

# Safety Assessments of R-152a and CO<sub>2</sub> for Mobile A/C

Mark J. Zima, Delphi

Delphi Team Members: Nacer Achaichia, Chrystel Arnaud, Jim Baker, Tim Cowell, Joe D'Ambrosio, Jerry Felschow, Mahmoud Ghodbane, Prasad Kadle, Bill Kumpf, Chantal Parenteau, Jean-Claude Petesch, Thomas Schoepf



# Probabilistic Safety Risk Analysis

- ⌘ Risk Analysis is the establishment of the potential or probabilities of potential unwanted events, i.e, mishaps.
- ⌘ The probabilistic safety risk assessment is one of the tools used by Delphi to evaluate potential safety risk both in terms of estimated frequency and possible consequences. This tool helps Delphi to focus its efforts in delivering a system with a reasonable and acceptable level of safety.
- ⌘ Methodology
  - There are several recognized methods to examine risks including Fault Tree Analysis, FMEA, Event Trees, Reliability Block Diagrams, etc.

# Probabilistic Safety Risk Analysis

- ▶ Fault Tree Analysis is widely used and was selected as the primary tool

## ≡ Fault Tree Analysis

- ▶ Potential key events contributing to unwanted event are established
- ▶ Interrelationships amongst contributing events are established
- ▶ Probabilities of contributing events are established
  - ▶ From data (existing or newly gathered)
  - ▶ From engineering judgment
  - ▶ From dedicated tests
- ▶ Probability of potential unwanted event is derived and key contributors identified

# Probabilistic Safety Risk Analysis

## ▮ Safety/Risk Standards

- There is no clearly defined overall system safety requirement for mobile A/C.
- There are General Safety Standards that can be used as Guidelines.
- For Europe, IEC 61508 “Functional Safety of Electrical / Electronic / Programmable Electronic Safety-Related Systems” is widely used.
  - May be applied to non-electrical systems
  - Risk tables as function of severity and probability of potential mishap
  - Safety Integrity Level characterizes the estimated/potential failure rate of ONLY THE SAFETY DEVICES in the system (SIL 1, 2, 3, or 4)
- For N. America, MIL-STD-882 is frequently used
  - Risk tables as function of severity and probability of potential mishap
  - Risk characterized from Low to High as defined in the standard

# Risk Assessment Studies

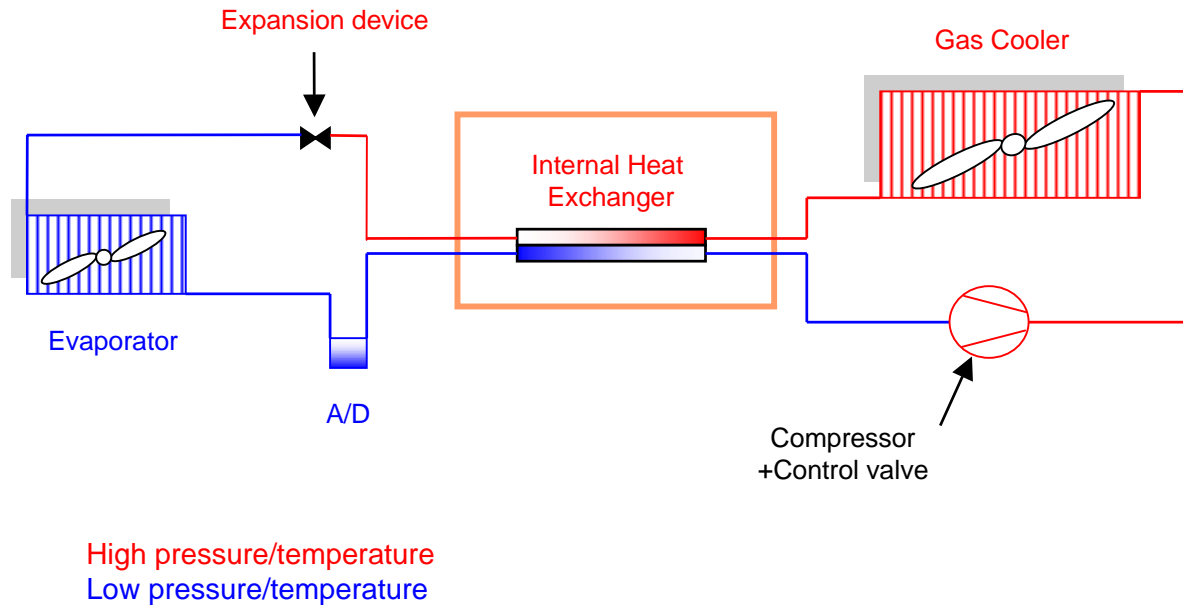
Delphi has conducted two safety studies

- ⌘ For the first study, Delphi contracted TÜV to do an objective assessment of potential risks for R-152a and CO<sub>2</sub> in mobile A/C.
  - Scope:
    - Study concluded March 2004
    - Normal day-to-day usage of vehicle and vehicle crash
    - Passenger cars and light-duty trucks with Internal Combustion Engines

# TÜV Probabilistic Risk Assessment

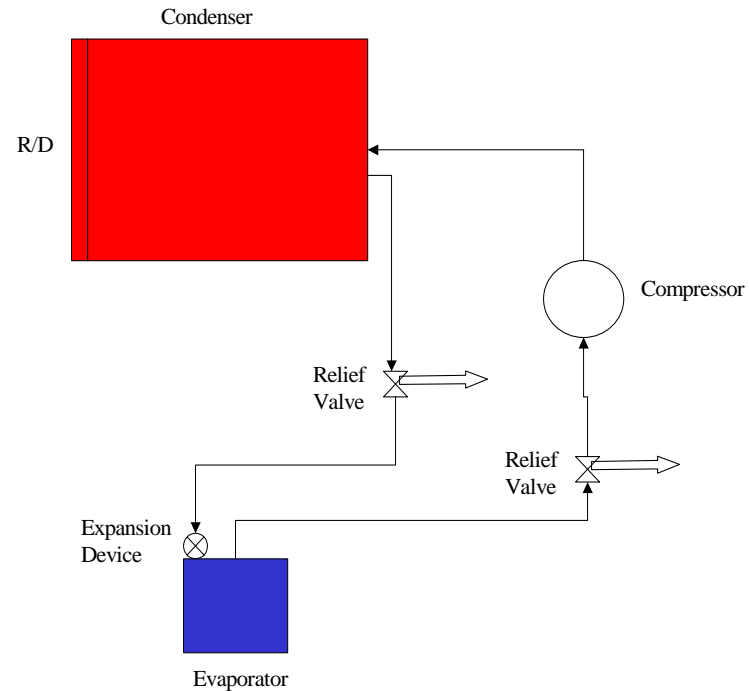
Designs considered in the study:

≡ CO<sub>2</sub> System



# TÜV Probabilistic Risk Assessment

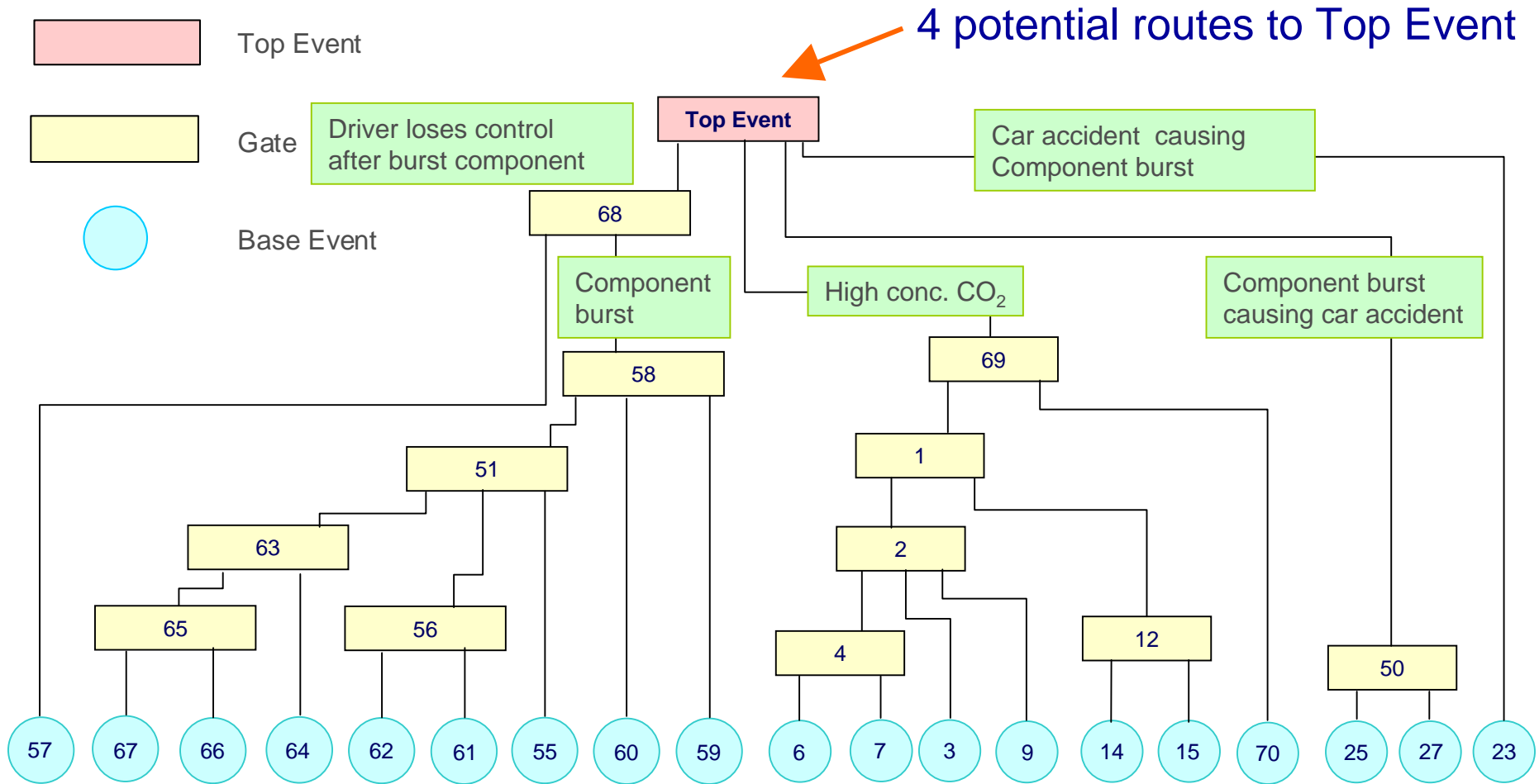
## ≡ R-152a System



## ≡ Data Sources:

- ▶ Non-electronic Parts Reliability Data
- ▶ German Crash Statistics
- ▶ Risk Assessment Reports
- ▶ Expert Opinions
- ▶ Engineering Judgment 7

# TÜV Fault Tree for CO<sub>2</sub>





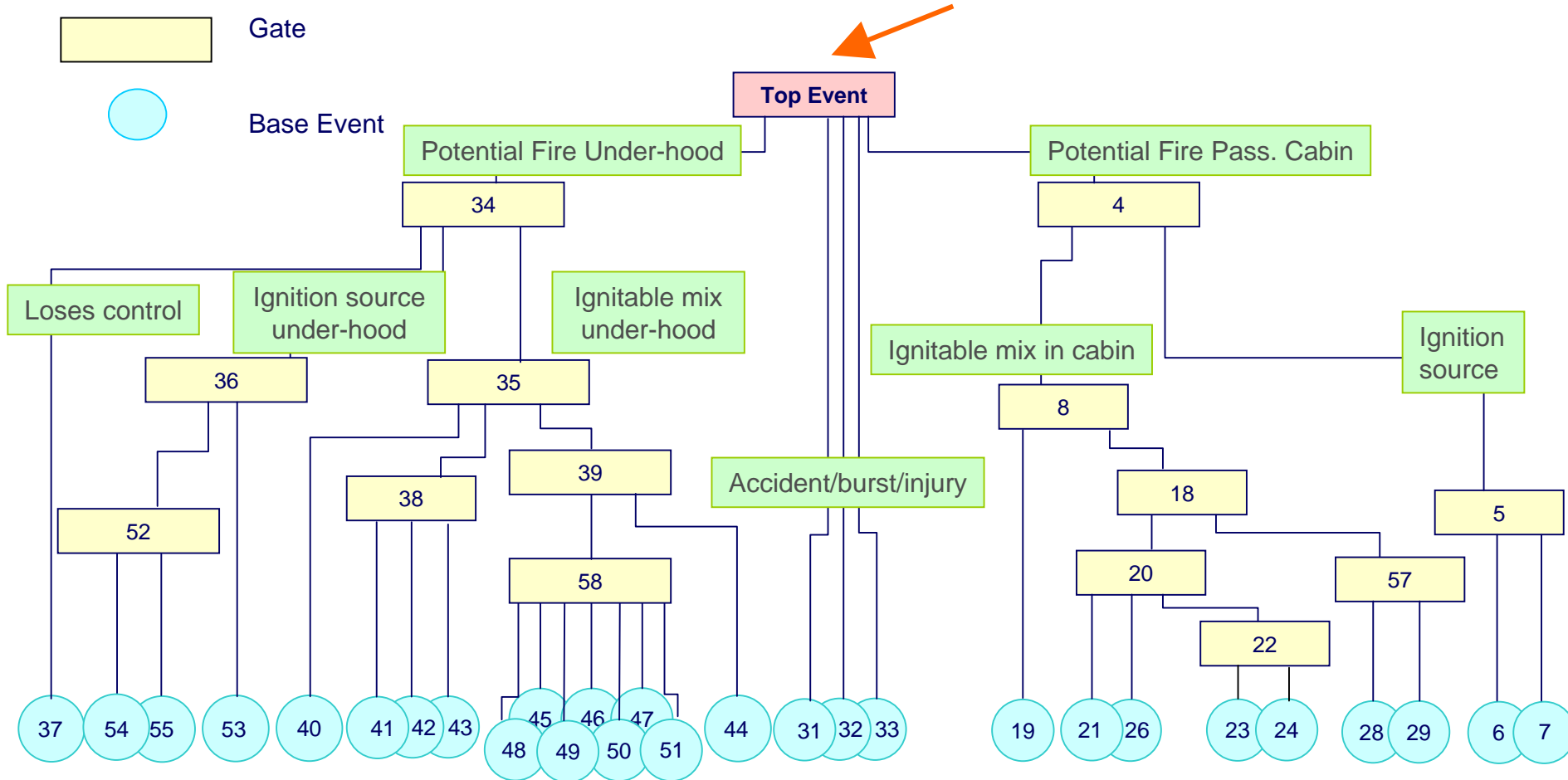
# TÜV Fault Tree for R152a

 Top Event

 Gate

 Base Event

5 potential routes to Top Event



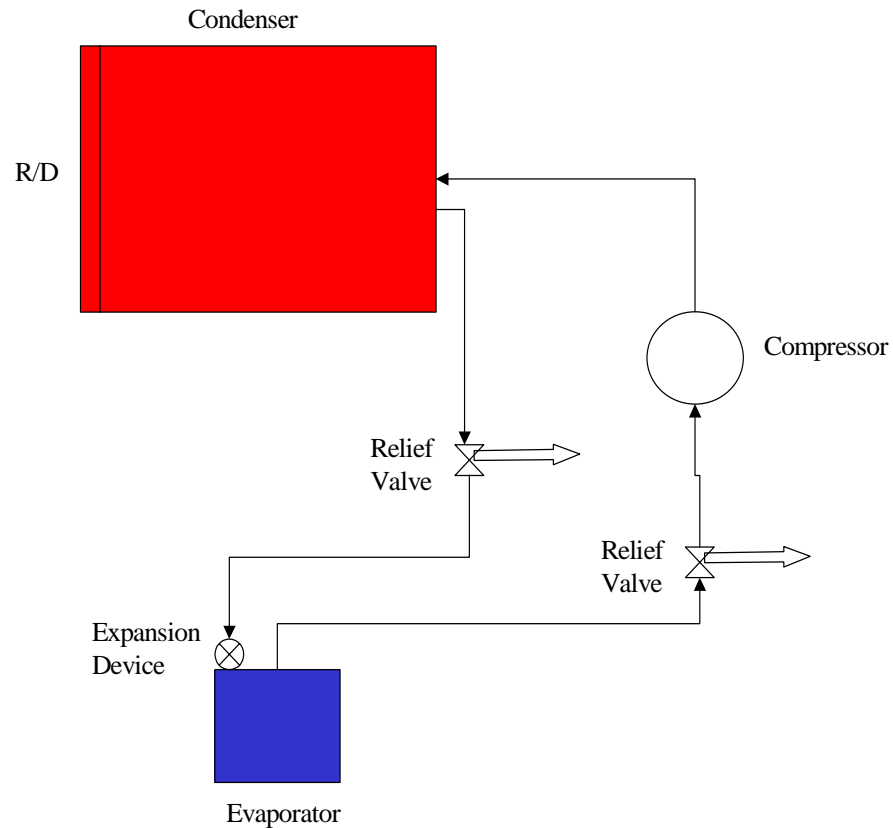
# Delphi Probabilistic Risk Assessment

- ≡ Purpose: In-depth study of the potential risks of R-152a in Mobile A/C
- ≡ Scope:
  - 15 month on-going study
  - Passenger cars & Light-duty trucks with Internal Combustion Engines
  - Engine Compartment & Passenger Compartment
  - Normal Usage, Vehicle Crash, and Professional Service Shop
  - Potential Fire / Explosion Issues
- ≡ Methodology
  - Individual Fault Trees for all the combinations above
  - FMEA Cross-Check is on-going
  - Delphi Safety methodology utilized
  - Outside consultants were integral part of team to provide flammability expertise

# Delphi Probabilistic Risk Assessment

## R-152a System Design:

Note: Analysis performed with and without Directed Relief System



# Delphi Probabilistic Risk Assessment

## Data Sources

### ≡ Normal Operation

- Warranty analysis data
- Technical Reports

### ≡ Crash

- Insurance Institute for Highway Safety post-crash A/C inspections
- OEM post-crash A/C inspections
- Real world post-crash A/C inspections (target of 200 vehicles)
- National Accident Sampling System/Crashworthiness Data Systems
- Technical Reports (NHTSA, etc.)

### ≡ Service

- Surveys of professional service shop personnel

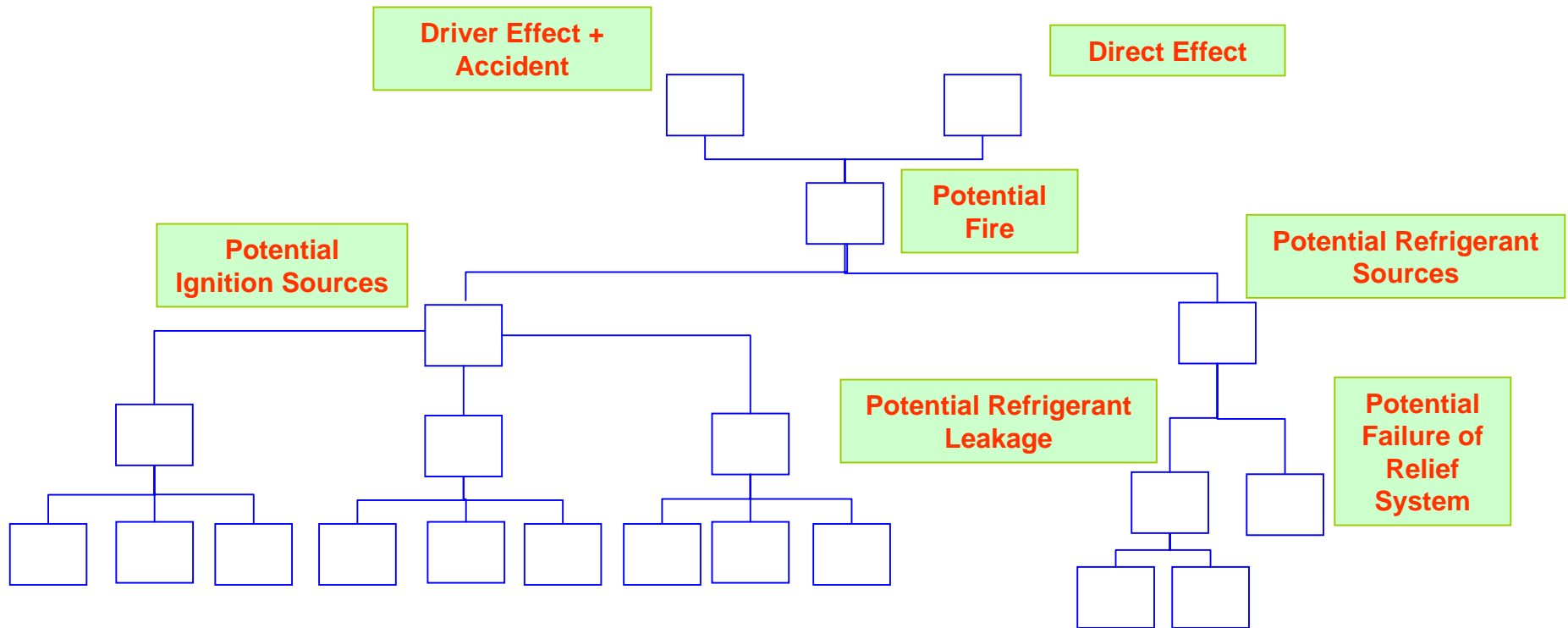
### ≡ Testing

- ≡ Team Engineering Judgment used when data insufficient or not available

# Delphi Probabilistic Risk Assessment

Fault Tree example:

≡ Potential Flash Fire, Passenger Cabin, Normal Usage



# Summary

## Status of Risk Assessments:

### ≡ TÜV Risk Assessments Completed

- No statistically-significant difference in risk between two refrigerants based on studied system architectures

### ≡ Delphi R-152a Risk Assessment

- Results to-date for probability of a potential high severity R-152a-related mishap have better than an order of magnitude correlation with TÜV Study
- Work in progress
  - In particular, Delphi is conducting studies to confirm/verify data found in the literature and/or provided to Delphi

- ≡ Safety does not seem to be the differentiating factor in the choice between these refrigerants assuming societal goal to move away from R-134a