Engineering Design
ENGR 13x2

Engineering Failure & Analysis

Agenda

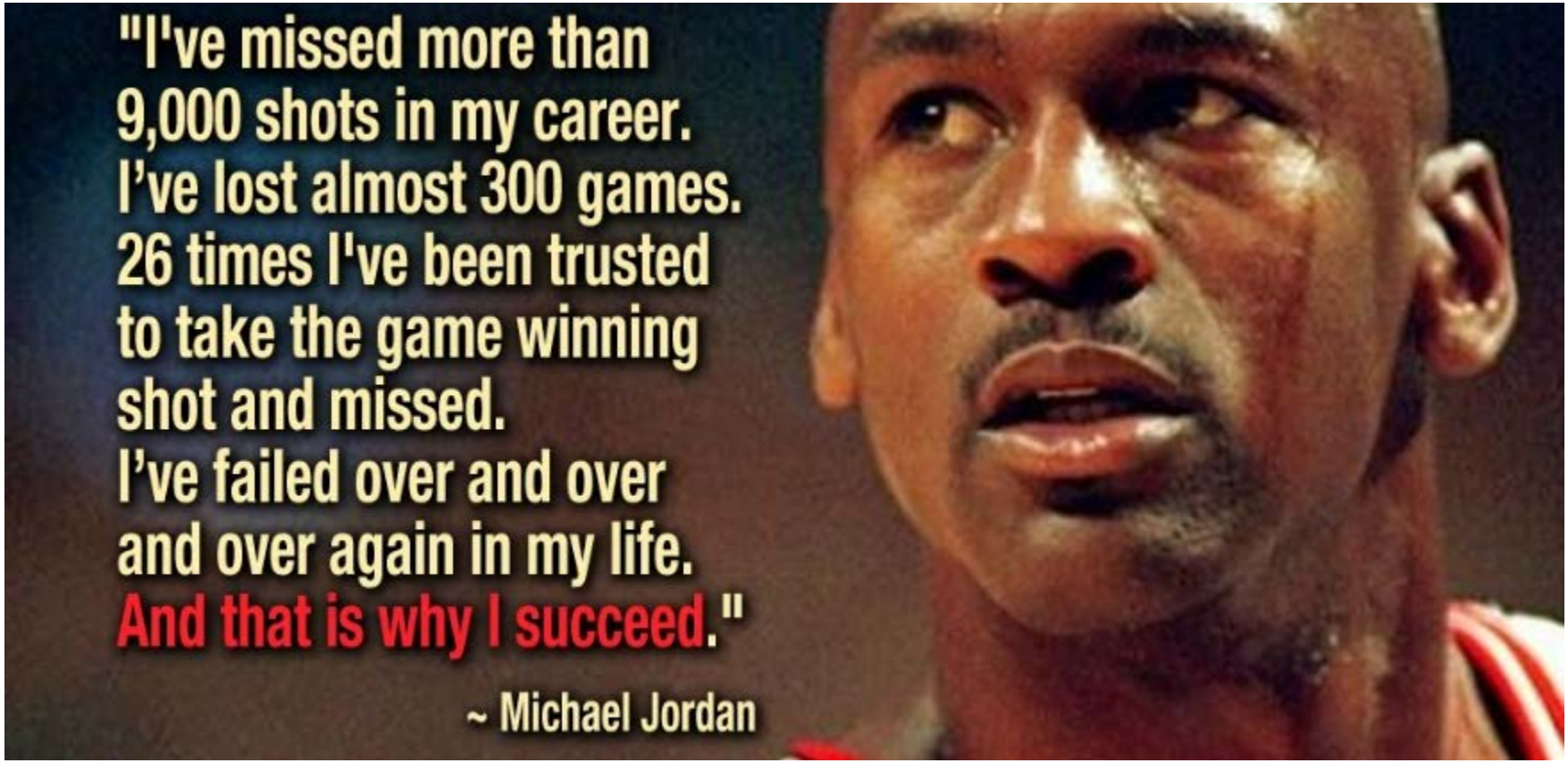
- Learning from failure
- Case studies in engineering failure
- Engineering Failure Analysis techniques

Learning from failure

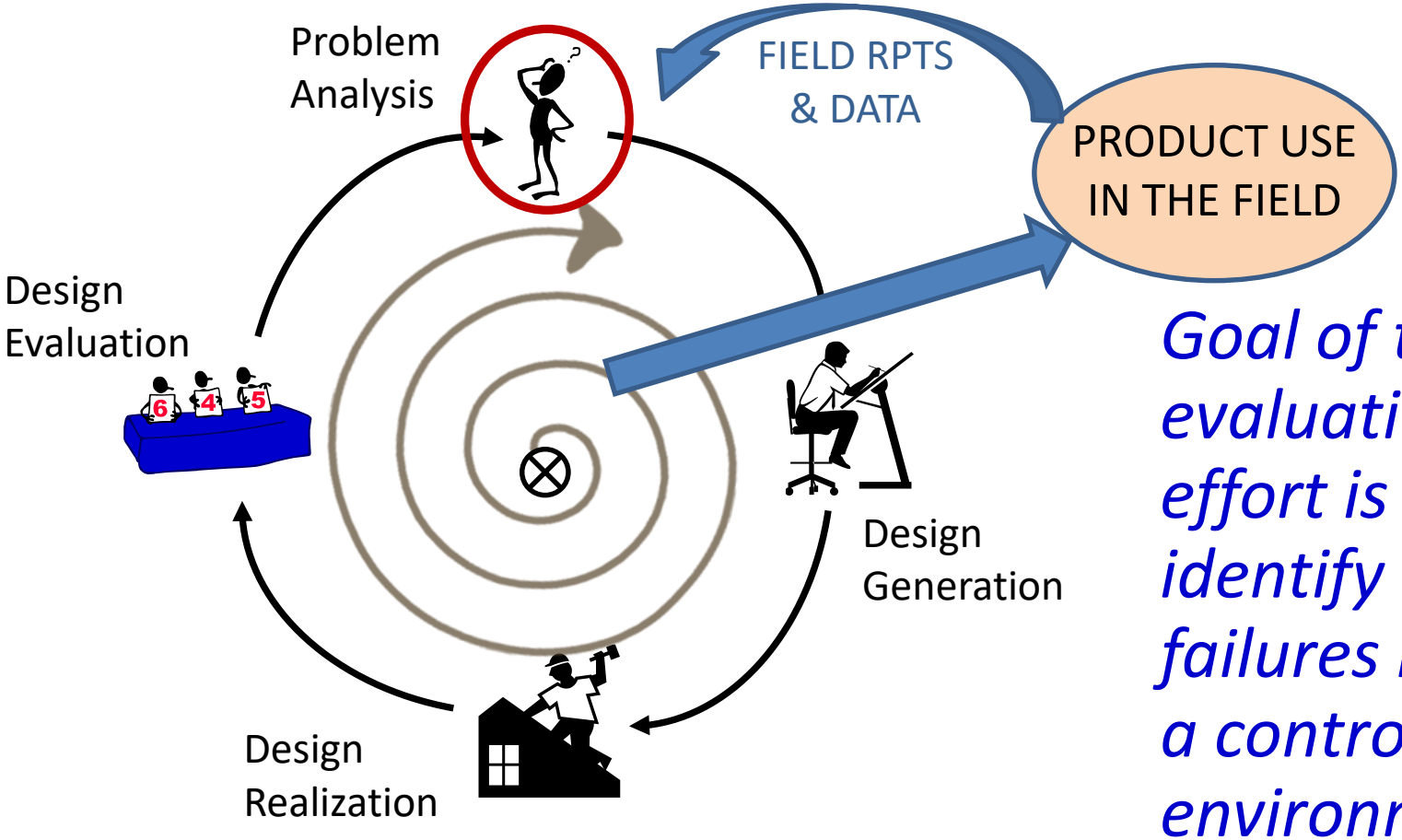
- Failure is a normal part of the design process
  - Not reasonable to expect a design to work properly the first time.
  - This can cause the design process to take longer than originally expected.
  - Always better to find a mistake early in the design cycle rather than let mistakes find their way to the final product.
  - Failures provide more information than “successes.”

Learning from failure

- “I have not failed. I've just found 10,000 ways that won't work.” *Thomas Edison*
- “Failure is the opportunity to begin again more intelligently.” *Henry Ford*



Engineering Design Process



Goal of test & evaluation effort is to identify failures inside a controlled environment.

- Goal of *safety engineering* is to identify and prevent hazardous failures BEFORE testing!
- Goal of *reliability engineering* is to reduce failure rates for cost and safety reasons.

Engineering Failure Case Studies

- Challenger (https://youtu.be/j4JOjcDFtBE)

O ring circle, weather, policy

- Tacoma Narrows

(https://www.youtube.com/watch?v=CsKKDLKYsVU)

lack of calculation, simply copy

- Deepwater Horizon Oil Platform

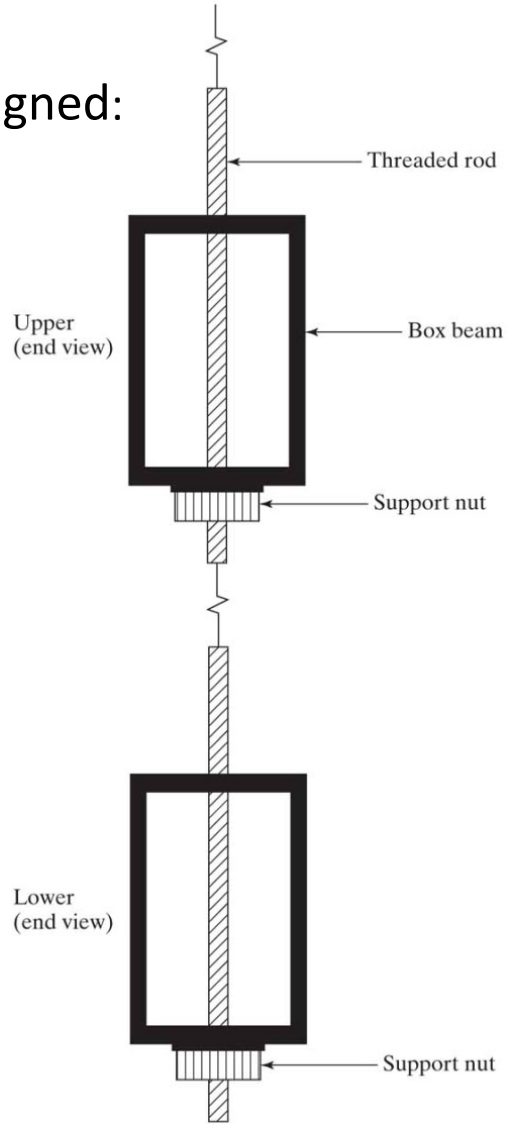
(https://www.youtube.com/watch?v=N4WtlbeYsoQ)

- Hyatt Regency Tragedy

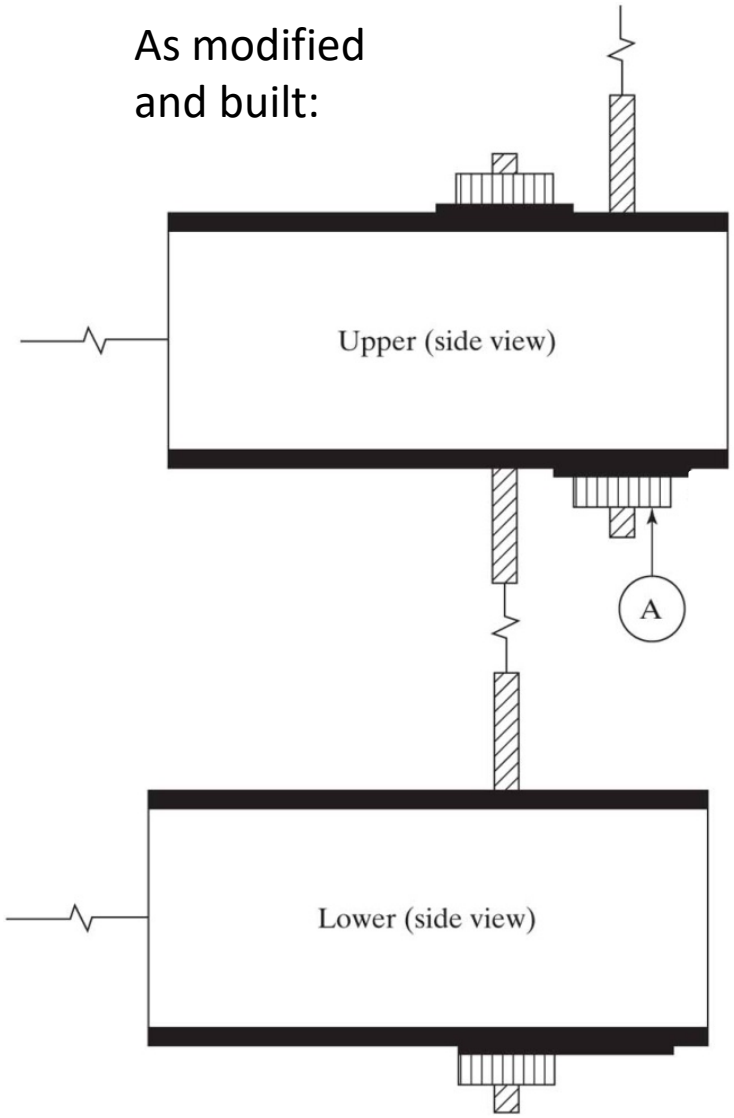
(https://www.youtube.com/watch?v=8EHn8M9lpuQ)

Hyatt Regency Tragedy

As designed:

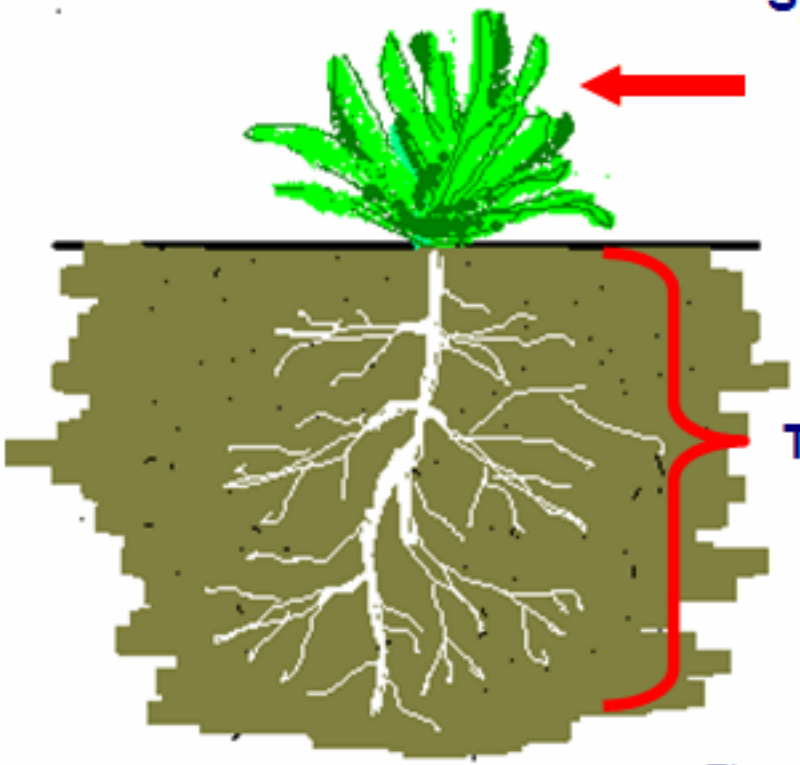


As modified and built:



“Root” Cause of the Failure

- Failure event is the result (symptom) of underlying causes and conditions



Symptom of the problem.
“The Weed”
Above the surface
(obvious)

The Underlying Causes
“The Root”
Below the surface
(not obvious)

The word root, in root cause analysis, refers to the underlying causes, not the one cause.

http://www.thinkreliability.com/Root-Cause-Analysis-CM-Basics.aspx

Tools for Analysis (preventative & forensic)

- 5 Why's
- Fault Tree Analysis
- Failure Modes, Effects and Criticality Analysis
- Ishikawa Diagrams

5 Why's

- For every event, ask "Why did this happen?" or "What caused this to occur?"
- Experience says 5 questions will usually get to a root cause
- Practice Example:
  - Event: Manufacturing robot stopped moving
  - #1 - Why did the robot stop?
    - Motor circuit overloaded, causing a fuse to blow
  - #2 – Why was the circuit overloaded?
    - Insufficient lubricant in the motor bearings resulting in a lock-up
  - #3 – Why was there insufficient lubricant on the bearings?
    - Oil pump was not circulating adequate amount of oil
  - #4 – Why was the pump not circulating sufficient oil?
    - Pump intake clogged with metal shavings
  - #5 - Why is the intake clogged with metal shavings?
    - No filter on the pump

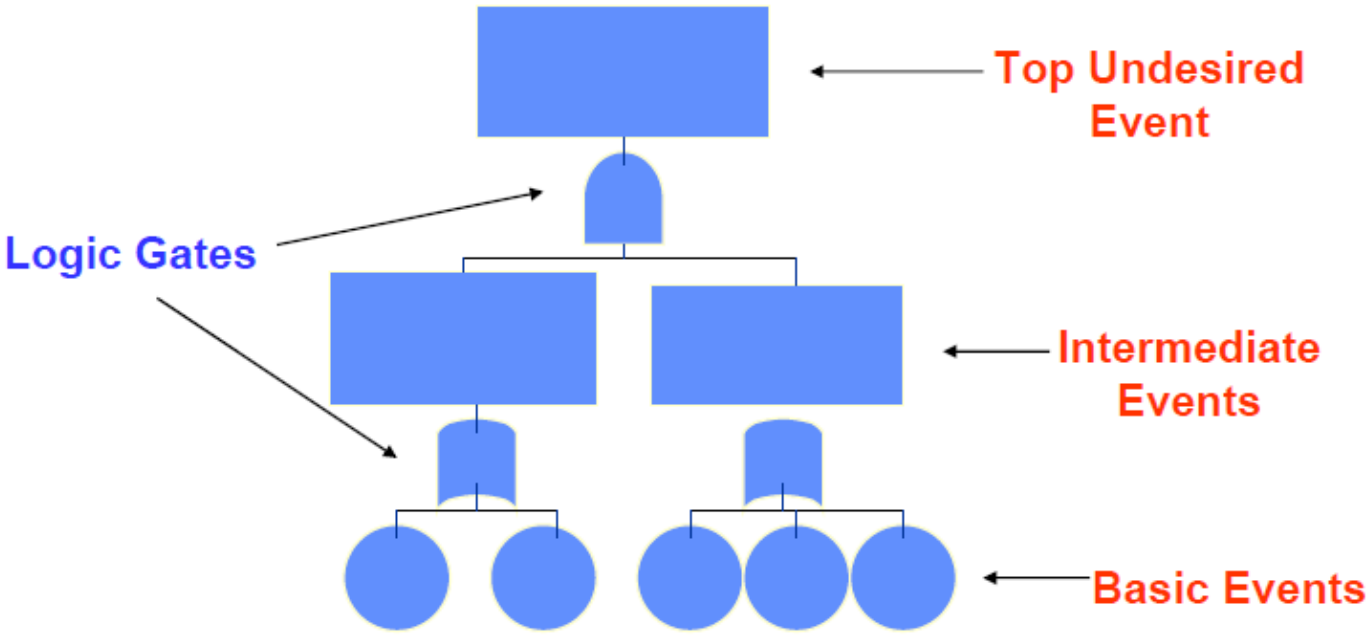
- Is "NO FILTER ON THE PUMP" a root cause?

Adapted from example attributed to Talichi Ohno (major contributor to Toyota Production System and several production quality principles in wide use currently) (source: http://www.taproot.com/archives/1001 accessed 11/21/15)

Fault Tree Analysis

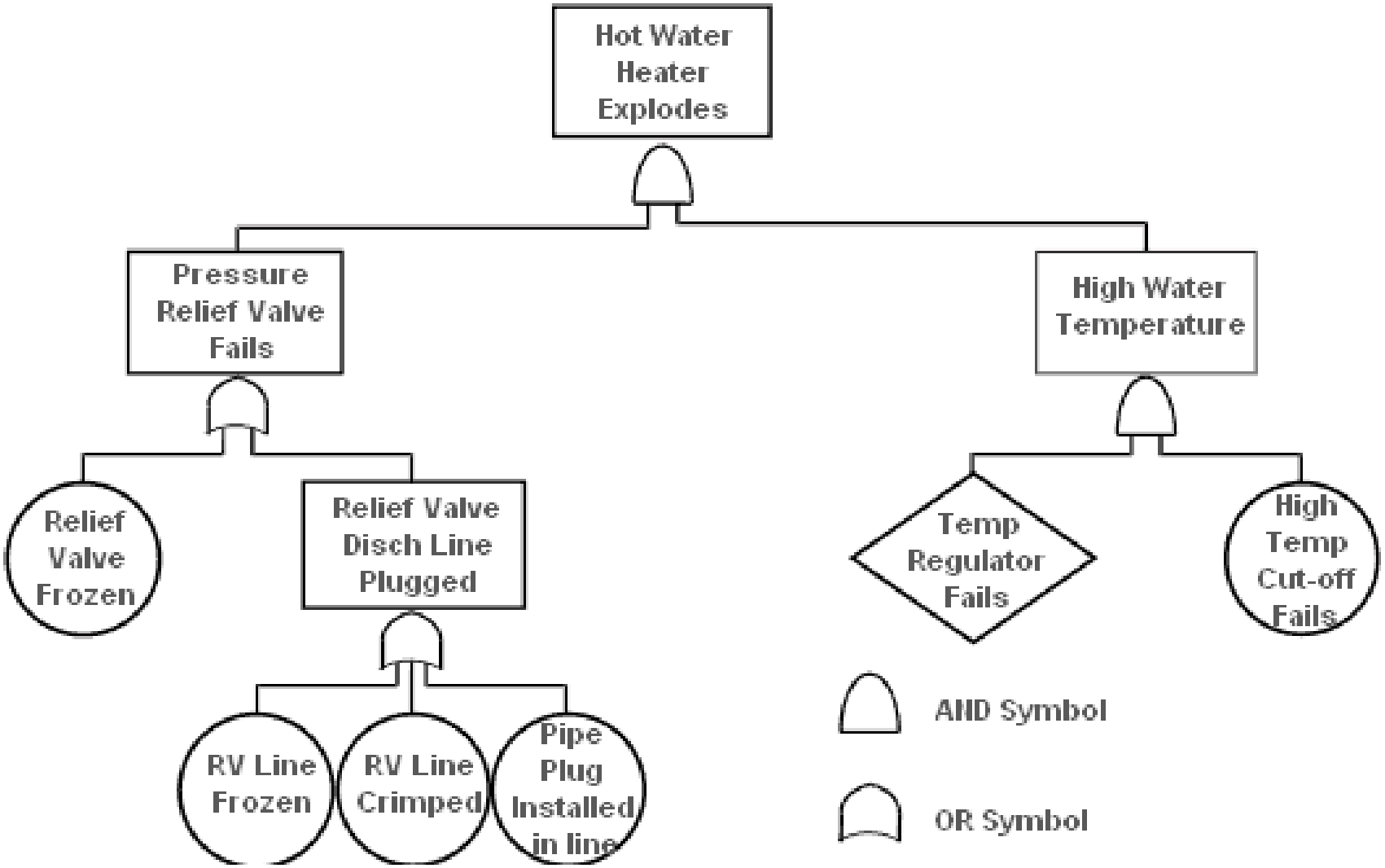
Top down logical analysis to determine potential root causes for undesired event

- "AND" and "OR" gates
- Drive down through system design to identify basic events
  - Design features, components or usage conditions that can lead to the undesired event



http://www.hq.nasa.gov/office/codeq/risk/docs/ftacourse.pdf

FTA Example



http://www.qualitytrainingportal.com/resources/problem_solving/images/fault_tree.gif

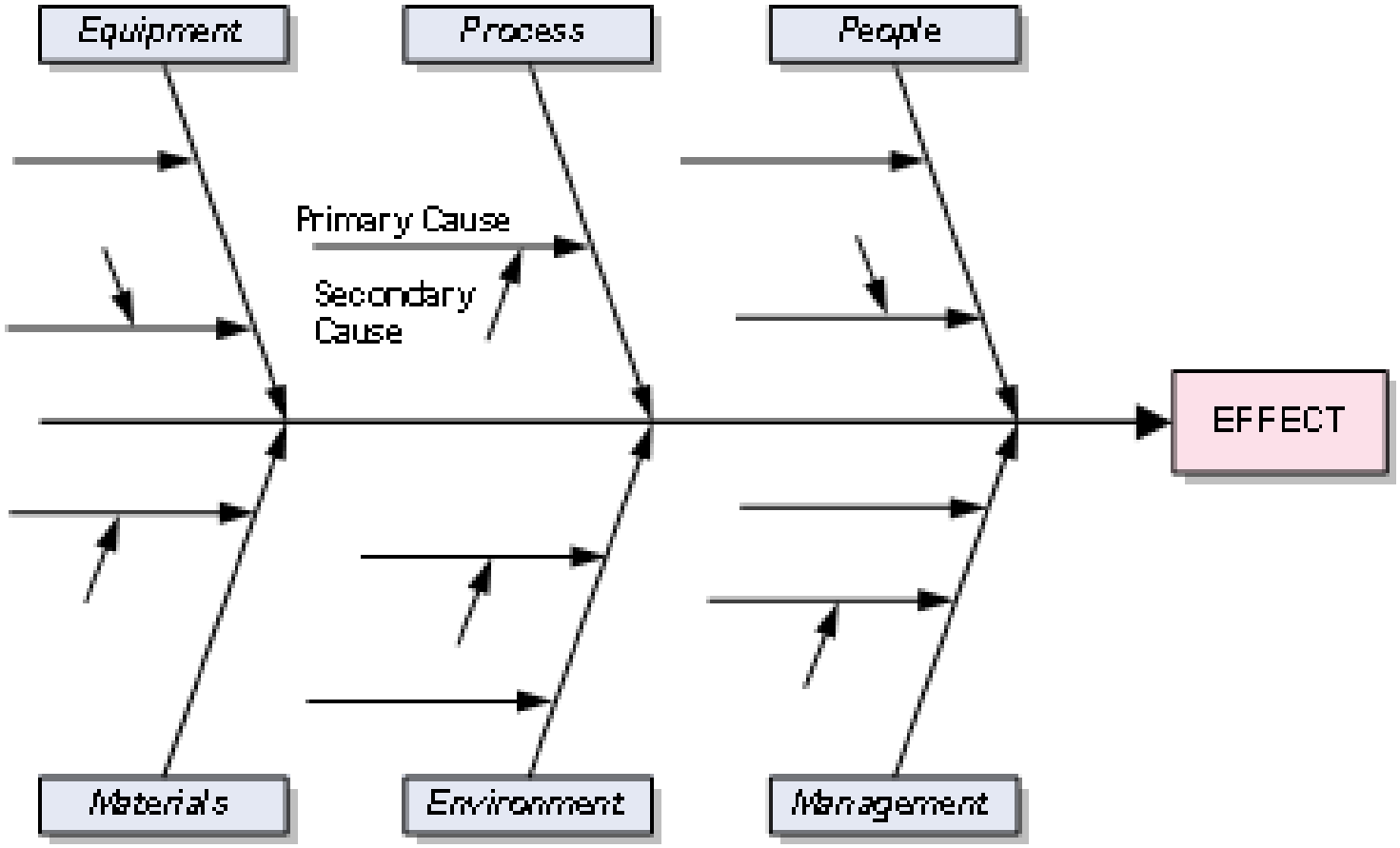
Failure Modes Effects and Criticality Analysis (FMECA)

Bottom-up analysis of the results of component or system failure and to identify potential causes for the initial component failure

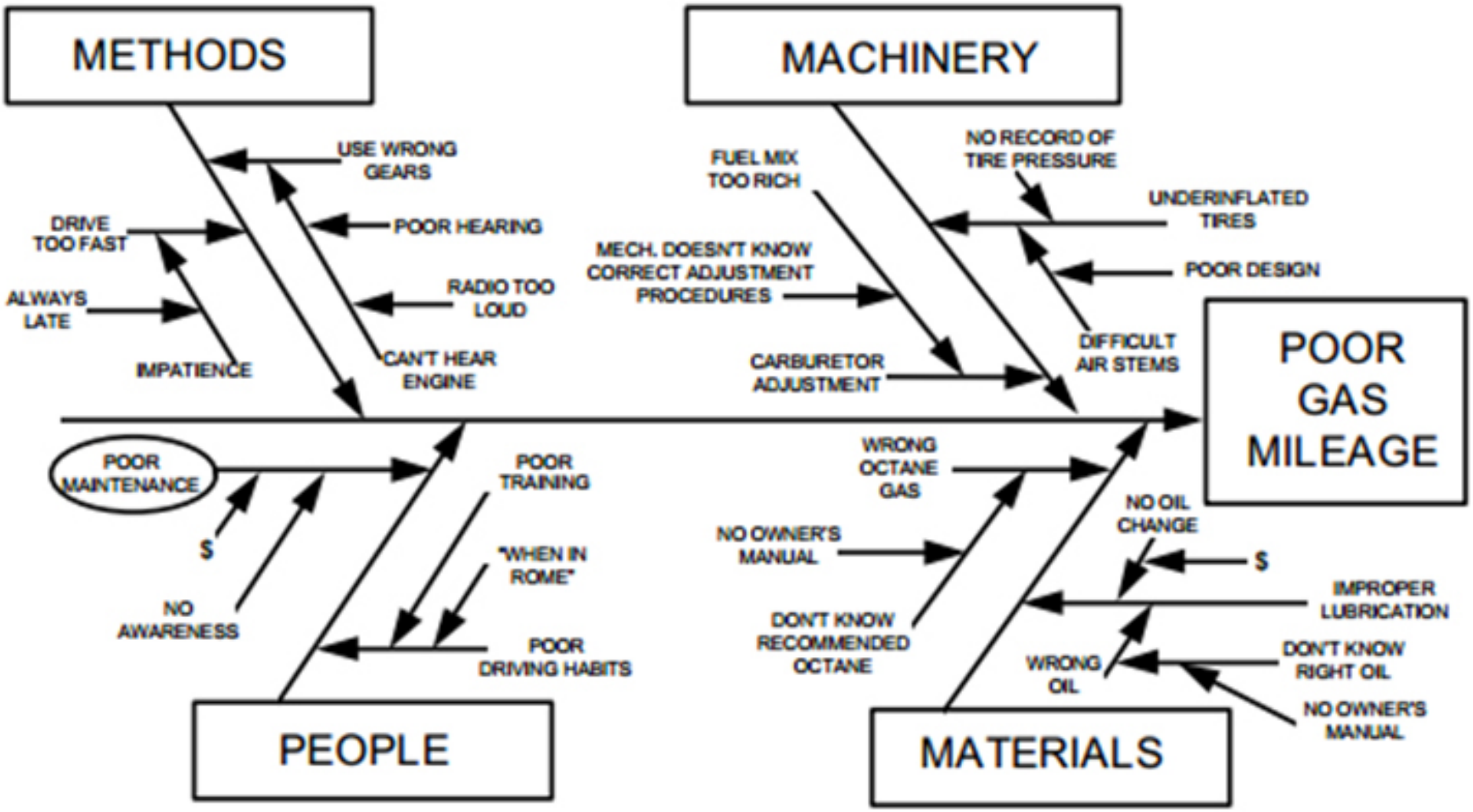
Part and Function	Potential Failure Mode	Potential Effects of Failure		SEV	Potential Cause(s) of Failure	OCC	Detection Method & Quality Controls	DET	RPN	Recommended Actions
Rifle Bolt ▪Chambers bullet ▪Locks into receiver ▪Fires Round ▪Sustains firing pressure on lugs ▪Provides extraction of spent case	Fracture	Catastrophic failure with destruction of weapon and injury to personnel		10	▪Shrinkage ▪Porosity caused by improper feed	6	▪Incoming Part Inspection ▪Dye penetrant testing	5	300	Initiate radiographic testing of all rifle bolts
	Jamming	Failure of weapon to function		8	▪Out of spec. Dimension ▪Change in shell refractory	5	▪Measure patterns ▪Confirm finished casting dimensions	3	120	Initiate SPC program to check and maintain bolt dimensions

Ishikawa (Fishbone) Diagrams

- Graphical extension of “5 Whys” with categories to stimulate thinking



Example Fishbone Diagram



http://tbandpstools.wikispaces.com/file/view/Cause%20and%20Effect%20-%20Step%205.jpg/411829436/Cause%20and%20Effect%20-%20Step%205.jpg

So What?

- What do you do with the information from forensic or preventative analyses?

- Existing products or systems:
  - Re-design, recall and retro-fit
  - Limit usage to less severe conditions
  - Limit usage to shorter lifetime
  - Develop and provide additional training materials and warnings
  - Pay the lawyers an extreme amount of money…

- New products or systems:
  - Redesign to remove or upgrade the inadequate component or sub-system
  - Redesign to add safety features to prevent or mitigate effects
  - Develop training and warning material to help users avoid the failures/hazards
  - Test products and systems in realistic environments to determine actual behaviors