

## Electric Vehicle Safety: Design & Research



**Alvaro Masias**

*Energy Storage Research, Ford Motor Company*

**ARPA-E Crash-Safe Energy Storage Systems for  
Electric Vehicles Workshop**

Denver, CO – November 12, 2012

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Design

Research

Power of Choice

ELECTRIFIED VEHICLES

TRIPLING

PRODUCTION CAPACITY

IN NORTH AMERICA BY 2013



# Ford Focus Electric



**Focus**  
**E-ELECTRIC**

LIQUID-COOLED  
**23kWh**

LITHIUM-ION  
BATTERY PACK

**110 MPGe**

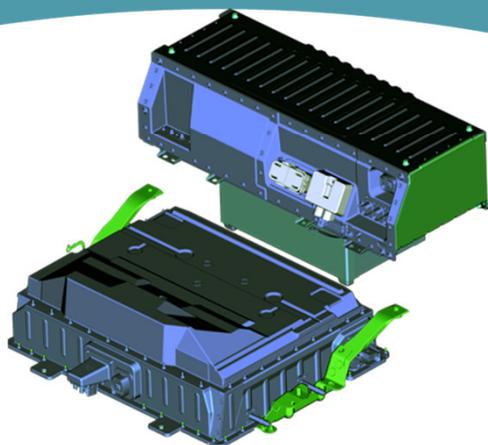
**5 PASSENGER**

**FASTER CHARGING**

**Advanced Li-Ion Battery**

**25-30% smaller**

**50% lighter**



**MORE EFFICIENT  
BATTERY  
TEMPERATURES**

# Reliability



Researching and developing modern electrified vehicles for decades

1996



1998



2004



2009



2010





**ONE FORD**

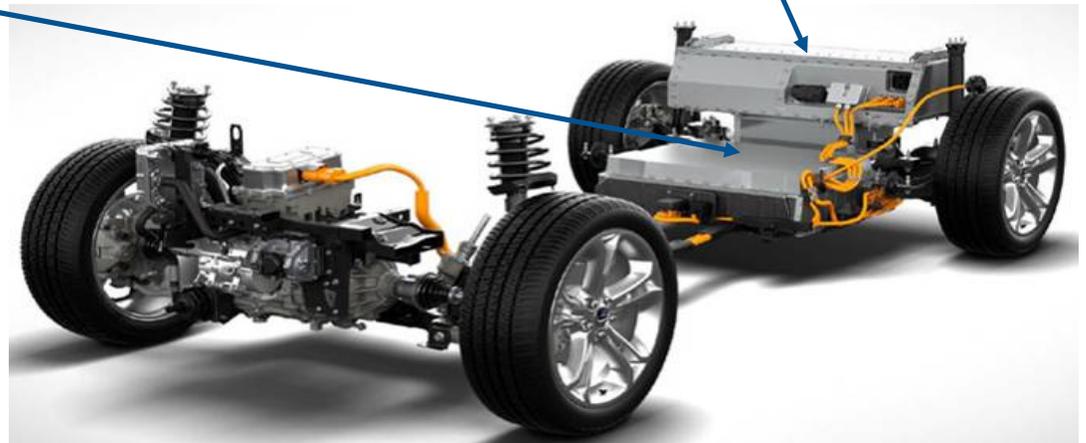
ONE TEAM • ONE PLAN • ONE GOAL

# Focus Electric Battery Location

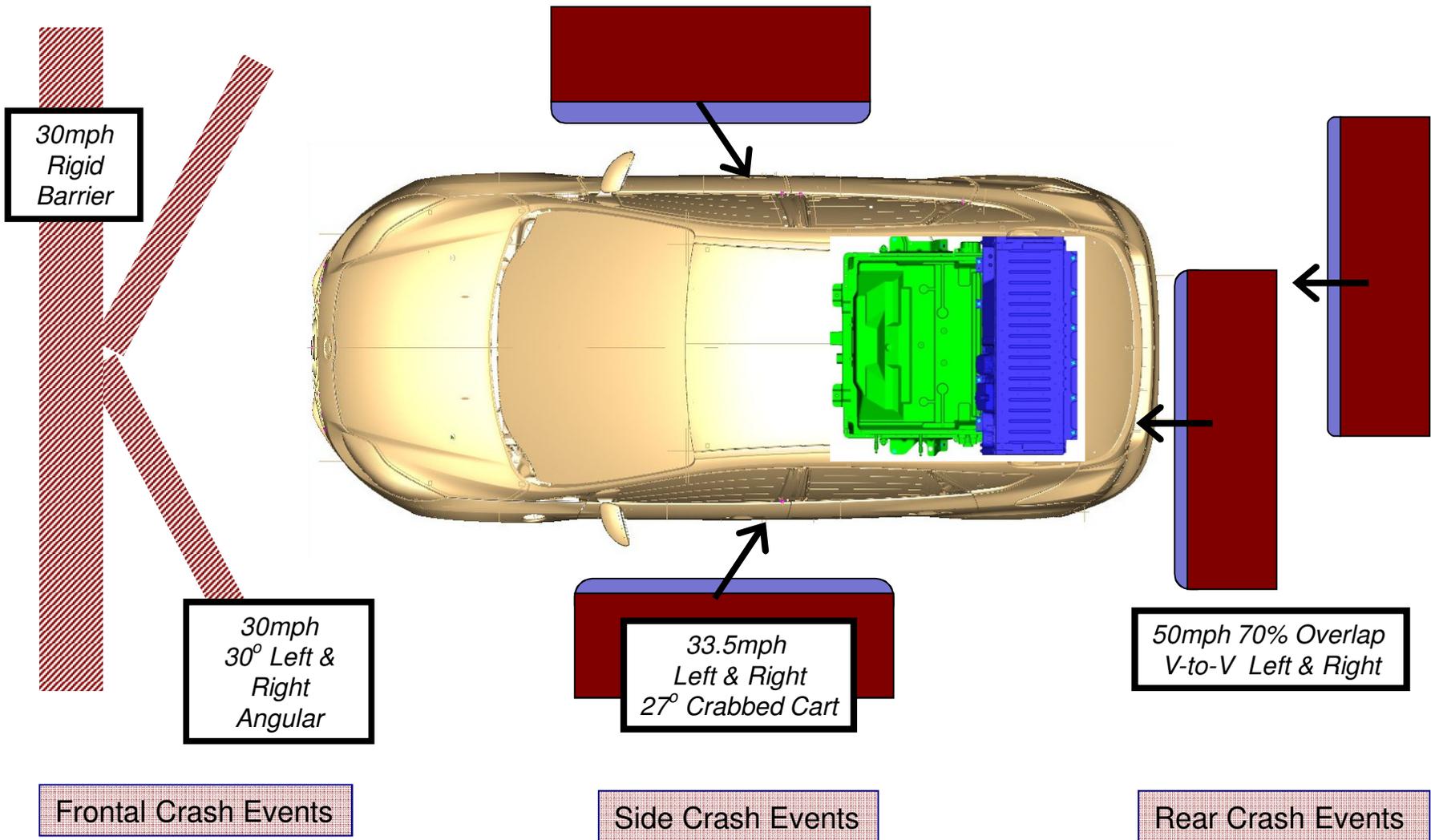
BEV Upper Battery Pack is mounted in the trunk behind the second row seats. Lower portion of pack extends through trunk floor to the outside of the vehicle



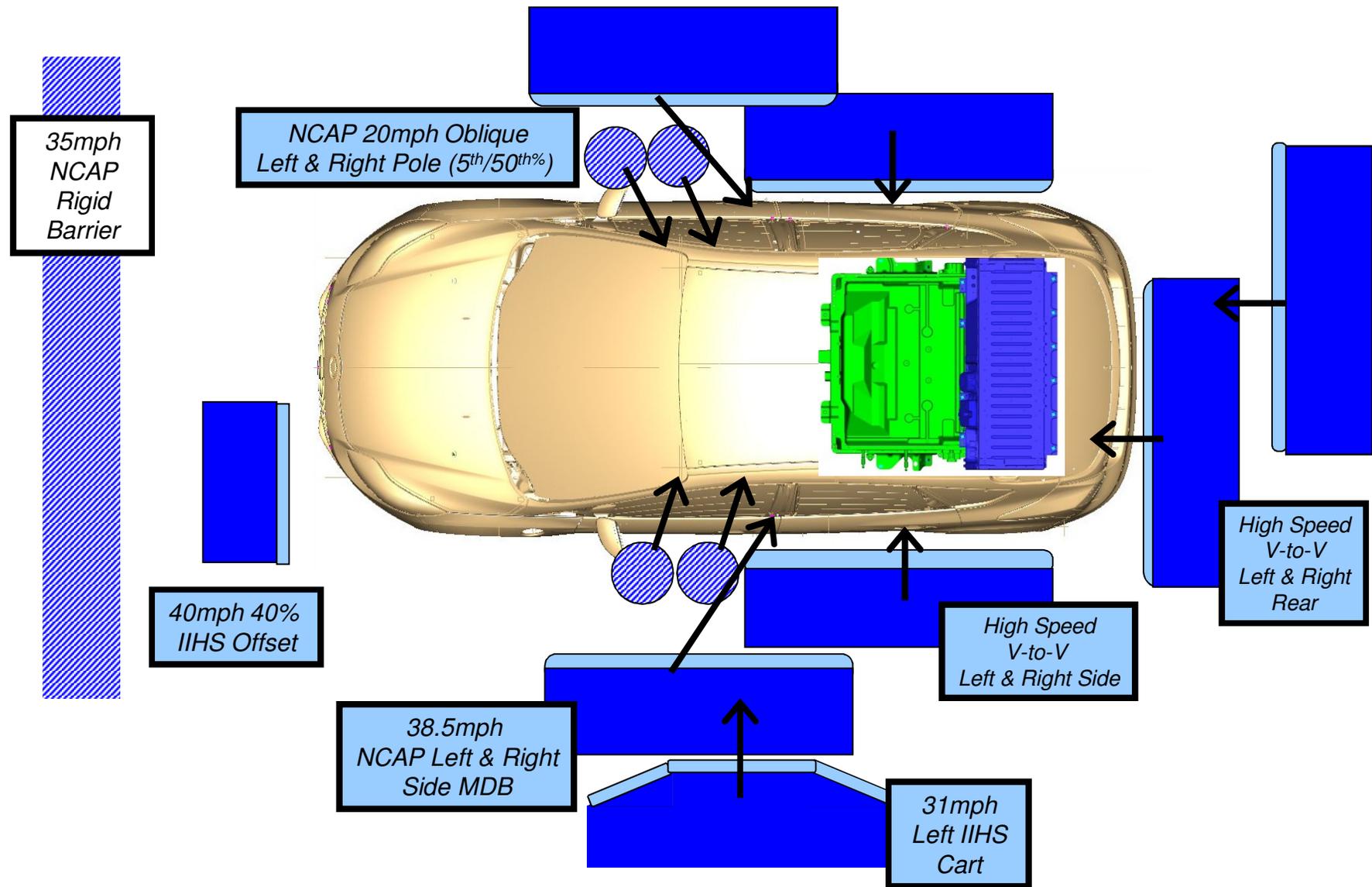
BEV Lower Battery Pack is mounted under the vehicle below the second row seats



# Crash Requirements – FMVSS 305



# Public Domain & Additional Ford Crash Testing



# FMEA Analysis

## Noise Factors & Failure Modes

Normal Conditions

Noise Factors

Off-Normal Conditions

Failure Modes

## Stress

Over Temperature

Over Charge

Over Discharge

External Short

Internal Cell Short

## Potential Effects

No Effect

Protection Activated

Damage/Retention

Leakage

Venting

Fire/Flame

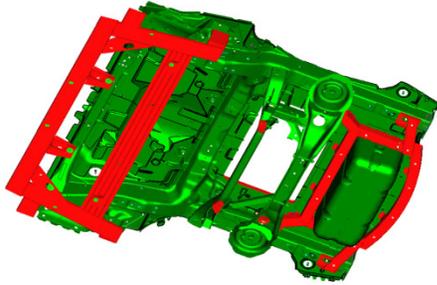
## Prevent Actions

**Vehicle Level Design Actions**

**Pack Level Design Actions**

**Cell Level Design Actions**

# Vehicle, Pack & Cell Level Actions



## Vehicle Level Actions

- Vehicle Structure
- Vehicle Cooling Sys
- Vehicle Control Sys
- Charging Control Sys

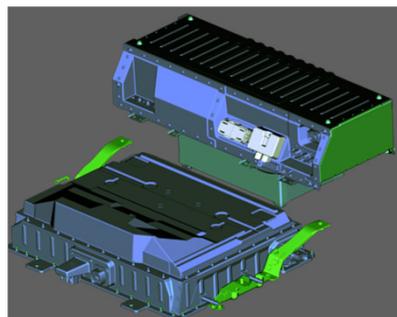
## Pack Level Actions

- Battery Pack Structure
- Vent Management Sys
- Pack Cooling Sys
- Battery Controls Sys
- Power Limits (Temp, Age, others)
- Over Temp
- Over Charge/Discharge
- ENS Control
- Cell Balancing
- Battery Sensors (V, I, T)
- Fusing



## Cell Level Actions

- Cell Chemistry
- Cell Design
- Cell Manufacturing (occurrence reduction)



# Typical Testing & Verification

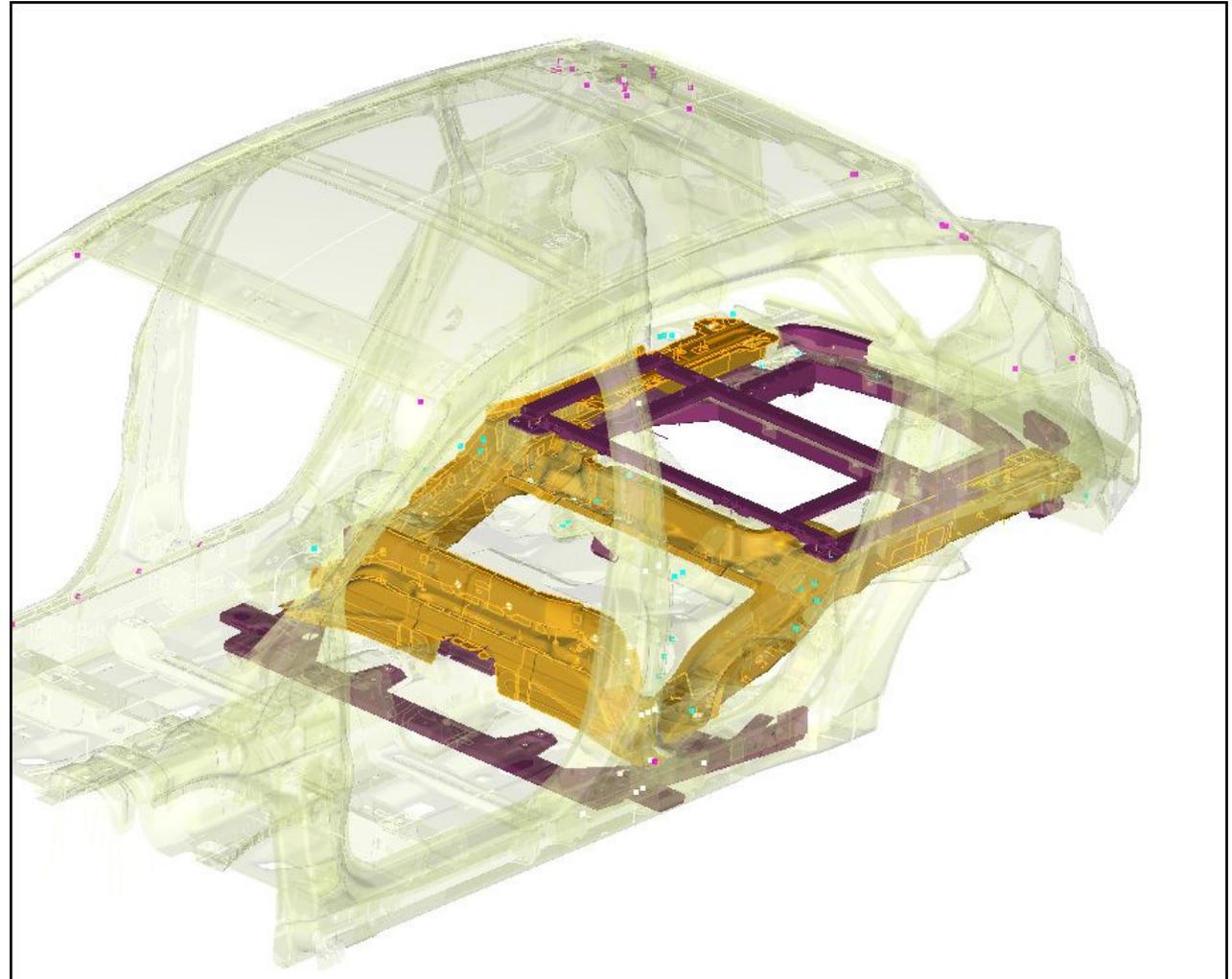
**Examples of typical tests that may be conducted on battery cells, battery pack assemblies, and/or entire vehicles.**

<b>Mechanical</b>	Vibration, Shock, Battery Enclosure Integrity
<b>Electrical</b>	Electrical Short Circuit, Over Charge & Discharge Protection
<b>Environmental</b>	High/Low Temperature Exposure, Thermal Shock, Humidity and Moisture Exposure, Corrosion, Immersion

# Focus Electric – Vehicle Level Structural Components

Unique  
Designed  
(Material &/or  
gauge revised)

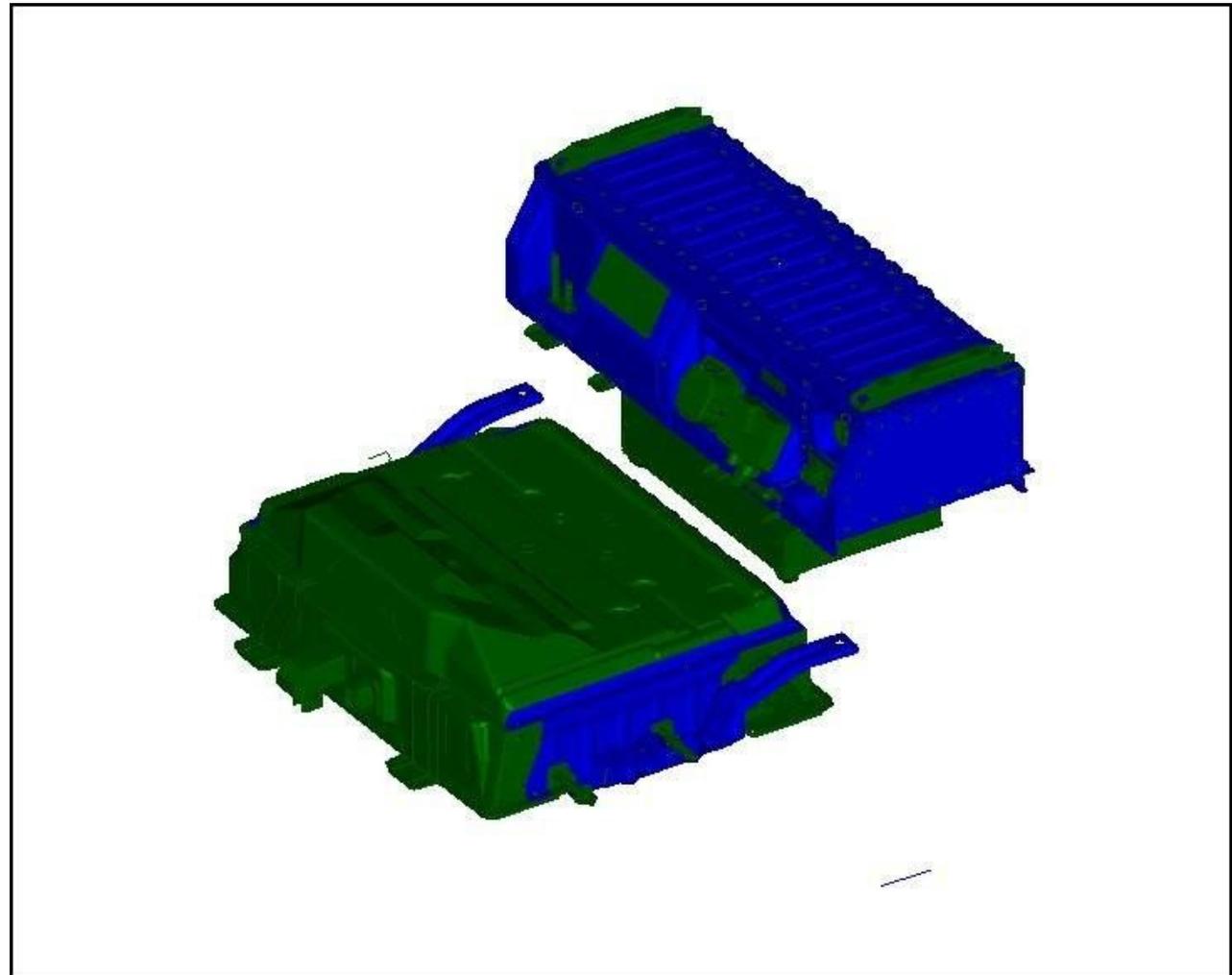
Structural additions  
for battery pack  
crash protection



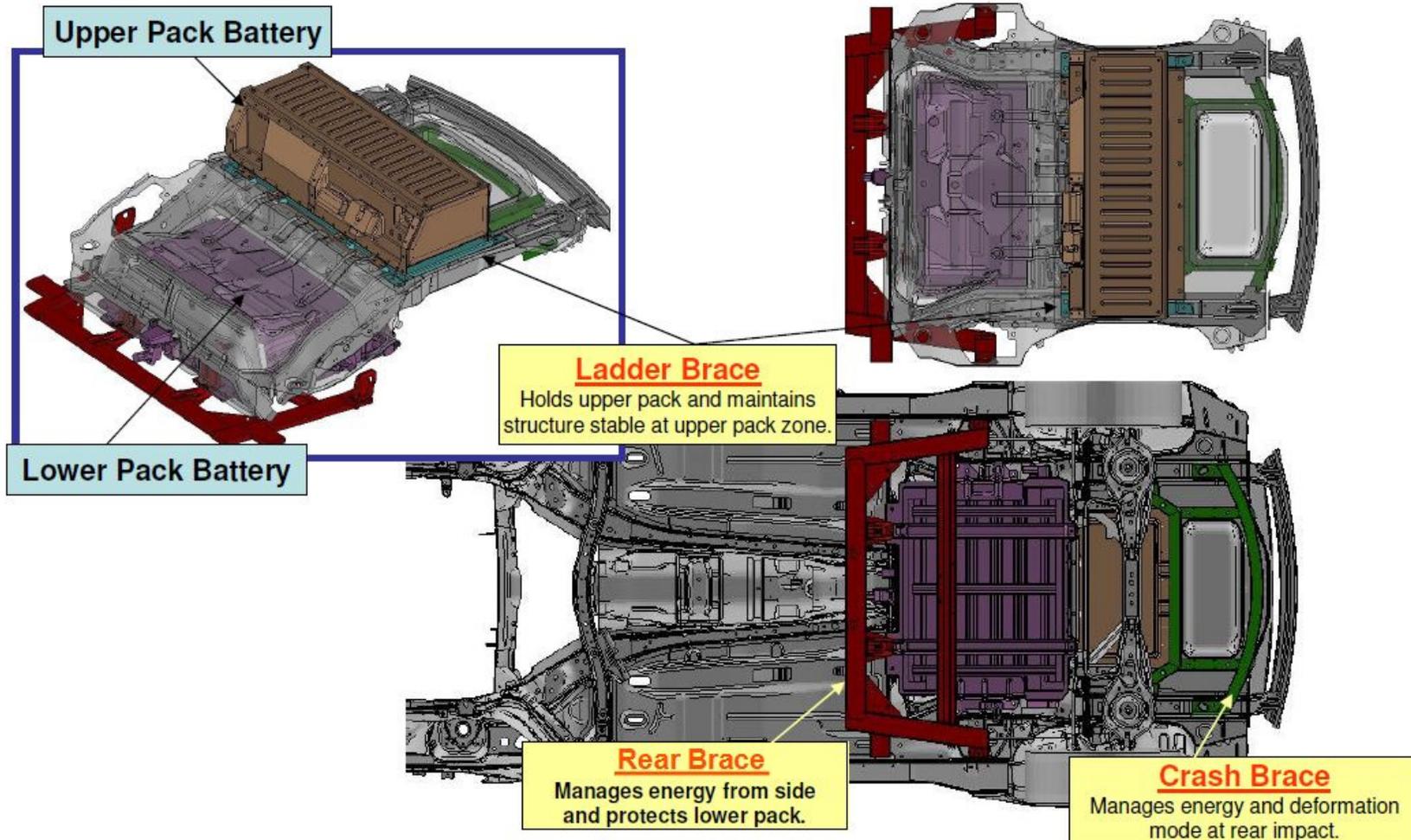
# Focus Electric – Battery Pack Level Structural Components

Battery Pack  
Casing

Casing  
modifications for  
enhanced crash  
protection



# Focus Electric – Rear Body Structure

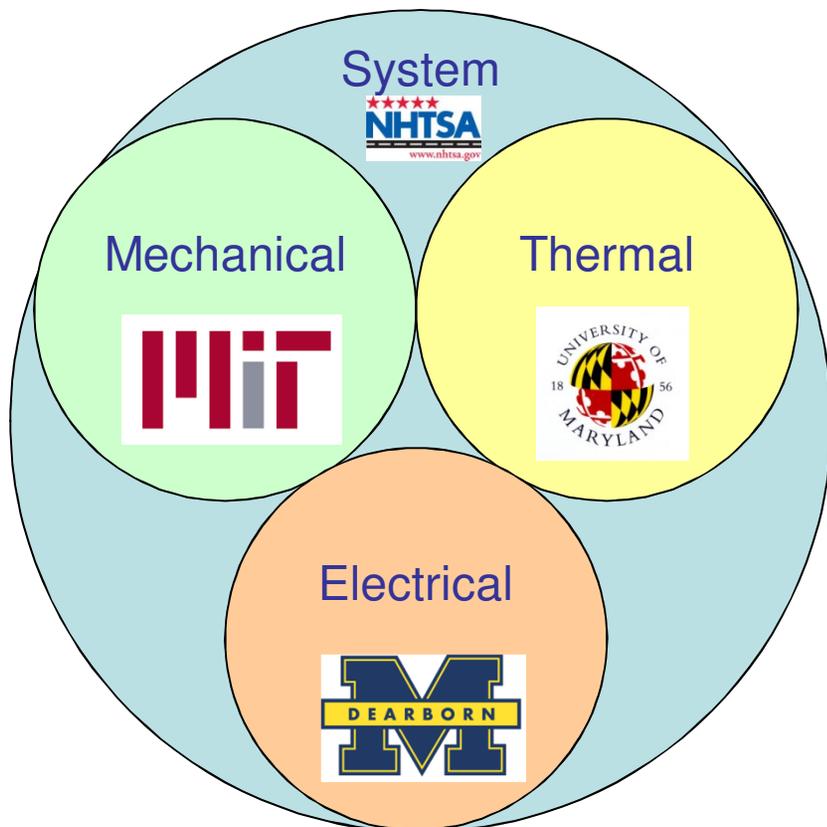


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# Battery Safety Research

## Battery Safety Hazards



**Fundamental**

**TBA**

## Project Summary

System: NHTSA Research Funding

- COTR Gorney (2yr)
- Vehicle Lithium Ion Battery Hazard Test Method Development



Mechanical: Ford-MIT Alliance Funding

- Prof. Wierzbicki (2yr)
- Lithium ion battery mechanical crush modeling and prediction



Thermal: Ford URP Funding

- Prof. Sunderland/Stoliarov (3yr)
- Lithium ion battery thermal hazard assessment & comparison



Electrical: Ford-UM Alliance Funding

- Prof. Mi (2yr)
- Battery management system (BMS) controls & requirements



Fundamental: TBA (Proposal Stage)

- Prof. John Doe (1+1.5yr)
- First Principles of Cathode / Electrolyte Interactions

**TBA**

# NHTSA Solicitation: Overview



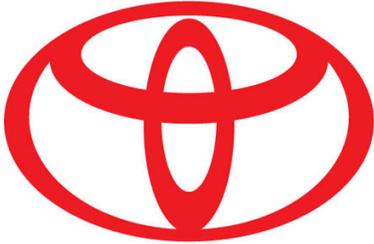
Scope	HEV/PHEV/BEV Li-Ion Battery
Purpose	Develop Safety Test Methods & Performance Safety Metrics
Tasks	<ul style="list-style-type: none"> <li>• Active – Single Failure</li> <li>• Passive – Single Failure + Loss of Control System</li> </ul>
Fault Origin	<ul style="list-style-type: none"> <li>• <u>Mechanical</u>: Crush, Penetration, Vibration, etc.</li> <li>• <u>Electrical</u>: Overcharge, Short Circuit, Overdischarge, etc.</li> <li>• <u>Thermal</u>: Fire Resistance, Thermal Control, etc.</li> </ul>



Timing	
Solicitation	1/26/11
Proposal	4/21/11
Award	9/30/11
Finish	9/29/13

# NHTSA Solicitation: Awards



Primary		
Sub-contractor		    

# Ford Approach: Overview



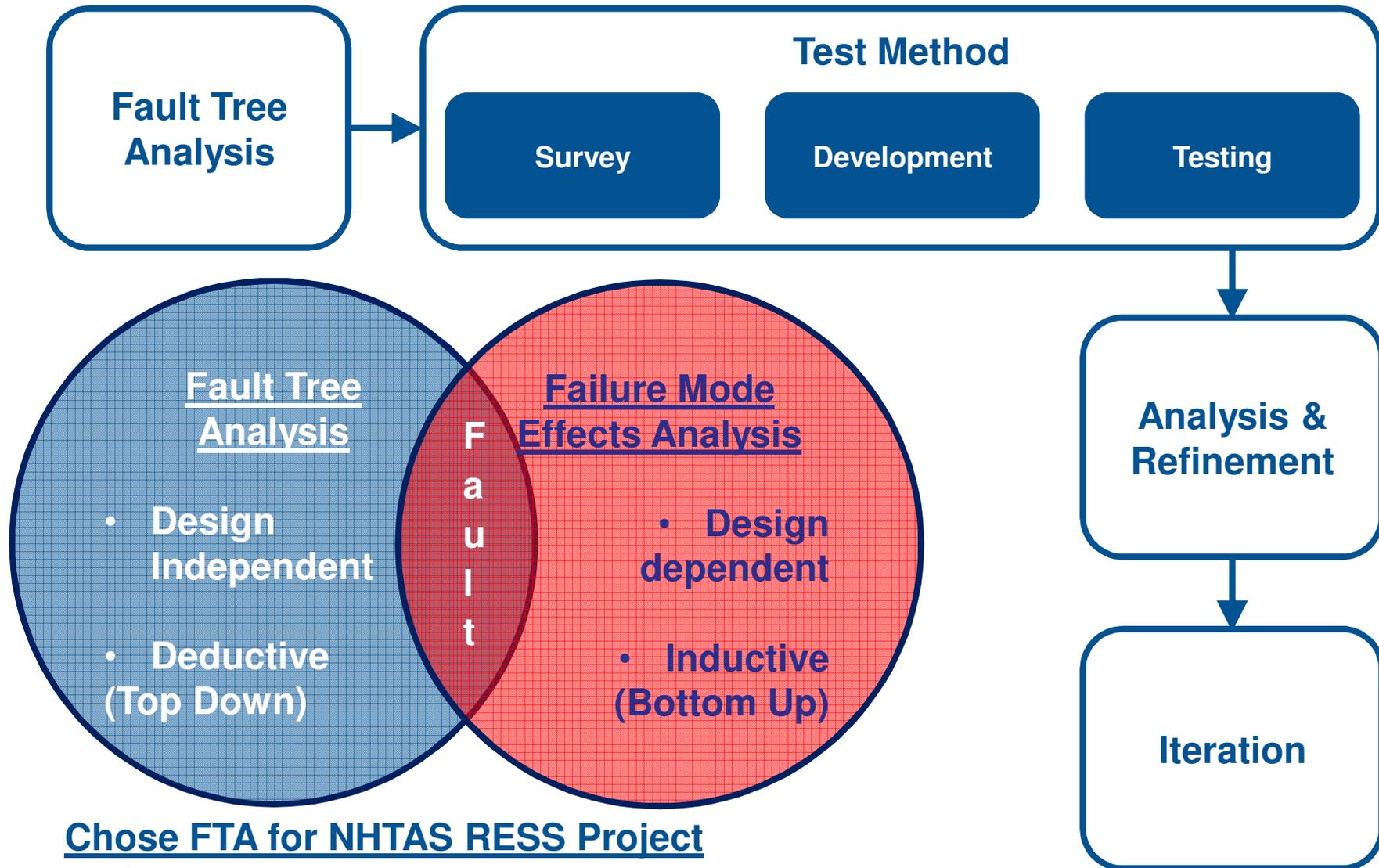
- **Goal:** Repeatable vehicle level Li-ion based RESS safety performance test procedures
- **Approach:** Define vehicle level performance tests which draw upon the cell, module and pack level information.



**ONE FORD**

ONE TEAM • ONE PLAN • ONE GOAL

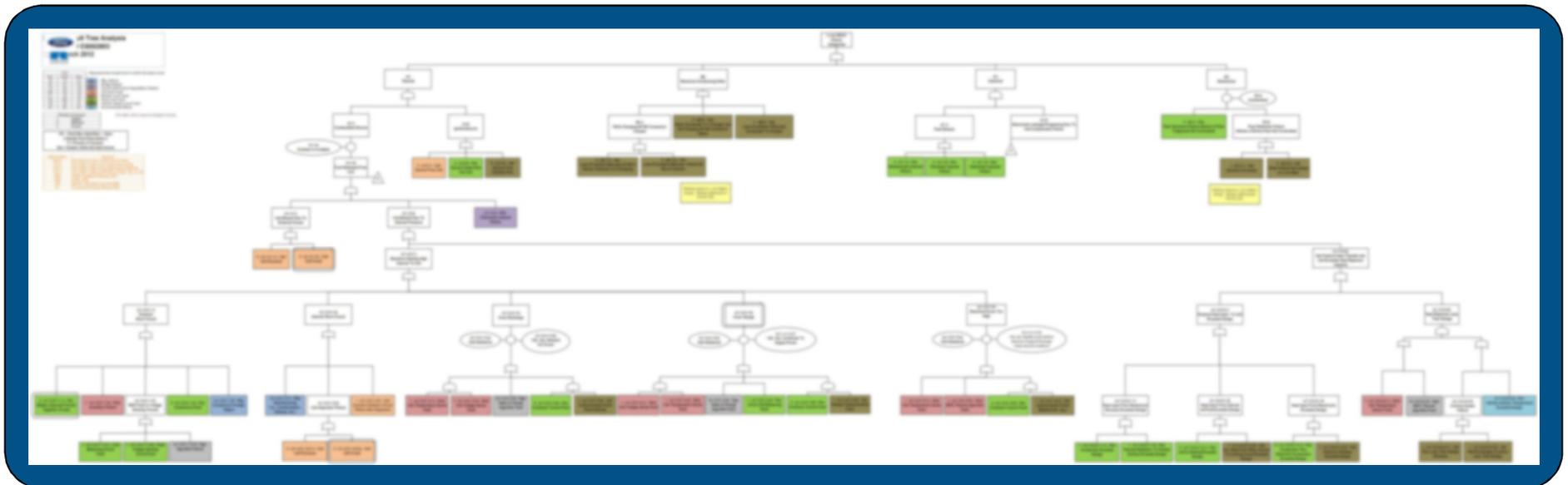
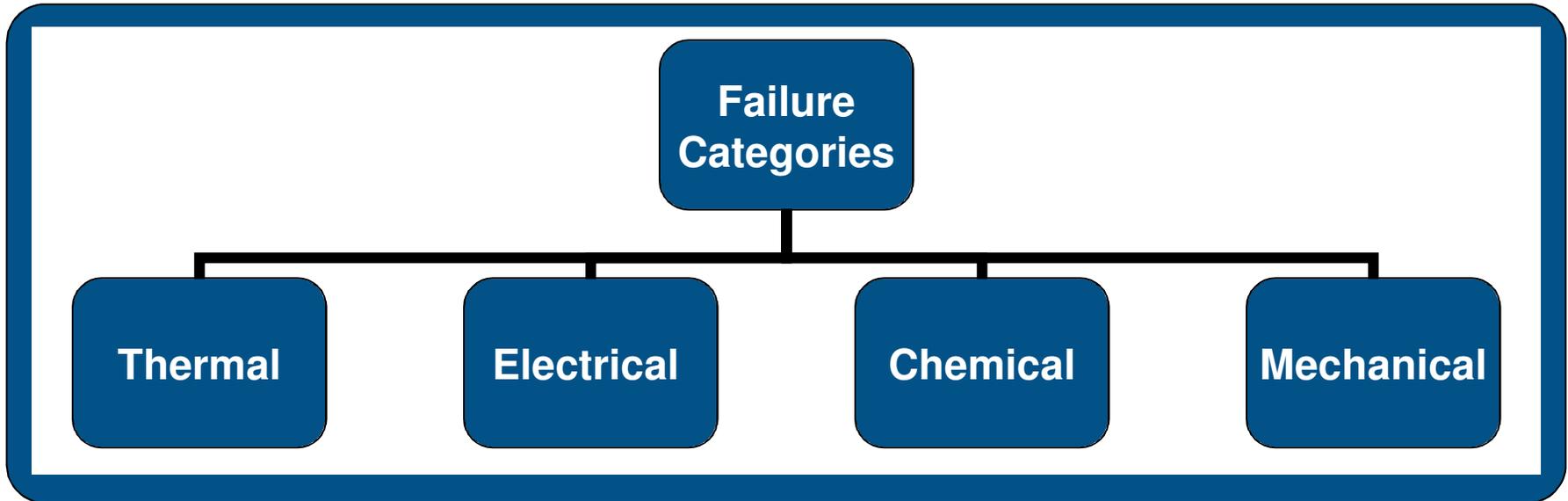
# Ford Approach: Process



## Chose FTA for NHTAS RESS Project

- Broadly applicable (Design Independent)
- Event Path Dependence (Multiple Fault Scenarios)

# Ford Approach: Fault Tree Analysis



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Great Products, Strong Business,  
Better World



**Go Further**

