# TRC3000 Automation Project

## Management: Failure Mode & Effects Analysis

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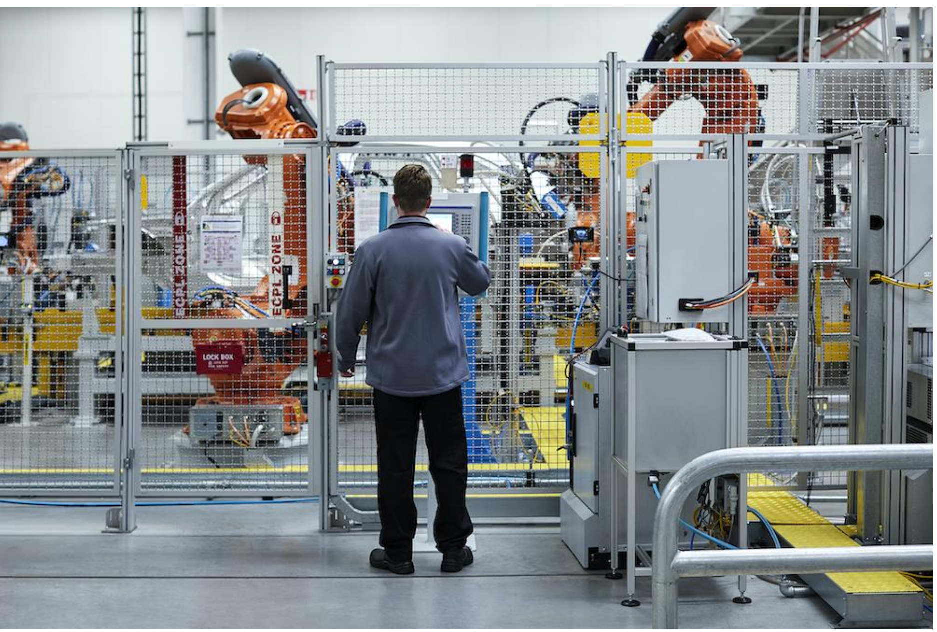
# Motivation

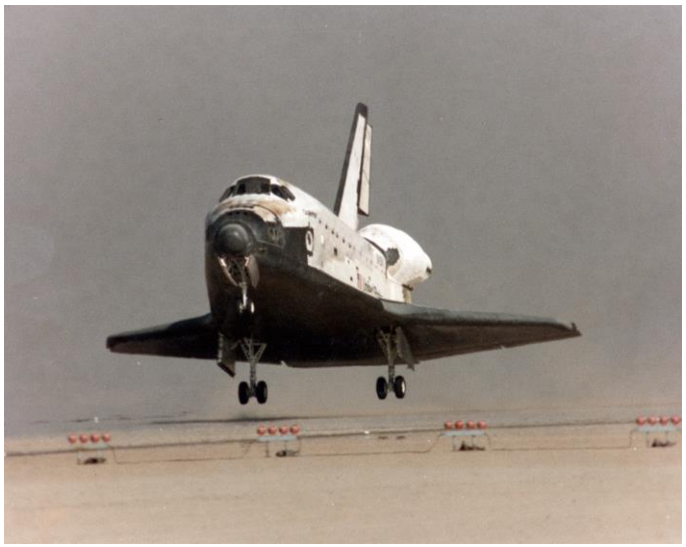


- FMEA seeks improvements in:
  - Safety
  - Quality
  - Reliability
- Other potential benefits that it brings
  - Improves company image
  - Reduces costly product recalls
  - Creates a record to differentiate from competitors

# History of FMEA

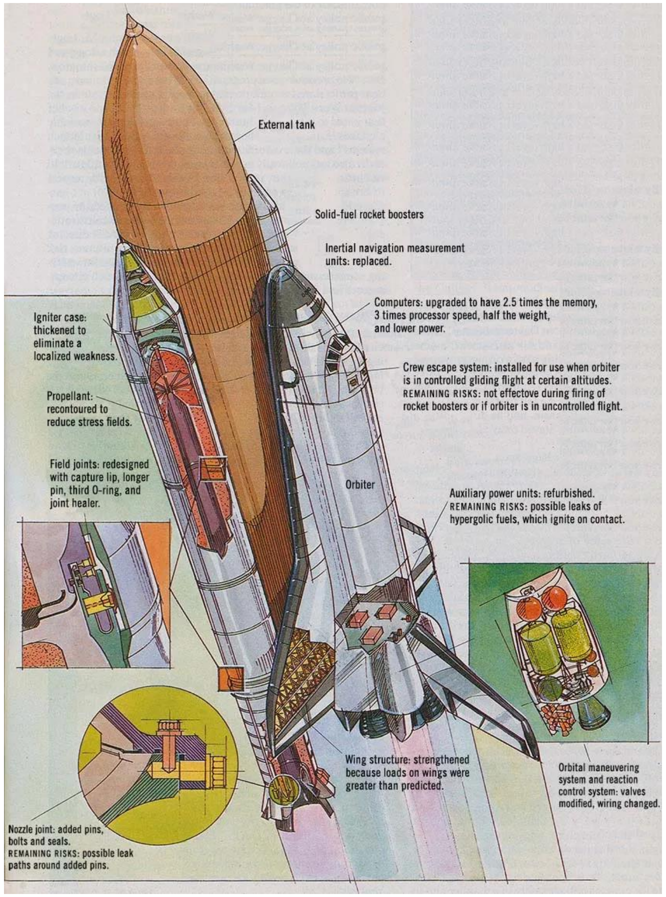
- Created by the aerospace industry in the 1960s.
- Ford began using FMEA in 1972 to analyze their engineering designs.
- Chrysler, Ford, and General Motors developed QS9000, an automotive equivalent to ISO9000. Design and process FMEAs were a standard for compliance with the QS9000
- Automotive Industry Action Group (AIAG) and American Society for Quality Control (ASQC) presented an FMEA manual that was approved by the Big Three automakers in 1993.

# NASA and FMEA (1)



- On April 4, 1983, Challenger launched on her maiden voyage
- On January 28, 1986, seventy-three seconds into the mission, the Challenger exploded, killing the entire crew
- "Statistics don't count for anything," - Will Willoughby, the National Aeronautics and Space Administration's former head of reliability and safety during the Apollo moon landing program.
- This design-oriented only view prevailed in NASA in the 1970s, when the space shuttle was designed and prototypes built by many engineers that worked on the Apollo program.

# NASA and FMEA (2)




- "The real value of probabilistic risk analysis is in understanding the system and its vulnerabilities," - Benjamin Buchbinder, manager of NASA's risk management program.
- After the Challenger disaster, NASA began using risk estimation to address the relative probabilities of a particular hazardous condition arising from failure modes, human errors, or external situations.
- Since then, NASA formally adopted the FMEA as its principal means of identifying design failures

# FMEA Procedure

1) Assign a label to each process or system **component**

2) List the **function** of each component

3) List potential **failure modes**

4) Describe **effects** of the failures

5) Determine failure **severity**

6) Determine probability of failure **occurrence**

7)Determine **detection** rate of failure

8) Assign **RPN**

9) Take **action** to reduce the highest risk

**10) Update the FMEA as action is taken**

# FMEA Worksheet

Example of Concept FMEA on Bicycle Brake Cable (with new nylon material)

| Function | Potential Failure Mode | Potential Effect(s) of Failure | Sev | Potential Cause(s)/ Mechanism(s) of Failure | Occ | Current Design Controls (Prevention) | Current Design Controls (Detection) | Det | RPN | Concerns |
|---|---|---|---|---|---|---|---|---|---|---|
| The brake cable provides adjustable and calibrated movement between the brake lever and brake caliper, under specified conditions of use and operating environment. | Cable breaks | Operator is unable to close brake calipers, wheel does not slow down, possibly resulting in accident. | 10 | Abrasive wear of nylon cable due to wrong material selected | 3 | Cable material selection based on ANSI Standard #ABC. | Cable strength test# 456 | 2 | 60 | Strength of new nylon cable material is less than steel for similar diameter |
| | | | | Nylon material becomes brittle due to low humidity and bending loads | 6 | | Testing samples undergo laboratory analysis for cracks per test regimen #456 | 5 | 300 | Brittle nylon material is major concern in low humidity applications |
| | Cable binds | Increased friction between cable and sheath, resulting in operator having to use greater effort to close brake calipers. | 7 | Bend or kink in cable due to mis-routing | 5 | Nylon cable material design guide #123 | Finite Element Analysis of all new cable material | 2 | 70 | Added controls will be needed in plant cable assembly |
| | | | | Inadequate or wrong lubrication between cable and sheath | 1 | Cable lubrication design guide #678 | Brake lever effort test #789 | 1 | 7 | |
| | Cable slips (at brake caliper or brake lever locking nut) | Brake caliper does not close properly when brake lever is pulled, resulting in inadequate friction between brake pads and wheel, with possibility of accident. | 10 | Brake cable diameter too small to maintain secure position when locking nut is engaged | 5 | Tolerance study of cable locking mechanism | Brake calibration test #567 | 2 | 100 | Redesign of cable locking mechanism will be needed |

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# Severity Ratings

| Ranking | Effect | Criteria: Severity of Effect |
|---|---|---|
| 1 | None | No effect. |
| 2 | Very Minor | Very minor effect on product or system performance. |
| 3 | Minor | Minor effect on product or system performance. |
| 4 | Low | Small effect on product performance.<br>The product does not require repair. |
| 5 | Moderate | Moderate effect on product performance.<br>The product requires repair. |
| 6 | Significant | Product performance is degraded.<br>Comfort or convenience functions may not operate. |
| 7 | Major | Product performance is severely affected but functions.<br>The system may not be operable. |
| 8 | Extreme | Product is inoperable with loss of primary function.<br>The system is inoperable. |
| 9 | Serious | Failure involves hazardous outcomes and / or noncompliance with government regulations or standards. |
| 10 | Hazardous | Failure is hazardous and occurs without warning. It suspends operation of the system an/or involves noncompliance with government regulations. |

# Occurrence Ratings

| Ranking | Effect | Criteria: Severity of Effect |
|---|---|---|
| 1 | None | No effect. |
| 2 | Very Minor | Very minor effect on product or system performance. |
| 3 | Minor | Minor effect on product or system performance. |
| 4 | Low | Small effect on product performance.<br>The product does not require repair. |
| 5 | Moderate | Moderate effect on product performance.<br>The product requires repair. |
| 6 | Significant | Product performance is degraded.<br>Comfort or convenience functions may not operate. |
| 7 | Major | Product performance is severely affected but functions.<br>The system may not be operable. |
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| 9 | Serious | Failure involves hazardous outcomes and / or noncompliance with government regulations or standards. |
| 10 | Hazardous | Failure is hazardous and occurs without warning. It suspends operation of the system an/or involves noncompliance with government regulations. |

# Detection Ratings

| Ranking | Criteria: Detection Probability |
|---|---|
| 1 | Almost Certain Detection |
| 2 | Very High Chance of Detection |
| 3 | High Probability of Detection |
| 4 | Moderately High Chance of Detection |
| 5 | Moderate Chance of Detection |
| 6 | Low Probability of Detection |
| 7 | Very Low Probability of Detection |
| 8 | Remote Chance of Detection |
| 9 | Very Remote Chance of Detection |
| 10 | Absolute Uncertainty – No Control |

# Risk Priority Number (RPN)

The RPN prioritizes the relative importance of each failure mode and effect on a scale of 1 – 1000. It is calculated as follows:

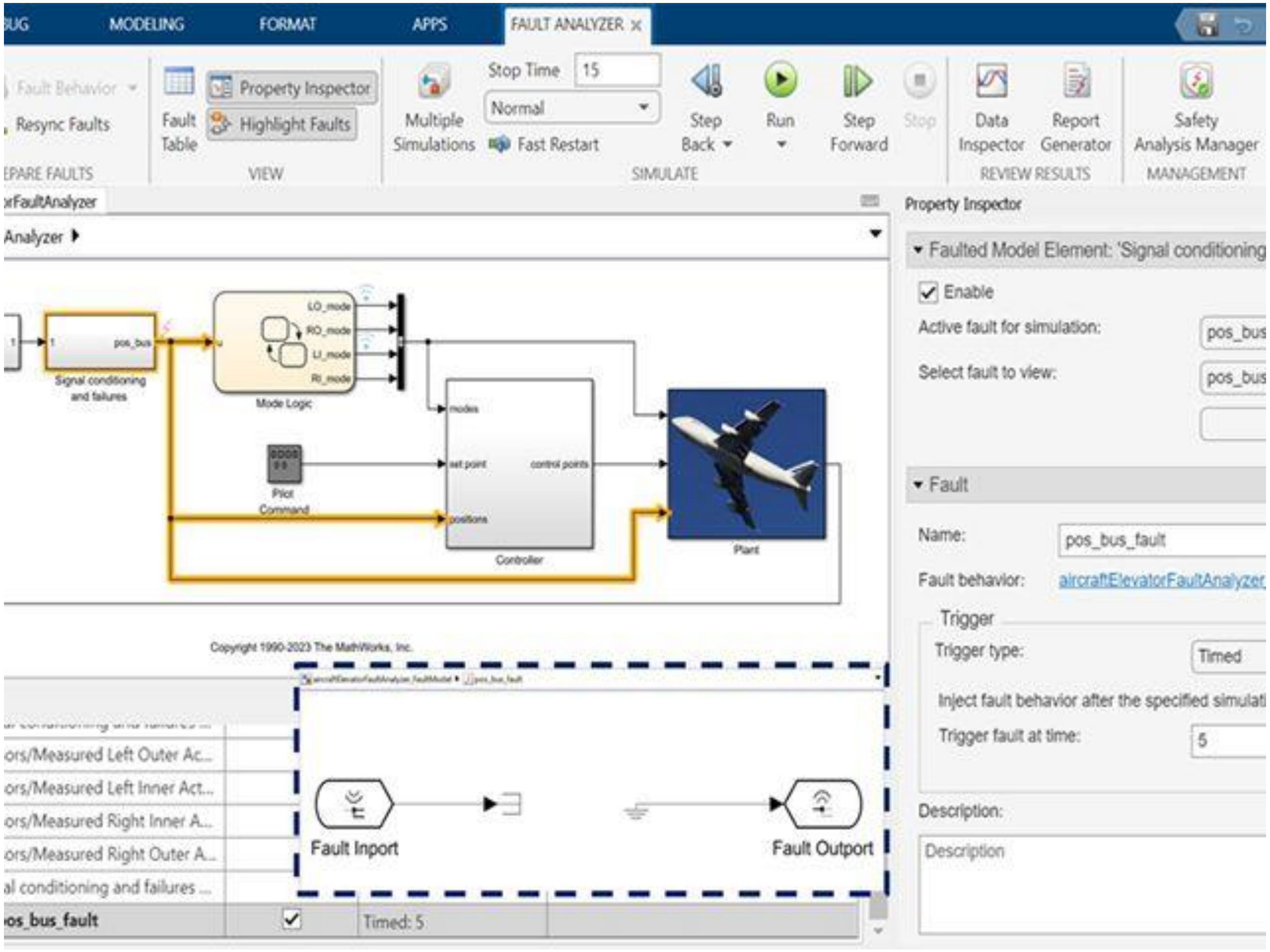
**RPN = (Severity) x (Occurrence) x (Detection)**

1. A 1000 rating implies a certain failure that is hazardous and harmful.
2. A 1 rating is a failure that is highly unlikely and unimportant.
3. Rating below 30 are reasonable for typical applications.
4. Ratings above 100 typically need to be attended to.

# Action Plans

- Based on the RPN number, some recommended actions to be developed include:
  - Assign responsibilities
  - Outline corrective actions
  - Revise test plans, material specifications
- These actions should be specific, not general action items.

# Simulink Fault Analyzer




Simulink Fault Analyzer enables systematic fault injection and safety analysis using simulation.

This can be used to identify possible faults so that RPNs can be assigned.