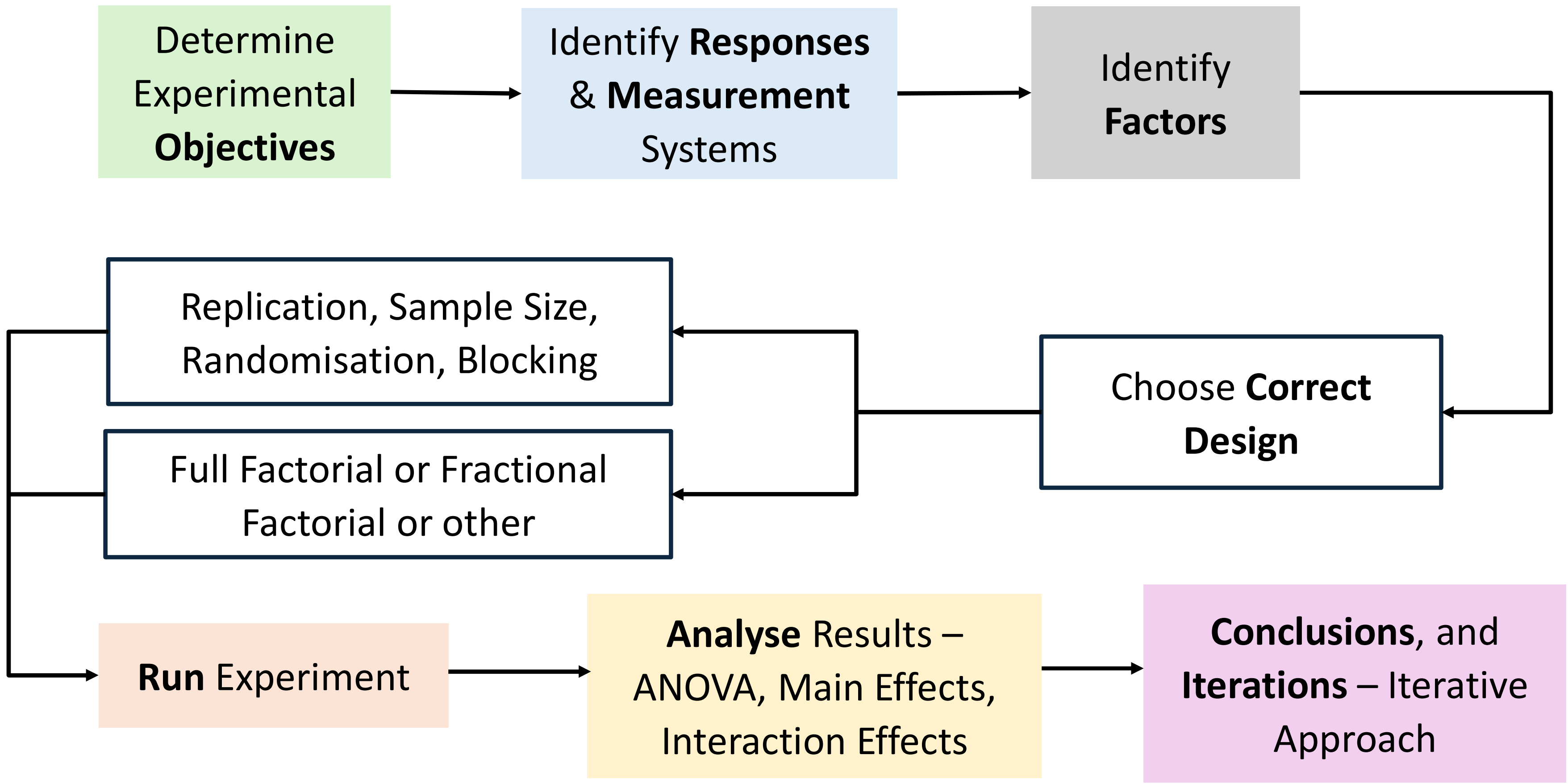
Random error:

- Unpredictable
- Var[illegible]
- e.g. slight variations in materials

Block what we can, randomise what we can't.

Blocking: Grouping to remove variations
Randomisation: Spread unpredictable effects

Steps of DOE in Reliability Engineering



Case Study: Car manufacturer

IDENTIFIES CAUSES OF FAILURE OR VARIATION

OPTIMIZES PRODUCT/PROCESS DESIGN

SUPPORTS ACCELERATED LIFE TESTING

LEADS TO MORE ROBUST, RELIABLE SYSTEMS

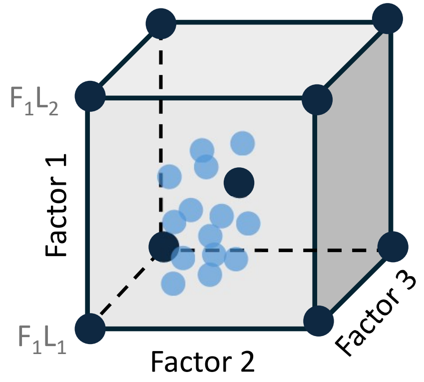
Case Study: Vehicle Actuator

Factor	Description	Low Level (-)	High Level (+)
A	Environmental Temperature	5°C	30°C
B	Humidity	30%	60%
C	Vehicle Speed	50 km/h	100 km/h
D	Vehicle Weight (Load)	1 Ton	2 Tons

- **Aim: Understand the impact of environmental factors on the MTBF (mean time between failures) of a vehicle's actuator**
- Identify factors with most significant impact from past failures
- This is a 2-Level, 4-Factor DOE
- A full factorial design will need 16 experimental runs (2^4)
- Choose a half-fractional factorial design with 8 runs to save time and cost of testing

Case Study: Vehicle Actuator

Run	Temp (A)	Humidity (B)	Speed (C)	Weight (D)	MTBF (hours)
1	–	–	–	–	66.63
2	–	–	+	+	60.31
3	–	+	–	+	50.25
4	–	+	+	–	56.46
5	+	–	–	+	77.25
6	+	–	+	–	69.98
7	+	+	–	–	66.91
8	+	+	+	+	74.88



- Table shows the levels used for each run and their respective results.
- By analyzing these results using software (Minitab or ReliaSoft's DOE++), or by using Maximum Likelihood Estimation and the Likelihood Ratio Test, the **significance of each variable** can be determined.
  - MTBF is higher when Temp (A) increases and decreases as Weight (D) increases
  - Humidity (B) and Speed (C) were not statistically significant
- Design can be changed to reduce weight and increase temperature if the MTBF is not satisfactory.

Summary

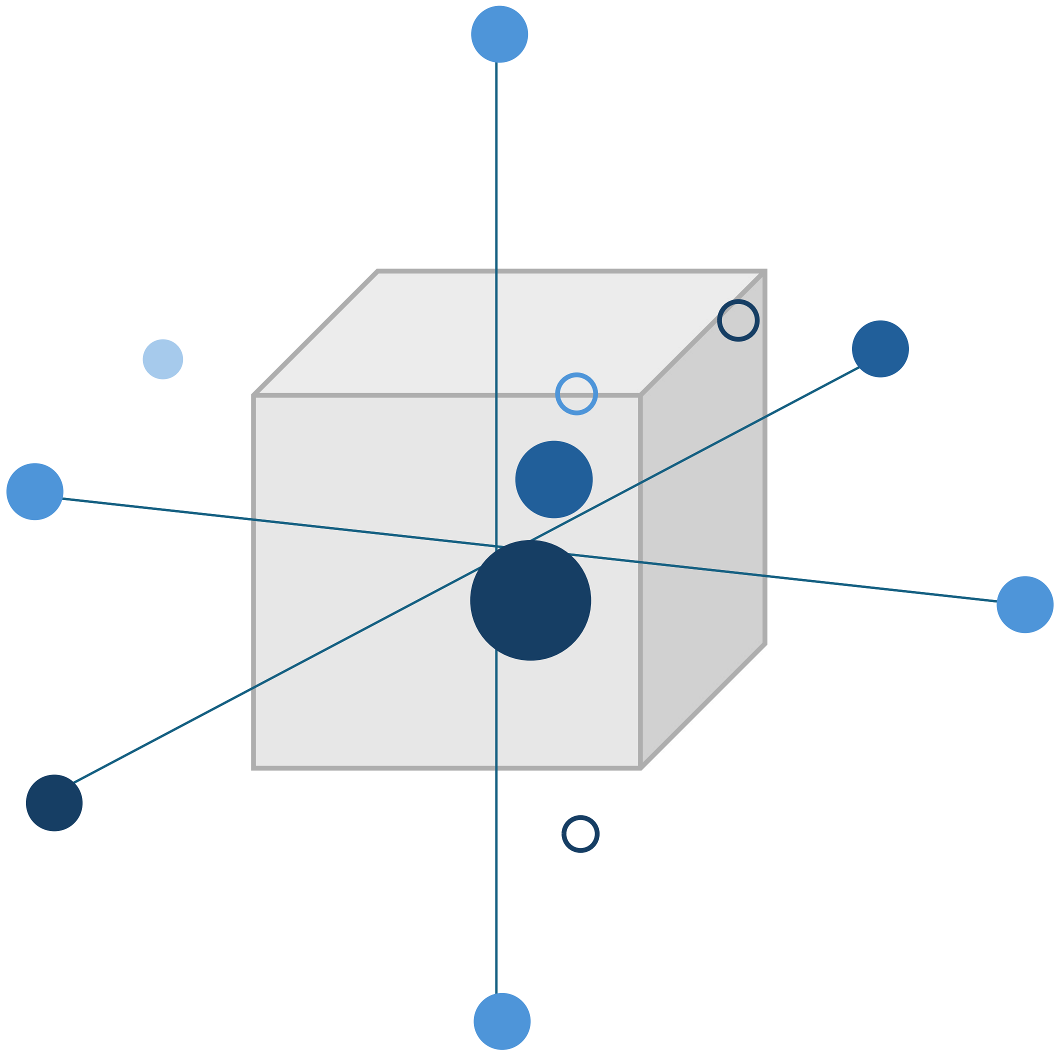
POWERFUL TOOL: IMPROVES PRODUCT **RELIABILITY** THROUGH STRUCTURED TESTING

ALLOWS ENGINEERS TO TEST **MULTIPLE FACTORS** AT **ONCE**, UNCOVERING **INTERACTIONS** THAT AFFECT PERFORMANCE

HELPS **IDENTIFY FAILURE DRIVERS** & **OPTIMISE DESIGNS** COST-EFFECTIVELY

REAL-WORLD EXAMPLES LIKE **VEHICLE ACTUATORS** SHOW HOW DOE LEADS TO **BETTER, LONGER-LASTING PRODUCTS**

DESPITE SOME **COMPLEXITY**, DOE OFFERS **MAJOR BENEFITS** WHEN CAREFULLY **PLANNED AND EXECUTED**

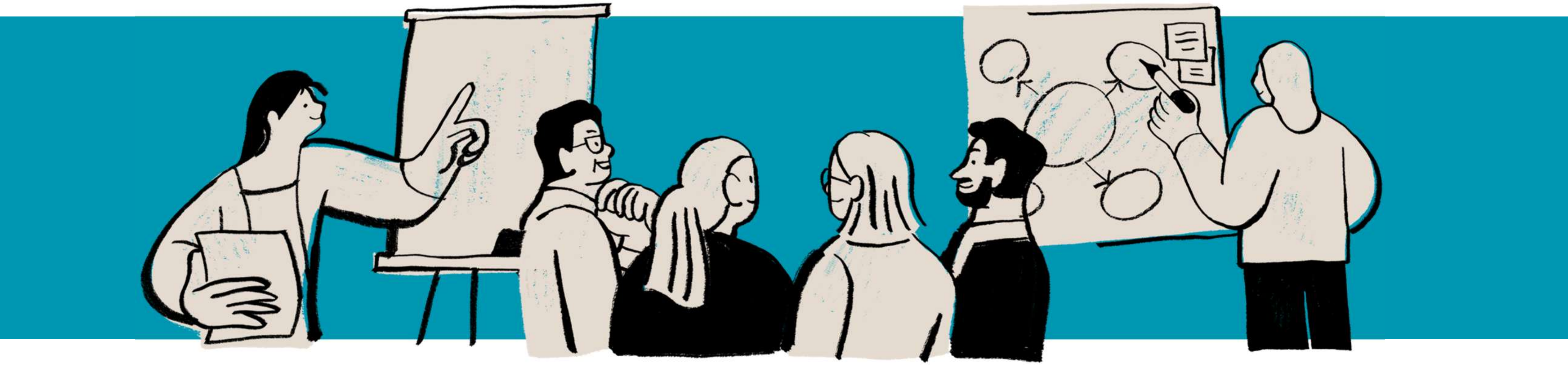


Thank you

GROUP 10

DESIGN OF EXPERIMENTS

Solutions for a Better Tomorrow



SU
MM
ARY

Understanding DoE Principles

What is DoE?

Design of Experiments (DoE) is a systematic approach to:

- **planning**,
- **conducting**,
- and **analysing** experiments.

Purpose of DoE in Reliability:

- Identify how various factors influence product reliability and performance.
- Helps engineers make data-driven decisions to improve product reliability.

How DoE Identifies Factors Affecting Reliability:

- Allows simultaneous investigation of multiple factors and their interactions (not one variable at a time).
- This efficiency helps pinpoint critical factors and interactions that significantly impact reliability.

Types of DoE in Reliability

Type	Description	Advantages	Disadvantages
Screening experiments	Identify the most significant factors affecting reliability by testing many variables with fewer runs.	• Efficient resource use • Simplifies problem space	• Limited detail on interactions • May miss subtle effects
Full Factorial Designs	Test all combinations of factor levels to uncover main and interaction effects.	• Comprehensive data • Captures all interactions	• Resource intensive with many factors
Fractional Factorial Designs	Test a strategically selected subset of combinations to reduce experimental runs.	• Reduced runs while estimating major effects and some interactions	• Confounding of higher-order interactions • Less detail than full factorial
Response Surface Methodology	Uses mathematical models to explore nonlinear relationships and optimize factor settings.	• Models complex interactions • Effective for process improvement	• Requires statistical expertise • Sensitive to model assumptions
Taguchi Methods	Focus on robustness by minimizing variability due to noise factors in the environment.	• Reduces variability • Efficient and practical approach	• May oversimplify interactions • Not purely statistical

Key Concepts and Benefits

Key Concepts:

- **Factors:**
  Inputs that we can change. (e.g. Materials, Temperatures)
- **Levels:**
  Specific settings for factors. (e.g. Type A, High/Low)
- **Response:**
  What we measure. (e.g. Lifespan, Failure Rate)
- **Interactions:**
  How inputs influence each other.

Core Benefits:

- **Identify Critical Factors:**
  Pinpoint what truly matters.
- **Reduce Variation:**
  Achieve consistent product performance.
- **Save Time & Cost:**
  Efficient testing, fewer experiments.
- **Improve Robustness:**
  Products work reliably, even with variations.

Making it Practical

The Experiment: A 3-Stage Process

1. **Planning** the Experiment
2. **Conducting** the Experiment
3. **Analysing** the Experiment

DoE in Dating: The Running Club Experiment

Goal: Maximising your chances of meeting a compatible partner at a Stellenbosch running club.
Objective: Find the strategy that leads to the highest number of quality social interactions.

Planning the Experiment

Factors & Levels: We identify the key variables within your control.

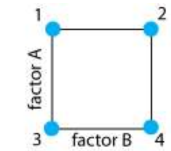
Factor	Description	Level 1	Level 2
A: Time of Day	When the run club is scheduled	Morning Run	Evening Run
B: Pace Group	The speed of the group you join	Fast Group	Social Group
C: Post-Run Beverage	The choice of post-run dink	Grab a Coffee	Grab a Beer

Choosing the Design:
To understand how these choices interact, we'll use a **Full Factorial** design, testing every combination.
Total Runs: 2 (Time) x 2 (Pace) x 2 (Beverage) = 8 Total Strategies

Conducting the Experiment

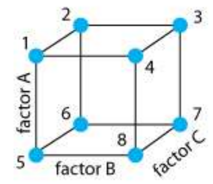
Execution: Over a period of several weeks, try 8 unique strategies.
Data Collection: After each run, record the number of meaningful conversations you had.

Run #	Time of Day	Pace	Beverage	Meaningful Conversations
1	Morning	Social	Coffee	4
2	Morning	Social	Beer	0
3	Evening	Fast	Beer	5
4	Morning	Fast	Coffee	8
...	...	...	...	...



factor levels

trial	A	B
1	+	−
2	+	+
3	−	−
4	−	+



factor levels

trial	A	B	C
1	+	−	−
2	+	−	+
3	+	+	+
4	+	+	−
5	−	−	−
6	−	−	+
7	−	+	+
8	−	+	−

Analysing the Experiment

Now we turn the data into a **winning strategy!**

Main Effect:
The analysis reveals which single factor has the biggest impact.
i.e. running in the **fast group** generally leads to more conversations (possibly due to longer post-run socialising)

Interaction Effects:
We discover how factors work together.
i.e. **Grabbing a beer** is effective for socializing in the evening; not so much in the morning. (DO NOT TRY THIS AT HOME)

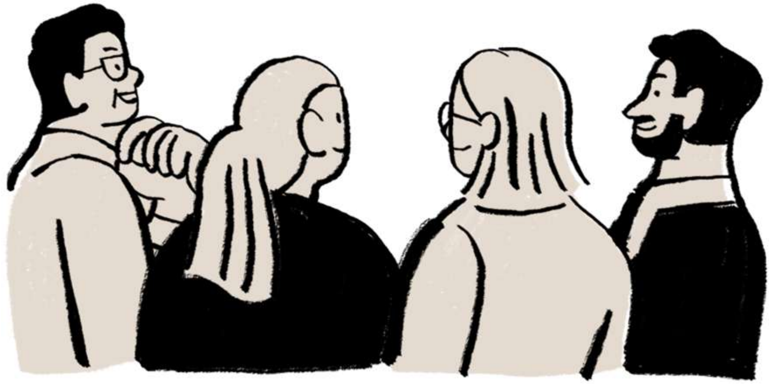
Winning Strategy:
The analysis points to the single best approach.
i.e. attending the **morning run**, joining the **fast group**, and **grabbing a coffee** afterwards.

Relationship with other Reliability Methods

Reliability Method	Relationship with DoE
Reliability Block Diagrams	DoE can isolate component-level effects to improve system-level reliability modelling.
Failure Mode and Effects Analysis	DoE validates which factors contribute the most to critical failure modes.
Weibull Analysis	DoE provides structured data for modelling time-to-failure using Weibull distributions.
Accelerated Life Testing	DoE helps plan stress levels to induce failure faster.
Monte Carlo Simulation	DoE informs input distributions and interactions for more accurate simulations.

THANK YOU

FOR YOUR ATTENTION!



Q&A

RCM Reliability Method

Presented by Group 11

How RCM Fits Into Reliability Engineering

What is Reliability Engineering?
The probability that an item will perform a required function without failure under state conditions for a stated period

Why does Reliability Engineering matter?

1. Prevents costly, unsafe failures
2. Optimizes maintenance efficiency
3. Forms the foundation for RCM

Purpose of Reliability Engineering?
Design, test, and improve systems so, they keep working well over time.

Reliability Engineering	Reliability Centered Maintenance
Identifies Failure Modes	Prioritization of Failure Modes
Applies Structured Methods	Targeted Maintenance Strategies
Time-Based Maintenance	Risk-Based Approach

What is RCM?

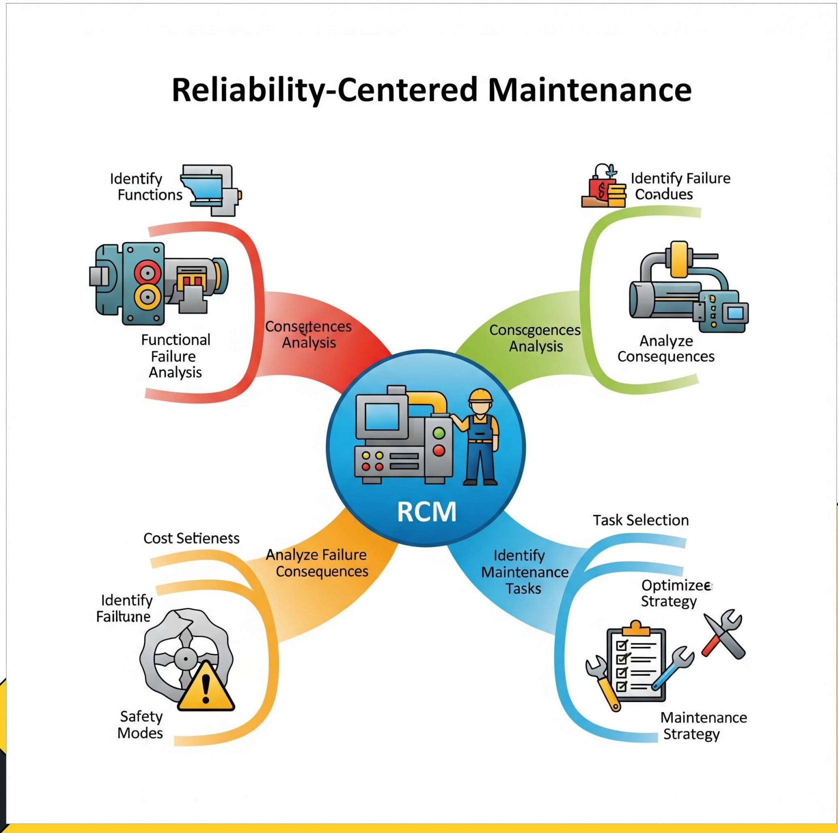
Definition: Structured approach to identifying the most effective maintenance strategy to keep equipment reliable, safe, and cost-efficient by analyzing its functions, failures, and consequences.

History:

- Developed in 1960s-1970s by US aviation industry.
- Adopted by nuclear, military and manufacturing industries.

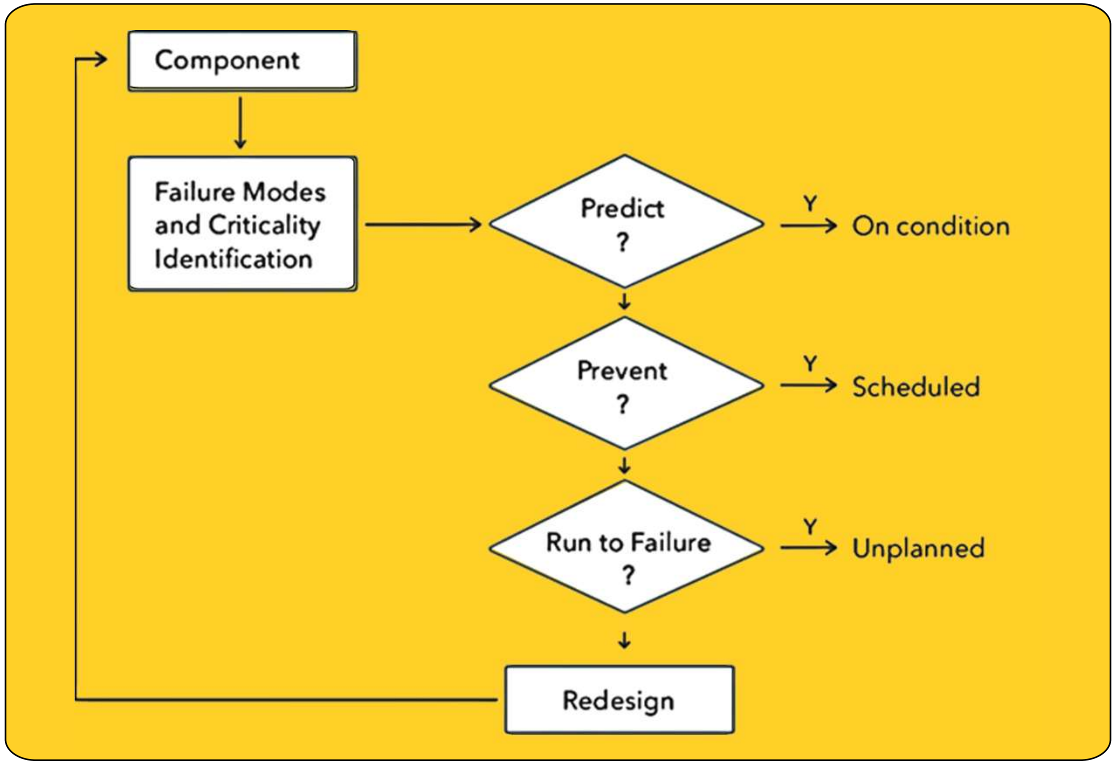
Purpose:

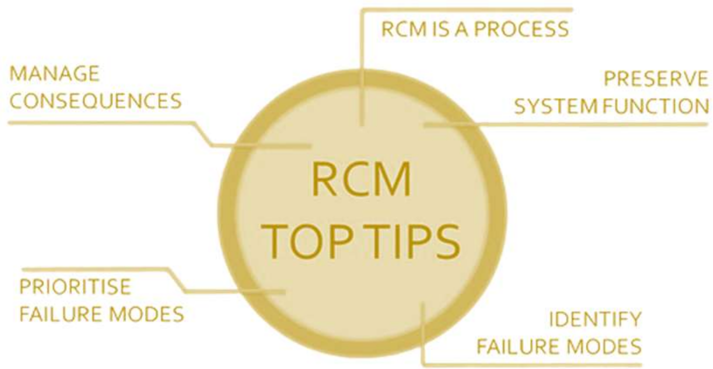
- Preserve system functions
- Manage failure modes
- Select maintenance strategies
- Safety, reliability and performance



How RCM Works?

- **Choose an Asset or System**
  Eg. Pump
- **Function**
  Define what it is supposed to do
- **Functional Failure**
  What can go wrong with performance? (Loss of function)
- **Failure Modes**
  What technically causes the failure (Root cause)
- **Failure Effects**
  Identify what happens when it fails
- **Consequence Assessment**
  Rate Severity: Safety/Environmental/Financial…
- **Maintenance Strategy**
  Prevent/Predict/let it fail/Re-design
- **Implementation, Monitor & Improve**





Example

RCM was applied to a steam processing plant at an Egyptian pharmaceutical mineral production company, with the **aim of cost reduction and improved system reliability**. By following the structured RCM methodology, including system selection, FMEA, etc, a preventative maintenance plan was developed, targeting critical components like boilers and pumps. Consequently, **downtime costs, labour costs, and spending on spare parts were all significantly reduced**.

Benefits & Limitations

Benefits	Limitations
• Cost-Effective Maintenance • Enhanced Safety & Compliance • Tailored Strategies • Supports Continuous Improvement	• Resource Intensive • Complex for Large Systems • High Initial Setup Cost • May Overlook Human Factors

Trade-Off
Precision vs. Effort

Recap

How does RCM fit into Reliability Engineering?

"RCM builds on reliability engineering, in that RCM is the applied strategy RCM is the applied strategy that focuses reliability principles where they matter most."

What is RCM?

"Structured approach to identifying the most effective maintenance strategy to keep equipment reliable, safe, and cost-efficient by analyzing its functions, failures, and consequences"

RCM Examples?

Steam Processing Plant

Benefits and Limitations?

"overall trade-off is precision versus effort: you get accurate, reliable maintenance, but it comes at a cost of time and resources"

How does RCM work?

1. Choose an Asset or System
2. Function
3. Functional Failure
4. Failure Modes
5. Failure Effects
6. Consequence Assessment
7. Maintenance Strategy
8. Implementation, Monitor & Improve

DOES ANYONE have questions?

THANK you

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Reliability-Centered Maintenance (RCM)

An Introduction to a Key Method in Reliability Engineering

Group 12

What is RCM?

Reliability-Centered Maintenance (RCM) is a corporate-level **preventative maintenance <u>strategy</u>** designed to **optimize maintenance <u>programs</u>** by establishing **safe minimum** levels of equipment upkeep.

-MaintainX (American industrial maintenance software company)

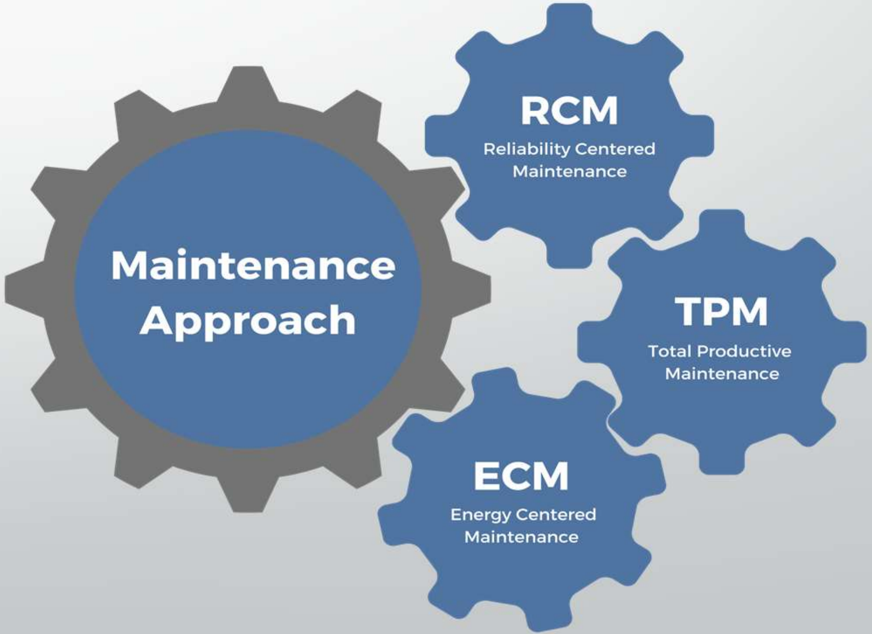
The 7 Steps
A bicycle example...

1. Select the asset or system (Choose what you want to take care of)
2. Define its functions (What is it supposed to do?)
3. Identify Functional Failures (What can go wrong?)
4. Identify failure modes (Why could it go wrong?)
5. Evaluate the effects and consequences (What happens if it goes wrong?)
6. Determine the appropriate maintenance strategy (What can I do to prevent that?)
7. Implement and optimize (Try it out and make it better)

Linking RCM to Reliability Engineering

- RCM is a **maintenance approach** to determine the most effective **maintenance strategy**.
- Common goals.
- Informed decisions.

- **Failure Rate**
- **MTBF**
- **MTTF**
- **PDF**



Maintenance Strategies in RCM

1. Preventative – scheduled time based servicing
2. Predictive – inspections to detect issues before failure
3. Run-to-failure – repairs only when components break
4. Redesign – upgrading or modifying components

Advantages and Disadvantages

Advantages

- **Enhanced Reliability**
- **Cost Savings**
- **Improved Safety**
- **Longer Asset Life**
- **Data-Driven**

Disadvantages

- **High Initial Cost**
- **Complex Process**
- **Time consuming**
- **Data Dependency**
- **Risk of Oversight**

Summary – Why RCM Matters

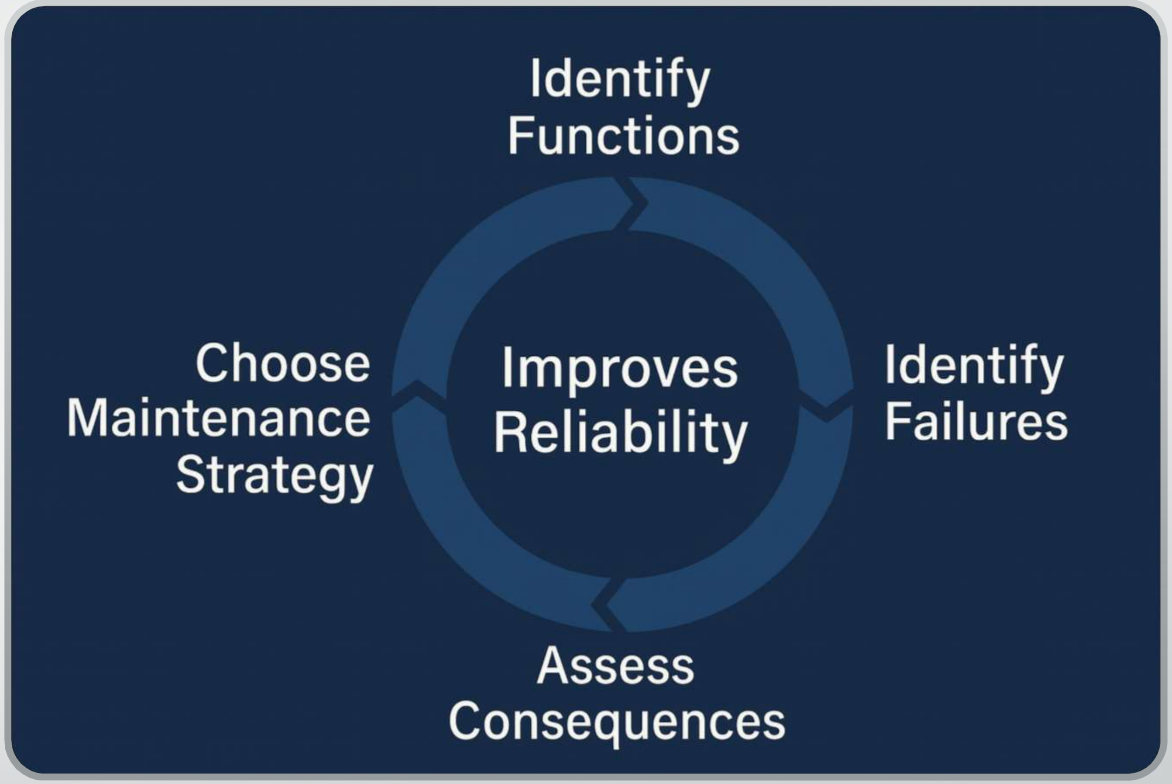
Makes sure assets (big or small) do what they're supposed to — like a bike that rides and stops safely.

Helps choose the right type of maintenance — not too much, not too little.

Prevents breakdowns before they happen — through inspections and planning.

Used from bicycles to aircraft and factories — same logic, just scaled up.

"RCM shifts the focus from doing maintenance for maintenance's sake to doing the right maintenance at the right time."



Questions and Engagement

- In what scenario would this method be applicable?
- Why was RCM developed?
- What are the typical challenges that can be faced by RCM when used in real life application?
- How does RCM differ from other reliability methods?
- How does RCM contribute and benefit to organizations?

Reliability Methods: ANOVA

Group 13

Agenda

Introduction to ANOVA

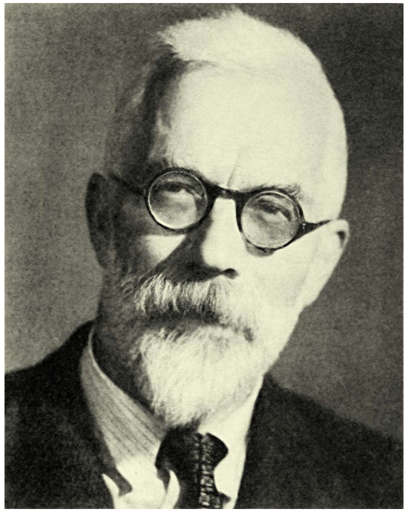
How ANOVA works

Types of ANOVA

Steps in conducting ANOVA

ANOVA in reliability engineering

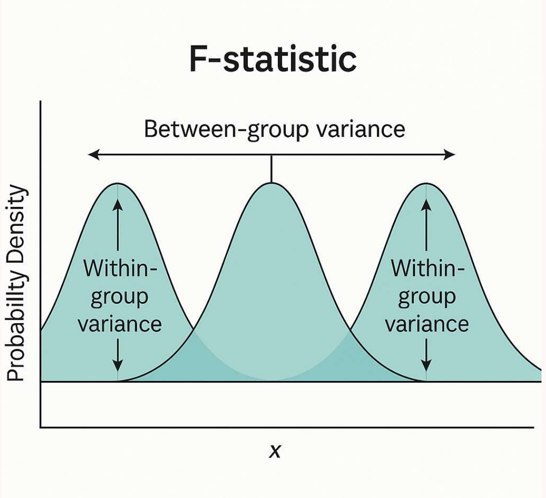
Practical Example



Introduction

- Developed by British statistician Ronald A. Fisher.
- He originally proposed it as a single unified framework to evaluate multiple groups within agriculture.
- ANOVA helps us answer the question whether the differences amongst group averages are due to actual effects, or just random chance.

How ANOVA works



Definition

ANOVA stands for *Analysis of Variance*. It's a statistical method used to compare the means of three or more groups.

Purpose

Determines if the difference between group means is statistically significant.

Concept

NOVA works by analyzing the **variance** (spread) within each group and between different groups.

Mechanism

It uses the **F-statistic**, which is the ratio of the variance **between groups** to the variance **within groups**.

Interpretation

A higher F-value indicates a greater likelihood that at least one group mean is significantly different.

Types of ANOVA

Type	Description	Use Case Example
One – Way ANOVA	1 independent variable (factor)	Comparing battery life of 3 brands
Two – Way ANOVA	2 independent variables	Studying effect of material & load
Repeated Measures ANOVA	Same subjects tested multiple times	Testing machine wear over time

Define hypothesis

Null Hypothesis (H_0): $\mu_1 = \mu_2 = \mu_3$

Alternative Hypothesis (H_1):

At least one μ is different

Check assumptions

ANOVA assumptions to check:

1. Normality
2. Independence
3. Homogeneity

ANOVA calculations

1. M_i & M

2. $SS_{Group} = \sum_0^{Group}\left((x-G)^2\right)$

3. $SS_{Between} = \sum_0^{Groups}(n_i(M_i - G)^2)$ & $SS_w = \sum_0^{Groups}(SS_i)$ & $SS_{Total} = (\sum x^2)_{total} - \frac{((\sum x)_{total})^2}{N}$

4. $MS_{between} = \frac{SS_{between}}{df_{between}}$ & $MS_w = \frac{SS_w}{df_w}$

Calculate F-Statistic

$$F = \frac{MS_{between}}{MS_{within}}$$

Interpret results

1. Determine p-value from F-statistic distribution table
2. Accept or reject Null Hypothesis

Steps in conducting ANOVA

ANOVA in Reliability Engineering

Purpose

- In reliability engineering, ANOVA identifies factors that can affect product reliability, predict failure rates, and optimize design parameters.
- ANOVA helps reliability engineers identify differences in reliability metrics (e.g., failure time, defect rate) across multiple groups or conditions.
- Enables engineers to evaluate the impact of design or process changes using statistical evidence.

ANOVA Best Practices

- Carefully Plan Experiments
- Check Assumptions
- Consider Interaction Effects
- Use Statistical Software

Practical Example

Example Scenario

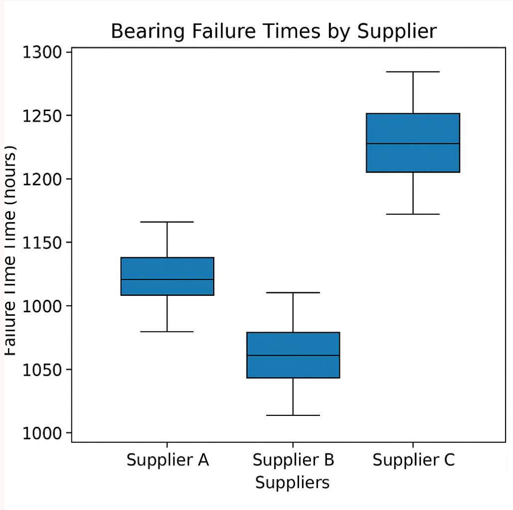
- A reliability engineer wishes to ascertain whether bearings from three distinct vendors (A, B, and C) have noticeably varying lifespans. To determine if the mean failure times vary, ANOVA is utilized.

ANOVA Result (Summary)

- Null Hypothesis H_0: All suppliers have equal mean failure time
- $F = \dfrac{\text{Between−group variance (MSB)}}{\text{Within−group variance (MSW)}} = 35.2$
- p-value: < 0.001
- Interpretation: Since $p < 0.05$, we reject H_0
- Conclusion: Supplier C bearings fail significantly earlier → drop Supplier C to improve reliability

Data

Supplier	Sample Data (hrs)	Mean (hrs)
A	1200, 1250, 1180, 1230, 1210	1214
B	1260, 1300, 1290, 1280, 1270	1280
C	1000, 1050, 1020, 980, 1010	1012



BOXPLOT FOR DATA

Thank you

Group 13

ANOVA as a reliability method.

GROUP 14

QUALITY MANAGEMENT 444

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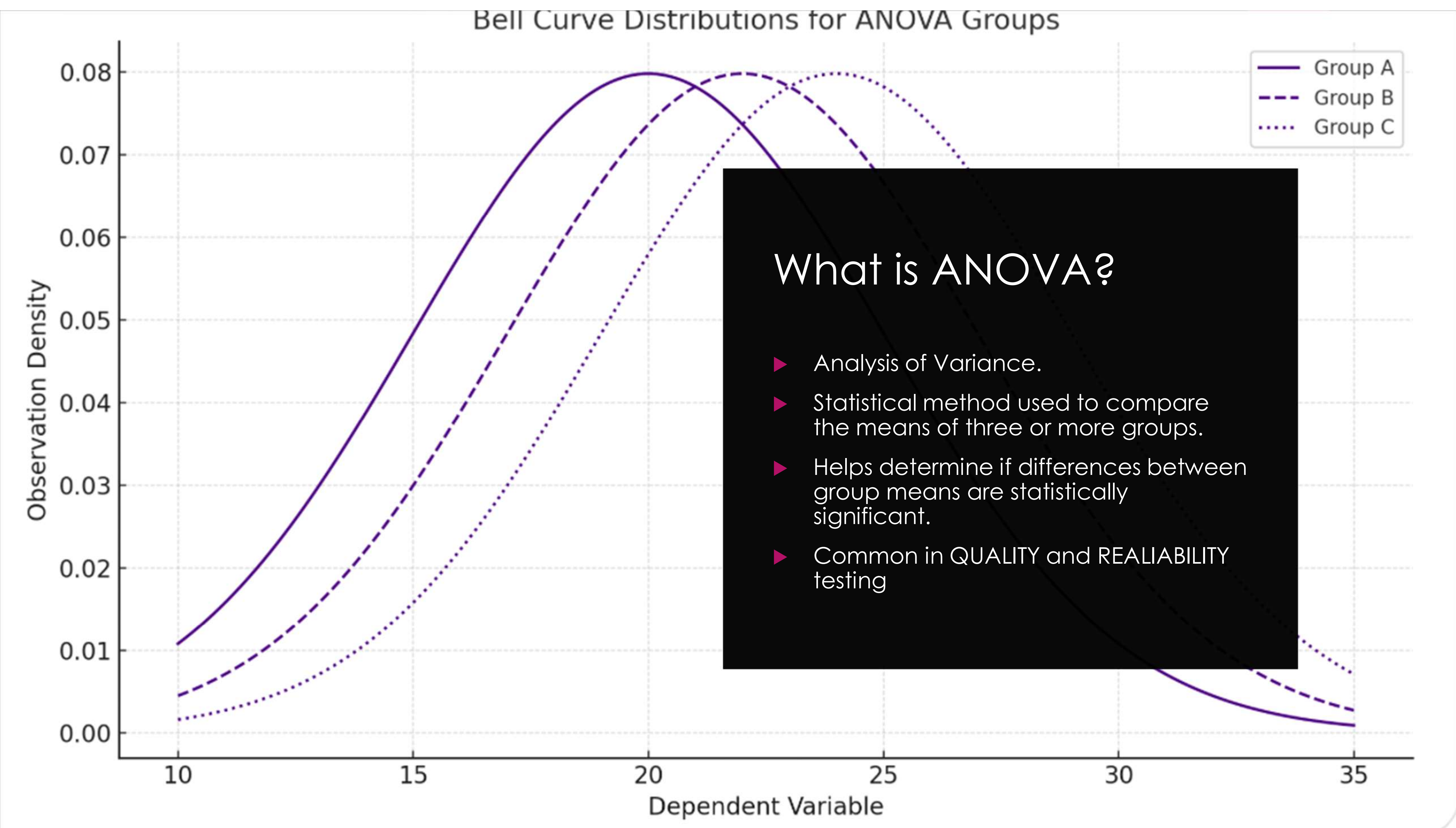


What is ANOVA?

- Analysis of Variance.
- Statistical method used to compare the means of three or more groups.
- Helps determine if differences between group means are statistically significant.
- Common in QUALITY and REALIABILITY testing

I. Choose what to compare
II. Collect the data
III. Check if the test is fair (similar sized groups, reasonable data patterns)
IV. Run ANOVA test
V. Test to see which groups are different
VI. Make decisions to improve group with outlying / weakest results

Step-by-Step: How ANOVA works:

How does ANOVA work?

Basic Terminology:

- Factors: The independent variables
- Levels: The groups within each factor
- Responsible Variable: The outcome your measuring
- Null Hypothesis: H_0 All groups means are equal
- Alternative Hypothesis: H_1 At least one group mean is different

Types of ANOVA:

- One-way ANOVA: One factor
  - Based on one factor
- Two-way ANOVA: Two Factors
  - Based on two or more different factors and their interactions

ANOVA in reliability Engineering:

- Compares mean time-to-failure across groups
- Commonly used to compare:
  - *Different production lines*
  - *Suppliers or materials*
  - *Operating conditions*
- Identifies factors linked to higher reliability

Benefits:

- Identifies high/low-performing groups
- Minimises errors by testing all groups together
- Provides data to guide decisions
- Tests multiple factors simultaneously

Limitations:

- Performs poorly with small samples
- Detects difference but not size or cause
- Assumptions must be met
- Struggles with heavily skewed data

Case-Study:

A MANUFACTURING FACILITY OPERATES FOUR DIFFERENT BRANDS OF HYDRAULIC PUMPS (BRAND A, B, C, D) ACROSS MULTIPLE PRODUCTION LINES. THE RELIABILITY ENGINEER WANTS TO DETERMINE IF THERE ARE SIGNIFICANT DIFFERENCES IN THE MEAN TIME BETWEEN FAILURES (MTBF) AMONG THE PUMP BRANDS TO OPTIMIZE MAINTENANCE SCHEDULES AND PROCUREMENT DECISIONS. THIS ANALYSIS WILL HELP IDENTIFY WHICH BRAND PROVIDES THE MOST RELIABLE PERFORMANCE AND WHETHER BRAND SELECTION SIGNIFICANTLY IMPACTS MAINTENANCE COSTS.

Step-by-step explanation

STEP 1: Problem Definition:

To determine if there are significant differences in mean time between failures (MTBF) among the brands

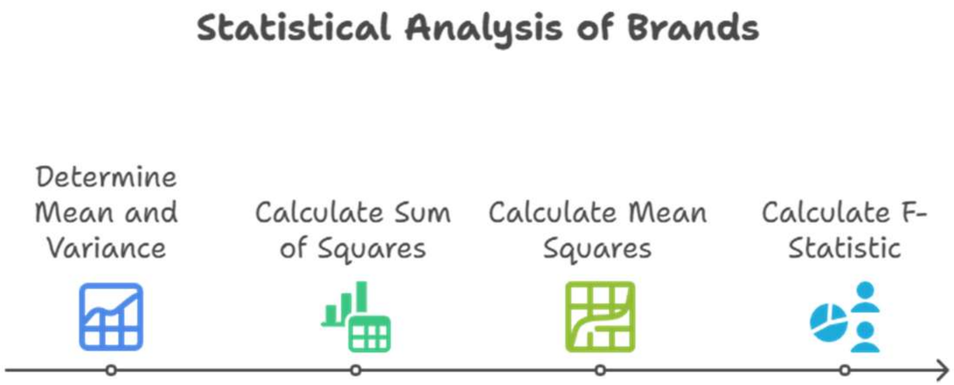
STEP 2: Collect Data

Brand A	Brand B	Brand C	Brand D
1,240	1,180	1,320	1,280
1,220	1,160	1,340	1,300
1,200	1,140	1,350	1,290
1,260	1,200	1,310	1,270
1,230	1,170	1,330	1,310
1,250	1,190	1,360	1,295

Time between failures data (hours).

STEP 3: Perform ANOVA Test

H_0 Null Hypothesis - $\mu_a = \mu_\beta = \mu_\gamma = \mu_D$ (all brands have equal mean MTBF)
H_1 Alternative Hypothesis **-** At least one brand has a different mean MTBF



Brand	**n**	**Sum**	**Mean ($\bar{x}$)**	**Variance (s^2)**
A	6	7,400	1,233.33	566.67
B	6	7,040	1,173.33	433.33
C	6	8,010	1,335.00	366
D	6	7,745	1,290.83	258.17

Source	**Sum of Squares**	**df**	**Mean Square**	**F-Statistic**
Between Groups	88,680.84	3	29,560.28	72.93
Within Groups	8,120.85	20	406.04	
Total	96,801.69	23		

STEP 4: Interpret Results

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares (MS)	F
Within	$SSW = \Sigma\,\Sigma\,(x_{ij} - \bar{x}_j)^2$	$df_w = n - k$	$MSW = SSW/df_w$	MSB/MSW
Between	$SSB = \Sigma\, n_j(\bar{x}_j - \bar{x})^2$	$df_b = k - 1$	$MSB = SSB/df_b$	
Total	$SST = \Sigma\,\Sigma\,(x_{ij} - \bar{x})^2$	$df_T = n - 1$		

Critical Value and Decision

- Degrees of freedom: $df_1 = 3$, $df_2 = 20$
- Critical F-value = 3.10
- Calculated F-statistic: 72.93

Since F = 72.93 > 3.10, we **reject the null hypothesis**.

STEP 5: Make decisions

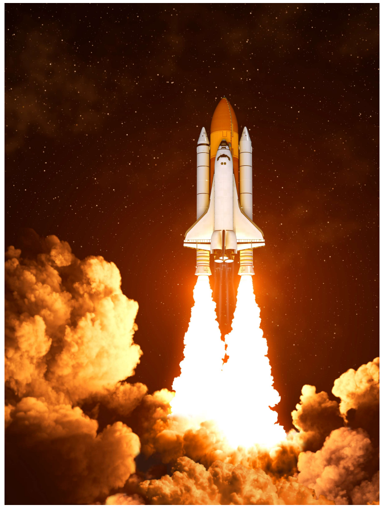
Identify causes and differences

Do a post-hoc analysis

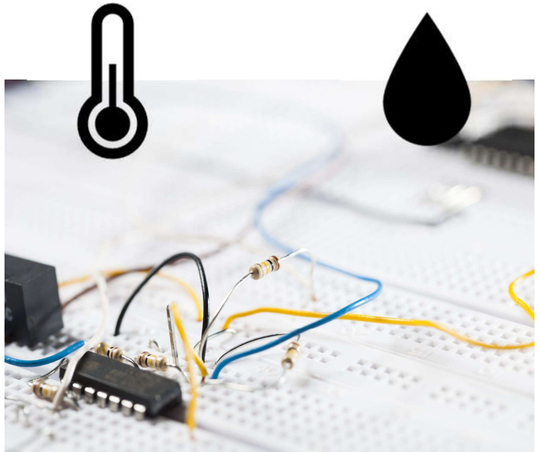
Targeted interventions

Real-World *Examples* of ANOVA in Reliability Engineering

Aerospace Reliability



Electronic Manufacturing



Beer Consumption by region

Thank you! Bring on the questions :)

HALT:

“HIGHLY ACCELERATED LIFE TESTING”

METHOD:

Subjects the product to stress at levels that are greater than the stress level the product will encounter under normal conditions to accelerate the failure of the product

QUALITIVE ACCELERATED TESTING :

Identifying failures without making predictions about the life of the product.

Advantages and Disadvantages of HALT

Advantage:

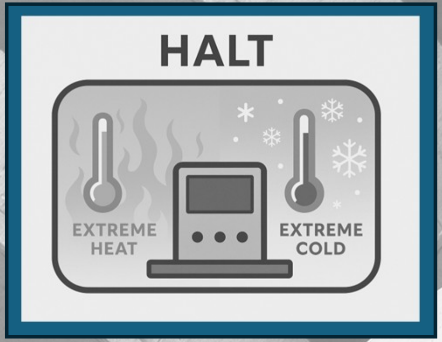
- supports design verification in a quick and easy way
- can reveal failures in a product in days instead of months

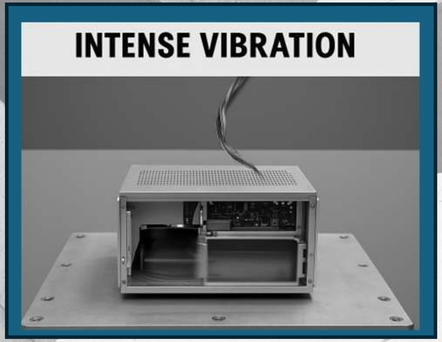
Disadvantage:

- it does not quantify the reliability of the product at normal use conditions

Stress used in HALT testing

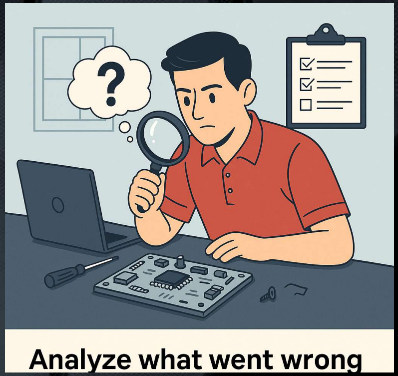
- Extreme heat and cold
- Intense vibration
- Electrical overloads





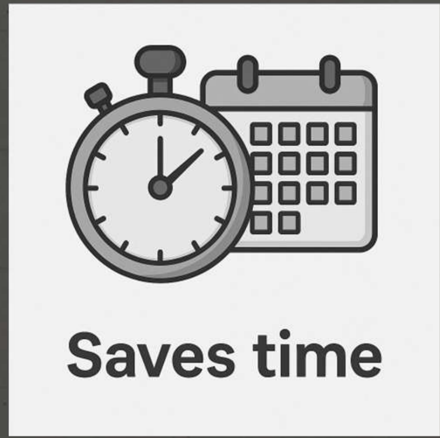
Engineers can:

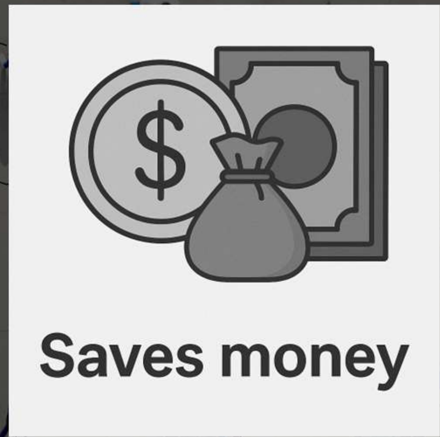
- Analyze what went wrong
- Improve the design
- Test again



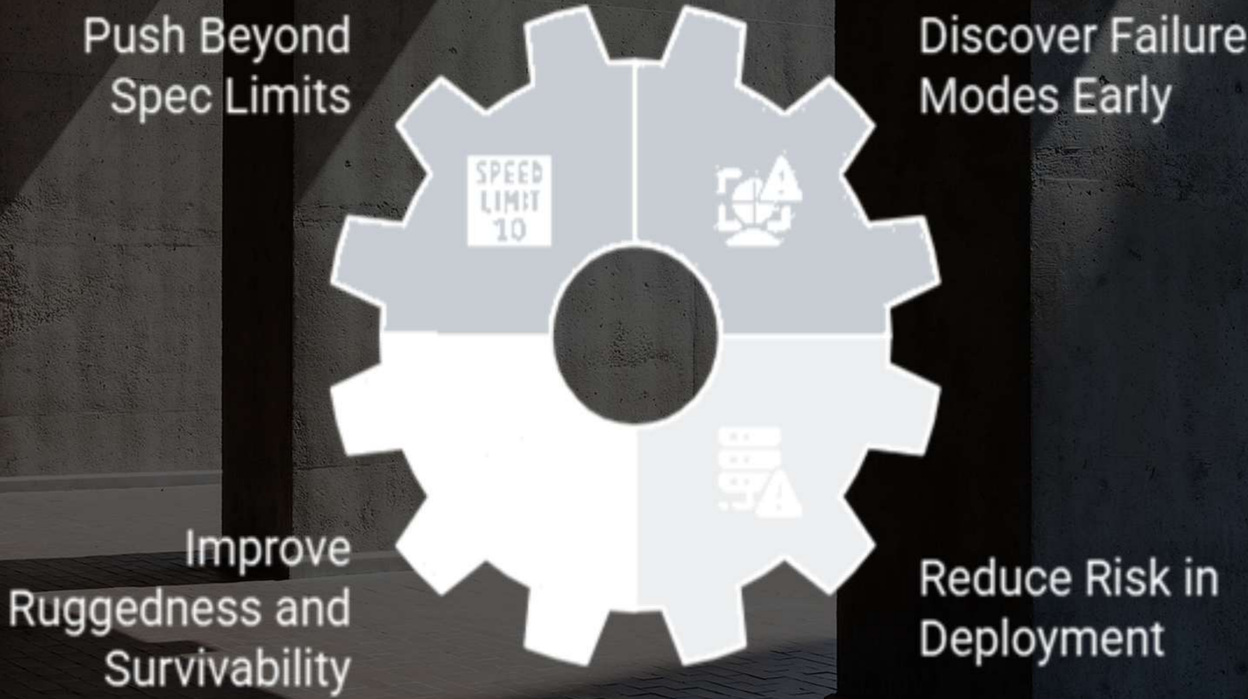
Results:

- Saves time
- Saves money
- Prevents problems before the product is launched



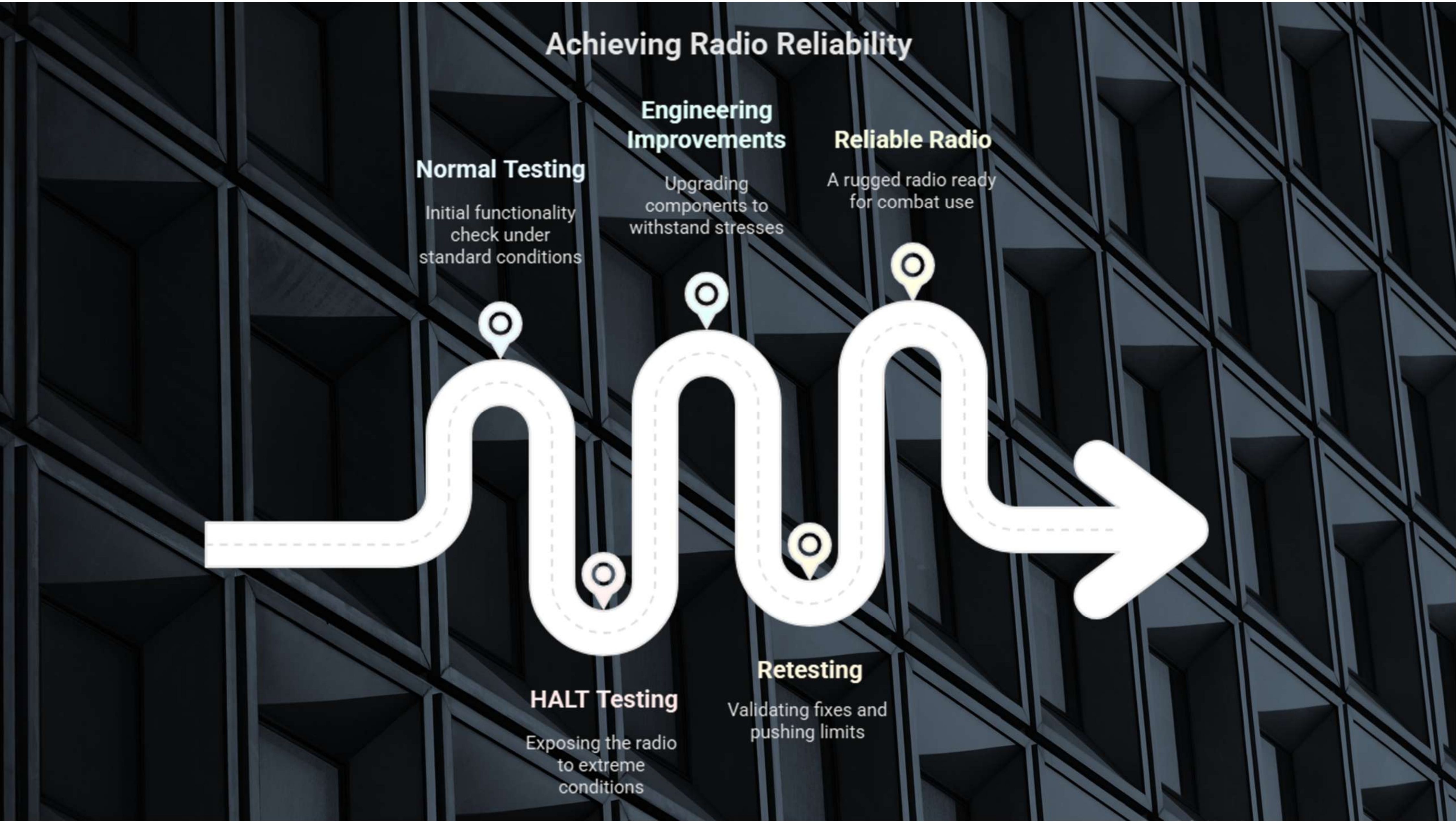


How HALT is used in Defense Reliability Engineering



HALT for a Tactical Radio System:

The military is developing a new **tactical radio** for soldiers, which must be reliable in diverse and extreme combat environments i.e. deserts, mountains, jungles, or urban warfare zones.



Achieving Radio Reliability
Normal Testing
Initial functionality check under standard conditions
HALT Testing
Exposing the radio to extreme conditions
Engineering Improvements
Upgrading components to withstand stresses
Retesting
Validating fixes and pushing limits
Reliable Radio
A rugged radio ready for combat use

HALT Testing

GROUP 16

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Highly Accelerated Life Testing (HALT)

- Is an **advanced product reliability testing method** used to uncover hidden design flaws early by exposing products to extreme environmental and mechanical stress – well beyond normal operating conditions.
- **Methods** used
  - Rapid thermal cycling
  - Extreme temperatures
  - Multi-axis vibration
- Performed during the **R&D and prototyping phase**
- **Improves**
  - Durability and Reliability

Objectives

Uncover Limits

Identify Failure Mechanisms

Generate data for Design Improvements

Why Halt Testing Matters

Reveals weak components, poor solder joints, or thermal mismatches before field failures occur

Drive design improvements by showing how and where failure happens

Eliminates guesswork and shorten iterative test cycles

Prevents expensive redesigns, warranty claims and recalls

Stages of HALT:

- Step-Stress Temperature Testing
- Rapid Thermal Transitions
- Random Vibration Testing
- Combined Environment Testing

Industries that use HALT

- Electronics
- Medical devices
- Automotive
- Aerospace
- Industrial equipment

Any application where products are exposed to harsh conditions such as temperature extremes, vibration, mechanical stress, – makes early detection of design flaws critical

Benefits of HALT Testing

- Uncovering design flaws early
- Streamlining the refinement process
- Reducing development risk
- Improve product reliability
- Shorten time to market
- Improve return on investment

HALT Practical Example

Let's say a company is developing a new electronic control unit (ECU) for automobiles. This device will be exposed to heat, cold, vibration, and electrical noise while in the car.

1. Early-Stage Testing
   - Engineers build a prototype of the electronic control unit and subject it to step-stress temperature testing (e.g., –60°C to +120°C).
   - At +105°C, the electronic control unit starts to fail intermittently.
2. Problem Identified
   - Engineers discover that a capacitor on the printed circuit board shifts a little at high temperatures, causing poor contact.

HALT Practical Example

3. Design Improvement
   - They redesign the circuit board layout and change the capacitor mounting method.
4. Retest
   - The modified electronic control unit passes temperature and combines thermal vibration testing without any problems.
5. Result
   - The electronic control unit is now far more robust than required, increasing its mean time between failure (MTBF) and customer confidence.

Impact on Reliability Engineering

Weak links are discovered before mass production

Failures that would have occurred in the field are eliminated.

HALT testing helped accelerate design iterations, avoiding trial-and - error in the field.

Thank You

HASS

HIGHLY ACCELERATED STRESS SCREENS

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WHAT IS HASS?

Hass is a production screening method used to ensure product reliability by exposing a product to accelerated stress conditions.

The stress conditions applied during HASS may include:

- **Rapid thermal cycling**
  - Products are cycled between high and low temperatures at aggressive rates, for example from -40°C to +90°C, stressing solder joints, adhesives, and seals.
- **Multi-axis random vibration**
  - Vibrations are applied in six degrees of freedom, across a wide frequency range (2 Hz to 10 kHz), to identify loose components or weak structural bonds.
- **Combined environmental stress**
  - Thermal cycling and vibrations are applied at the same time to detect failure modes that only occur under combined stress.
- **Product-specific electrical stresses**
  - Voltage margining tests a product by running it at slightly higher or lower voltages to check tolerance.
  - Frequency margining varies operating frequencies to ensure timing stability.
  - Power cycling repeatedly turns the product on and off to expose thermal and electrical weaknesses.

WHY HASS METHODS ARE APPLIED AFTER HALT

- During HALT (Highly Accelerated Life Test) testing, the product's destructive limits are determined
- HASS uses stress levels below these limits to ensure that good products are not damaged while still identifying any hidden defects.

HOW IS HASS USED?

We start by selecting a batch of finished products — sometimes every unit, or just a sample depending on how strict the quality requirements are.

These units are loaded into a HASS chamber and set up for stress testing.

- The idea here is to catch any hidden defects *before* they go out to customers.
- But we don't just randomly pick stress levels — they're chosen based on earlier HALT testing, which tells us the product's limits.

Once the units are inside, we run a pre-set stress profile.

- This usually includes things like rapid temperature cycling and multi-axis vibration — often both at the same time. But here's the important part: the stress levels are pushed high, but not too high. We're careful to keep them below the product's actual breaking point. For example, if a product fails at 100°C, we might only go up to 80°C in HASS. That way, good units won't get damaged, but any weak ones will likely break during the test.

While the stress is running, the products are monitored continuously — either during the test or afterwards.

HASS is usually split into two phases:

- **"Precipitation" phase**, which uses high stress to shake out any flaws
- **"Detection" phase**, where we ease off slightly to see if any damage shows up. Sometimes, flaws only become visible once the stress is reduced again.

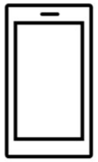
If a unit fails, it's pulled from the batch and investigated.

The ones that pass, we know are solid. They've survived conditions way beyond what they'll see in the real world.

INDUSTRY EXAMPLES OF WHERE HASS IS USED:

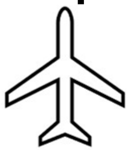
HASS is applied to a wide range of industries and product types, including electronic devices, mechanical systems and even consumer goods. Hass is particularly valuable for products where reliability directly impacts customer satisfaction, safety and brand recognition. Exposing products to extreme conditions, HASS helps identify defects before products reach the market.

Electronics



The electronics industry is one of the largest sectors that uses HASS testing. Devices like smartphones, laptops, printed circuit boards, and other consumer electronics are subject to temperature fluctuations, humidity, and handling stresses. HASS helps uncover latent defects early, ensuring product reliability and reducing returns.

Aerospace



In aerospace, where systems must function flawlessly under extreme conditions, HASS is essential. It is used to test avionics systems, flight control units, radar systems, and communication devices. These components must perform reliably under intense heat, vibration, and high-altitude pressures, and HASS ensures they meet these demands

INDUSTRY EXAMPLES OF WHERE HASS IS USED:

Medical devices

In an industry where products are used for the care and safety of patients, HASS is used to test certain surgical instruments, implanted devices, diagnostic machines and monitoring systems to ensure these devices work well in life critical situations

Telecommunications

Telecommunications infrastructure relies heavily on uptime and durability. HASS is applied to components such as routers, switches, fibre optic modules, and satellite communication systems. By identifying weak points early, HASS is used by companies to test products so that they can minimize costly downtime and reduce the need for frequent part replacements

Automotive

Brand reputation, customer satisfaction, and customer safety are essential in the automotive industry, and HASS is used to ensure durability and reliability of automotive components. It is used to test the vehicles engine control units, airbag systems, infotainment systems and different sensors.

HOW IS HASS APPLICABLE IN RELIABILITY ENGINEERING?

HASS is a reliability engineering technique that is used to identify and eliminate defects in products to maximize their lifespan and quality.
During HASS Testing a test duration and sampling rate is determined, this data is used to analyze the products performance under defined stress conditions.

How the collected data is used:

Collecting HASS Test Data → Analyzing HASS Test Data → Identify Defects And Failures → Address Defects And Failures → Improve Product Design and Manufacturing

HASS testing is carried out during the production and quality control phase to ensure that each product meets specific reliability standards before leaving the factory.
HASS is a rapid screening tool and it applies short-duration stress tests to a sample of units from each production lot.
This approach helps to detect defects early, ensuring consistent product reliability without requiring full-lot testing.

BENEFITS OF PRODUCT TESTING WITH HASS

Benefits of HASS testing:

- Reduced field failures.
  - Products are more likely to perform reliably when used by the customers.
- Reduced warranty and service costs
  - Defect containment
  - Identifying failures early prevents defective products from reaching the customers.
- Improved yield monitoring.
  - Tracking the type and number of failures found during HASS testing allows the manufacturer to monitor the production process.
- Continuously monitoring the processes
  - Tracking the manufacturing consistency over time to identify trends and improvement areas.
- Customer satisfaction and brand protection
  - Ensuring field reliability and confidence in the product.

COMPARISONS WITH OTHER METHODS AND THE FUTURE OF HASS

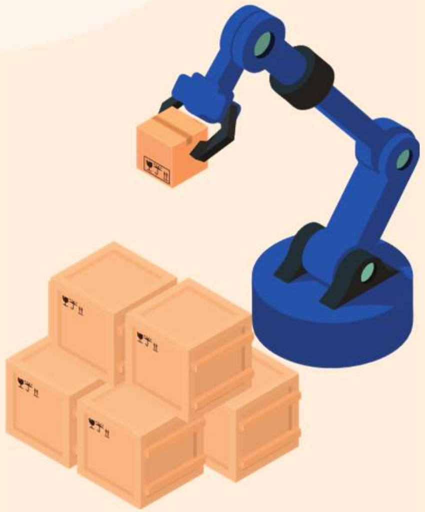
Method	Primary purpose	Phase Applied	Key difference from HASS
QFD	Align design with customer needs	Design	HASS does physical testing and QFD planning
FMEA	Identify potential failure modes	Design / Analysis	HASS does empirical testing and FMEA analytical testing
FTA	Analyse root cause of failures	Design / Analysis	HASS does stress screening and FTA diagnostics
HAZOPS	Ensures product safety	Process design / Operation	HASS analyses product reliability and HAZOPS analyses production safety
DOE	Optimise design through experiments	Design / Testing	HASS does stress-based testing and DOE statistical testing
ANOVA	Analyse experimental data	Design / Testing	HASS does production testing and ANOVA statistics
RCM	Plan maintenance strategies	Operation / Maintenance	HASS does physical testing and RCM maintenance
HALT	Improve design robustness	Design / Prototyping	HASS does production-phase testing and HALT design-phase testing
FRACAS	Track and manage failures	Full life cycle	HASS does physical testing and FRACAS management

Thank you!

Questions?

QUALITY MANAGEMENT 444

Highly Accelerated Stress Screening



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J Lancefield (25855875)

H- Highly,
A-Accelerated,
S- Stress,
S- Screening

A production-phase reliability test used to uncover manufacturing defects that may cause failures in real-world use.

Table of Contents

01. What is HASS?

A reliability test that forces weak components or flaws to fail during testing, before the product reaches the customer, by applying controlled yet extreme stress conditions. (Hobbs, 2005).

This testing method:

- Enhances product quality and reliability
- Reduces warranty costs and liability
- Increases customer satisfaction

(CVG Strategy, 2025)

Unlike traditional tests focused on compliance, HASS is a discovery-oriented process, actively looking for hidden defects rather than simply confirming specifications adherence (Hobbs, 2005).

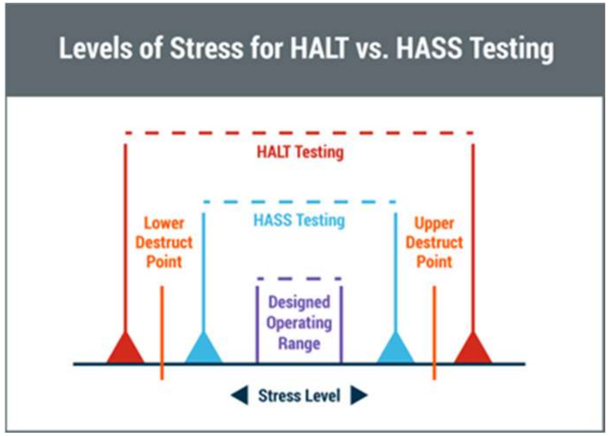
02. How does HASS work?

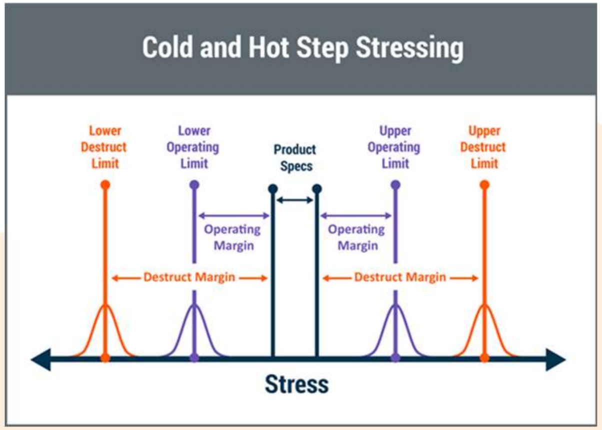
A mix of thermal and vibrational stress is applied to products during production. These stress levels are carefully defined using data from Highly Accelerated Life Testing (HALT), a procedure performed during product development to identify a design's breaking points (CVG Strategy, 2025).

- HALT helps determine the maximum safe stress limits.
- HASS then applies these limits in production to uncover process-related defects that may have emerged after HALT.

(Hobbs, 2005)

Because of this structure, HASS is not recommended without first conducting HALT, as it relies on HALT data to avoid over-stressing or under-testing the product (Hobbs, 2005).





03. Benefits of HASS

HASS is designed to:

1. Accelerate the detection of manufacturing flaws.
2. Shorten corrective action timelines.
3. Prevent early life field failures.

Additionally, since the testing process is time-compressed, it allows for:

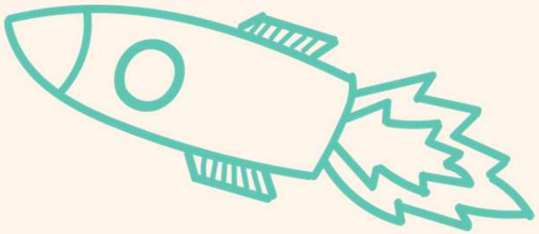
4. Reduced equipment requirements.
5. Lower manpower and operational costs.
6. Faster throughput on production lines.

(CVG Strategy, 2025)

However, due to high stress levels involved, test procedures must be designed to avoid causing unnecessary fatigue damage to otherwise good units (CVG Strategy, 2025).

04. Real-world applications

Modern HASS systems are compact and energy-efficient, making them highly adaptable to production environments, especially in industries where product reliability is mission-critical (CVG Strategy, 2025).



Originally popular in consumer electronics, HASS is now also used in sectors such as:

- Automotive
- Aerospace
- Medical technology

(CVG Strategy, 2025)

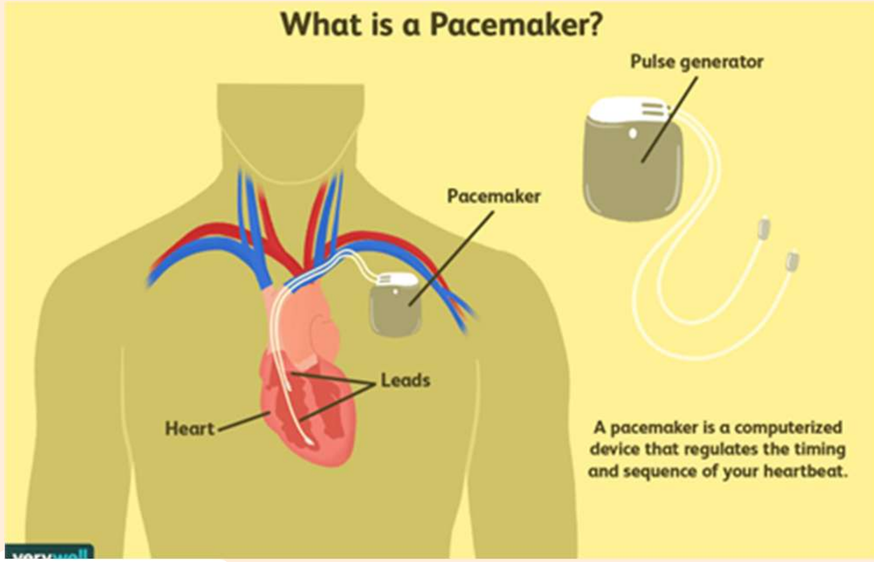
05. Practical Example

HALT and HASS testing are essential as their absence can have major repercussions. By applying these tests, manufacturers can ensure their products to have more robust designs, discover the design's limitations, and more accurately predict its life expectancy.

The value of these tests can be illustrated by using implantable cardiac devices as an example.

Implantable cardiac devices are medical devices, such as pacemakers, that are implanted under the skin.

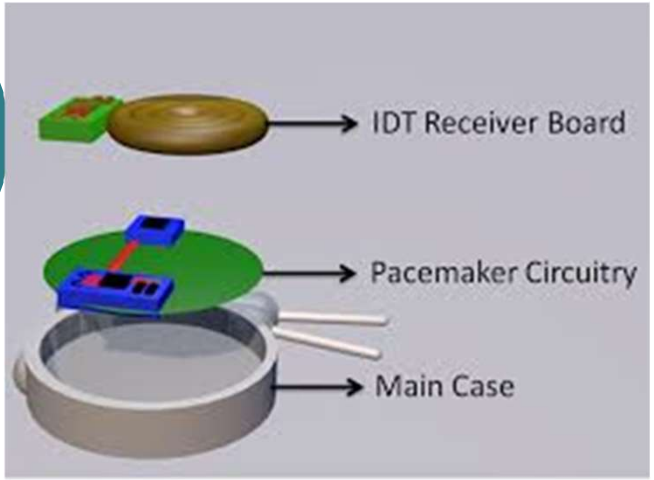
They send electrical pulses to the heart to maintain a regular rhythm and even a single early-life failure can be fatal.



Reasons for using HASS with cardiac devices:

Devices have long lifespans (10yrs), high reliability requirements, and are non-replaceable in nature.

Must undergo intensive screening to uncover any latent defects before product is ready for deployment.



Common causes of failure in pacemakers include: Hermetic seal or Encapsulation failure, or Battery defects.

Must determine failure modes and root causes of these issues.
Biomedical Engineers can identify these issues early by applying HASS testing.

Both HALT and HASS testing are done in a special chamber where a series of tests are executed on the product to define its operational and destructive limits. HALT/HASS chambers subject products to extreme temperature cycling and vibration to detect design and manufacturing defects. This is a picture of the chamber:

HASS Testing Steps

HASS consists of several steps during production aimed at finding defects and opportunities for improvement. By applying these steps to the example of the pacemaker, they may look as follows:

1. **Precipitation**
   Expose latent defects by applying stresses beyond normal operation. The various types of HASS tests will be discussed below.

2. **Defect detection**
   Any devices containing manufacturing defects will fail one/more of the tests applied in step one.

3. **Failure analysis**
   Evaluating potential reasons for failures and eventually determining the Root Cause. This may include micro sectioning the failed parts and using various software to identify the problem.

4. **Corrective action**
   The Root Cause identified in step 3 is addressed and corrective action is taken to remedy it.

5. **Verification of corrective action**
   This ensures that the corrective action taken eliminates the identified problem. The relevant defect should now no longer appear in statistically significant sample sizes.

6. **Enter the fault and the fix into a database**
   The issue is logged into a database in order to document failure modes and causes, which can be used as preventive design measures in future models.

7. **Subject the device to HALT and HASS testing for a second time.**
   This ensures that the improved margins are retained.

Different Types of HASS Tests

There are various types of HASS testing, as explained in step 1. Below, three are explained.

Temperature Testing

Pacemakers are subjected to rapid thermal cycling varying from negative temperatures to 85C over a compressed timeframe to simulate the effect of fluctuating body temperature on the device. This test detects microcracks in the solder joints and reveals battery or seal failures.

Vibration Testing

Pacemakers are subjected to random vibration noises in the x, y and z axis directions with frequency ranges varying from 5Hz to 2000Hz. This simulates product handling and body movements. These vibrations cause mechanical pressure on internal electrical components and aid in revealing weak or fragile assembly.

Electrical Testing

Electrical testing is done via power cycling, a process during which the device is repeatedly turned on and off. The goal of this is to reveal battery regulation issues. Another way to do this is electrical overstress screening, during which controlled electrical spikes are applied within safe but stressful limits.

06. References

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Thank You

FRACAS (Failure Reporting, Analysis, and Corrective Action System)

Group 19

Understanding the basics

What is FRACAS:

- FRACAS = Structured, closed-loop process for **improving reliability**.
- Logs every failure or incident in detail.
- Ensures **root causes are found and fixed** – not just patched.
- Used across industries (manufacturing, aerospace, automotive).

Visuals:

- Diagram: "Report → Analyze → Correct → Verify → Track".

Importance in reliability

- Drives **continuous improvement** of systems/products.
- Reduces repeat failures → saves **cost and downtime**.
- Tracks **key metrics** like MTBF (Mean Time Between Failures).
- Integrates with other reliability tools (FMEA, Root Cause Analysis).

Method (How it Works)

- **Failure Reporting:** Log when/where/how failure occurred.
- **Analysis:** Root cause investigation (5 Whys, Fault Tree, FMEA).
- **Corrective Action:** Fix problem, redesign, or improve process.
- **Verification & Tracking:** Ensure fix works and monitor performance.
- **Visuals:**
- Flowchart with arrows (closed loop).
- Example icons for each step (report form, magnifying glass, wrench, check mark).

How FRACAS keeps Formula 1 teams on track:

Repeated **gearbox sensor failures** during testing & pre-season

Failures logged using a **FRACAS system**: when, where, and conditions.

Root cause found:

excessive vibration & heat damaging supplier sensors.

Corrective actions:

Added thermal shielding.

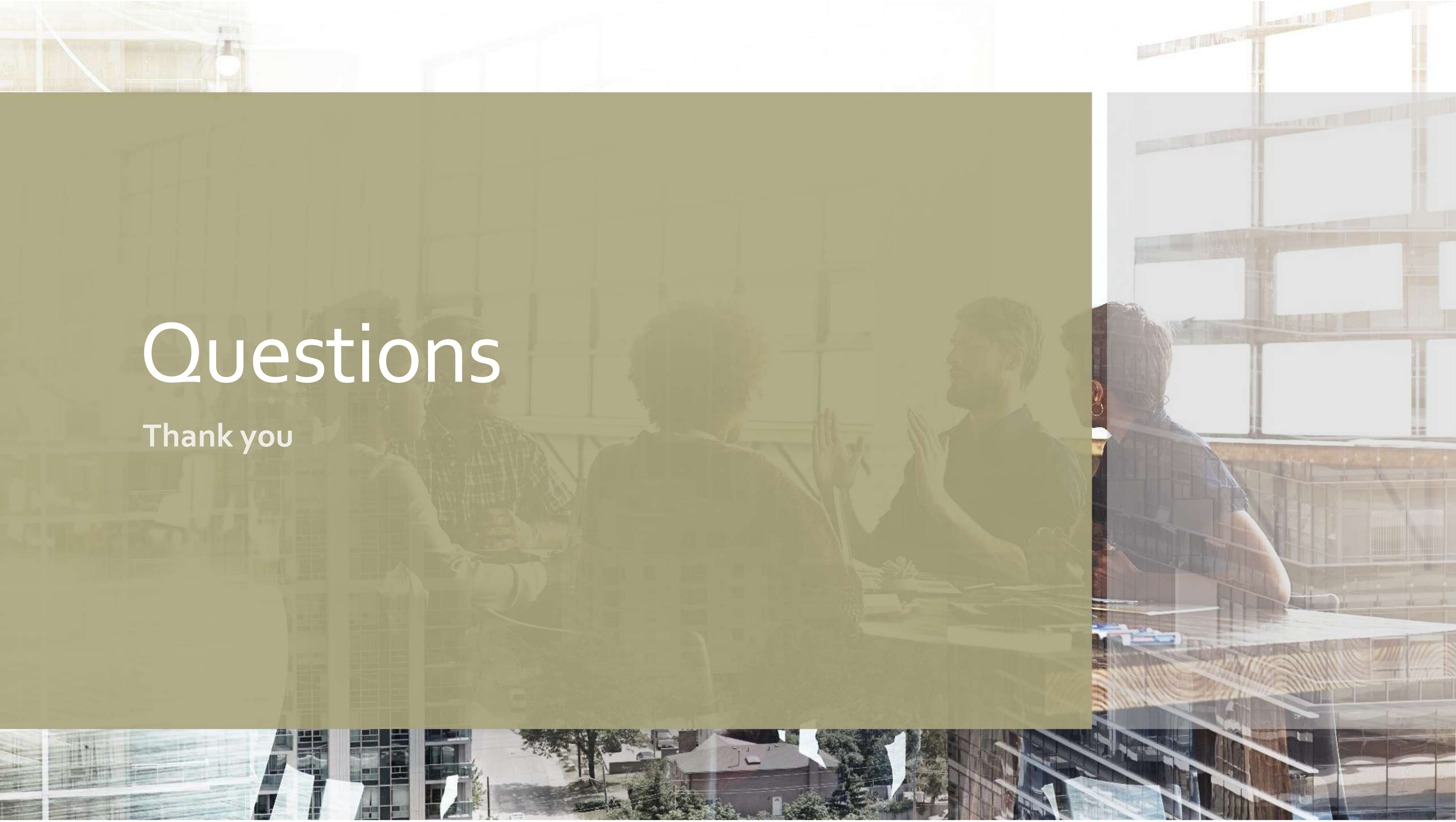
Improved durability standards.

Result:

78% reduction in failures, fewer race retirements, better performance.

Benefits

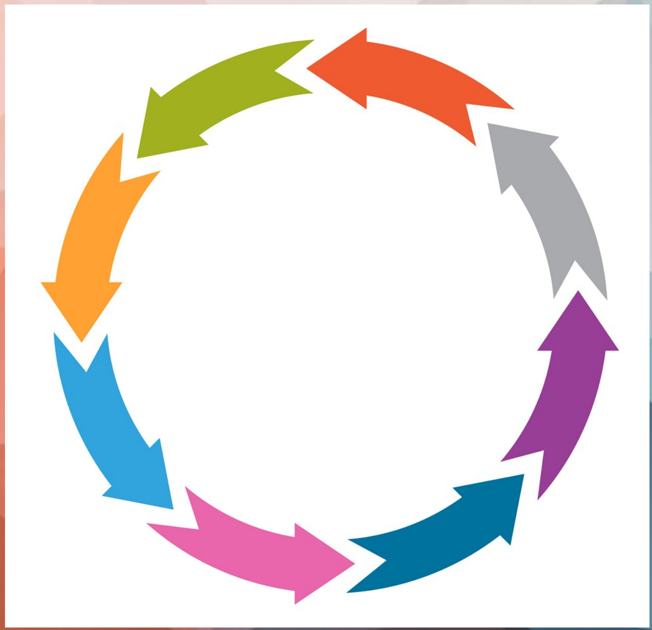
•Fewer failures → lower maintenance and warranty costs.
•Builds a **failure knowledge database** for future designs.
•Improves customer satisfaction and safety.
•Strengthens reliability culture in organizations.


Questions
Thank you

Quality Management 444

FRACAS

What happens after something goes wrong…?



Team 20

Definition:

*"**FRACAS** is a disciplined closed-loop system for **reporting**, **analysing**, and **correcting** failures to improve **reliability** throughout a system's lifecycle."*

F – failure
R – reporting
A – analysis
C – corrective
A – action
S – system

Context & Origin:

FRACAS originated in the **defence and aerospace industries** during the 1960s–70s as part of broader system safety and reliability initiatives. Agencies like the **U.S. Department of Defence** and **NASA** needed structured approaches to manage failure events in complex, high-risk systems.

FRACAS evolved with computerised maintenance management systems (CMMS) and Enterprise Resource Planning (ERP) tools, allowing better **integration** of failure **data and analytics**. Today, FRACAS tools often include **dashboards**, **predictive analytics**, and **automated alerts**.

Why use FRACAS?

Benefits:
- Improved reliability
- Data-driven decisions
- Regulatory compliance
- Cost reduction
- Customer satisfaction
- Knowledge retention

Implementation industries:
- Aerospace & Defence
- Automotive
- Energy
- Medical Devices
- Rail & Transportation
- Manufacturing

THE 3 MAIN STEPS OF FRACAS

STEP 1: FAILURE REPORTING

YOUR LOGO

Equipment Damage Report Form

Employee Name

First

Last

Departemnt

Email

Equipment Involved

Description of Damage

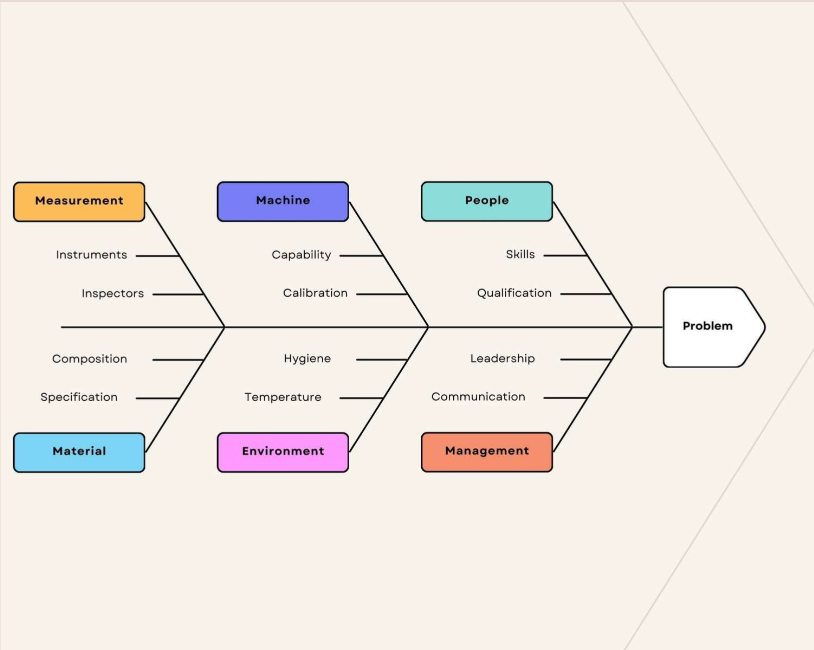
Immediate Actions Taken

1. Standard failure report: asset ID, timestamp, operating & test conditions, symptom snapshot

2. Capture context: who found it, steps leading to incident and immediate actions

3. Real-time digital entry: everyone can access the record as soon as it's logged

STEP 2: ANALYSIS



1. Lead engineer assembles cross-functional RCA (Root Cause Analysis) team.
2. Toolbox: 5 Whys, Fishbone, FMEA (Failure Mode and Effects Analysis).
3. Outcome: single verified root cause.

STEP 3 CORRECTIVE ACTIONS

1. Implement corrective & preventive measures. Fix faults, guard against repeats.

2. Verify effectiveness. Test, monitor metrics, confirm MTBF rise.

3. Close record & update knowledge base. Lessons are stored; loop restarts stronger.

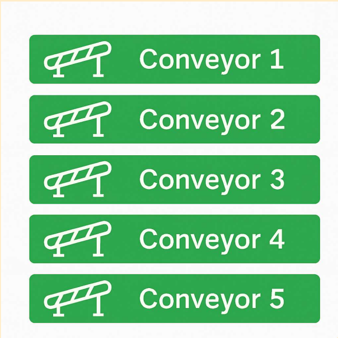
BEARING FAILURE CASE STUDY

CASE STUDY DESCRIPTION

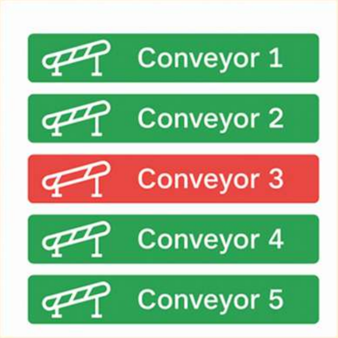
Bearing Seizure Incident

A critical bearing on a conveyor belt system experienced a seizure during normal operation in a factory environment. This mechanical failure led to the unexpected shutdown of the production line and numerous parts damaged.

FAILURE REPORTING

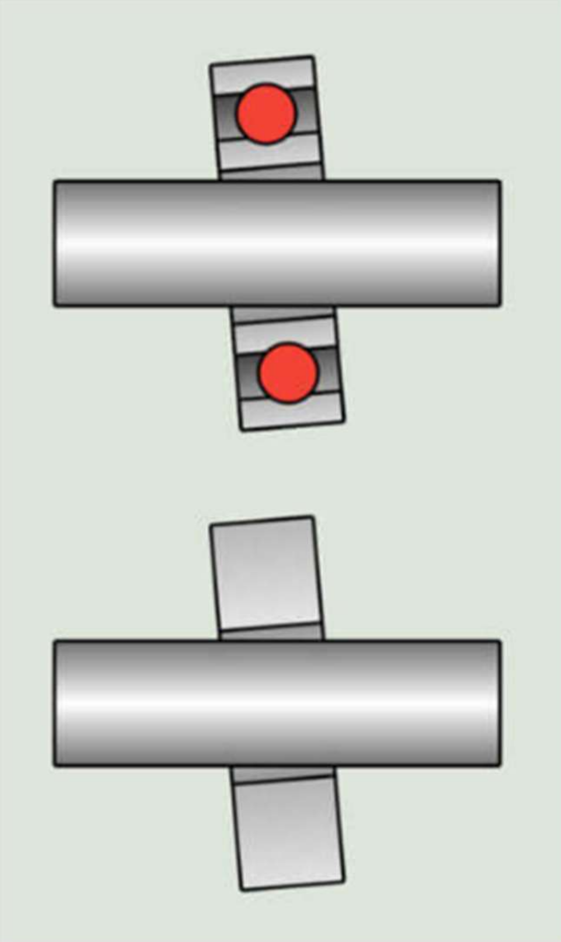


Visual Equipment Monitoring
The failure reporting system shows the status of all the conveyor belts in the factory.



Failed Component Highlighting
The failed conveyor belt is distinctly highlighted to identify the system failure quickly.

ROOT CAUSE DETERMINATION



Root Cause Identification

Investigation pinpointed shaft misalignment as the main cause of bearing failure.

Training Deficiency

Inadequate operator training contributed directly to improper shaft alignment during a routine service.

CORRECTIVE ACTIONS

Immediate Conveyor Belt Repair

Short-term corrective actions involved quick replacement of damaged and failed parts.

Long-Term Education Programs

Long-term measures focused on mandatory comprehensive education programs for mechanic skill enhancement.

Tools and Metrics

Metrics

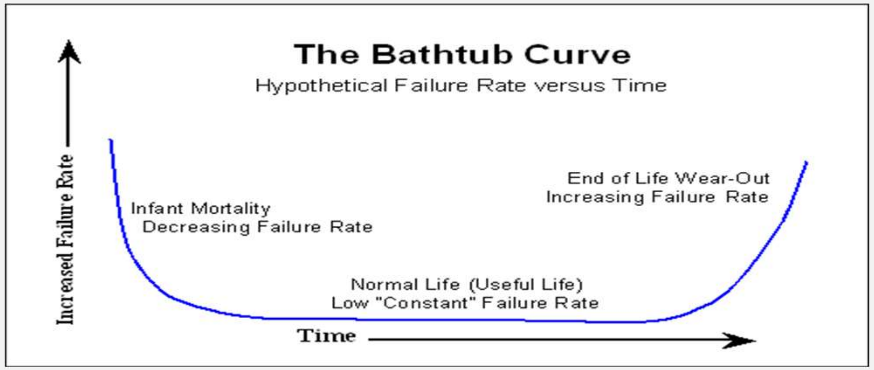
- Components and their cumulative failures
- Root Cause Categories (Human, Mechanical, Electrical)
- Root-cause identification time

Corrective Action Metrics

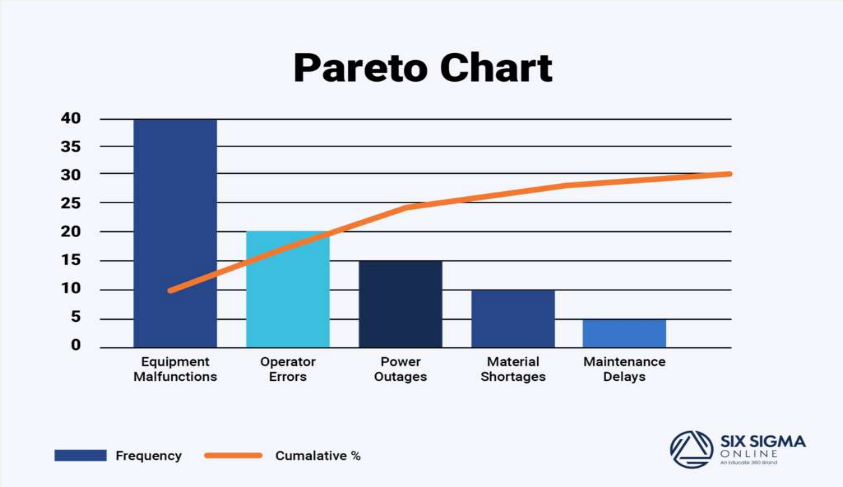
- Reliability growth, Impact of corrective actions
- MTBF
- MTTF
- MTTR

Tools used in FRACAS

Monitoring and Analysis



Root Cause and Corrective Action:



FROM **PREDICTIONS** *TO* **REAL FAILURES**: FRACAS VS FMECA

DISTINCTIONS:

FRACAS VS FMECA

FMECA

Pre-deployment (Design Phase)

- **Failure Modes, Effects and Criticality Analysis**
- Uses judgement & estimated failure rates
- To predict & prioritise potential failures
- Issues are potential and addressed before failure; predictive

FRACAS

Post-deployment (operational phase)

- **Failure Reporting, Analysis and Corrective Action System**
- Uses actual failure data from system
- To track and analyse real failures
- Issues are addressed after failure; non predictive

Limitations of FRACAS? Why use FRACAS?

Limitations:

- Human Nature: Requires reporting of failures!
- Data integrity: How accurate, consistent and trustworthy is your data?
- Non Predictive: Lags behind.

Why?

Limitations of FRACAS? Why use FRACAS?

Limitations:

- Human Nature: Requires reporting of failures!
- Data integrity: How accurate, consistent and trustworthy is your data?
- Non Predictive: Lags behind.

Why?

- Its real data!

It is used to capture and fix real-life reliability issues. Data is golden, it allows for systematic problem solving and improvement.

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Thank you!

Any questions?

Team 20