National Transportation Safety Board

NTSB Investigations of EV Fires

Electric Vehicle Safety IWG
Global Technical Regulation Session 16

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Agenda

- Introduction of NTSB
- Investigations into electric vehicle fires
- Supporting Data
- Factual Observations/Open Questions

(At this point we can only provide factual data and pose questions.)

National Transportation Safety Board

- Independent U.S. Federal Agency (not part of DOT)
- Investigate accidents and incidents involving transportation in all modes:
  - Office of Aviation Safety
  - Office of Railroad, Pipeline, Hazardous Materials
  - Office of Marine Safety
  - Office of Highway Safety
- Develop factual conclusions and safety recommendations

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Office of Highway Safety

- Field Investigations
- Major Investigations
  - Vehicle, Roadway, Human Performance, Motor Carrier, Survival Factors, Reconstruction, Recorders
  - Public meeting, final report adopted by Board, public docket
- Special Investigation Report (SIR)
  - Previous: Tire Safety, Pedestrian Safety, Forward Collision Avoidance Systems, Commercial Onboard Video Systems, Rear Seat Safety
  - Current: Electric Vehicle Safety, Autonomous Vehicles


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Electric Vehicle Safety Is A World Issue

E-bus fire during operation (USA)

BMW i3 in Norwegian test (Norway)

Electric Smart car on charger (UK)

Zotye taxi in operation (China)

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NTSB Special Investigation Began With:

Lake Forest, CA: August 25, 2017 (HWY17FH013)

Then added 5 NTSB field investigations

- Las Vegas, Nevada: November 8, 2017 (HWY18FH001)
- Culver City, CA: January 23, 2018 (HWY18FH004)
- Mountain View, CA: March 23, 2018 (HWY18FH011)
- Ft. Lauderdale, FL: May 8, 2018 (HWY18FH013)
- West Hollywood, CA: June 15, 2018 (HWY18FH014)

Initial Investigation: Lake Forest, California

Tesla Model X struck culvert, then home, post crash fire

- Ignited house
- Unable to extinguish
- Burn/smoke for 5+ hours
- Re-ignited on tow truck
- Re-ignited at tow yard

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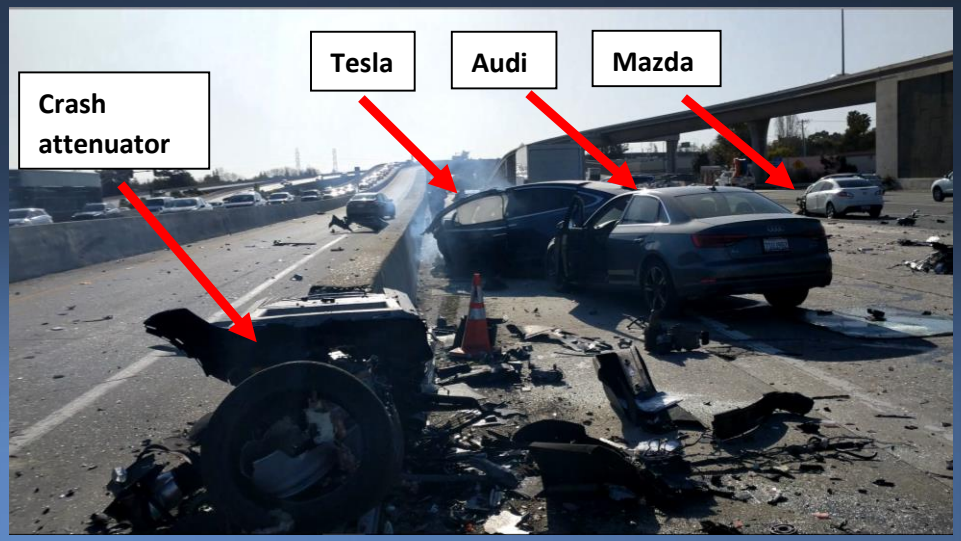
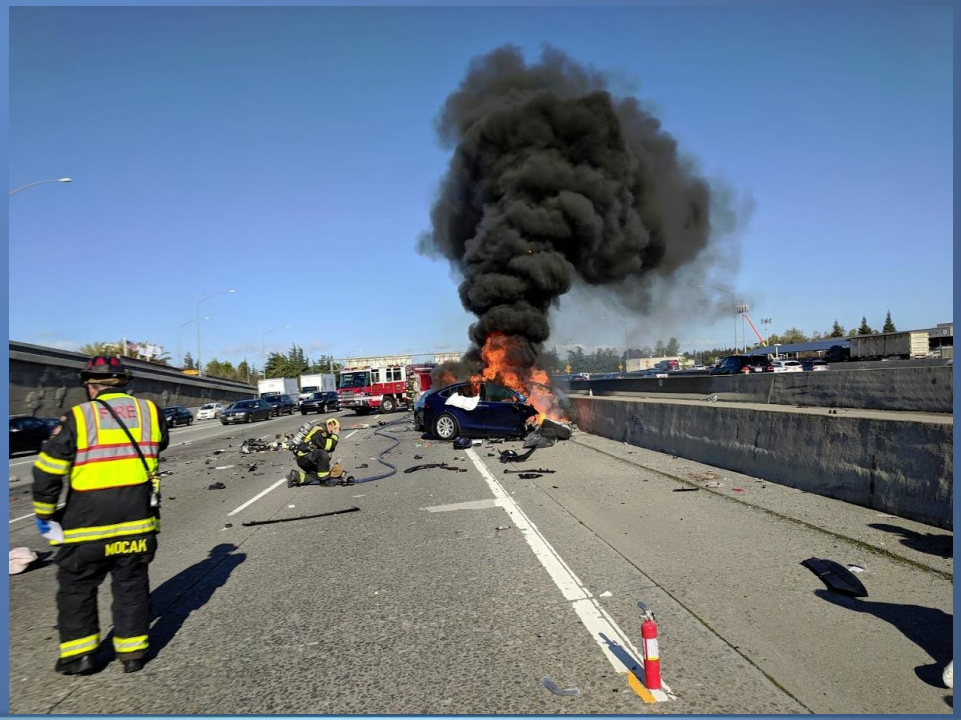
Mountain View

- Tesla Model X in “auto-pilot: mode, struck attenuator/gore area and other cars
- Fire extinguished quickly on scene
- High voltage and fire safety concerns closed important highway for hours
- Re-ignited twice at tow yard, days later





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Ft. Lauderdale

- Tesla Model S struck wall and pole at high speed
- Battery case ruptured, immediate fire into cabin
- Fire initially extinguished quickly
- Re-ignited during loading on tow truck
- Re-ignited again at tow yard

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West Hollywood

- Tesla Model S primary battery fire while driving in city
- Driver pulled over, got out, recorded event, called Tesla
- Fire fighters put out flames quickly, smoke continued
- Fire fighters removed panels, severed cut loop, smoke continued
- Concern for re-ignition but did not re-ignite
- Battery pack needed removal and disassembly to drain residual energy

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Investigations include

Fires with battery case damage

- Lake Forest, California
- Mountain View, California
- Ft. Lauderdale, Florida

"Spontaneous" fires with no crash

- West Hollywood, California

Accidents with no fire

- Las Vegas, Nevada
- Culver City, California
- South Jordan, Utah

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Establishing Supporting Data Set (~30 Cases, others being evaluated)

Numerous reported EV fires are not related to primary battery

For example:

- Numerous Toyota Prius ICE fires
- BMW i3 range extender (ICE) fires
- Arsons against a series of Teslas
- Automobiles burned for TV & media
- Elect fires external to primary battery

Nissan Leaf instrument panel

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Supporting Data-Set Includes
(Includes some not in USA)

17 Tesla fires (currently)

Numerous Teslas without fire →

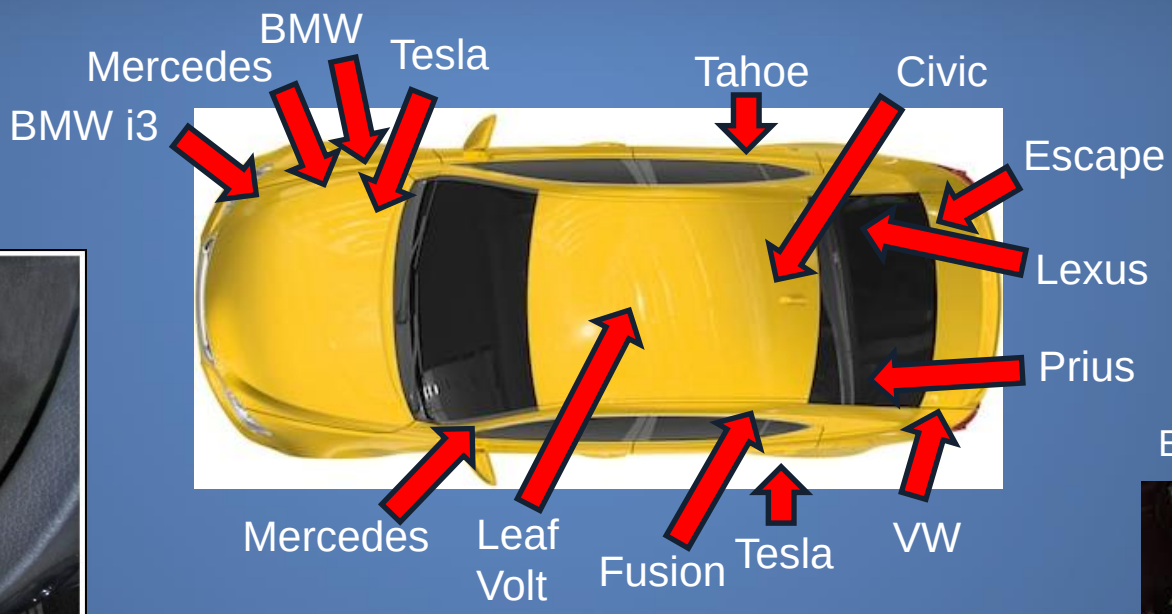
Fires involving other manufacturers

- BMW
- Smart
- Multiple busses
- VW →

Numerous EV/HEV/PHEV without fire

Observations #1 and 2: HV Disconnects

#1: No standardized location(s) for responders; various pull-plug and cut-loop methods; Many require some disassembly for access
(note: gasoline fill ports on ICE vehicles are vulnerable)



Example: Mercedes C

Example: Prius

#2: External markings not required for firefighters
(Rescue unsure if car is safe can delay extrication, examples being evaluated)

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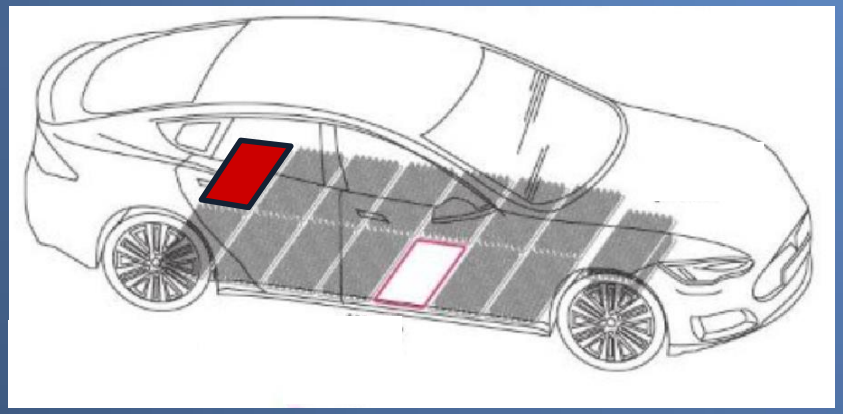
Design to minimize thermal propagation

- Protected battery location
- Armored cases
- Narrow walls between modules to minimize heat transfer
- Electric isolation of damaged/runaway cells
- Separation of cells into isolated modules

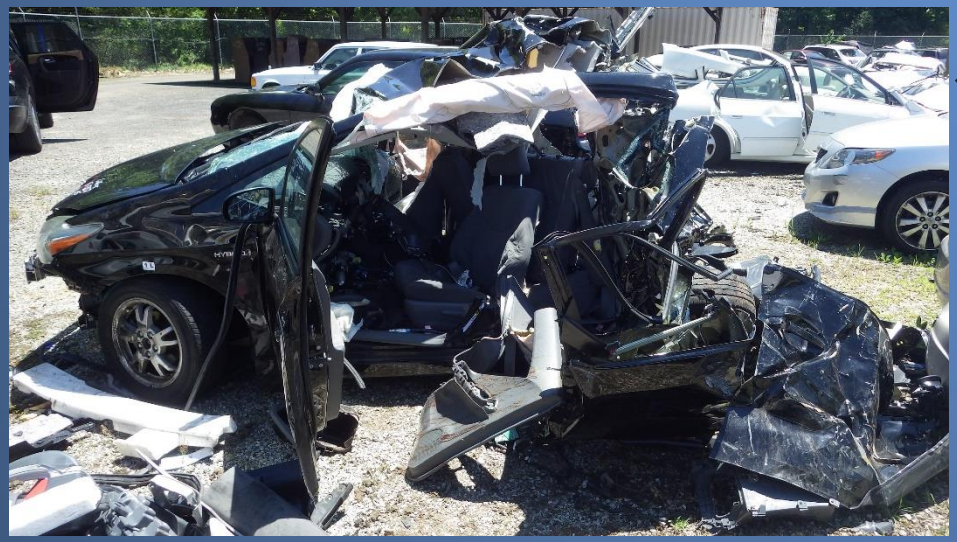
(Physical damage causes trapped electrical and chemical energy at module level. Threat requires battery removal and disassembly.)

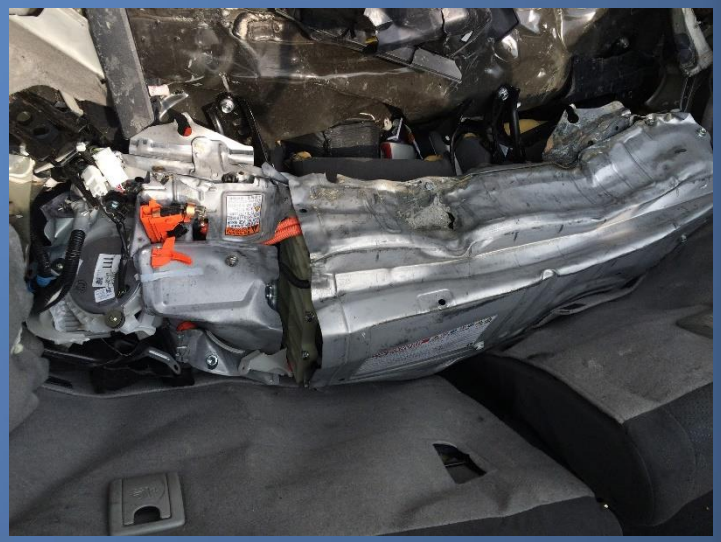


Tesla with no fire – Culver City

NTSB Major Investigation of Multivehicle Crash
(Chattanooga TN, June 25, 2015)

- Semi-truck impacted Pius at about 80 mph in a traffic que
- Crushed Prius battery
- No fire or smoke





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Observation #3 and #4: Design Mitigation

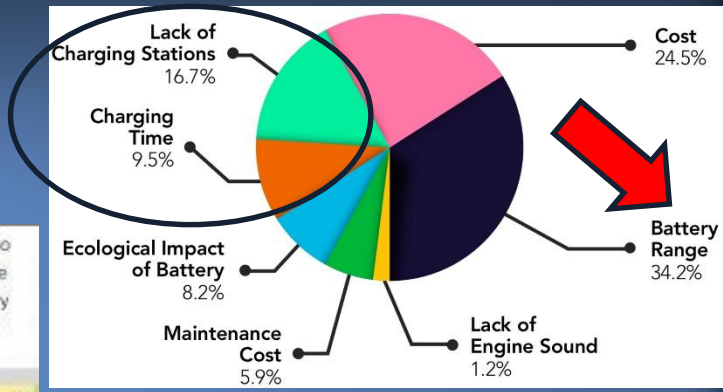
#3: Mechanical deformation of case defeats design protections

#4: Without physical protections, some chemistries still have not resulted in fire or thermal propagation

Severe Chevrolet Volt and Prius crashes without fire

Chemistries are selected for range and other design targets

Buyers want range, ability to charge, and rapid charging as top priorities

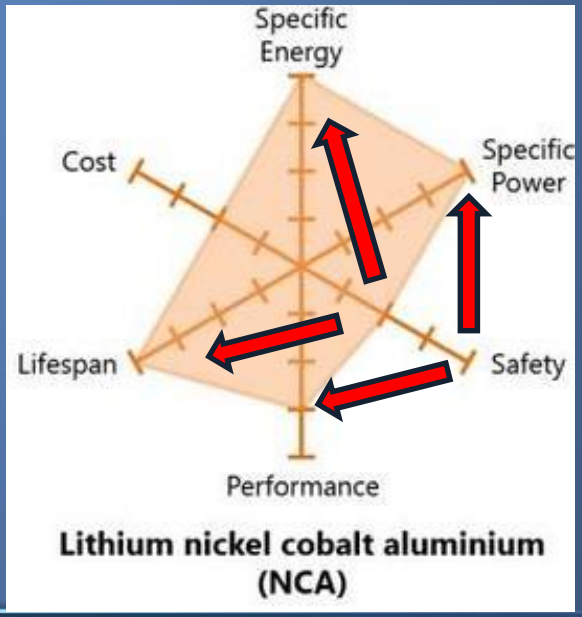


Comparing All Available Electric Vehicles

www.GreenThenSolar.com

	Price		Miles on a Charge	Time to Charge Battery (hrs on 240V)
2014 Tesla Model S (85kWh)	$88,000	Large Car	265	12
2014 Tesla Model S (60kWh)	$81,000	Large Car	208	10
2014 BYD e6	$52,000	Small SUV	127	6
2014 Mercedes-Benz B-Class	$50,000	Midsize Car	87	3.5
2014 Toyota RAV4 EV	$48,000	Small SUV	103	6
2014 BMW i3 BEV	$46,500	Subcompact Car	81	4
2014 Honda Fit EV	$37,500	Small Station Wagon	82	4
2015 Fiat 500e	$32,000	Minicompact Car	87	4
2015 Nissan Leaf	$30,000	Midsize Car	84	8
2014 Ford Focus Electric	$28,000	Compact Car	76	3.6
2015 Chevrolet Spark EV	$27,000	Subcompact Car	82	7
2014 Mitsubishi i-MiEV	$23,500	Subcompact Car	62	7
2014 Smart fortwo electric drive	$23,500	Two Seater	68	6
2013 Scion iQ EV	Not Available	Minicompact Car	38	4

Price data from www.kbb.com, www.truecar.com; Other data from www.fueleconomy.gov



Lithium nickel cobalt aluminium (NCA)

Goals may require flammable chemistry

(images from internet graphics)

Observation #5: Current EV Population

No Fires

Nissan Leaf
- > 300K
- No known battery fires

Prius
- > 1.5 million
- No known primary battery fires in service

Chevrolet Volt
- > 200 K
- No known primary battery fires in service

Fires

Tesla
- ~ 350,000
- 17+ fires (0.005%)

Busses, Various Makes
- Unknown fleet size
- At least 4 fires

LiFan 650EV

BMW i3
- ~ 100 K
- At least 3 fires

#5: There is a difference in these groups. Can we differentiate and should we? (NHTSA contracted with Sandia Labs – looking at defining acceptable limit of flammability and protection)

Emergency Response Guides

"Battery fires can take up to 24 hours to extinguish"

"**Consider allowing the battery to burn** while protecting exposures."

"A burning or heated battery **releases toxic vapors**. These vapors may include volatile organic compounds, **hydrogen gas**, carbon dioxide, carbon monoxide, soot, particulates containing oxides of nickel, aluminum, lithium, copper, cobalt, and hydrogen fluoride."

"Responders should always protect themselves with full PPE, including a SCBA, and take appropriate measures to **protect civilians downwind from the incident**."

"…at least one hour before the vehicle can be released to second responders…"

"It can take **approximately 3,000 gallons of water**, applied directly to the battery, to fully extinguish and cool down a battery fire"

Tesla Powerwall and Cabinet Material Safety Emergency Guide

- Virtually all fires involving lithium-ion batteries can be controlled with water. To date, water has been found to be the most effective agent for controlling lithium-ion battery fires. Water will suppress flames and can cool cells, limiting propagation of thermal runaway reactions.

- If possible, direct the application of water towards openings in the battery pack enclosure, if any have formed, with the intent of flooding the pack enclosure. **The objective is to contact the surfaces of the affected and surrounding individual battery cells with water.**

(Note: Temperatures required to melt separator materials for thermal runaway are greater than 100 C (boiling water)

Other users of Li-Ion chemistries

- Maritime industry and others (buildings) require ability to flood cells
- Fire department hose connectors are standardized
- A study for the New York Fire Department found "... extinguishing requirements for batteries need not be excessive if an intelligent, system-level approach is taken that includes external fire ratings, **permits direct water contact**, and implements internal cascading protections..."
- Large General Electric installations have flooding capability

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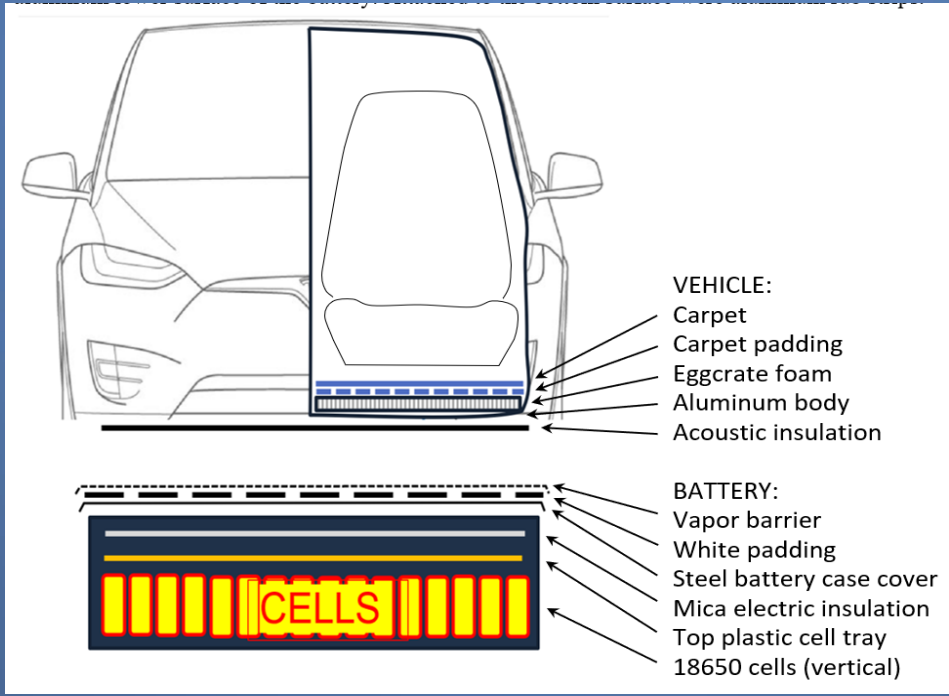
Observation #6 and #7: Guidance

Vehicles / Batteries are designed to shed water

#6: Water is effective only when it can get to the cells

#7: If cooling is not accomplished, resources and hazards can multiply



Hours of smoke and potential re-ignitions?

Data set includes examples of:

- Confined spaces (Note tunnel below)
- Injuries to first responders, potentially to public
- Lengthy closures of large areas for hours and of highways
- Potential injuries and damage to second responders
- Re-ignition has occurred six days after accident

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Thank You!

QUESTIONS?

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