

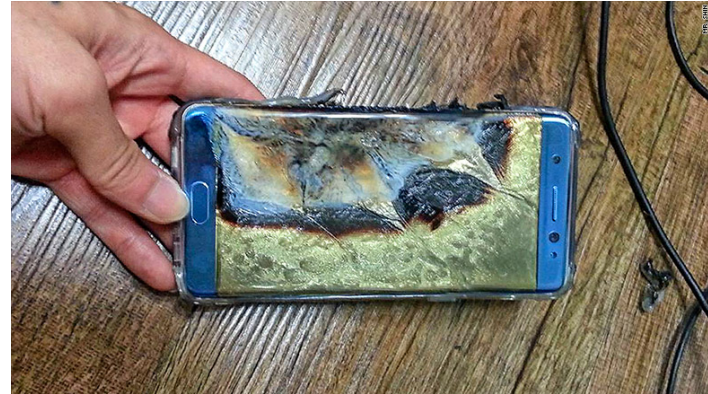


# **What can we Learn from the Samsung Galaxy Note7 Battery Safety Event**

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# Samsung Galaxy Note7 Smartphone Recall



- Launch globally date: August 19, 2016
- Full recall date: October 13, 2016
- Product name: Samsung Galaxy Note7 smartphones
- **Hazard:** Lithium-ion battery in the Galaxy Note7 smartphones overheat and catch fire, posing serious fire and burn hazard to consumers.
- **Units: 1.9 Millions**

Source: US Consumer product safety commission

# Samsung Note7 Incidents/Injuries

- 96 reports of batteries in Note7 phones overheating in the U.S.,
- Samsung has received 13 reports of burns and 47 reports of property damage associated with Note7 phones.



The Galaxy Note 7 implicated in dramatic Jeep and house fires, reports say



# iPhone Mobile Phone Battery Explosion 2016



**An Apple iPhone 6 exploded in cyclist's pocket**

“I saw smoke coming out of my back pocket... I was completely bewildered about what it was. All of a sudden I felt a surging pain in my top right leg. I heard a kind of a snap and I could feel the thing melting through my shorts”.



# Moli Energy – Lithium Metal Battery Explosion - 1989

- Moli Energy Canada was the first to mass produce lithium metal rechargeable 18650 cells on 1988
- Used in Cellular phones in Japan
- Explosion of a cellular phone battery in the face of a customer lead to a recall of 1.5M cells in 1989
- Shown to be safe in the lab
- Root Cause – Lithium metal plating during charge – Dendrites that led to a short circuit and thermal run away
- The recall and compensation to injures lead to bankruptcy of the company



# Sony Laptop Battery recall 2006



P/N

Lot Number

**Cost for Sony: 1B\$ estimate**  
**7 million 18650 cells affecting 6 PC makers**  
**These lithium ion batteries can overheat, posing a fire hazard to consumers**

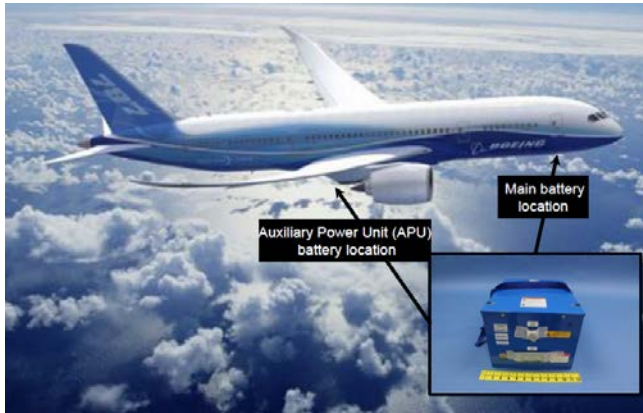
# Nokia Recall Cell-phone Batteries 2007



**Cost for Nokia: 150M\$ estimate**

**BL-5C Panasonic batteries to have internal short circuit  
These lithium ion batteries can overheat, posing a fire  
hazard to consumers**

# Boeing Dreamliner Battery Fire 2013



**Cost for Boeing: 600 M\$ estimate**  
**Expected smoke event: 1 every 10 millions flights hours**  
**Cause: Internal short circuit in one cell**



# Why that is happened?

External Short circuit

Internal Short circuit

- Particle
- Dendrites
- Separator failure
- Impact/puncture

Overcharge

Overdischarge

External Heating

Mechanical Damage

Elevated Temperatures  
Generate Heat

Heat Dissipation <  
Heat Generation

Thermal Run Away

Vent, Flaming Vent

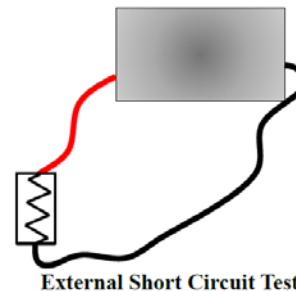
Rupture

Fire

Heat Dissipation >  
Heat Generation

Safe!!!

Leaking of  
Noxious or acid  
gasses, Strong  
acids,  
Flammable  
gasses and  
liquids

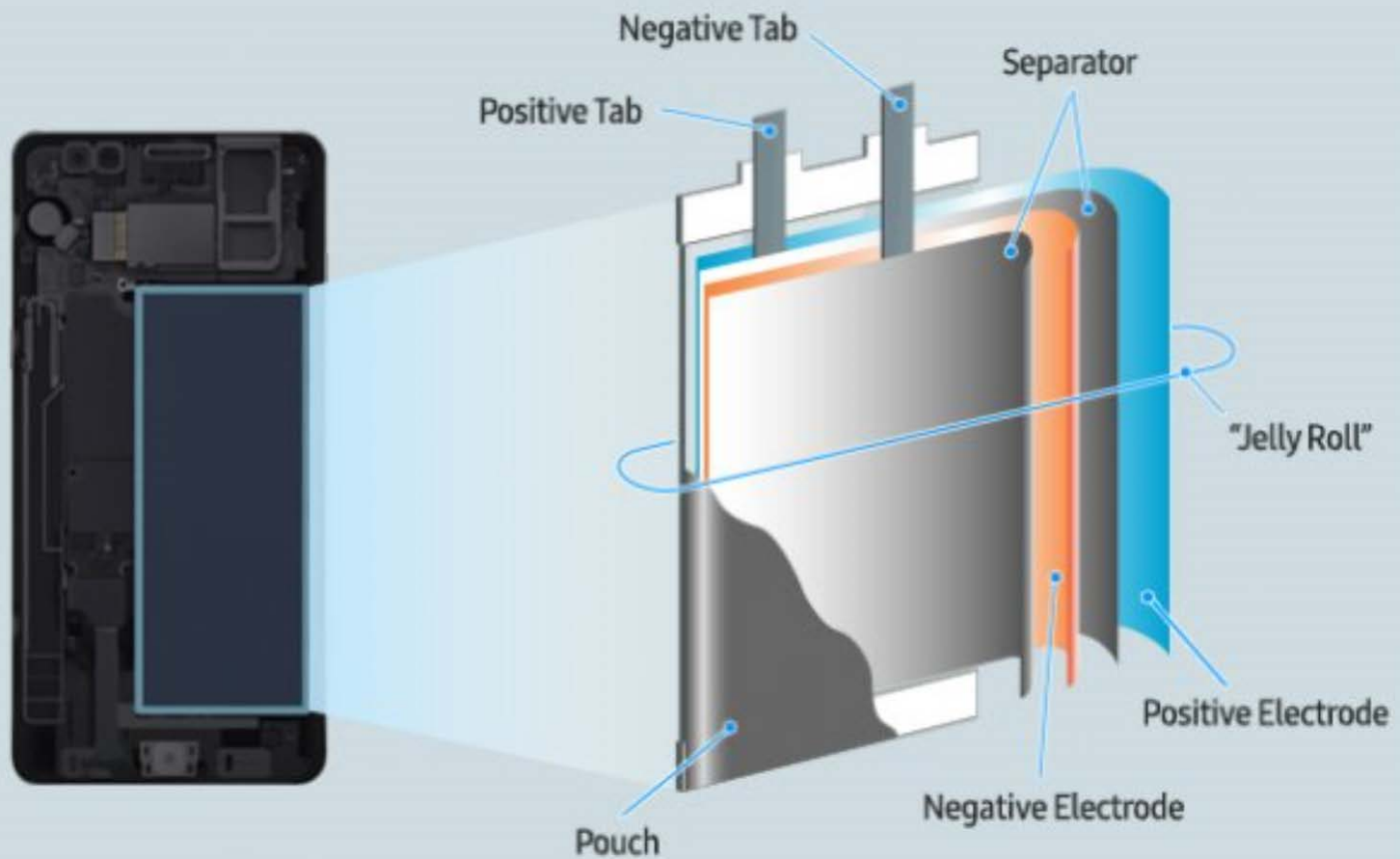


# What Cause the Samsung Galaxy Note7 Safety Problems

- **Samsung didn't disclose officially the battery safety root cause till 1/2017 – My personal assumption was:**
- **Samsung used a high energy cathode for maximizing the battery energy density**
- **Thin separator was used for freeing volume for more active materials**
- **Charging the battery cause some sort of lithium metal plating as a dendrites at the end of charge – May be due to fast charging capability of 10 min charge for 4 hour battery run time**
- **On some cases lithium dendrites penetrate the thin separator and cause Internal short circuit, heat and fires**

# Li-Ion with Wound Internal Construction

Lithium-Ion Battery Structure



# Samsung Galaxy Note 7 Battery Hold an Impressive 3,500mAh Despite its Slim Profile



An estimation of 250 WH/kg and 700 Wh/l at cell level – that is the highest energy densities known for smart phone batteries !!!



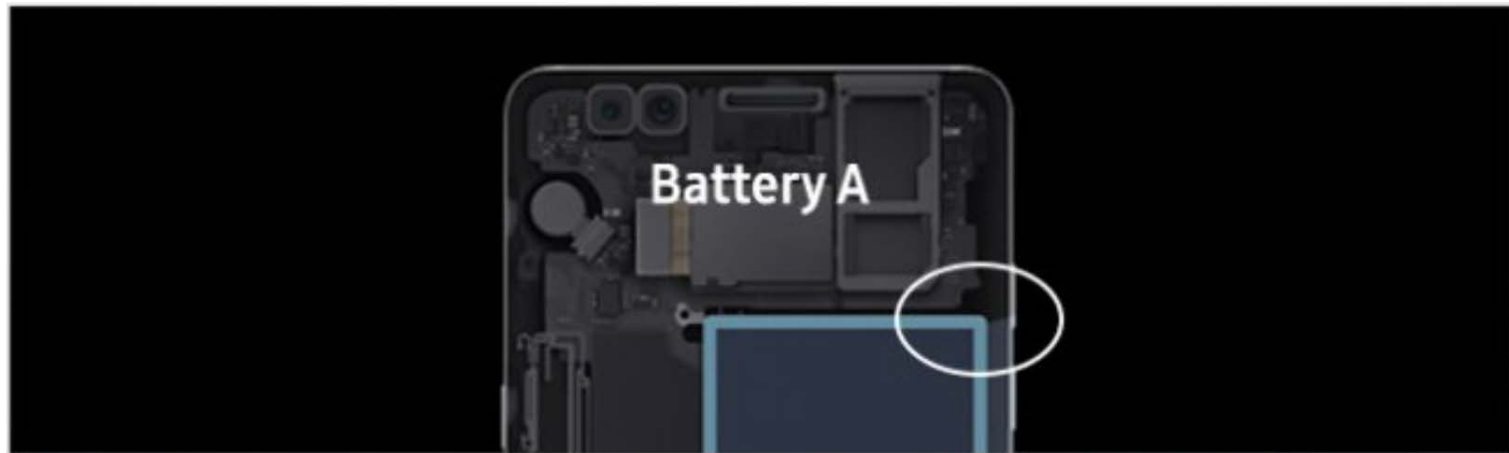
# **Samsung Reaction**

- **2/9/2016 First recall of Galaxy Note7 used Samsung Korea made batteries and replaced it by Galaxy Note7 used ATL china made batteries (65/35 supplier split Samsung SDI/ATL)**
- **15/9/2016 After reports of the same safety events with the Galaxy Note7 used ATL china made batteries Samsung halted that recall**
- **Then Samsung stop marketing the Note7 and to concentrate on full worldwide recall for not taking any extra risks for customers safety**
- **Samsung start with internal investigation supported also by 3<sup>rd</sup> experts**

**Samsung took the responsibility**

# **Samsung Official Investigation Results 22/1/2017**

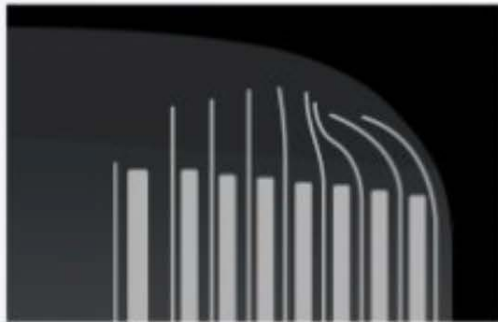
- **Samsung said over 700 researchers and engineers spent months analyzing 200,000 Note 7 devices and 30,000 Note 7 batteries**
- **Samsung conducted an internal review and sought independent reviews from UL, a safety science organization, Exponent, a US-based consulting and engineering firm and TuvRheinland, a German-based company**
- **Samsung Electronics has found internal short circuiting in Galaxy Note 7 batteries caused the phones to heat up and catch on fire**



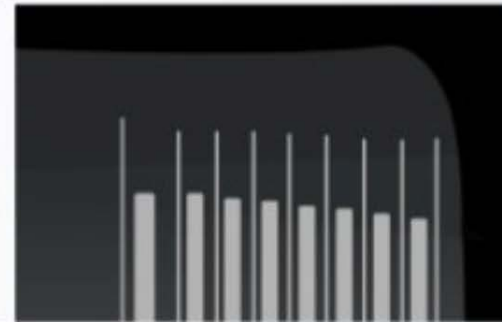
**Abnormal**

**Normal**

Main Cause



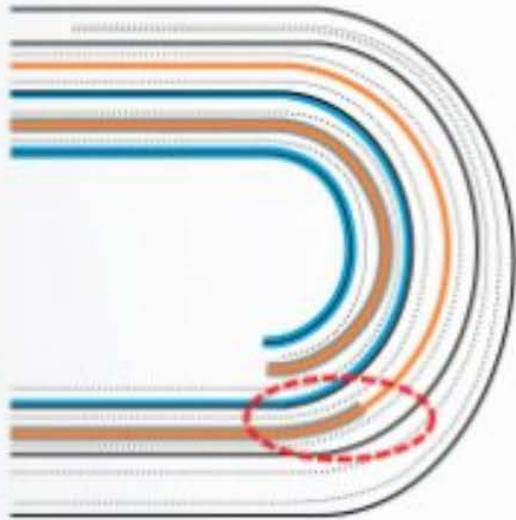
The negative electrode was deflected in the upper-right corner of the battery



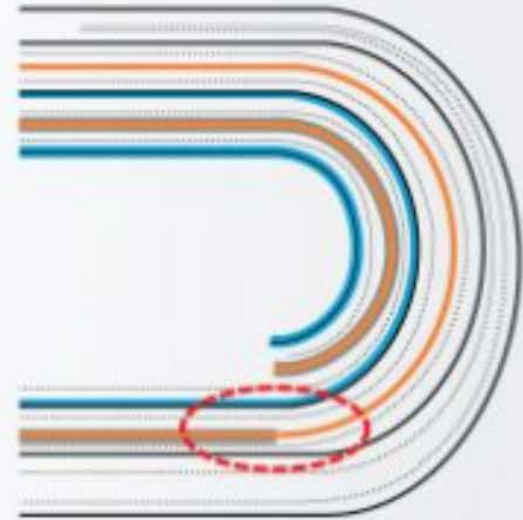
The negative electrode is not deflected

There was an issue with the upper right hand corner of the battery cell. “The main cause for the incidents was deflections in the negative electrodes

## Additional contributing factor



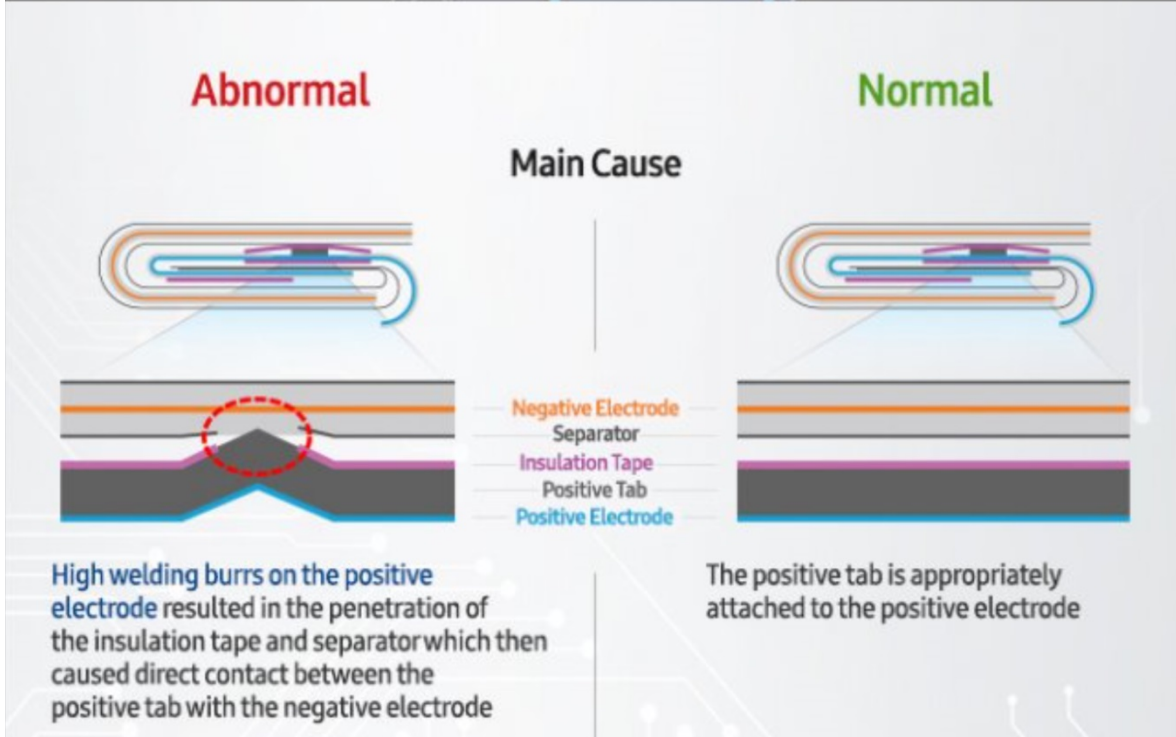
The tip of the negative electrode was incorrectly located in the curve, not the planar area



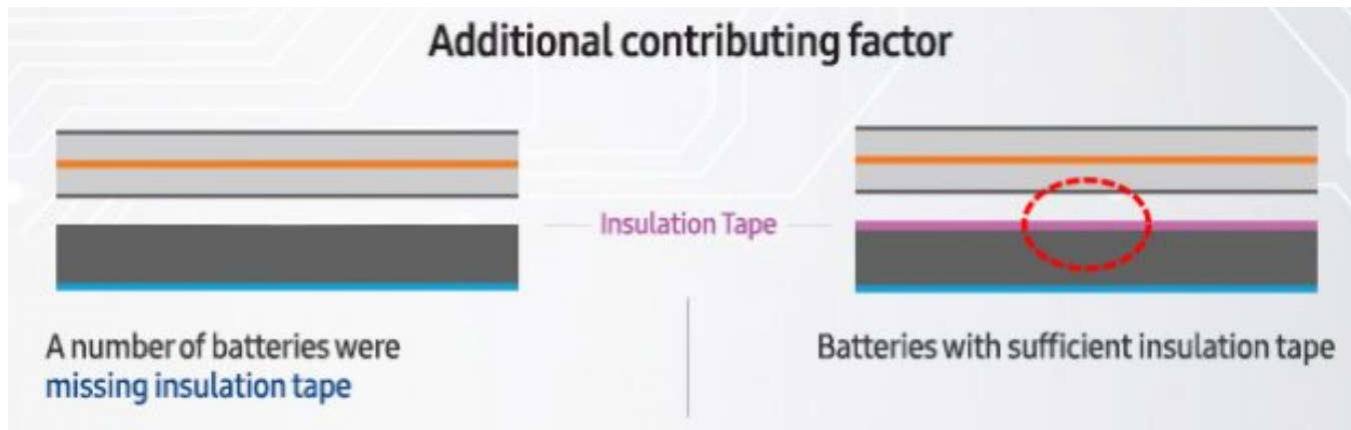
The tip of the negative electrode is correctly located within the planar area

**-adding incorrect positioning of the negative electrode tip also led to a higher likelihood of incidents**

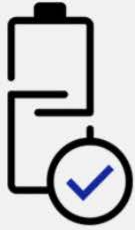




melted copper on the negative electrode area. There were welding issues that led to contact between the positive and negative layers, resulting in short circuits



- **Samsung said it has improved its processes and faults would not happen again**
- **Samsung said it has developed a battery check protocol and has invited researchers and academics to provide analysis to ensure battery safety**
- **In a bid to regain customer confidence, Samsung said it implemented a range of quality control and safety measures for their handsets, including an 8-point battery safety check**



## Durability Test

It starts with enhanced battery testing, including overcharging tests, nail puncture tests and extreme temperature stress tests.



## Visual Inspection

We visually inspect each battery under the guideline of standardized and objective criteria.



## X-Ray

We use X-ray to see the inside of the battery for any abnormalities.



## Charge and Discharge Test

The batteries undergo a large-scale charging and discharging test.



## TVOC Test

(Total Volatile Organic Compound)  
We test to make sure there isn't the slightest possibility of leakage of the volatile organic compound.



## Disassembling Test

We disassemble the battery to assess its quality, including the battery tab welding and insulation tape conditions.



## Accelerated Usage Test

We do an intensive test simulating accelerated consumer usage scenarios.



## $\Delta$ OCV Test

(Delta Open Circuit Voltage)  
We check for any change in voltage throughout the manufacturing process from component level to assembled device.

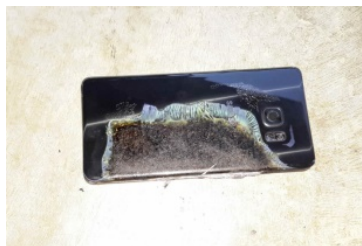
- **Samsung said 96 per cent of 3 million devices sold and activated globally had been returned**
- **Samsung took a \$US5.3 billion loss from its operating profit due to the Note 7 debacle - one of the worst technology recalls in recent times**



Koh Dong-jin, president of Samsung Electronics' Mobile Communications Business, speaks during a news conference at its headquarters in Seoul to summarize findings on a review of the disastrous launch of the Galaxy Note 7. (Kim Hong-Ji/Reuters)

# What Should We Learn?

- Battery safety event damage could be huge and not proportional to the battery cost
- Damage is higher as the device market is larger
- The damage is huge as well as when the device mission is critical (Like in Space or Military)
- Companies with no deep pockets will may bankrupt because of battery safety event damage
- Batteries are not just another component and there is a need to understand them from all aspects including the safety before designing them into a device

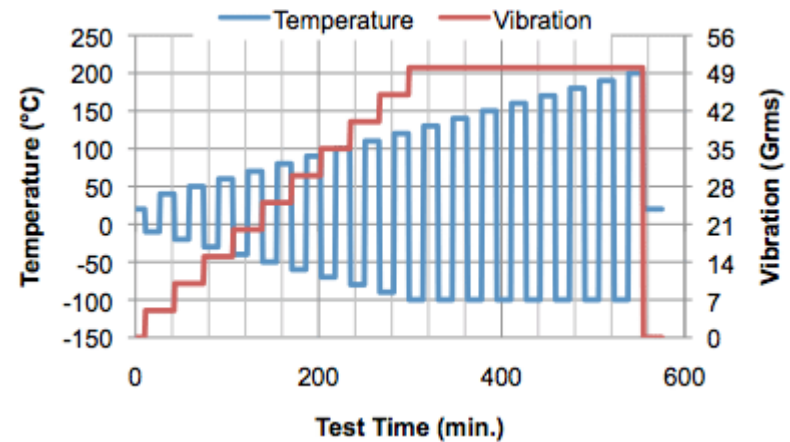
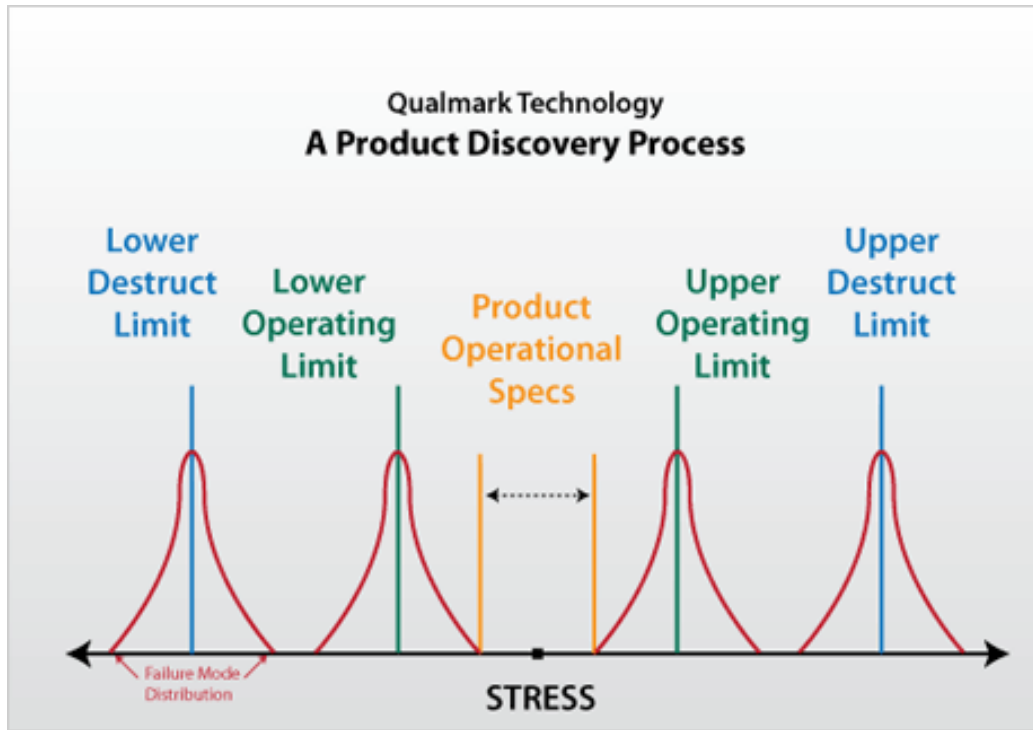


# Recommendations

- Cells/batteries makers should review and improve their cells/batteries safety validation process
- Testing for specs are not sufficient and shouldn't be the only safety validation process
- HALT-HASS testing methodology can add to the cells/batteries robustness and make them safer
- Based on the potential damage a battery safety validation process should be apply on 2 separate independent labs
- Running several months internal operation pilot before marketing starts

**In the race for performance we shouldnt forget Safety!!!**

# Halt (Highly Accelerate Life Testing) – Hass (Highly Accelerate Stress Screening)



# Halt-Hass Process

- Battery testing affects human lives by enforcing performance and safety standards.
- Halt-Hass tests use combined testing scenarios in a testing chamber to stress simulate failure modes.
- Running Halt-Hass process to a battery can ensure passing easily battery testing standards (UN, J2464, UL2054, UL1642, IEC 62660-2...)





# Thank You for Your Attention



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