

Battery Safety Science Webinar Series

Advancing safer energy storage through science

April 19, 2021

Electric Vehicle Fire Data and Concerns for First and Second Responders

Host
Presenter

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Practical Electric Vehicle Firefighting

An ISO 17840 based class

Robert L. Swaim

Founder: www.HowItBroke.com

NTSB Engineering National Resource - Retired



R.Swaim

Safety Risks to Emergency Responders from Lithium-Ion
Battery Fires in Electric Vehicles

Safety Risks to Emergency
Responders from Lithium-Ion
Battery Fires in Electric
Vehicles.

NTSB SR-20-02, 11/13/2020



National
Transportation
Safety Board

Safety Report

NTSB/SR-20/01
PB2020-101011



Lake Forest CA 8/25/2017

Source: NTSB Public Docket

Orange Co. Fire Authority



Resources

NFPA

www.EVSafetyTraining.org

Training developed with manufacturers, agencies, and organizations

Trained >1900 trainers in majority of States

>30,000 trained

Extensive resources

Online info

Online classes

Field emergency guide

SAE J2990

Hybrid and EV First and Second Responder Recommended Practices

UL FSRI - Firefighter Safety Research Institute

Firefighter research and training is online and free

www.ulfirefightersafety.org

Two firefighter demographics

Source: NFPA Feb 2020 based in 2018 data

1,115,000 total, 67% are volunteers, 92% male

Location:

About half in rural community <2,500 population, majority are volunteers

About 2/3 of US population served by professional or mixed departments

Education:

High school with non-degree EMT award and specialized training

More of professionals have bachelor degrees in:

Business (22%), Protective Services (18%) Source: datausa.io

Age and experience:

27% between 30-39 years old,

41% with >10 years experience

Volunteer:

Most common non-FF employment: #1 Repairing, #2 Equipment Maintenance



R.Swaim

The "only" two firefighter EV concerns and issues

Fear of the unknown – Will it bite me?

1. Fire related concerns

- What is a battery? What does one even look like?
- What is an EV and how are they different than a "normal" car?
 - Most volunteer FF are employed in repair fields
- What burns and how?
- Will it explode?
 - Stories and urban legends
- How bad is the smoke?

2. Electric related concerns

- Is the hose stream electrified?
- Is the vehicle body electrified?
- Is fire while hooked up to a charger a hazard?
- What is trapped energy and why is it a hazard?

Firefighters need more knowledge to even know what concerns they should have around an EV

What needs to be done?

3. Tactical concerns

- How to approach an EV?
- How to identify an EV?
- Move or immobilize?
- How to disable the HV hazards?
- Threats to extricating victims?
 - How close can FF get?
- Dismay at lack of design standards threatening responders and victims
- Working around trapped energy?
 - How to extinguish? Water? Foam? Which foam? ABC?
- Why won't it go out? Targeting separate fuels in a fire
 - Need for additional FF for oversight

4. Situational concerns

- How does EV firefighting fit into hundreds of years of training?
 - CTIF – International Association of Fire and Rescue Services
 - ISO – International Standards Organization (Ref. 17840)
 - SAE – Society of Automotive Engineers (Ref. J2990)
 - NFPA – National Fire Protection Association
- What EVs tend to have fires and where?
- What's typical versus how bad can an EV fire be?
- Complacency
- EVs other than cars?

Will it bite me? What firefighters want to know

1. **Fire** related concerns

Three cell shapes/formats

Hazard typically is based in chemistry and not format

Prismatic cells frequently used for large & industrial batteries.

Cylindrical cells shown as an assembly with a battery management circuit board for charging.

Typical vape, power tool, or mower battery.

Pouch cells are least expensive to manufacture. Used in cars, cell phones, and tablets.

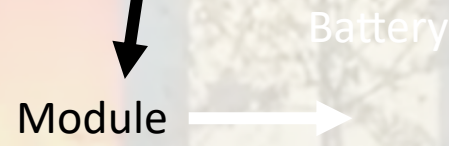
The GM "Ultium" is shown below.

Single Pouch

1. Fire concern
What does an EV battery even look like?
Cells versus assemblies

Pouch Cells

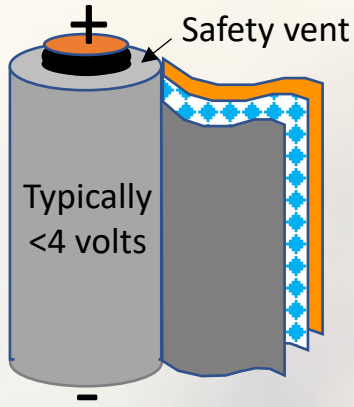
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What is in a lithium-Ion battery

Cells are designed to vent and may burn but not be explosive

1. Fire concern
Why does a battery burn?



Cathode (+)

Aluminum foil with oxide coating

Separator

Porous polypropylene membrane (typ.)

Anode (-)

Copper foil with porous carbon coating

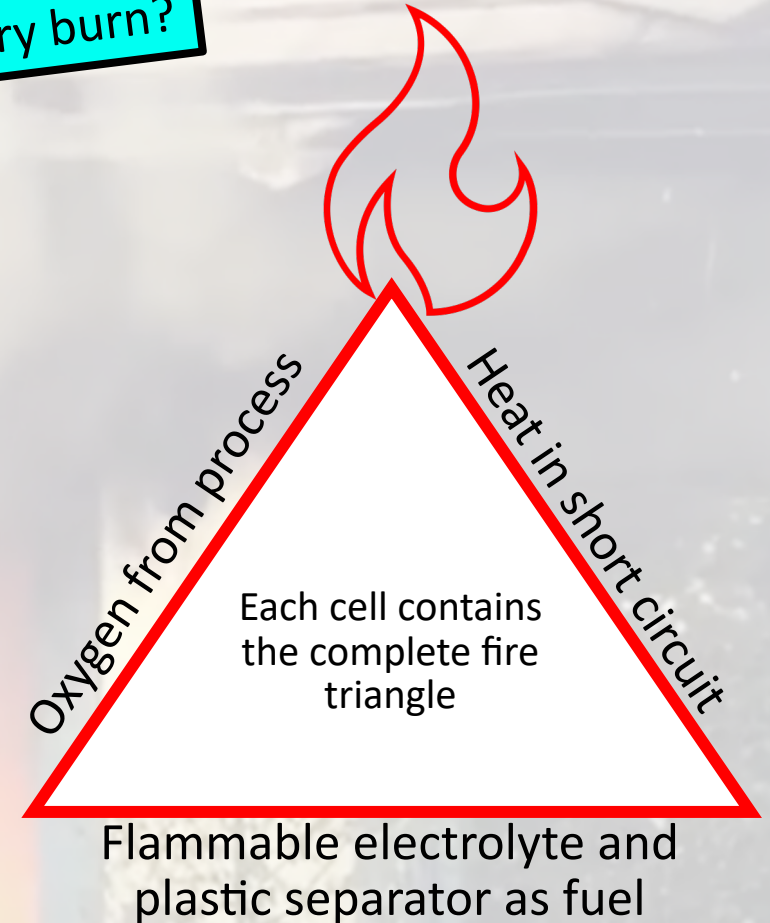


Electrolyte = light oil that feels like diesel fuel

Carries dissolved lithium salt ions

(NO FLAMMABLE METAL IN RECHARGEABLE CELLS)

Mythbusting



Flammability and hazards vary

Many types of battery chemistry

Shows delivered power & energy of various types

1. Fire concern
Do all batteries burn?

Trade-offs of variables to meet design goals

Faster charging

Increasing hazard

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400 miles
Car battery

Early EV & PHEV
<80 miles

Lead acid & AGM

Phones, toys & consumer items

Variables include:
Weight
Temperature tolerance
Maintenance
Voltage
Recycling

RANGE

Specific Energy

Cost

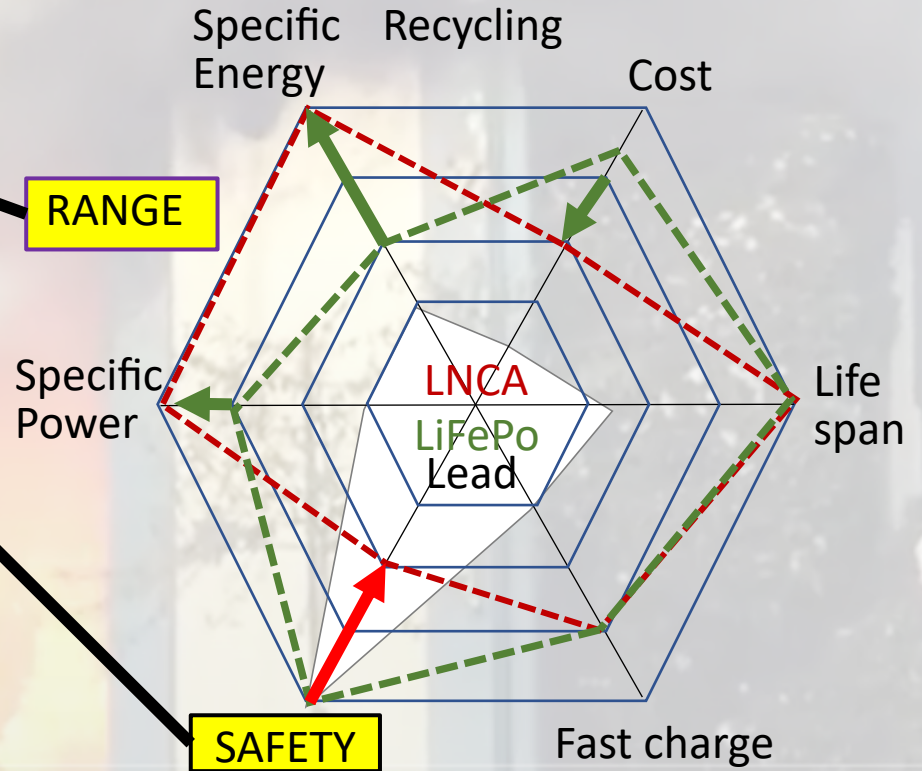
Specific Power

LNCA
LiFePo
Lead

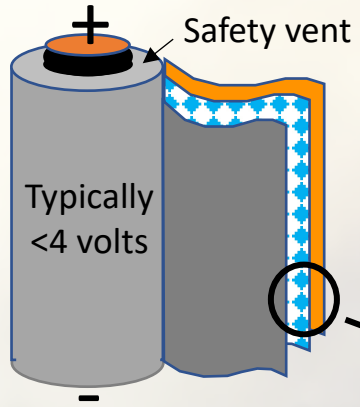
Life span

SAFETY

Fast charge

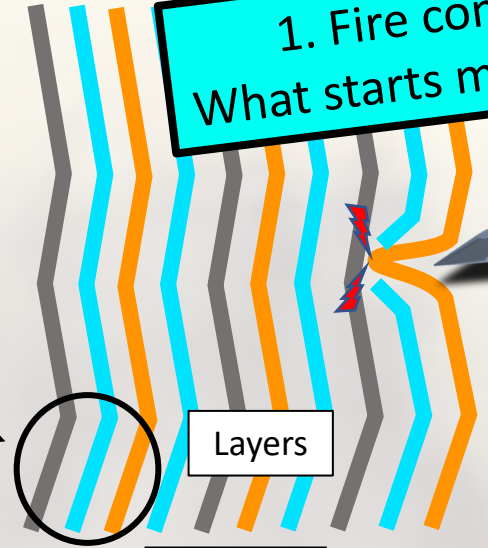


Thermal runaway process



Layers:
Cathode (+)
Separator
Anode (-)

1. Fire concern
What starts most fires?

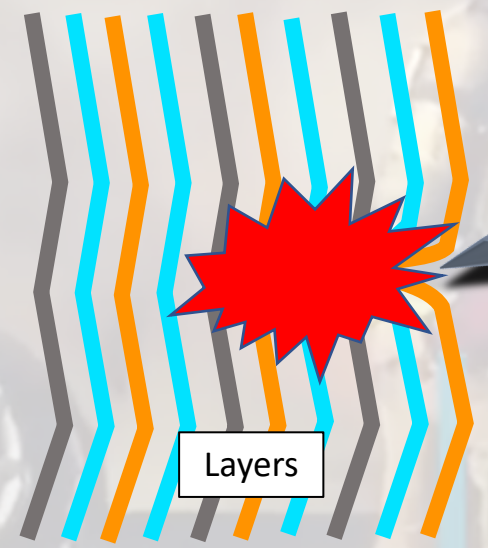


A. Typically some damage creates short circuit within a cell

1. Damaged separator allows current to rush between anode and cathode
2. Heat generated expands hole and melts progressive separator layers, expanding current rush



Temp <100C
can stop
thermal
runaway
process



B. Heat energy

3. Electrolyte ignites when flammable limit is reached
4. Pressure in cell increases until it vents or bursts



C. Smoke/Flames

Introduce "thermal runaway" concept with small cells

Lithium Ion cells contain both electrical and chemical energy

Internal short circuit (ISC) heat may ignite electrolyte. Heat ignites adjacent cells.

Venting of electrolyte may heat and smoke without ignition or it may ignite.

Demonstration of lithium ion bat

1. Fire concern with small cells
What burns and how?

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Vape device ignited in pants pocket



Watch and listen for individual cells to ignite

Source: FAA

Thermal runaway in large cells

Cells vent at intervals as each sequentially heats.

Vent like roman candles. Smoke is flammable & toxic

Burning plastic and electrolyte can spit from case

1. Fire concern for big cells
What burns and how?

787 Battery smoke in 2006 GSYuasa test

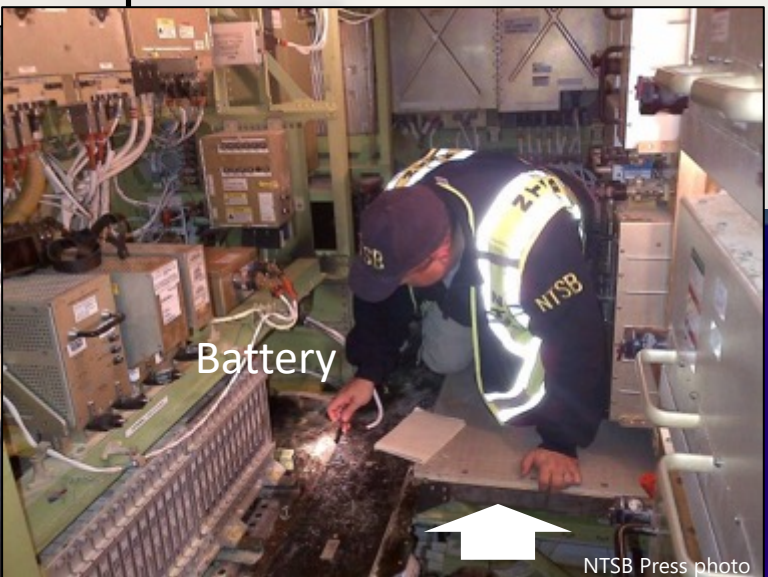


NTSB Public Docket photo

NTSB Public Docket photo



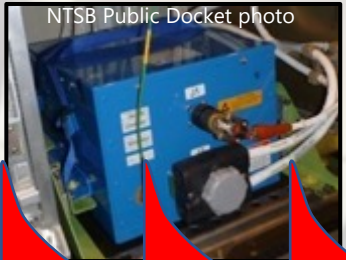
NTSB Public Docket photo



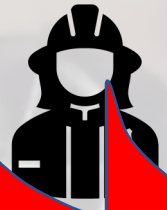
NTSB Press photo



787 Battery in NTSB thermal runaway test at UL



NTSB Public Docket photo



Heat and smoke



Time 8 cells ignited at 15 minute intervals

Initial battery smoke content

Think plastic fire with nasty additives

Depends on constituent materials

Spectrum analysis of burning batteries found:

- Carbon Monoxide
 - Carbon dioxide
 - Methane
 - Ethylene
 - Acetylene
 - H₂O
 - Dimethyl carbonate
 - Ethylmethyl carbonate
 - Eye & lung irritating acids
- } Can not breath
- } Can ignite
- } Hazardous Materials

1. Fire
Relating smoke hazard for
firefighters who regularly smell smoke

**WEAR YOUR SCBA
& COVER ALL SKIN**

Soot may contain cobalt oxide, nickel oxide, manganese oxide, and other heavy metal skin irritants

Electric Vehicles

1. Fire concern How EVs are different

Electric vehicles move by power of a traction battery

Normally have TWO batteries,

- 1. Cabin & systems, 12V
- 2. High Voltage (HV) Traction, 355 to 560+ volts
Battery Management System (BMS) integrated or separate

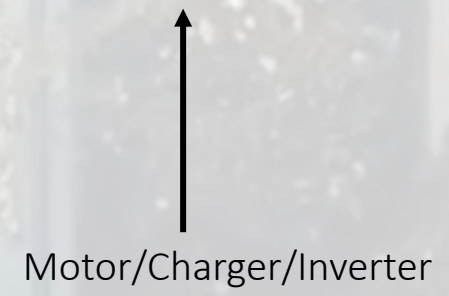
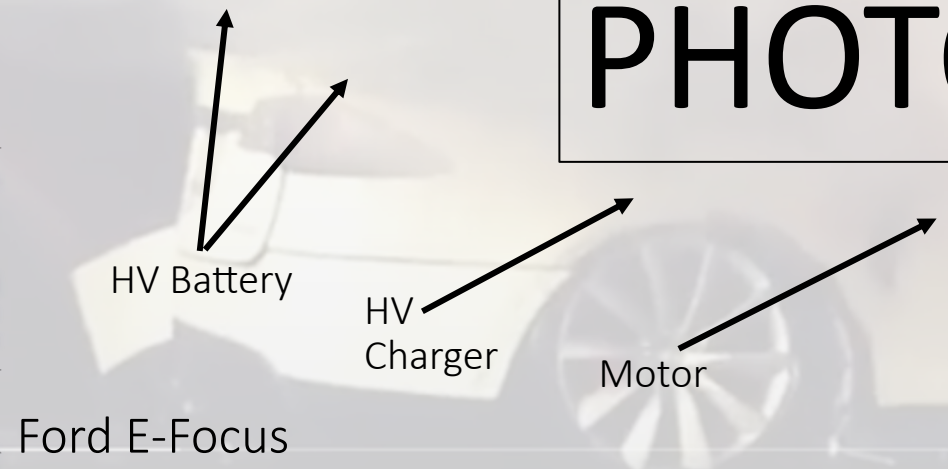
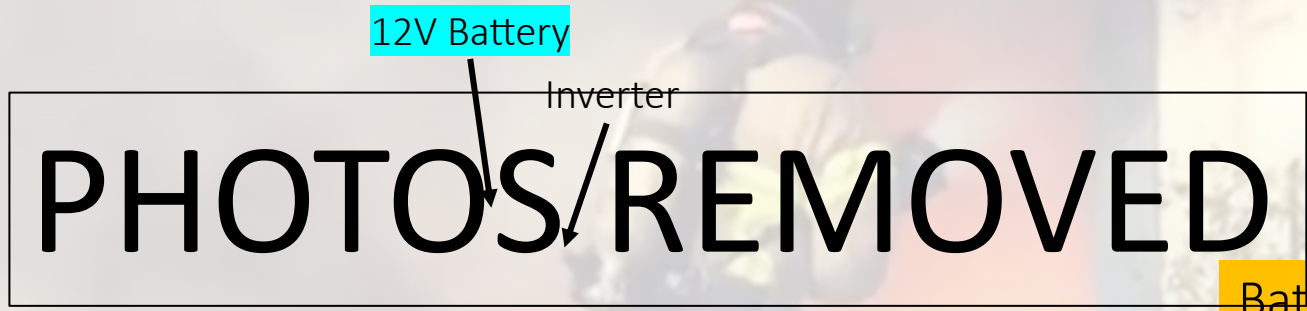
FF Risks:

- 12V Battery activating airbags & restraints
- Burning plastics
- HV Traction battery fire
- Electrocution by high voltage
- Arc Flash

EV WITH BATTER(IES) BUILT INTO BODY (TYPICALLY OLDER)
"INTEGRATED" STYLE

BATTERY/MOTOR ASSY BENEATH BODY
"ROLLER SKATE" STYLE

Orange denotes high voltage >30 VAC or 60 VDC



Ford E-Focus

VW ID.3

Will it bite me? What firefighters want to know

2. **Electric** related concerns

Electrical concerns for firefighters

12V battery controls safety devices:
Airbags, seat belt pretensioners, door locks

EV will have a HV traction battery
Typically 300+ Volts

HV battery "Stranded energy"
Electrocution
Concerns at hose nozzle
At or in the vehicle

Arc flash

Re-ignitions

2. Electrical concern
Introduction to added EV hazards

Burned three times including 6 days after accident



EV Battery safeguards

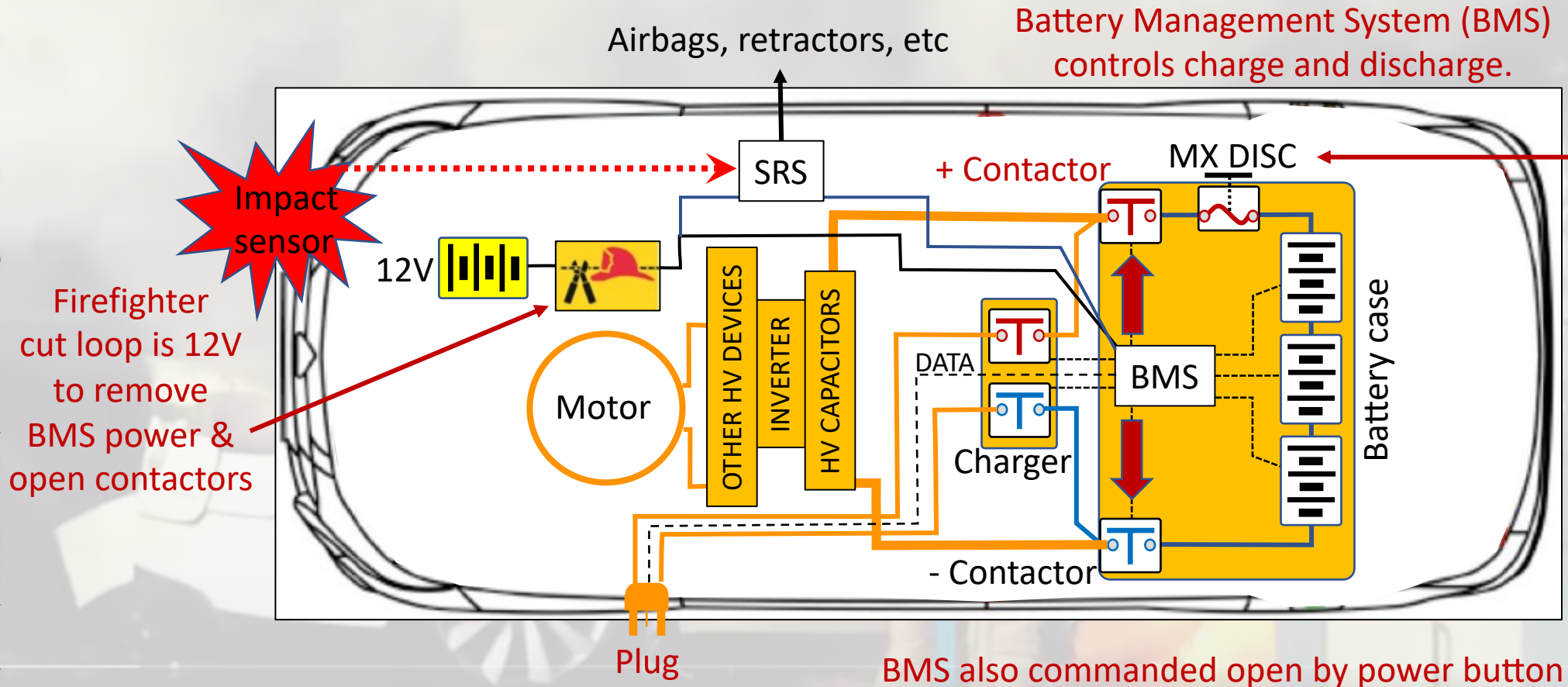
2. Electrical Background on EV differences

Upon impact 12V Safety Response System (SRS) should:

- Deploy airbags. DANGER: Two stage airbags remain dangerous with 12V available
- Unlock doors
- Retract seatbelts

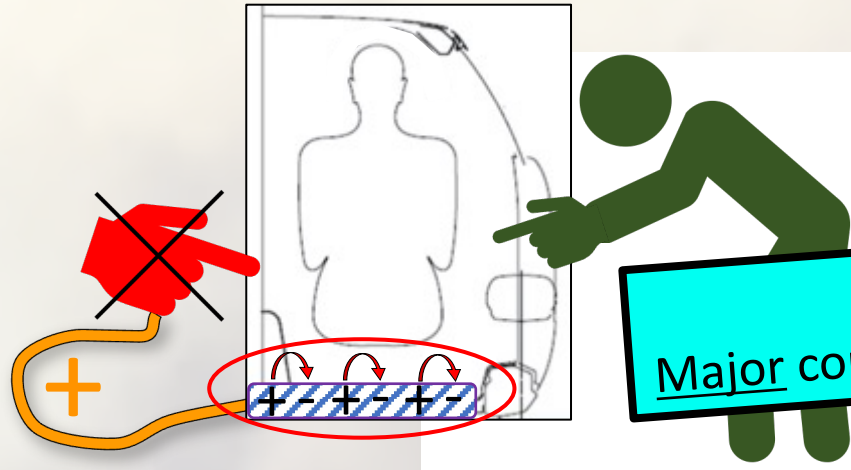
In EV the BMS opens battery contactors. DANGER: Welded contacts can power cables
DANGER: Trapped energy and arc hazards

Manual maintenance disconnect can open HV circuit

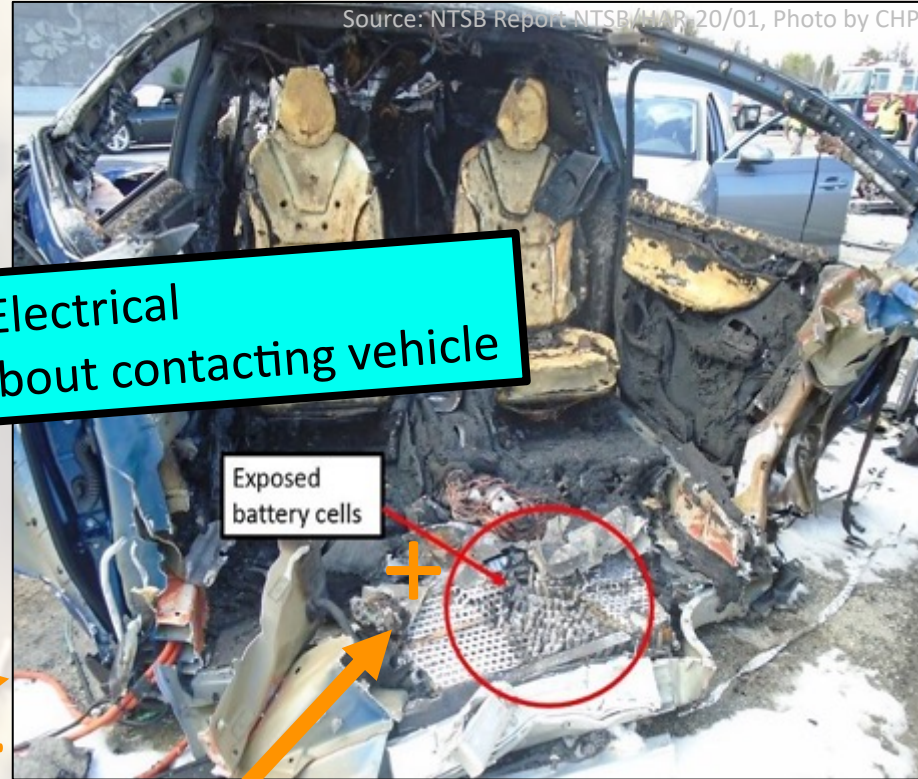


Stranded energy - Electrocutation at or in vehicle is possible

1. The car structure and occupants should not be electrified to touch



2. Electrical
Major concerns about contacting vehicle



2. Risk is from getting between exposed HV parts to become part of the circuit. Examples:

A. An exposed hand touching orange cables with the other hand on the car body.

B. Leaning on exposed internal HV battery parts. Internal HV parts may **not** be orange!

This large piece of grey metal is an internal HV bus bar.

C. Standing water charged by HV



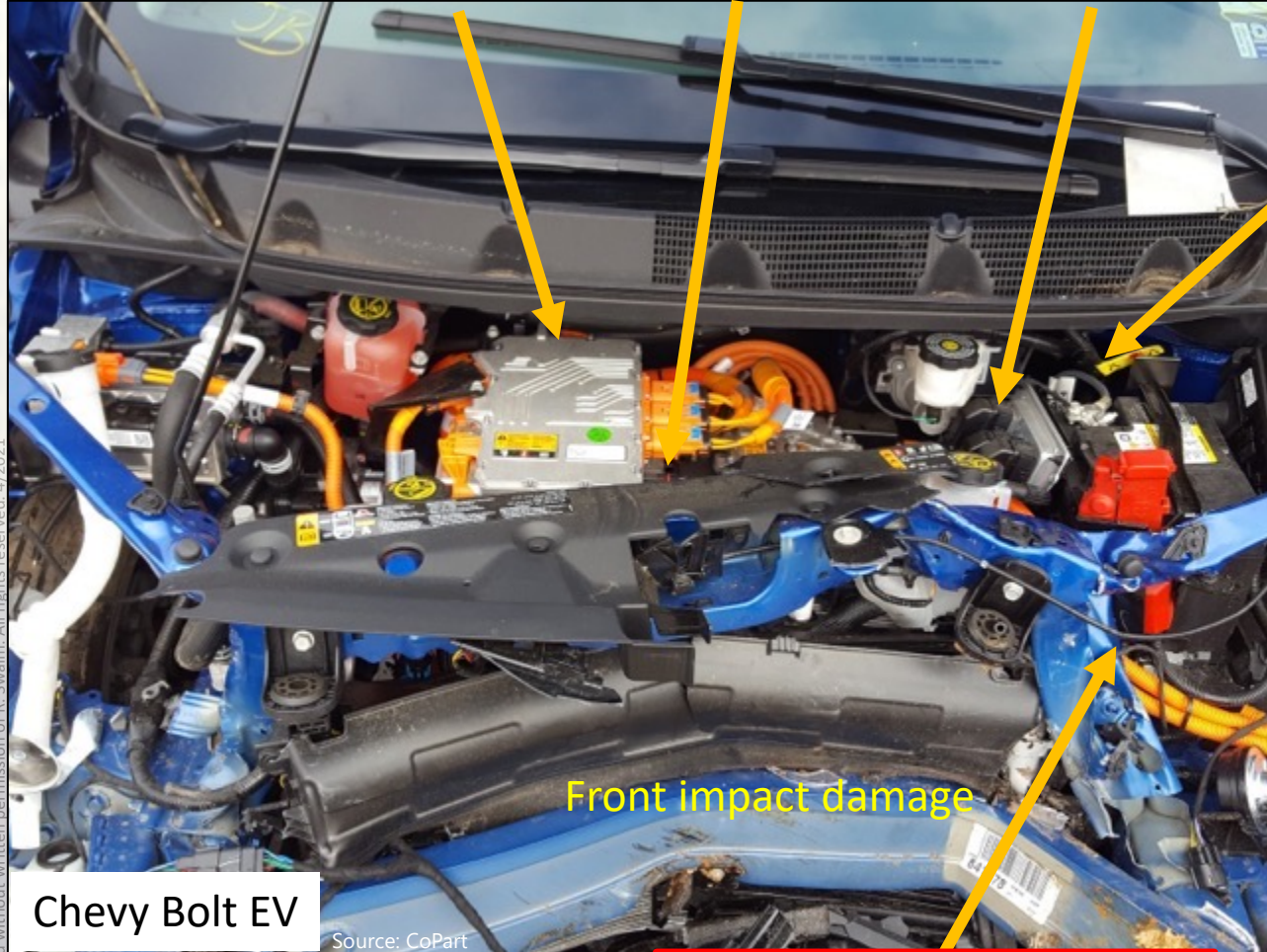
Bus bar wrapped in heavy rubber and labeled

Beware of high voltage dangers

High power distribution module

3 phase inverter beneath

360V Aux Pwr Module



Chevy Bolt EV

Source: CoPart

12V battery cable and HV cables crushed together

2. Electrical
Damage may add hazards to crash vehicles
Responder actions may create hazards

Cut loop over orange cables

Debris found loaded on deformed battery



Source: NTSB docket HWY18FH013

Tesla Model S

Plastic insulation may be broken or burned away

Stranded energy is a shorting and **arc flash danger!**

Car struck concrete wall at 86 mph. Flooding open area of battery extinguished fire with 200-300 gallons of water.

CBS News photo shown in NTSB report



2. Electrical
FF are not aware of this hazard
and it needs emphasis

At tow yard



5" Arc hole found through top of battery



Arc flash hole into passenger footwell



Cells found in passenger footwell



Numbers denote modules

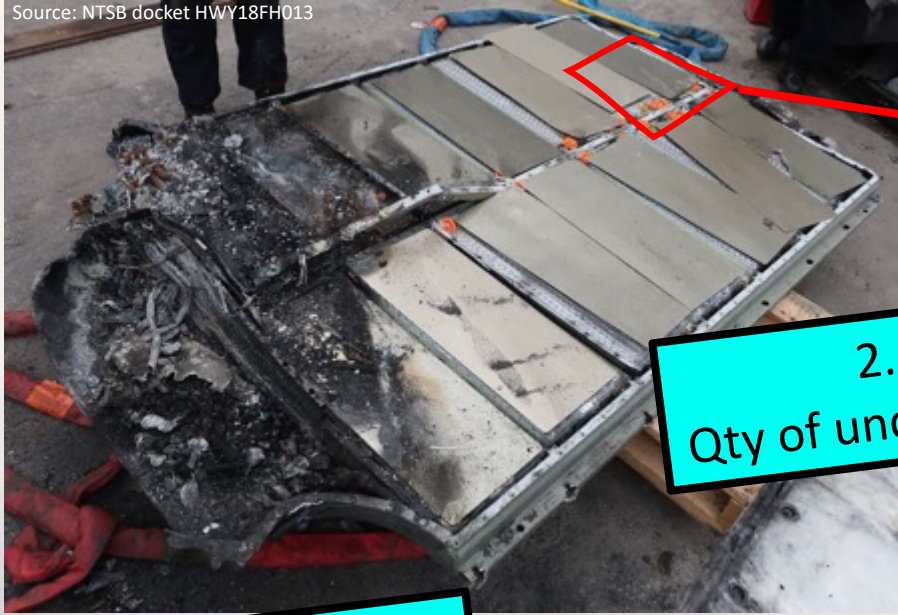
Stranded energy is a short circuit and **arc flash danger!**

Also an example why you should never attempt to pierce a battery

Note how few modules were consumed.
Missing insulation created potential HV shorts

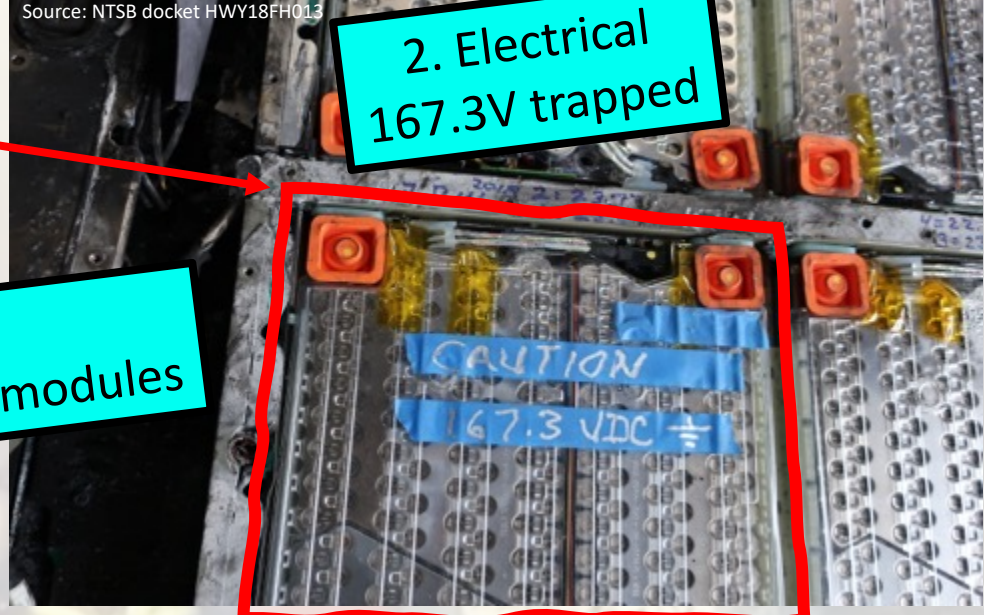
167.3 Volts in this module days after the accident!!!

Source: NTSB docket HWY18FH013



2. Electrical
Qty of undamaged modules

Source: NTSB docket HWY18FH013



2. Electrical
167.3V trapped

2. Electrical
Missing plastic insulation

Plastic insulation burns away, allowing cells to short.

Do not step on or press on damaged batteries.

EV Charging stations

Vehicle:

Is disconnection during charge a hazard?
How to physically disconnect?

Chargers and cables:

When are the HV cables charged?
Can cable be cut?
How to turn off power to the station?
What HV is at a damaged charger?

2. Electrical concerns
Lack of standards in status colors,
Lack of physical protection,
Lack of electrical protection,
Lack of emergency shutoff

Blue or green LEDs denote charging in process
But colors are not standardized



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Common US chargers:

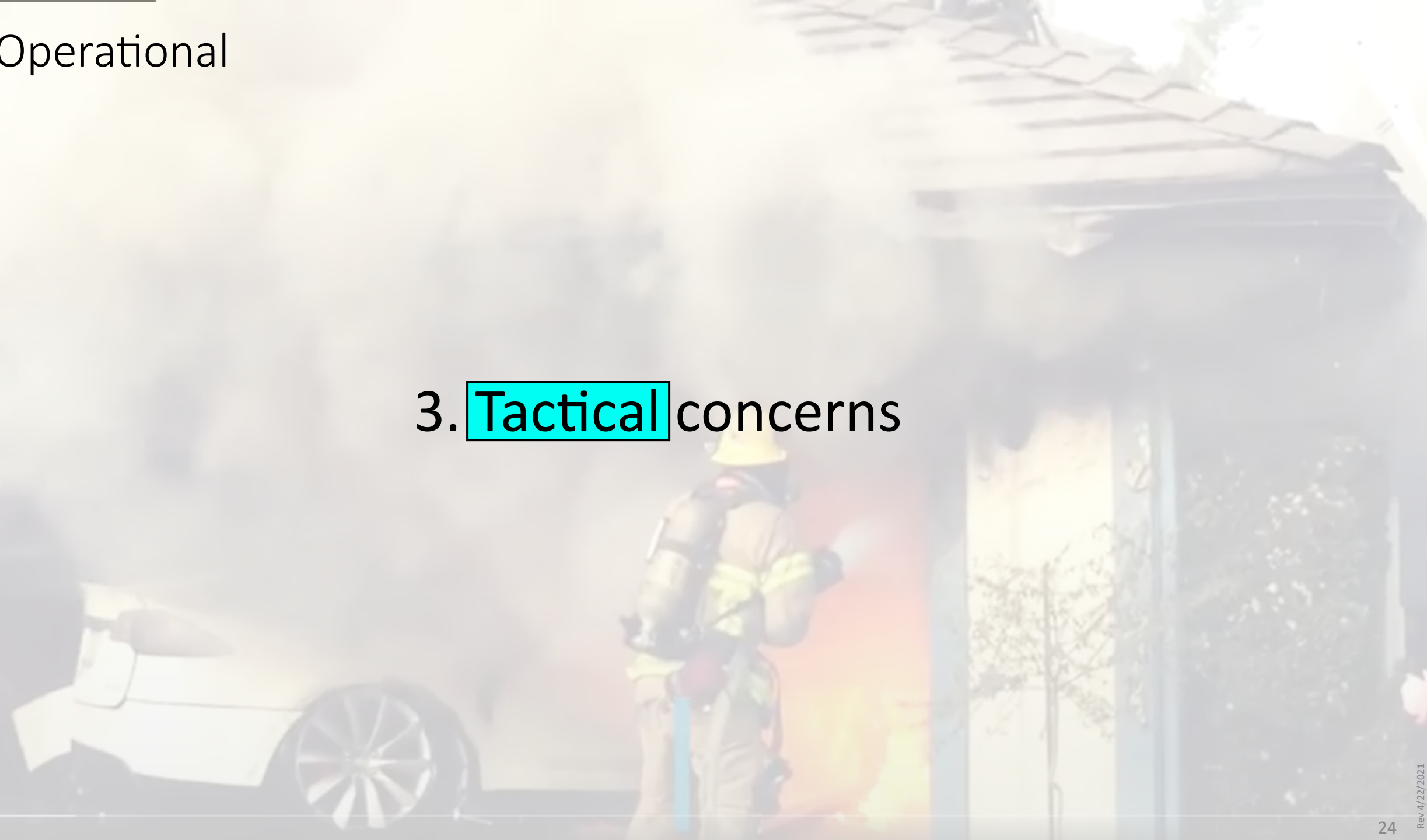
No protective vehicle barrier for many

HV source enters base, below contactors

No visible emergency "panic buttons"



3. Tactical concerns



Approach hazards

3. Tactical Intro to how an EV adds differences at scene

Same as in ICE vehicles

- Approach from 45 degrees
- Wheel chocks
- Set parking brake
- Vehicle into park
- Turn off ignition
- Disconnect 12V battery

EV sides add hazard:

Battery venting -Note that fire is beneath doors →

EV adds front and rear hazards:

- Venting fire at front in impact damaged areas
- Some vehicles may vent at rear
- Fuel tanks in hybrids and hydrogen vehicles
- Rolling vehicle hazard (throttle is electric)

EV charging station power is high voltage

Mitsubishi Outlander EV



Hydrolysis can create flammable gas
Fire took hours to extinguish

Identifying vehicles with traction batteries can be hard



3. Tactical
Concern for identifying hazard type
Only one of these variants has had fires

Hybrid

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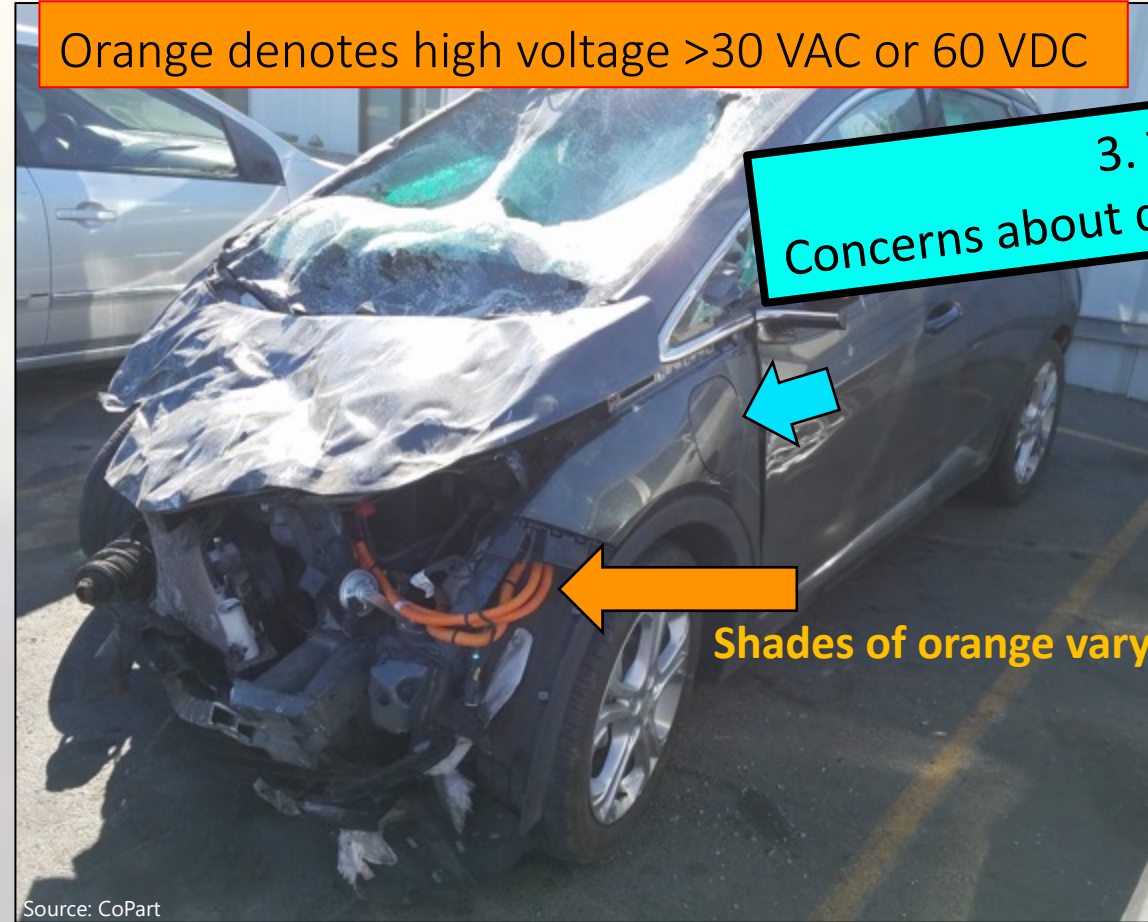
Clues beyond the badging:

Orange color

Name badge clue is missing

Charge port in front of driver door (Ford, Chevy), nose (Hyundai, Kia, Nissan), or left tail light (Tesla)
Port displaced into door hinge

Orange denotes high voltage >30 VAC or 60 VDC

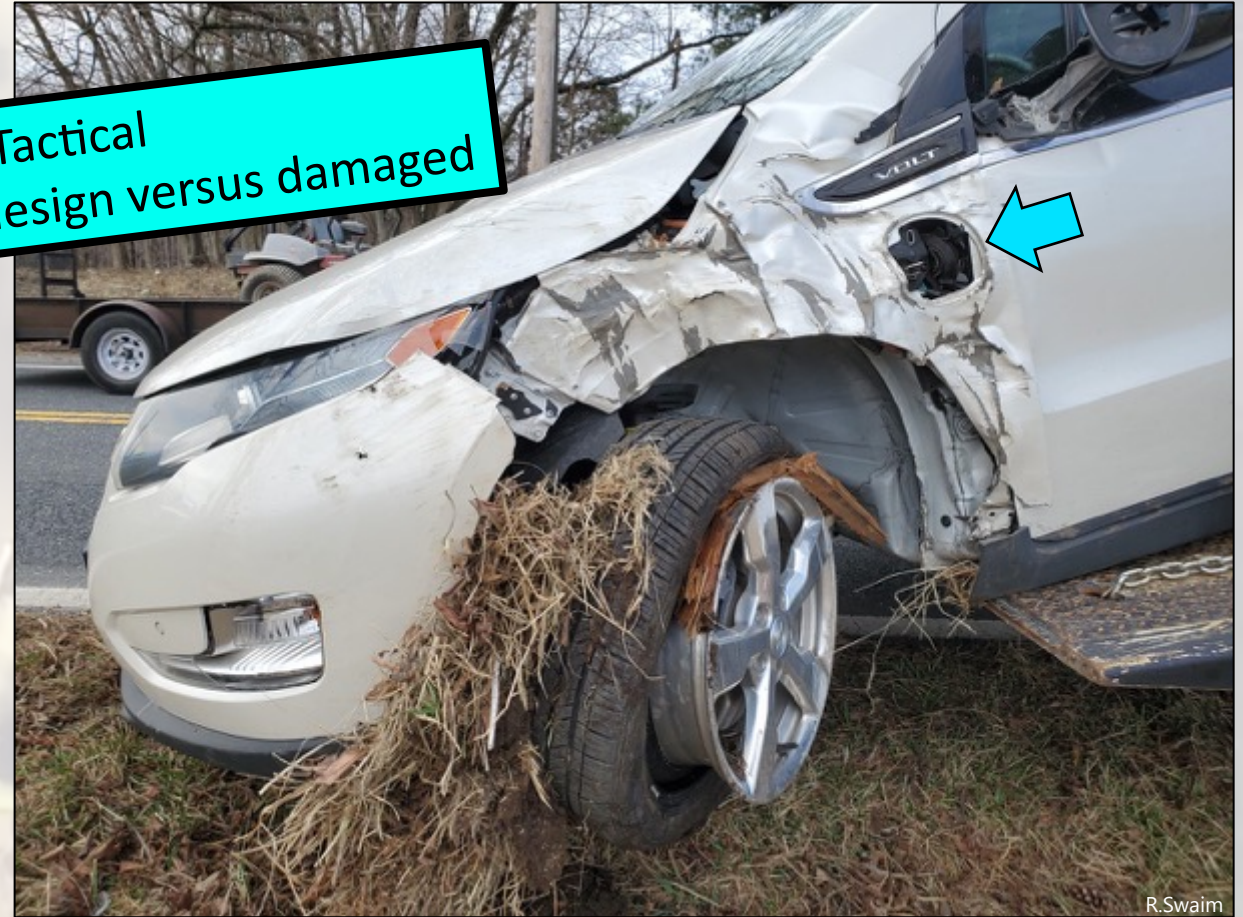


Source: CoPart

Chevrolet Bolt EV

3. Tactical
Concerns about design versus damaged

Shades of orange vary



R.Swaim

Chevrolet Volt hybrid

Seeing leaked "coolant" can indicate damage to the HV battery and extra care should be taken

Disabling the 12 volt battery – Not standardized

Example shows variety of Toyota Prius battery locations

12V battery:
Deploys airbags.
Unlocks doors
Retracts seatbelts
Opens HV contactors

Prius 2003

Prius 2004 & 2010

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Prius 2016

Prius 2012

3. Tactical concern for both ICE & EV:

The 12V battery controls potential hazards so cable must be cut ASAP.
A lack of standards threatens firefighters and victims.

Move key fob or key card far from vehicle

Turn off vehicle

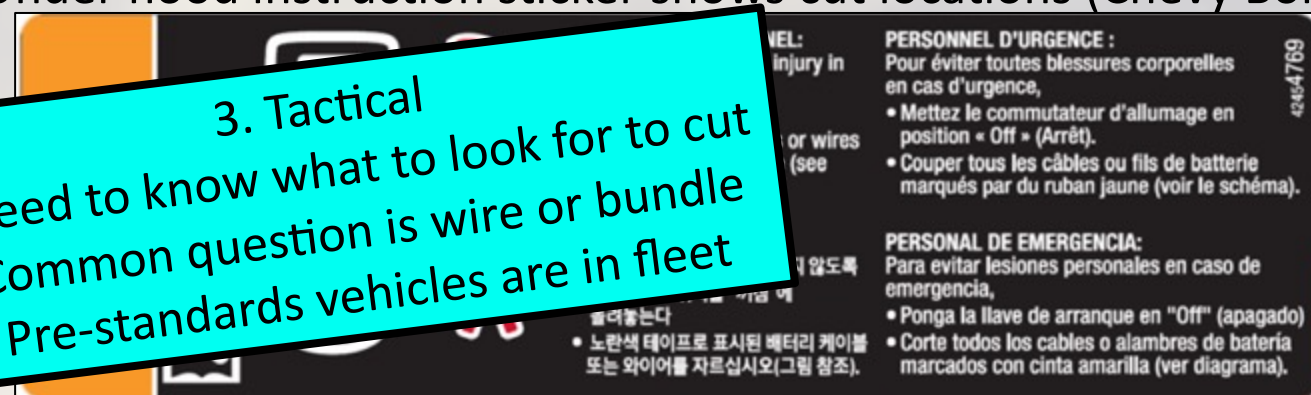
Double cut cables to prevent reconnection

Wait at least a minute before cutting near safety devices after cutting 12V power

Orange means high voltage - Cut loop info

1. Cut loops are control circuits that **do not** contain high voltage
Airbag deployment should have already restricted HV to within the HV battery
2. The helmet and cutter symbol is an ISO standard so look for it
3. **The shades of orange and tag details vary**
4. Fire may burn tag, leaving ERG as means to find the cut loops

Under hood instruction sticker shows cut locations (Chevy Bolt)



Source: Chevrolet

3. Tactical
A. Need to know what to look for to cut
B. Common question is wire or bundle
C. Pre-standards vehicles are in fleet

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Never
cut here

Cut only
at symbol

PHOTO
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Pre-standard exceptions exist



Source: Chevrolet

HV Disconnects are not standardized and may need tools

1. Pull plugs by hand (typically hidden)
2. Cut loops requiring cable cutter
3. Cut loops requiring circular saw
4. Twist knob by hand (typically hidden)
5. Fuse - hard for gloved hand

3. Tactical Variety of HV disconnects

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1. Chevy Tahoe

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4. Ford Escape

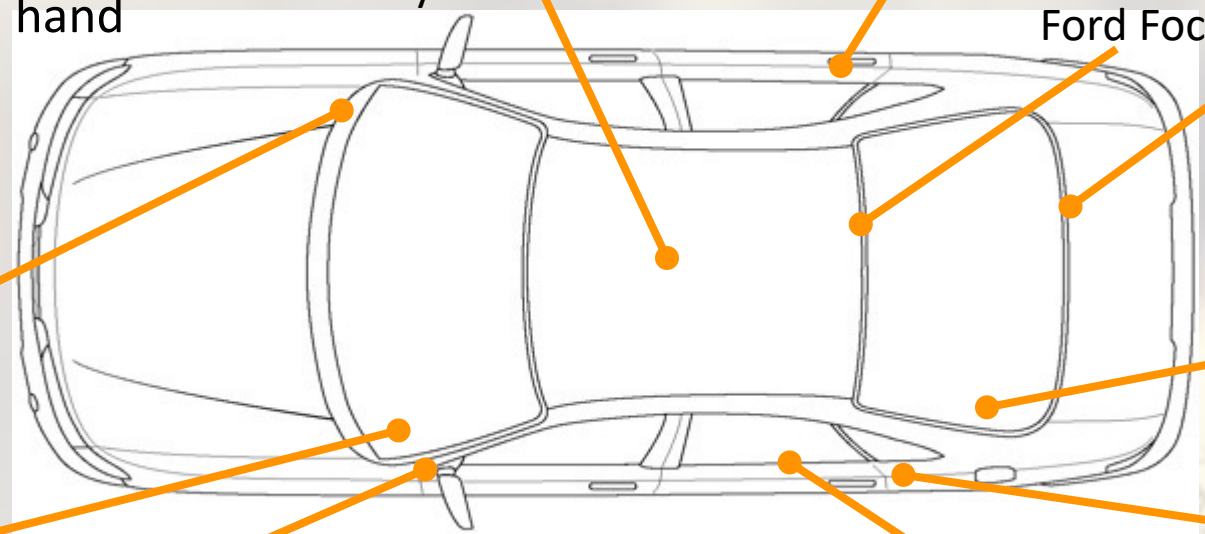


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1. Prius

PHOTO REMOVED

5. Smart EV

PHOTO REMOVED

2. Mercedes

PHOTO REMOVED

1. Highlander

PHOTO REMOVED

3. Tesla secondary cut loop

"Sheets" may lack key details – Try to access full ERG

PRIUS
Emergency Response
Quick Guide
MY: 2016 -

Missing HV disconnect

HYBRID

	IG/POWER SW		Fuse Box		12V Battery
	Airbag (incl. Inflator)		Inflator		High Voltage Battery
	High Voltage Components		Fuel Tank		Gas-filled Damper
	Seat Belt Pretensioner (Gas Generator)		Structural Reinforcements		Airbag Computer
-	-	-	-	-	-

PRIUS50_LHD_1

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PRIUS
Emergency Response
Quick Guide
MY: 2016 -

Disable Vehicle

1. Turn off the power switch (ignition) and the engine. Do not start the engine.
2. Move the vehicle to a safe location, at least 5 m (16.4 ft) or more away from the scene.
3. Disconnect the high voltage battery.

Access to 12V Battery

1. Turn off the power switch (ignition) and the engine.
2. Remove the front wheel cover and the 12V battery cover.
3. Disconnect the 12V battery.

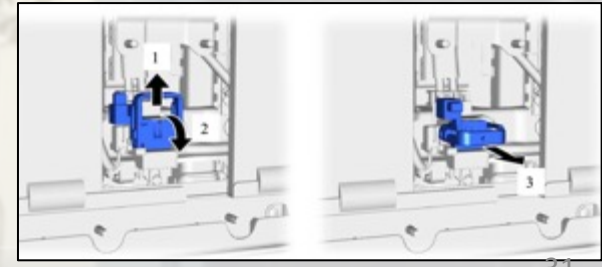
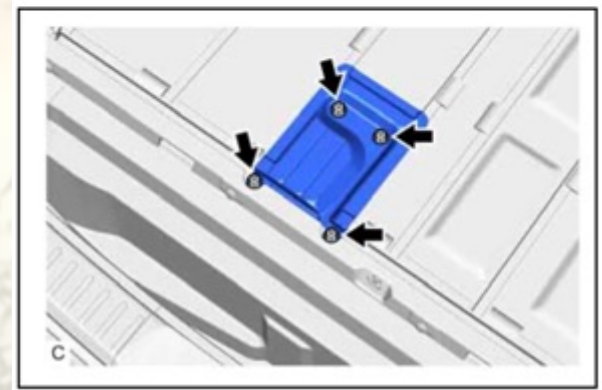
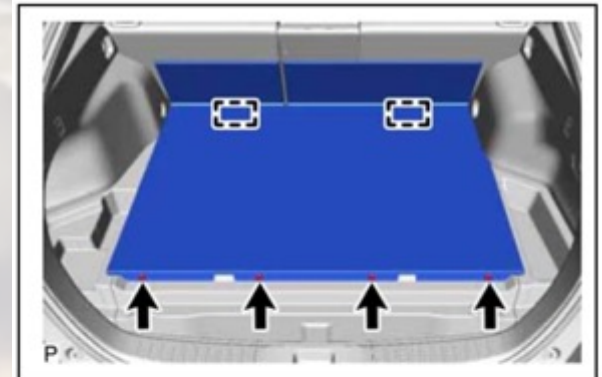
Towing Information

More details, please refer to "Emergency Response Guide".
<http://www.techinfo.toyota.com>

© 2016 Toyota Motor Sales, USA

3. Tactical
Missing detail as mentioned in NTSB study

The full ERG is needed to find the HV disconnect, as shown below



HV - Some disconnects may be impractical to access

Chevy Volt is an example of how impractical some access may be with fire present

- To reach disconnect:
 - Get past victim(s)
 - Open arm rest
 - Remove storage tray
 - Pull back white cover
 - Press a tab
 - Pull out the pull plug



3. Tactical
Potentially inaccessible disconnects with fire or damage mentioned in NTSB study

OR
Cut loop hidden in side wall of trunk



Emergency Response Guides (ERG) show where the disconnects are

Google: NFPA EV ERG

Emergency Response Guides (ERG) have critical answers

ERGs assume user is already fully trained and certified for rescue.

ERGs ONLY provide basic guidance to disable, plus locations of HV components to avoid, such as airbags, inflation cylinders, seat belt pre-tensioners, and areas resistant to cutting.

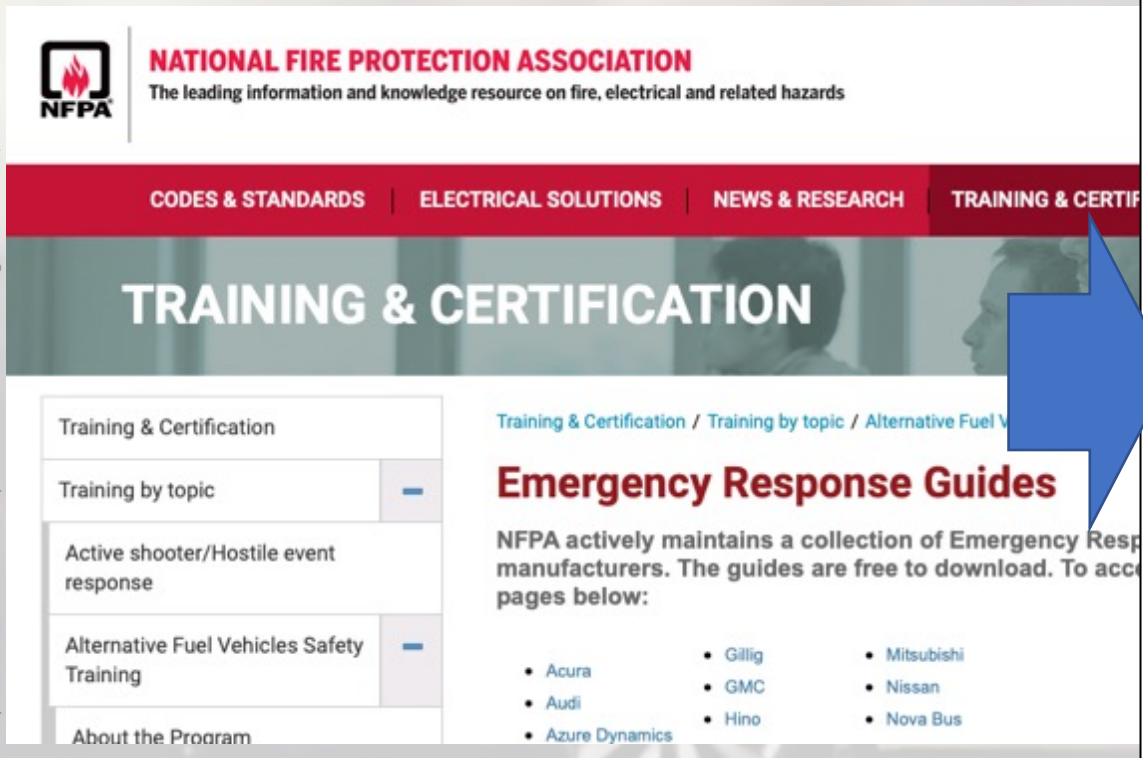
Problem is in variations, even between different manufacturers.

Most ERGs are linked at the NFPA Website

Downloadable response guides from Tesla:

- Emergency Response Guide: Tesla Model S EV 2012 - 2015
- Quick Response Guide: Tesla Model S EV 2012 - 2015
- Emergency Response Guide: Tesla Model S EV 2016 - 2018
- Quick Response Guide: Tesla Model S EV 2016 - 2018
- Emergency Response Guide: Tesla Model S EV Dual Motor 2012 - 2015
- Emergency Response Guide: Tesla Model X EV 2016 - 2018
- Quick Response Guide: Tesla Model X EV 2016 - 2018
- Quick Response Guide: Tesla Roadster EV 2008 - 2009
- Quick Response Guide: Tesla Roadster EV 2010 - 2013

4. Operational FF not yet aware of resources



Minimal electric hazard at hose nozzle

Water shorting of cells within the battery case creates a closed circuit

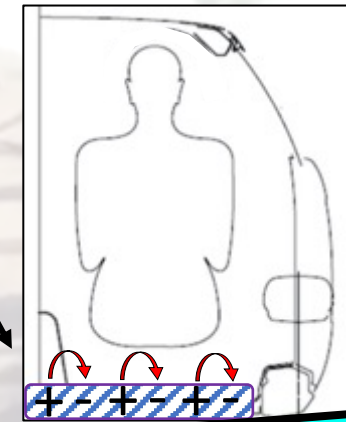
Two examples of test results:

1. <math><0.4V</math> and <math><2\text{ mA}</math> reached nozzle in testing by Maryland Research Fire Institute (MRFI) on electric vehicle batteries up to 400 VDC. (Photos below)

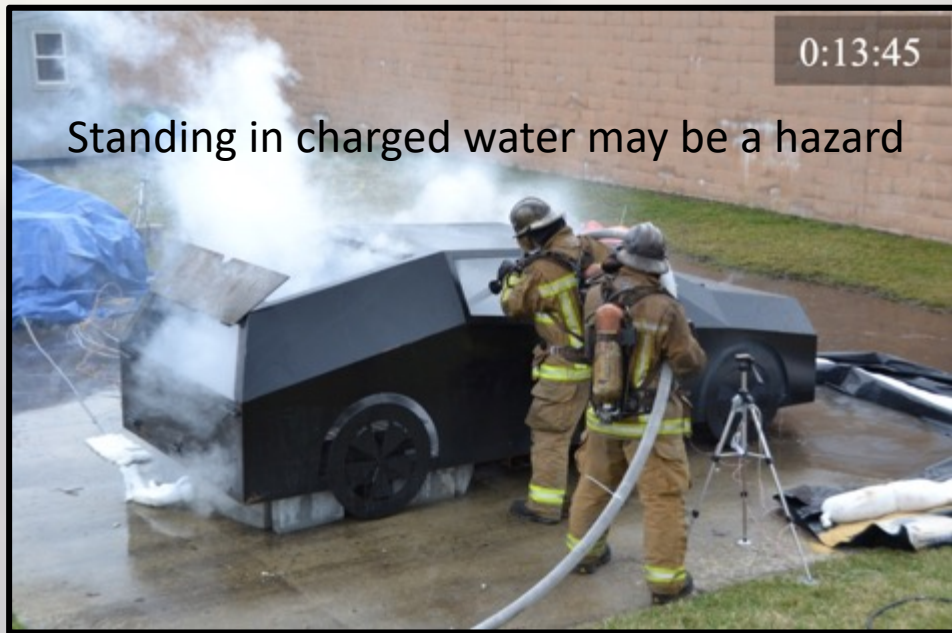
Source: <https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Electrical/EVBatteriesPart2.ashx>

2. Water found safe to use at 10 feet on a 1,000 volt (1 kV) source with jet or spray.

Conclusion of testing by Amped I, LLC, for ConEdison on Feb 3, 2018 pertaining to stationary Essential Supply System (ESS)



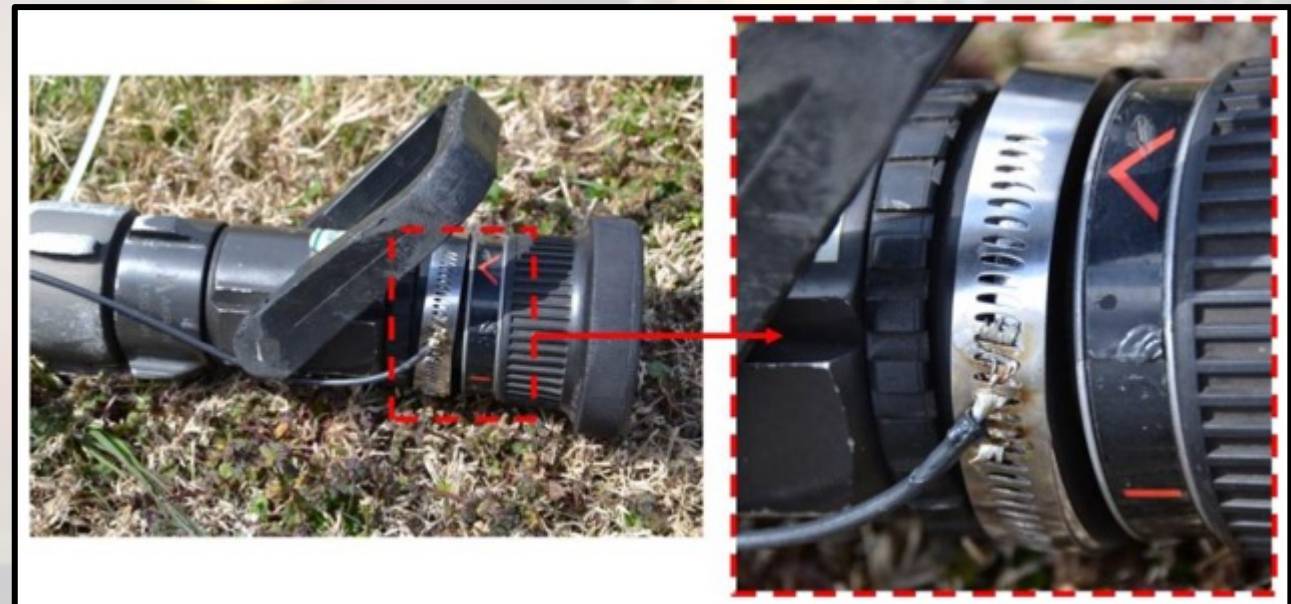
3. Tactical
Major concerns about electrocution hazards



Standing in charged water may be a hazard

Batteries can re-ignite after water drains away
This battery re-ignited 22 hours later

MRFI Measurement of electrical energy reaching nozzle found safe levels of energy

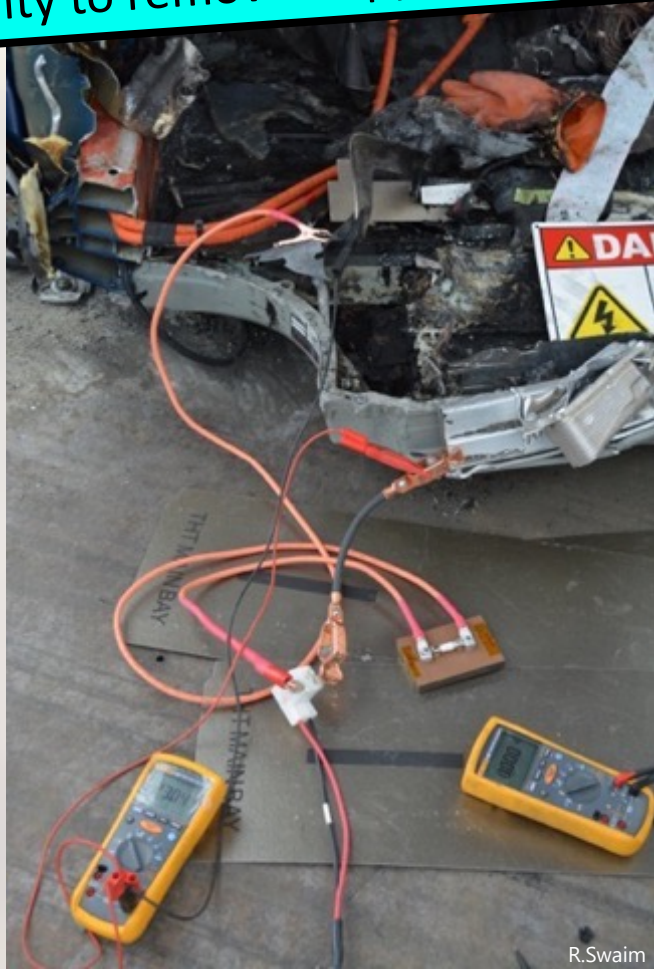


Inability to draw down stranded energy

3. Tactical Inability to remove trapped energy hazard



Factory provided resistor bank could not reach isolated modules



Ad hoc resistor ineffective
Would take weeks



- Saltwater immersion can be effective
1. For the cells/modules the water can reach
 2. Requires a week of time
 3. Can release hydrogen

Cars now have multiple fuels

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Ford Comet

3. Tactical
Be aware of WHAT is burning
Battery? Plastic interior? Surroundings?

Metal

Plastic

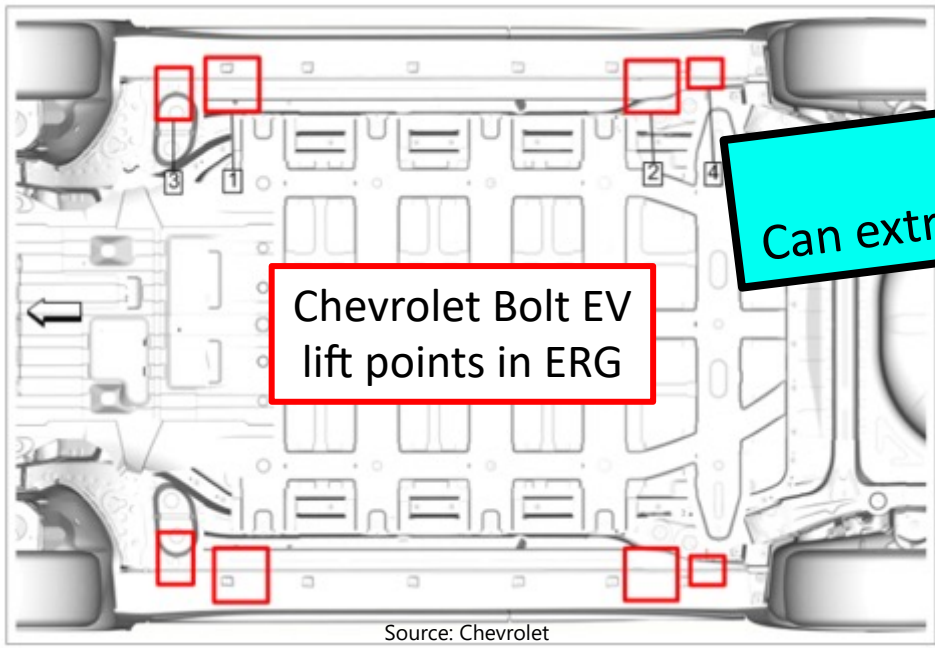
1960	20 Lbs	Plastic plus gasoline
2020	~772 Lbs	Fuel fire then plastic fire Almost 50% volume with only 10% weight

Current car fires are like dumpster fires.
A metal box of burning plastic.

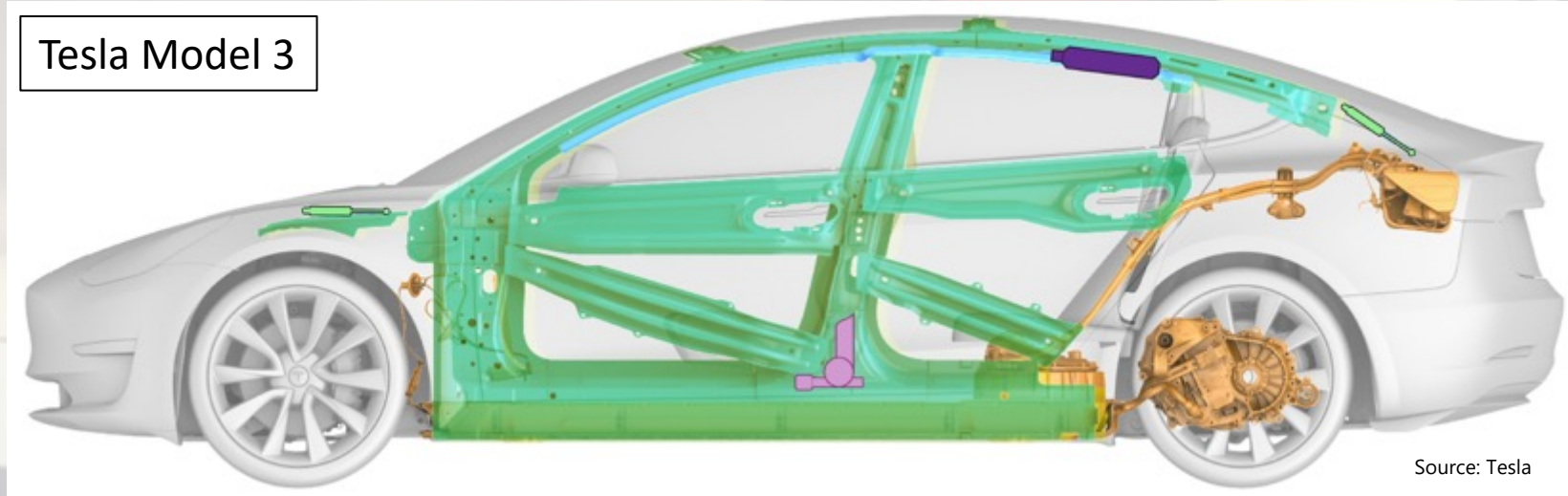
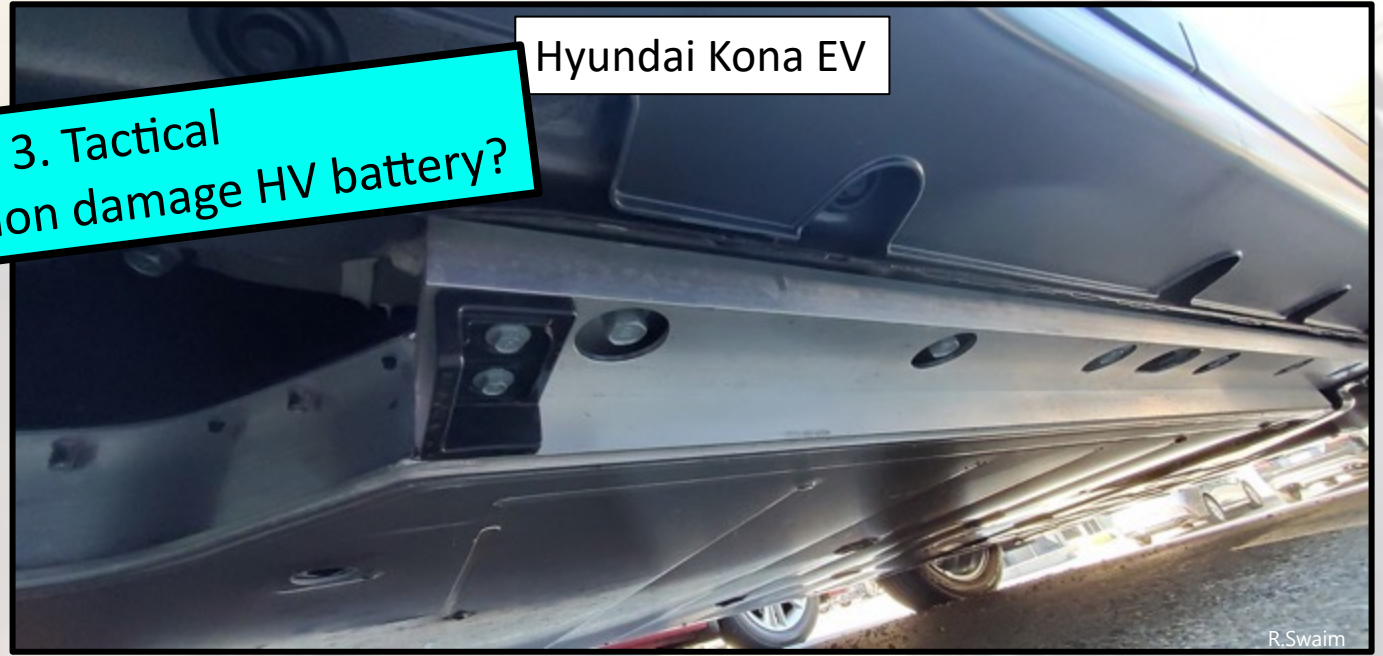
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Lifting and shoring



3. Tactical
Can extrication damage HV battery?

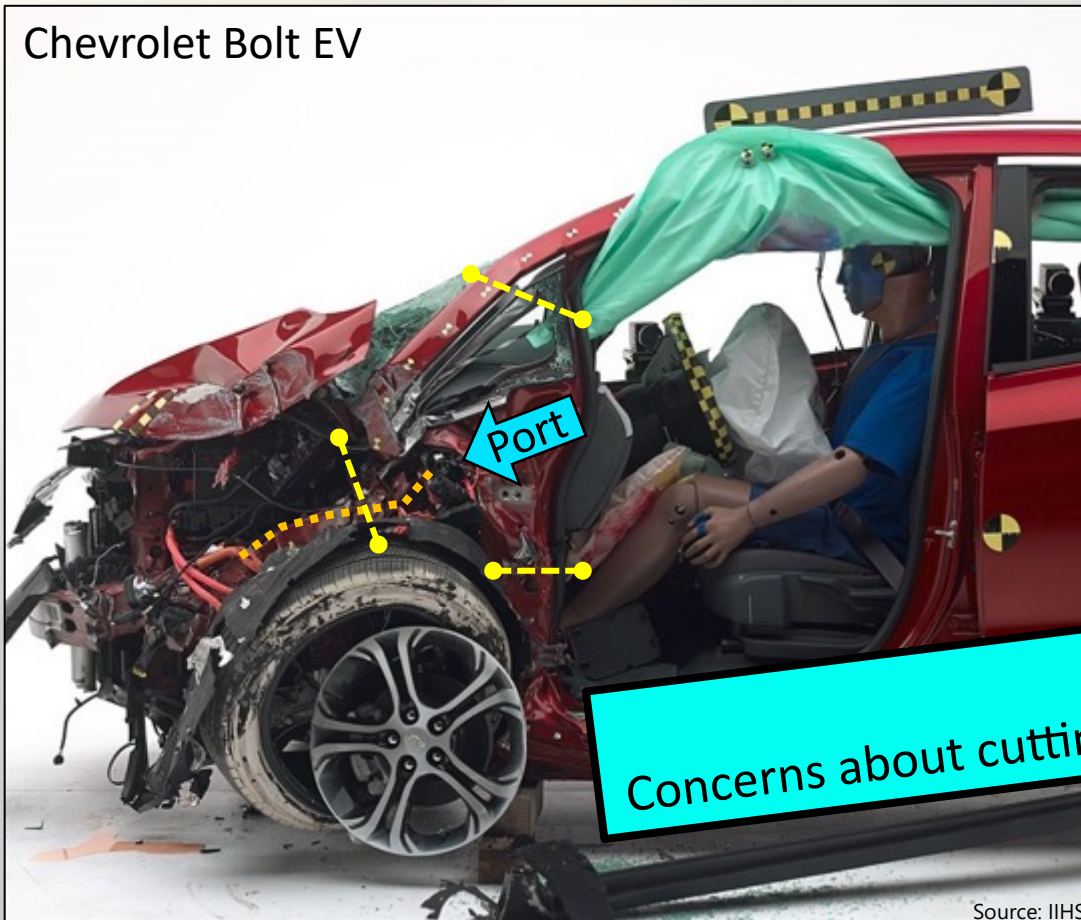


Cuts near charge ports at door hinges and HV cables

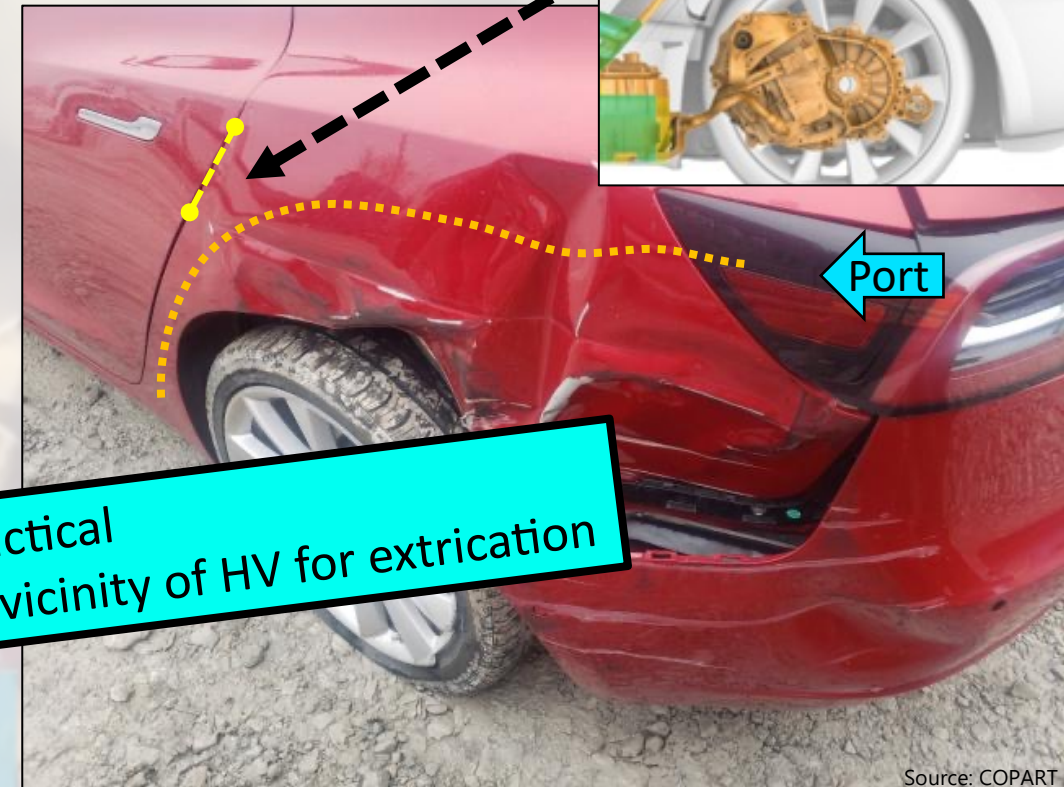
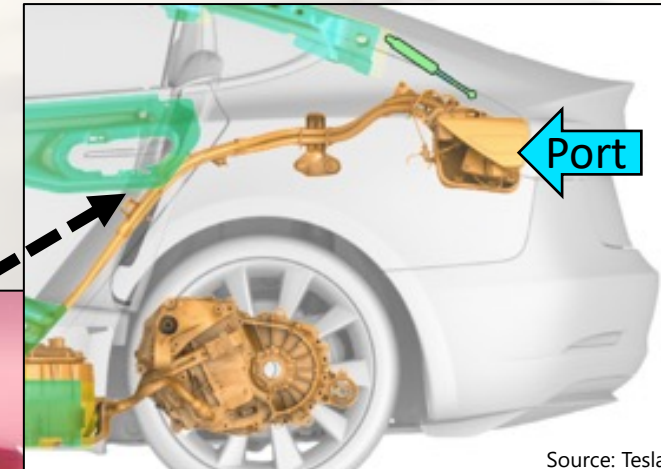
Normally unpowered without charger station providing data signal to BMS

If no ERG and in doubt can cut at B pillar and force door(s) open

Avoid cutting the door sills or rockers



Tesla – HV Cable is in door sill near door catch



3. Tactical
Concerns about cutting in vicinity of HV for extrication

Tesla – ERG will show which models have a secondary FF cut point in rear door sill to isolate the HV battery

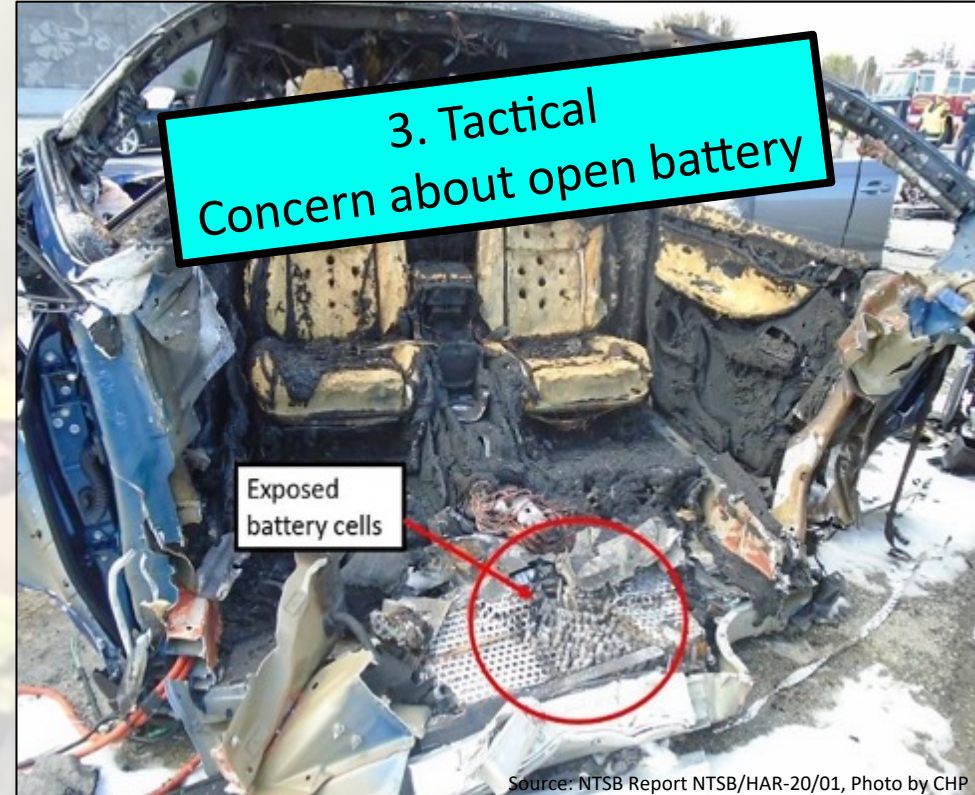
Extrication

Much like any other vehicle once electric aspects are accounted for.
Use the ERG to know where HV hazards are
Be aware of smoke, sound, and leaking fluids!



Fire blanket may be placed over door sill in case battery vents

Fiberglass blanket can add additional (poor) electric insulation layer



Individual cells may launch

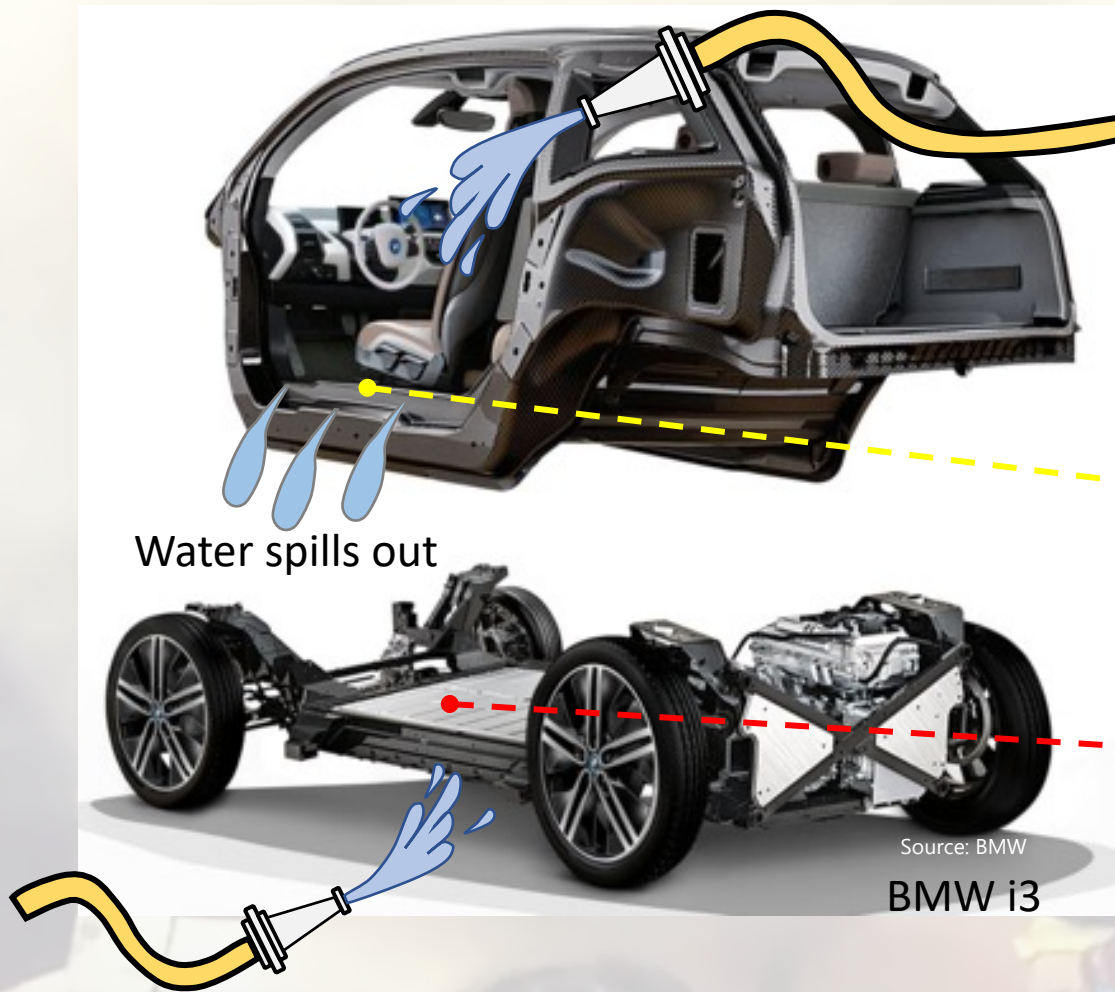
Hazard is the burning electrolyte

Water in vehicle cabin does not reach cells

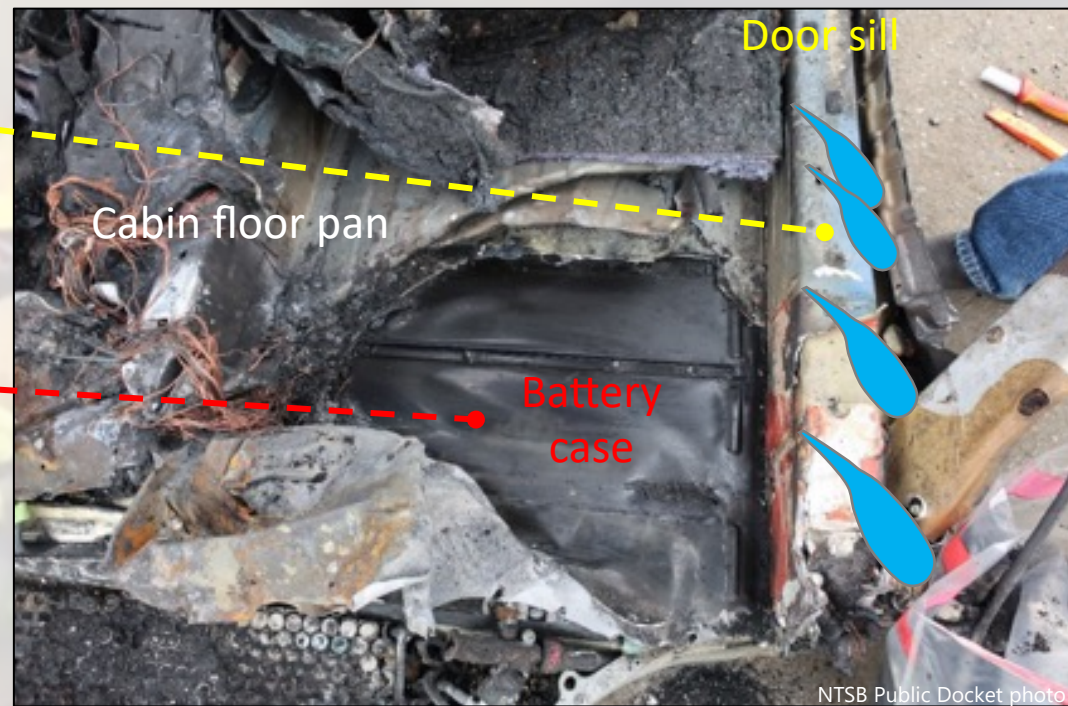
The body is a tub and separate from the sealed battery beneath

3. Tactical How to extinguish a battery fire

This will only address the body plastics fire (Class B)
Because water will not reach cells



Cool the bottom
If the battery is a fuel



Layers between cabin floor
and top of sealed battery case

Try to get water into the battery case if possible

Some new EVs have a designed opening for firefighting. Consult ERG

Concentrate water at exposed cells to flood battery case

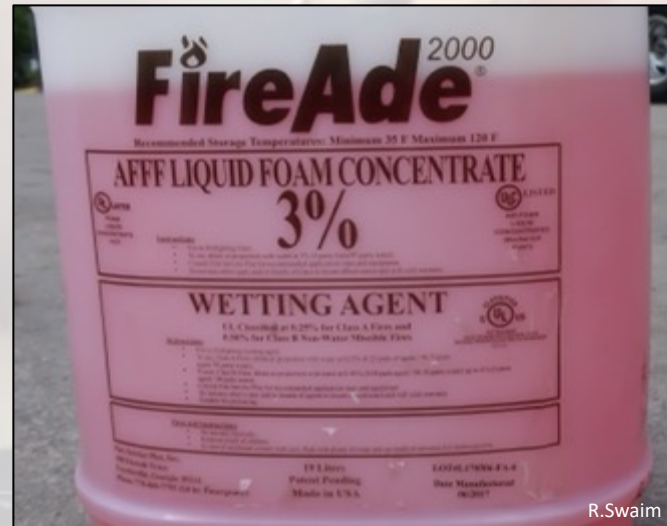
3. Tactical
A. Concern about effective water usage
B. Concern about how to use foaming agents



Venting indicates where case was open

Use only enough to help wet and penetrate

Do NOT to trap heat with foam



Related note – MSDS for Tesla Powerwall ESS recommends getting water into racks

Alternative- Submerge the battery

European method for fast result addresses both battery and plastics

Water electrolysis may create flammable gas after removal

3. Tactical
Awareness of an effective alternative



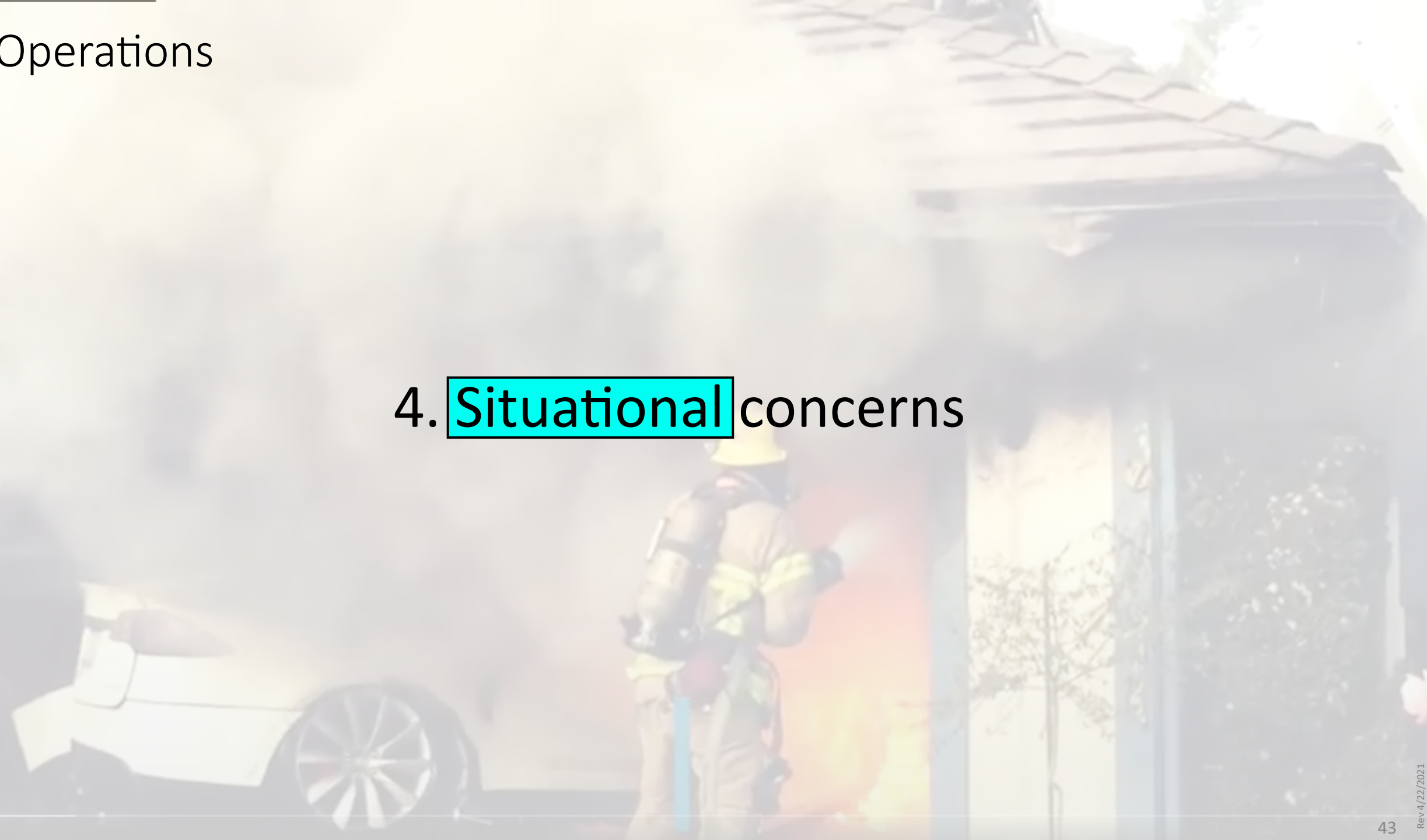
Purpose built

Ad hoc using a dumpster

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Adding salt to water has been used to drain trapped energy with time

4. Situational concerns



How to fit into existing firefighter work flow

Two major accomplishments for EV firefighters:

2015: ISO 17840 - Information For First And Second Responders, Road Vehicles

0. Rescue Sheet(s)

1. Identification / recognition

2. Immobilisation / stabilisation/ lifting

3. Disable direct hazards / safety regulations

4. Access to the occupants

5. Stored energy / liquids / gases / solids

6. In case of fire

7. In case of immersion

8. Towing / transportation / storage

9. Important additional information

10. Explanation of the used symbols

2018: NFPA collected manufacturer emergency information

4. Situational
Firefighters know this work flow
so EV responses need to fit into it

Background: When & where have EVs caught fire?

Over half of cars burnt were on charge or not moving

Most vehicles were under two years old

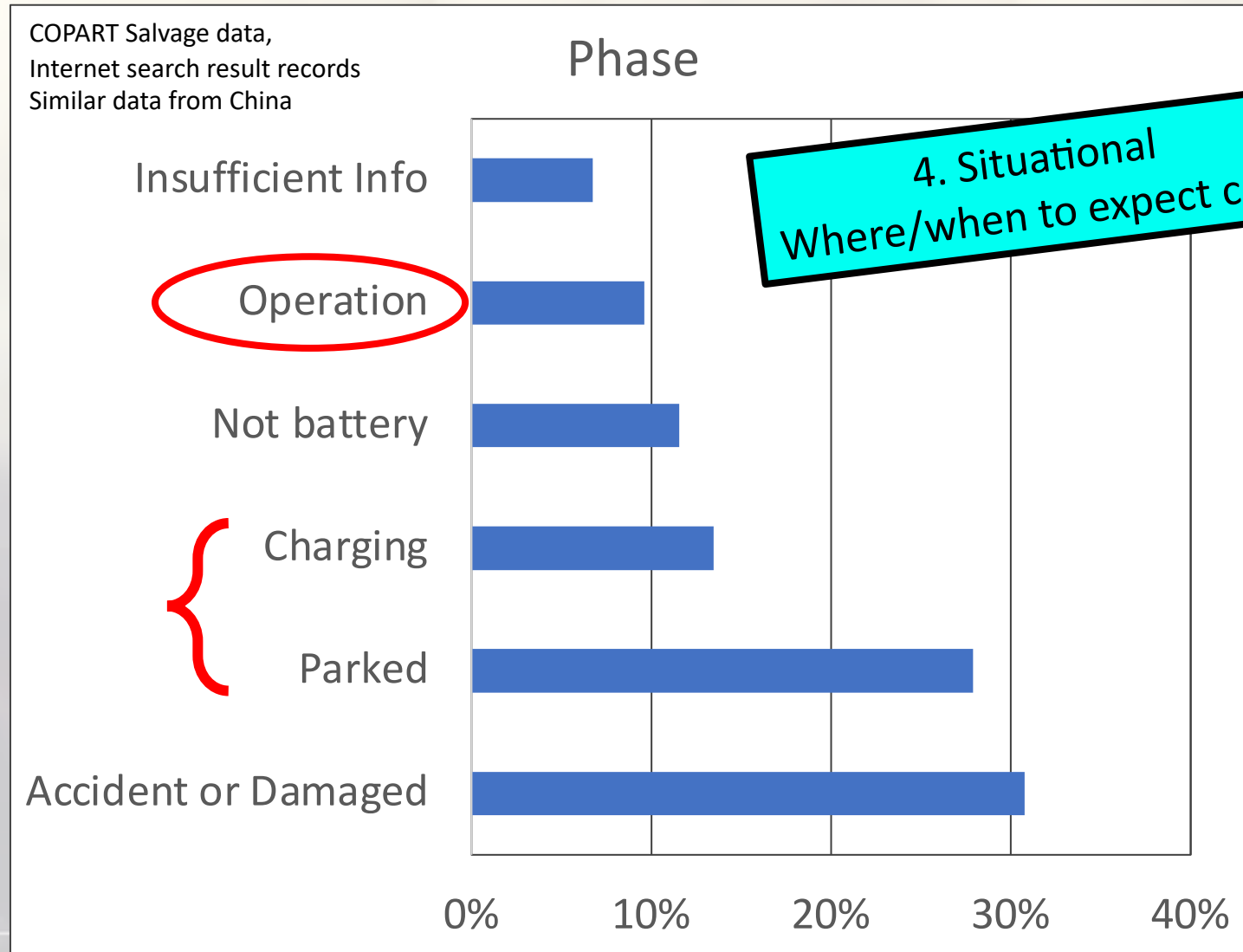


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Hyundai Kona,
Montreal,
July 2019

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Background: Which burn more often?

No data separates the electric from gasoline drive components

Sample of total (not just burned) U.S. salvage vehicles equipped with traction batteries*

Tesla	142
Toyota Prius	679
Lexus	122
BMW	54
Infinity	9
Mercedes	5
Acura	4
Volvo	2
Cadillac	1
Jaguar	1
Total Hybrid	833

Only fully electric vehicle on list

4. Situational
Data does not
differentiate
12V Battery versus
HV battery versus
ICE engine



Prius ICE engine fires led to recall

Damaged Volt 12V battery
ignited surrounding materials

* Copart data obtained 6/20/2019 regarding salvage vehicles with fire loss for all reasons, including arson and adjacent to other fire. Photos by Copart

Complacency is a FF concern

Salvage records show only 1 in 143 wrecked EVs experienced fire

Note: This does not mean they became salvage due to fire.

Typical EV accident

The driver walked away
No smoke
No fire

4. Situational
Complacency due to low ratio of fire events



* Copart data obtained 6/20/2019 regarding salvage vehicles with fire loss for all reasons, including arson and adjacent to other fire

Give battery-powered vehicles space

Venting and thermal runaway – NO explosions – Exceptional bad day example

Clue to move away fast:

Watch for flash of van tail lights,
venting sound,
smoke,
pressurized vent flames

Watch for quieter periods
followed by venting of
additional modules

Watch for truck fuel shift from
plastic to battery venting

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4. Situational
Video shows how bad situation can get
and how much room is needed

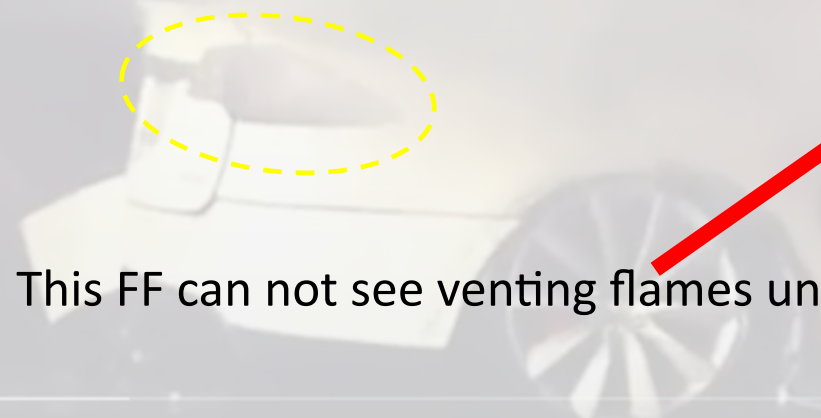
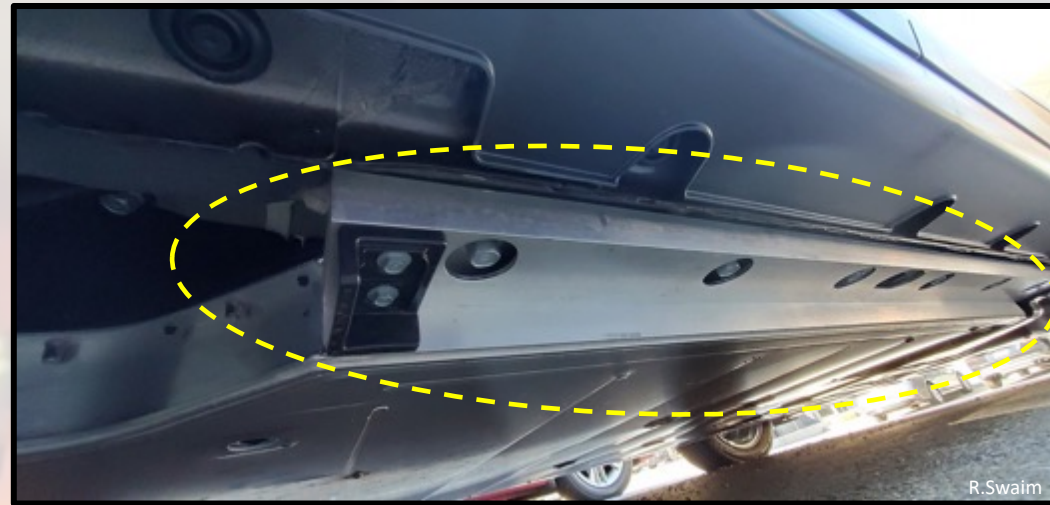
Should vehicle first be immobilized or moved?

Potential to do injury
Potential structures to ignite
Need space to work

4. Situational
Need for continuous oversight because firefighters will press forward

Confined space

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2020, Hyundai Kona, Korea

This FF can not see venting flames underneath

Once in place, always block the wheels to prevent movement.
EVs have electronic controls and car can move silently

Extinguish

Think of individual fuels

Key for battery is to stop or slow propagation between cells

Aggressive Method: Plan on LOTS of water
(ABC Dry chemical is ineffective)

or

Defensive Method: Let it burn out if isolated

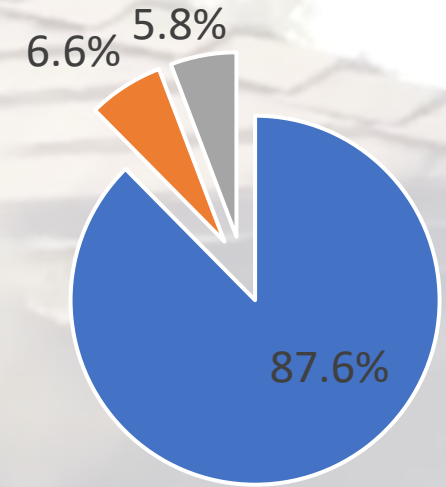
4. Situational
- A. EV responses need to continually be aware of what fuel is burning. The background photo has three separate fuels in the battery, plastics in car, and house structure.
- B. Responders have two opposite ways to deal with EV fires

1 in 8 EV fires are commercial vehicles

Trucks and busses

Bigger batteries operating with or near greater numbers of people

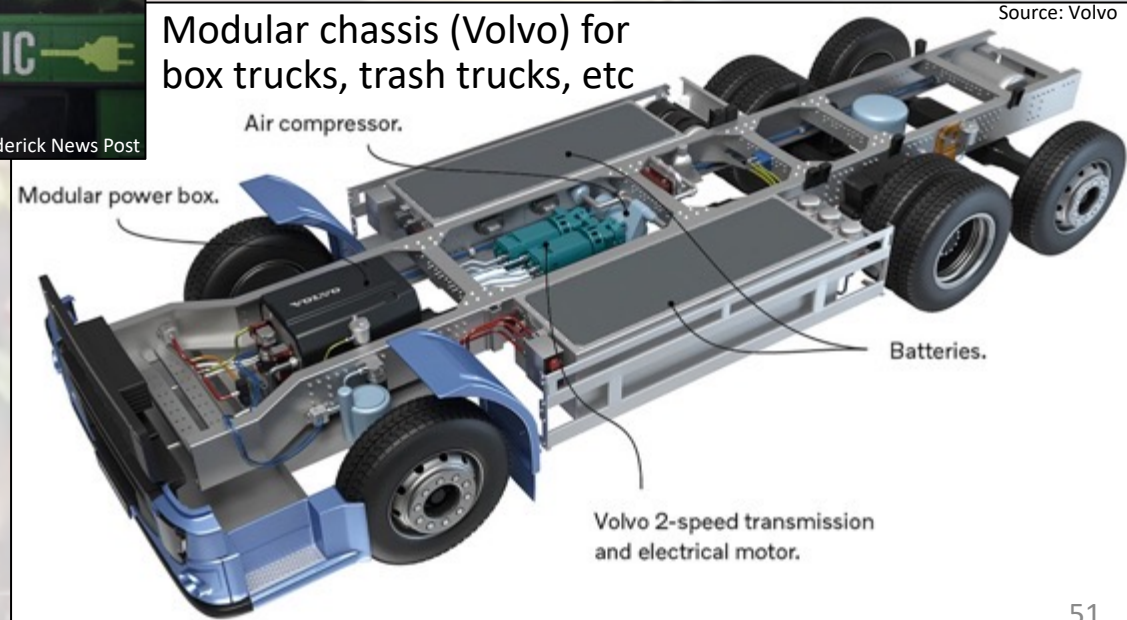
By Vehicle Type



■ Car/Pickup ■ Bus ■ Truck



4. Situational
Most people are unaware of commercial EVs



Li-Ion already unseen in use on busses, trucks, and rail

Replacements for lead acid and Ni-Cad non-traction batteries

Cab controls, HVAC, and radios for 6 hours (advertised)

4. Situational concerns
Smoke from large formats with passengers, in tunnels
limits vehicle access, may limit battery access

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Plan responses:
In a tunnel?
With smoke?
Flame?
Passengers?
Third rail?

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Concern about large batteries being introduced

- Lithium hybrids in US market as yard engines
- Commuter light rail
- Locomotives used in Europe
- Caterpillar locomotive up to 2.2 MW
- GE up to 2.4 MW



4. Situational
About here students' eyes get big



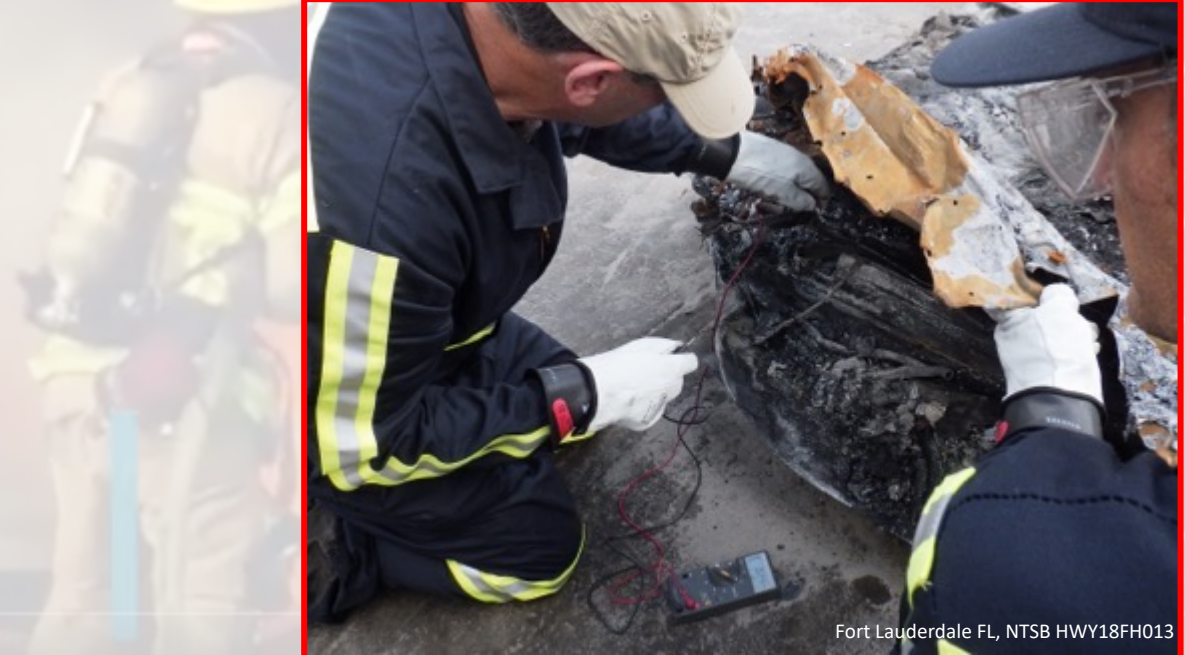
GE Transportation's Battery-Electric Locomotive

Massive power generation capabilities up to **2400 kWhrs**

Huge fuel savings of at least **10-15%**

GE Transportation

Summary and Investigating an EV fire



UNDERWRITERS LABORATORIES®

- Thank you for your time.

-

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