A Hierarchical View of Accidents

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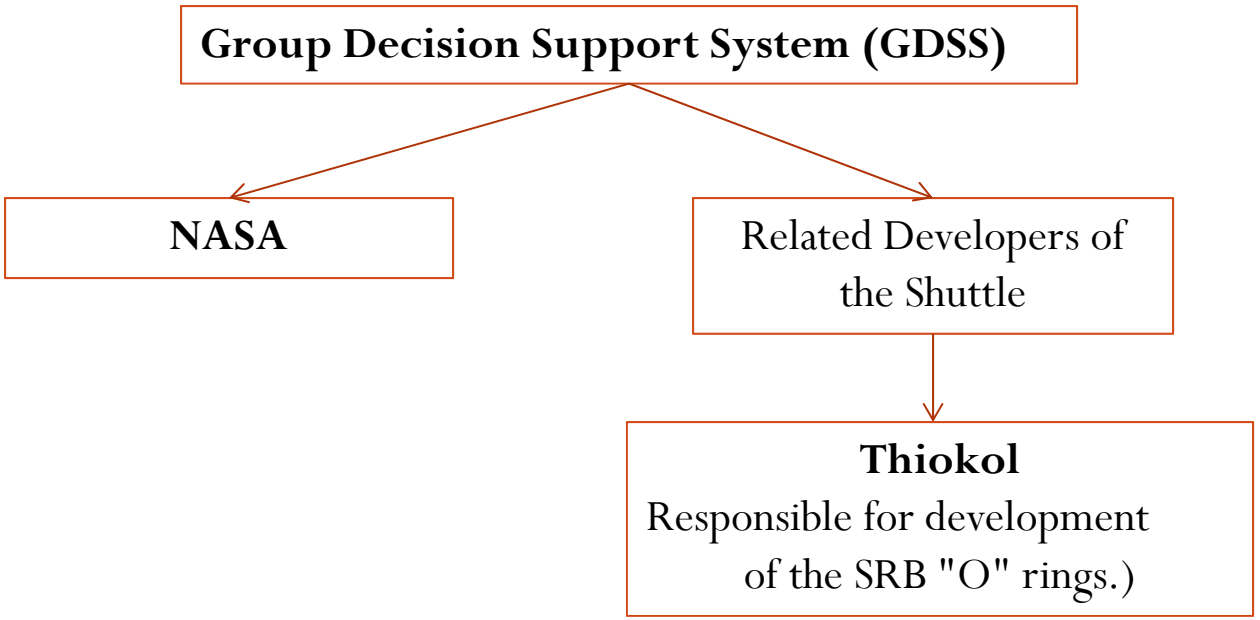
The Space Shuttle Challenger Disaster

*We saw that NASA had no system for fixing the [Shuttle O-ring] problem, even though engineers were writing letters like "**HELP**!" and "This is a **RED ALERT!**" nothing was done.*

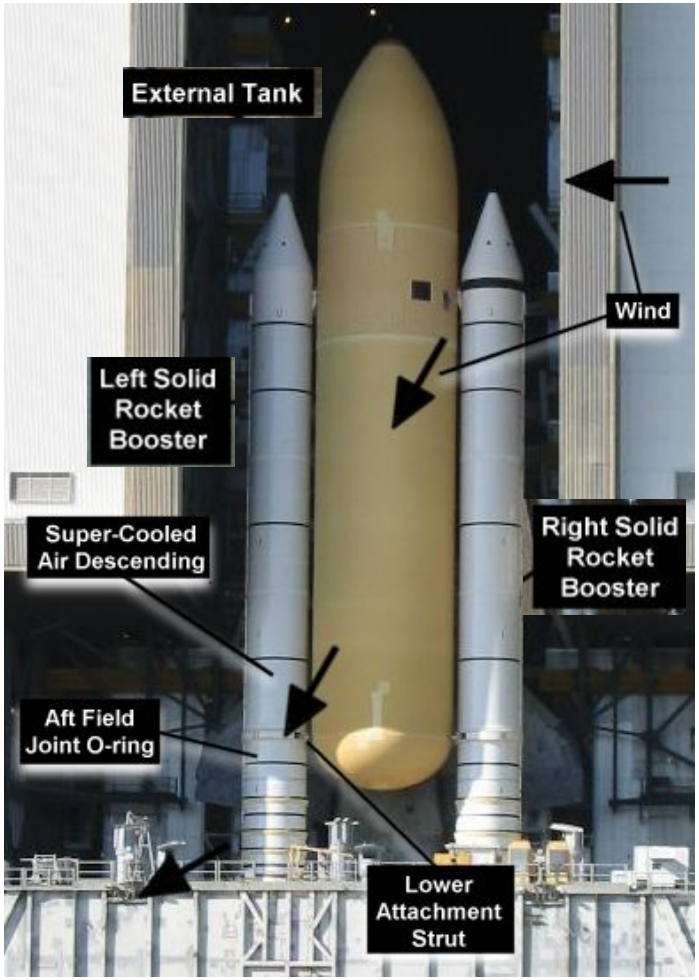
Richard P. Feynman

The Space Shuttle Challenger Disaster



Thiokol engineers were very concerned that the abnormally cold temperatures would affect the "O" rings to nonperformance standards.

The Space Shuttle Challenger Disaster

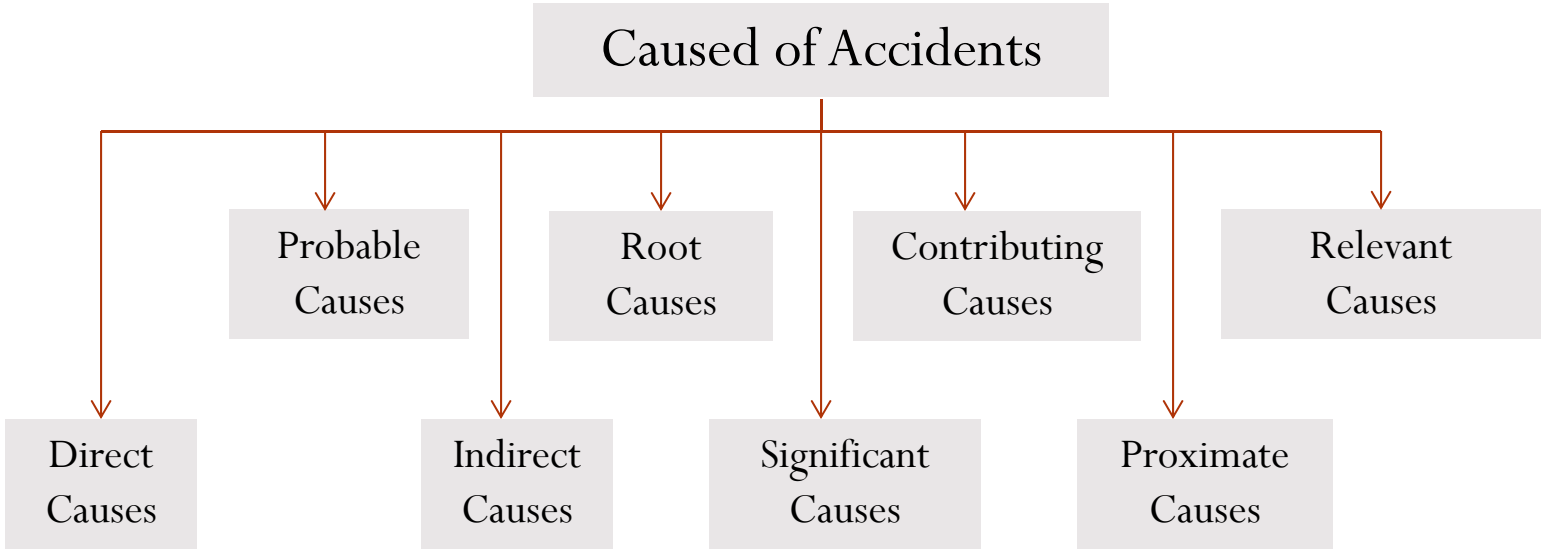


- NASA was informed that their GDSS had a flawed data base.
- Thiokol representatives recommended not to launch until the outside air temperature reached 53° F.
- NASA responded with pressure on Thiokol to change their decision.

My God, Thiokol, when do you want me to launch, next April?

The Concept of Causality

To prevent Accidents we must understand what causes it.



The Concept of Causality

Some accidents are so complex and full of uncertainties that they defy simple explanations of their cause.

Water accidentally entered a Methyl Isocyanate (MIC) storage tank (right), triggering an uncontrollable chemical reaction and blasting a cloud of toxic gases.

Result

3,000 people were killed
10,000 suffered permanent disabilities
200,000 was injured

Disaster Dicember 1984.Bhopal, India.

The Concept of Causality

Bhopal disaster due to vapor (MIC) escaping to atmosphere

Methyl isocyanate (MIC) - lethal compound used in the production of insecticides

TANK 610

Pressure in tank 610 builds up due to chemical reaction. MIC vapor escapes, rupturing safety valve

TANK 619

Tank 619 was empty but nobody opened the valves between the two tanks to relieve the pressure in 610

Refrigeration System

Turn off so tank 610 could not be cooled down to slow reaction

Vent gas scrubber

Supposed to spray caustic soda on escaping vapors to neutralize them. Scrubber shut down for maintenance

Water curtain

Could not neutralize some MIC. Designed to reach height of 40 to 50 feet. MIC vapor vented over 100 feet above ground

Flare Tower

Could not be used because a length of pipe was corroded and had not been replaced

The Concept of Causality

Were all these failures a matter of once-in-a-lifetime coincidence?

Vent Scrubber

Flare Tower

Water Spouts

Refrigeration Unit

Monitoring Instrument

A closer look shows a different picture

It is not uncommon for a company to turn off passive devices (e.g. Refrigerators Units)

The Concept of Causality

Closer look of the causes of the Bhopal disaster:

- The chemical has to be maintained at temperature no higher than 5° Celsius (A high temperature alarm was to sound if the MIC reached 11°)
- The refrigerator unit was turned off, and the MIC was usually stored at nearly 20°.
- The plant management adjusted the threshold of the alarm from 11° to 20°
- The vent scrubber was designed to neutralize only small quantities of gas at low pressures and temperatures: The temperature of gas was at least 80° more than the scrubber could handle.

The Concept of Causality

Closer look of the causes of the Bhopal disaster:

- The flare tower (which was supposed to burn off released vapor) was totally inadequate to deal with the estimated 40 tons of MIC that escaped during the accident.
- Alarms at the plant sounded so often (the siren want off 20 to 30 times a week for various purposes) that an actual alert could not be distinguished from routines events.
- The warning siren was not turned on until two hours after the MIC leak was detected and then was turned off after only 5 minutes (Company policy)

The Concept of Causality

Cause → Effect

- A condition or event may precede another event without causing it.

- A condition may be considered to cause an event without the event happening every time the condition holds.

Nothing Happens

An accident occurs

Subjectivity in Ascribing Causality

- The causes of an accident are rarely perceived identically by:
  - Corporate Executives
  - Engineers
  - Operators
  - Insurers
  - Lawyers
  - Politicians
  - Press
  - State
  - Victims

The specification of possible causes will necessarily bear the marks of conflicting interests

Subjectivity in Ascribing Causality

A study found that:

- Workers who were satisfied by their jobs attributed accidents mainly to personal accidents
- Workers who were not satisfied more often cited non-personal causes that implied the company was responsible.

Other studies suggest that the position in the organization affect the attribution of accidents

- The lower the position in the hierarchy, the greater the tendency to blame accidents on factors linked to the organization.
- Individuals with high position in the hierarchy tend to blame workers for accidents.

Oversimplification in Determining Causality

Out of a large number of necessary conditions for the accident, one is often chosen and labeled as the cause.

e.g. A car skidding in the rain may involve many factors:

- Wet road
- Driver's lack of attention
- Lack of anti-skid brakes

Crash of an American Airlines DC-10 at Chicago's O' Hare Airport in 1979.
The NTSB (U.S. National Safety Transportation Board) blamed only "*Maintenance-induced crack*"

Reality: Design error that allowed the slats to retract if the wing was puncture. Leading to future accidents related to the same error.

The Legal Approach to Causality

- Lawyers and insurers often oversimplify the causes of accidents.
- They recognize that many factors contribute to an accident, but identify a principal factor for liability reasons.
- This practice will not give many benefits if the goal is to understand and prevent accidents.

Human Error

- The most common oversimplification is blaming the operator.
- Considering human error alone as a cause of an accident does not prevent future errors caused by humans.
- It is too limiting to be useful in identifying what to change in order to increase safety.

Coupling Accident on Railroad

Human Error
(Coupling Accident on Railroads)

- It used to be one of the principal causes of injury and death to railroad workers.
- Managers claimed that such accidents were due to only to worker error and negligence.
- Finally the government required that automatic couplers be installed.

Technical Failures

- Oversimplification concentrating only on technical failures and immediate physical events.

Result

-- 23 deaths

-- 53 injuries

-- $50 million in damages

Explosion at a Chemical Plant in Flixborough, Grate Britain, June 1974

Technical Failures

- The official accidents investigators devoted most of their effort determining which of the pipes was the first to rupture.

- The British Court of Injury concluded that "The disaster was caused by a coincidence of a number of unlikely errors "

    - Allowing Unqualified personnel to make important modifications to equipment.

    - Making engineering changes without properly evaluating of safety.

    - Storing large quantities of dangerous chemicals close to potentially hazardous areas of the plant.

Organizational Factors

- The causes of accidents are frequently rooted in the organization. Its culture, management, and structure.

Three Mile Island (TMI) Accident on March 28, 1979

The report contains 19 pages of recommendations

- 2 of Technical Matters
- 17 concern Management, Training, Shortcomings in the nuclear industry

Organizational Factors

Three Mile Island (TMI) Accident

Causes:

Failures in the non-nuclear secondary system, followed by a stuck-open pilot-operated relieve valve (PORV) in the primary system, which allowed large amounts of **nuclear reactor coolant** to escape.

Recommendations after the accident:

- Utilities and suppliers must establish appropriate safety standards.
- Review and Analysis of operating experiences
- Changes with respect to realistic deadlines
- Integrate management responsibilities
- Define roles and responsibilities
- Attract highly qualified personnel
- Devote more care and attention to plant operating procedures.

Lessons learned from TMI

Normal Accident Theory (NAT)

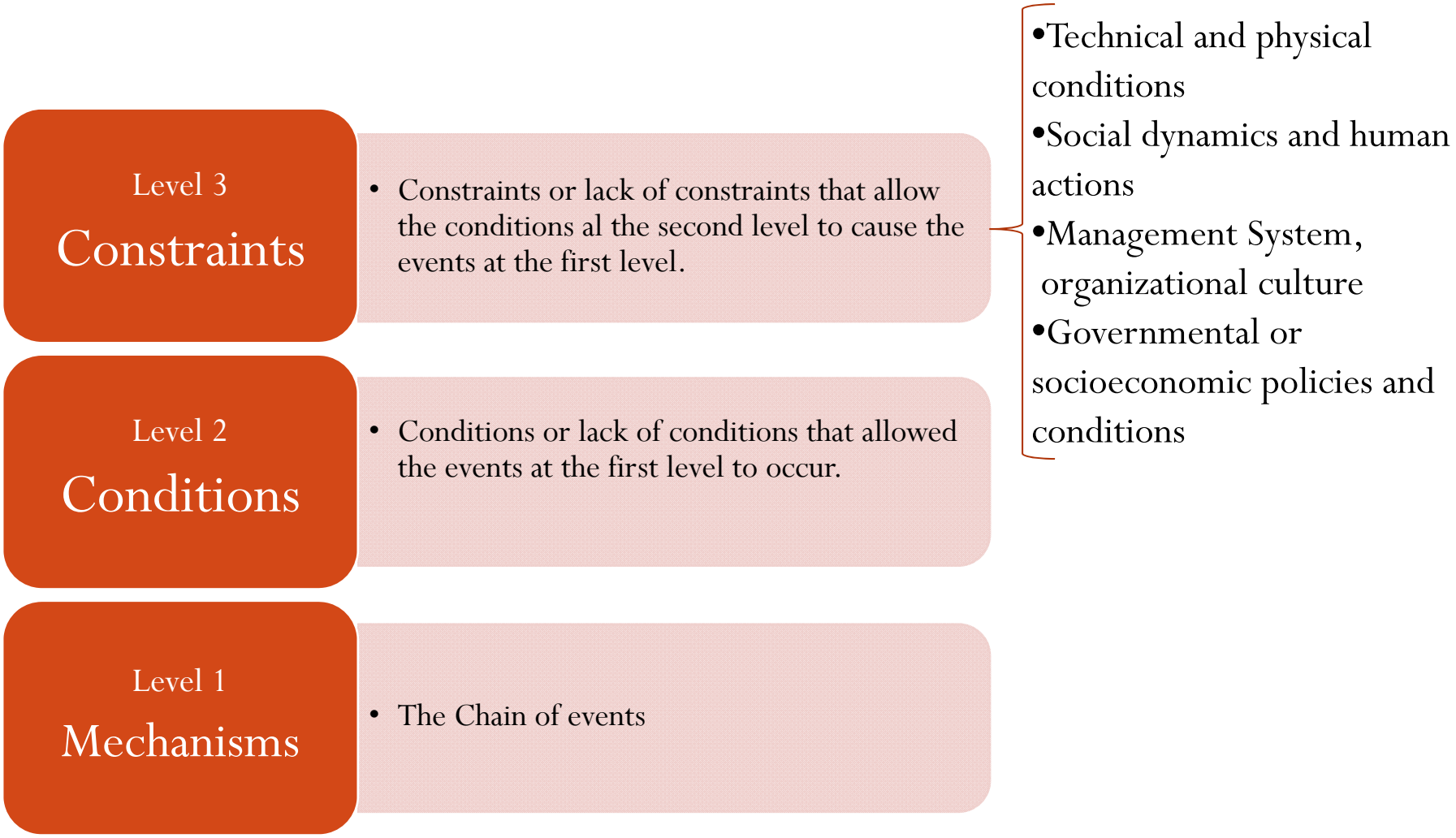
The Three Mile Island accident inspired Charles Perrow to proposed the NAT.

NAT

Accident occurs, resulting from an unanticipated interaction of multiple failures in a complex system.

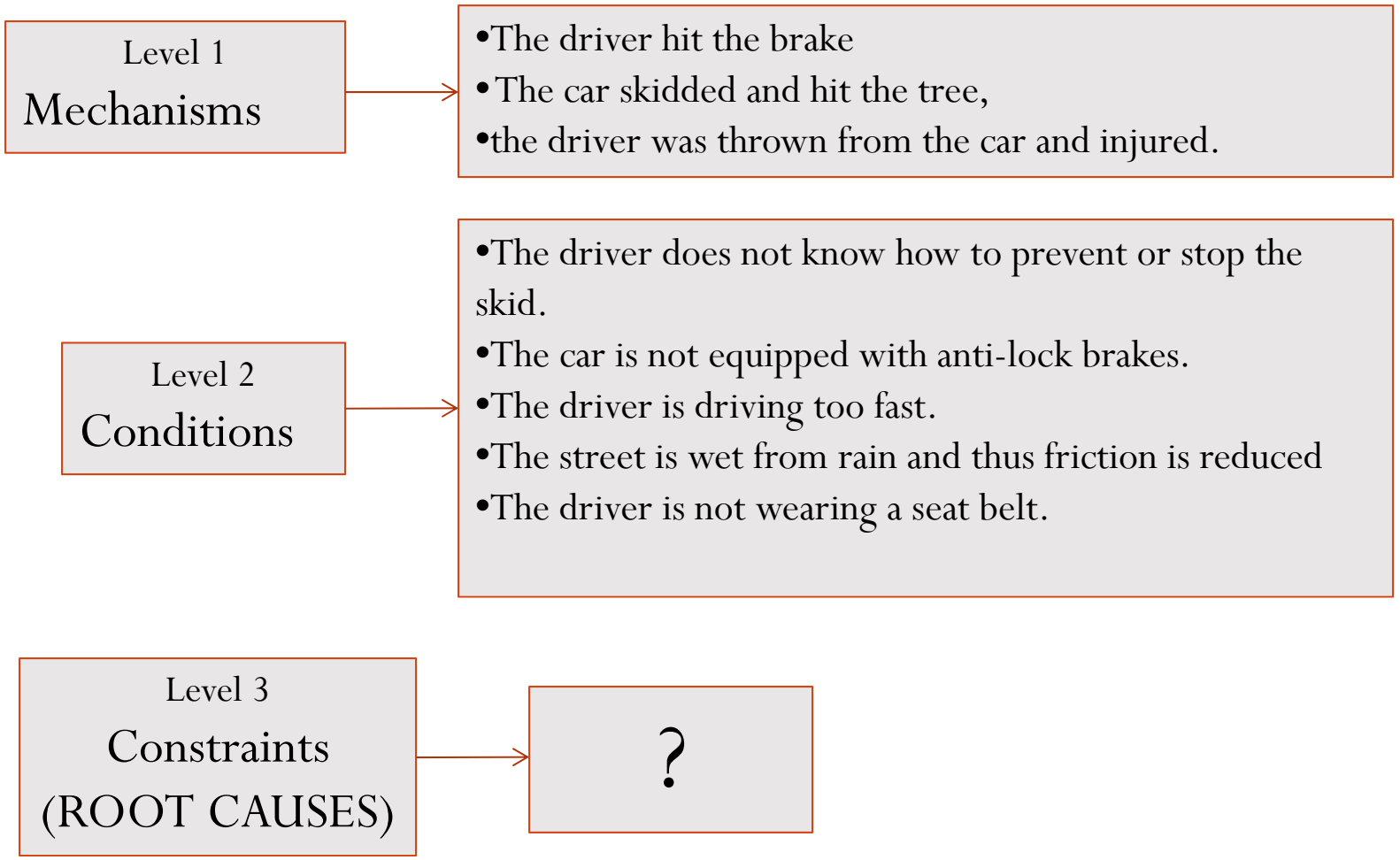
TMI was an example of this type of accident because it was "unexpected, incomprehensible, uncontrollable and unavoidable".

A Hierarchical Approach to Causality



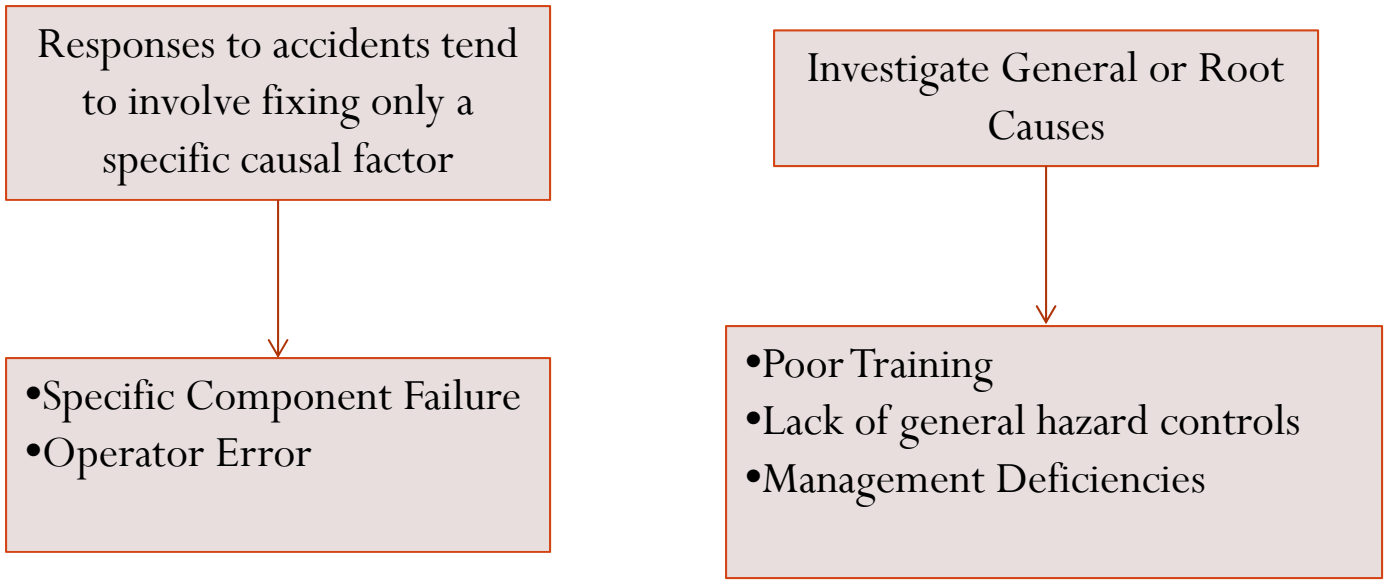
A Hierarchical Approach to Causality

Example



A Hierarchical Approach to Causality

The third level - Constraints - referred to as the "***root***" caused of an accident. They are weaknesses that not only contributed to the accident being investigated but also can affect future accidents.



Lesson is clear:

To reduce the risk of accidents, root causes must be identified and eliminated

THANKS