Tablet Fire Extinguishment Testing

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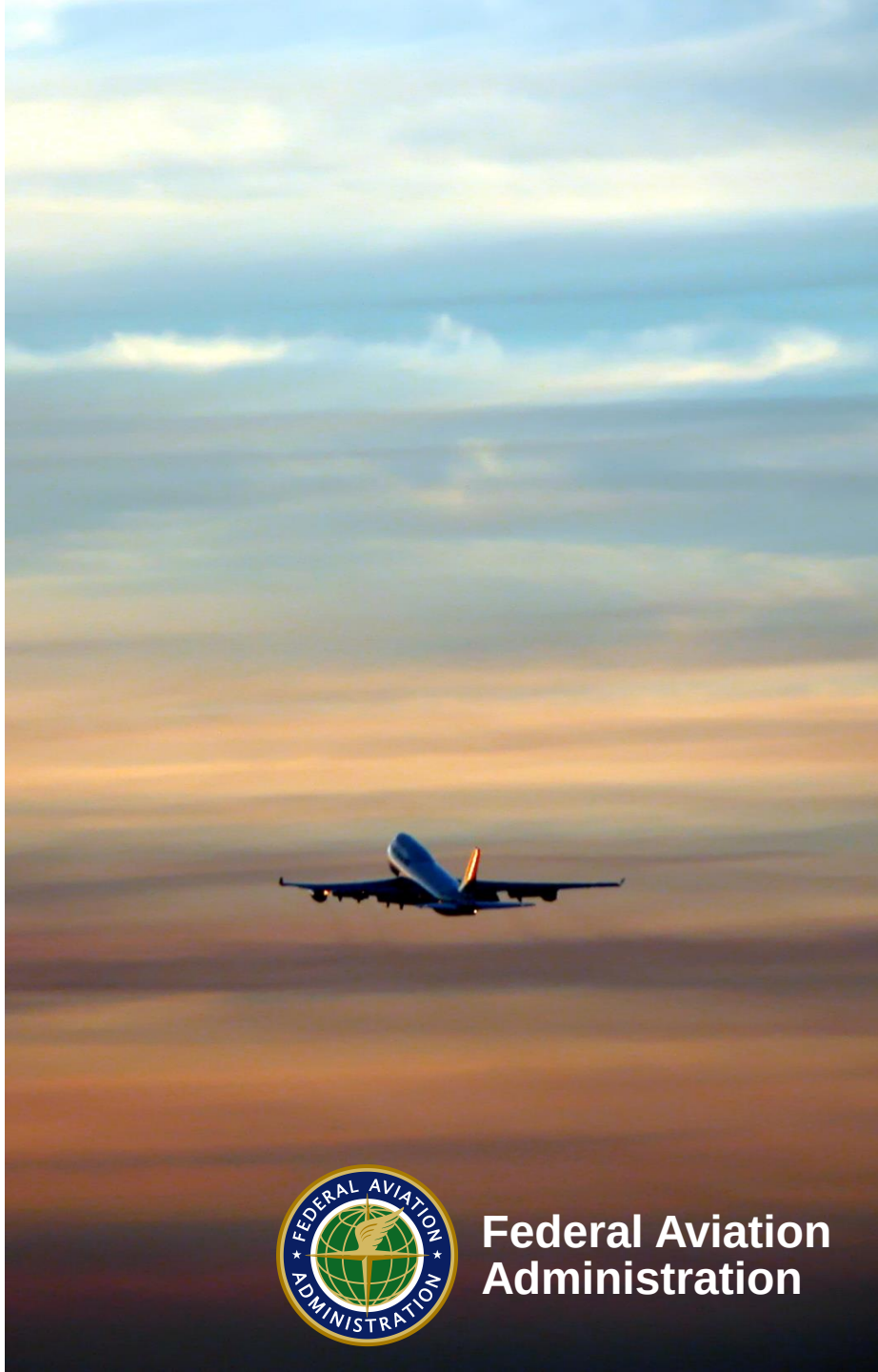


Background

- **SAFO 09013 was released in 2009 to provide guidance to operators on how to manage lithium battery fires in PEDs**
  - Use fire extinguisher (halon, halon replacement or water) to extinguish any flames
  - Douse the device with water or other non-alcoholic liquids to cool the device and prevent TR propagation
  - Do NOT pick up the device
  - Do NOT cover the device or use ice to try to cool it

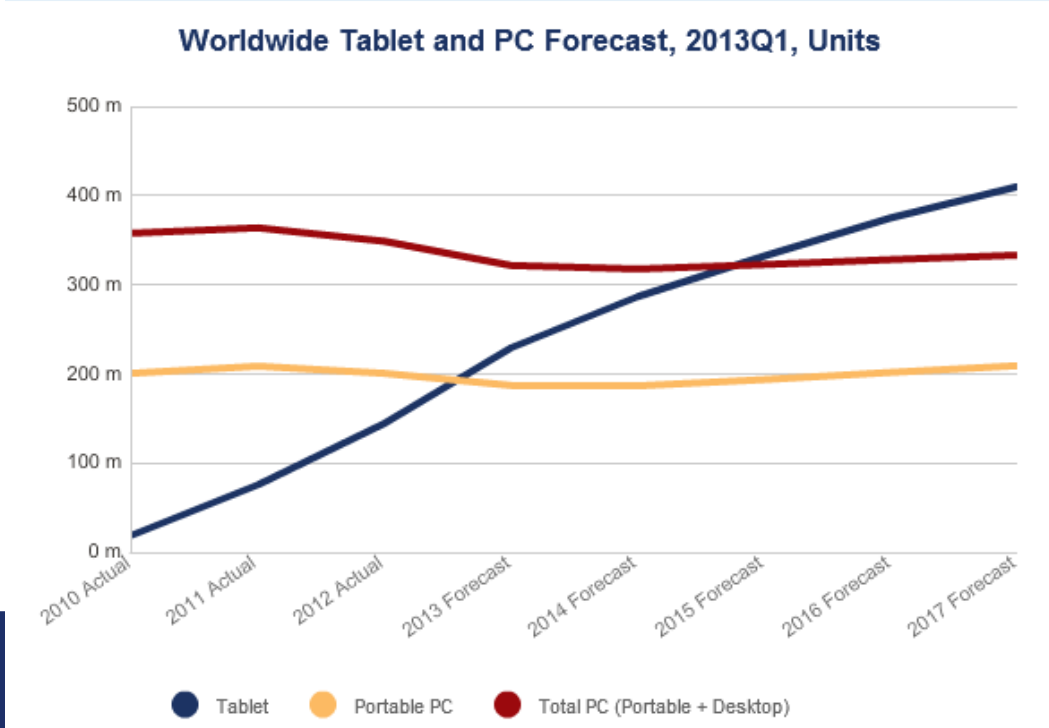
Background

- **The guidance in this SAFO was based on testing conducted with laptop devices**

Background

- SAFO 09013 was released in June, 2009
- First iPad was released April, 2010
- Since then, tablet sales have surpassed laptop sales

IDC
Analyze the Future



http://www.idigitaltimes.com/tablet-sales-vs-laptop-sales-three-reasons-why-android-devices-will-surpass-desktop-pc-shipments

Background

- **With the change in technology since the release of SAFO 09013, the question is:**

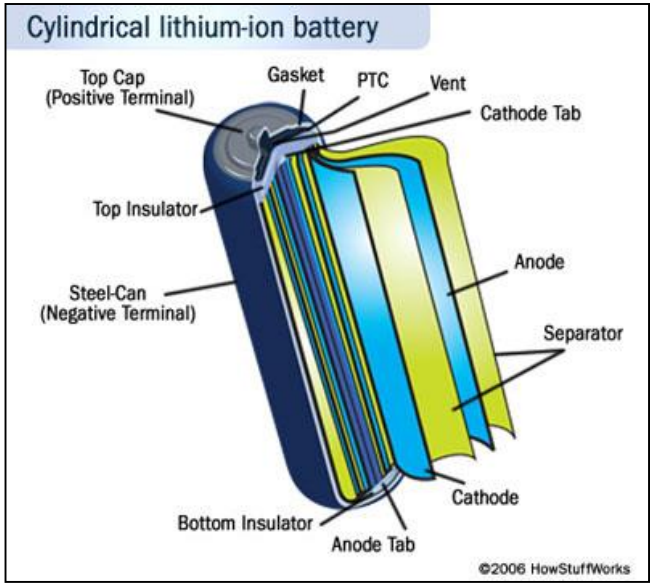
Is the guidance that it provides still the most accurate, practical, and effective means for handling of a PED fire on commercial aircraft?

Background: Tablets vs Laptops

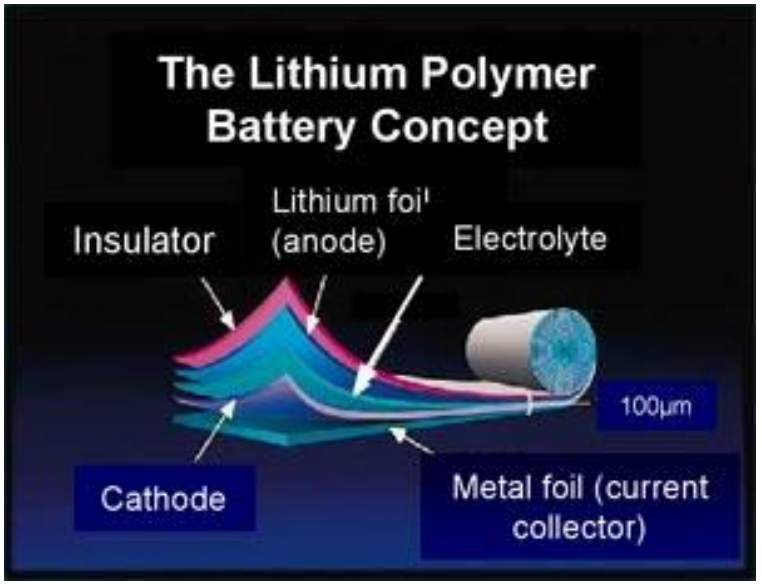
- **There are numerous differences between laptops and tablets that may impact fire handling procedures:**
  - Battery types – Polymer vs Cylindrical
  - Battery Configuration – Cell to cell surface contact area
  - Form factor – Keyboard vs Tab
- **In addition, new materials such as Magnesium Alloys present concerns in both laptops & tablets**
  - Potential for mag-alloy case to ignite?

Battery Types

- **Cylindrical cells**
  - Designed venting port
  - TR gases released as a forceful jet in 2 stages

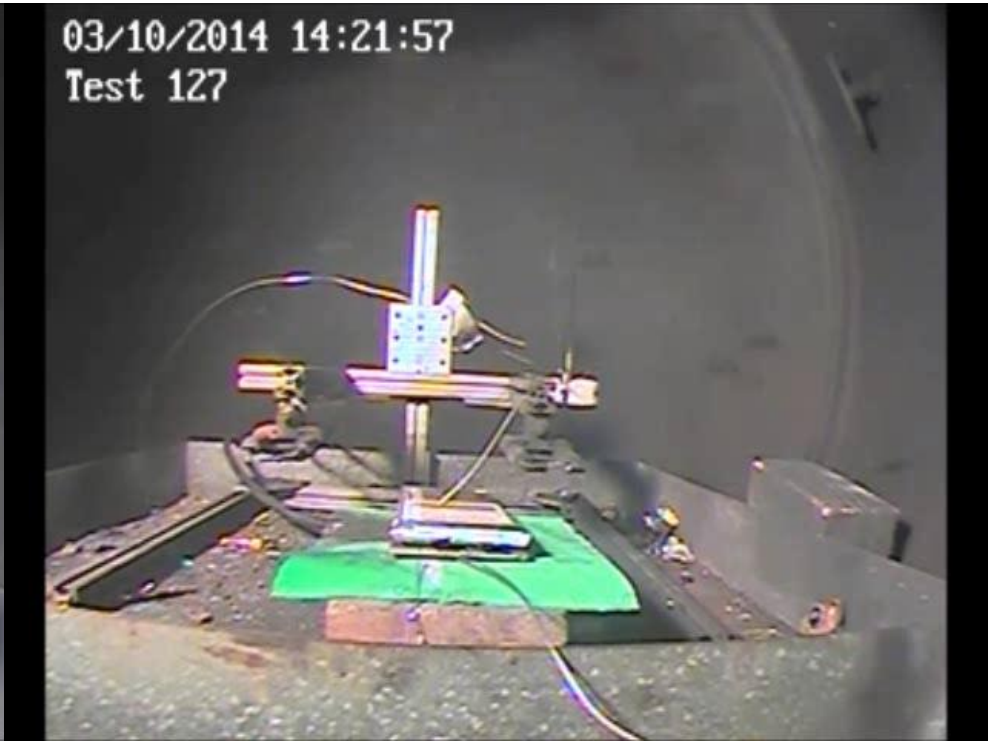


- **Polymer Cells**
  - No designed venting port
  - TR gases released from seam rupture
  - Higher energy density/cell



Battery Types

18650 Cylindrical Cell
$LiCoO_2$ Chemistry
9.62 Whr



Polymer Cell
$LiCoO_2$ Chemistry
37 Whr

Battery Configuration

- **Laptop Batteries**
  - Typically 9-12 18650 cells
  - Large surface contact area between cells → increased heat conduction

- **Tablet Batteries**
  - Typically 2-4 polymer cells
  - Small surface contact area between cells → decreased heat conduction

Form Factor

- **Keyboard**
  - Allows for water penetration to batteries
  - Horizontal position

- **Tablet**
  - No openings for water penetration
  - Can be mounted/used in any position

Magnesium-Alloy Casings

- **Burns at a temperature of ~5600°F**
- **Extremely difficult to extinguish**
- **If melted, or broken into small pieces, easily ignitable**

Tablet Test Program

- **Objective is to identify if SAFO 09013 provides the best guidance for fighting a fire initiating from a tablet device.**
- **Three Tablet types utilized**
  - Tablet Type 1: 2 LiPo cells, 27.62 Whr
  - Tablet Type 2: 2 LiPo cells, 30.0 Whr
  - Tablet Type 3: 4 LiPo cells, 42.2 Whr magnesium-alloy casing

Tablet Test Program

- **Tablets were tested laying horizontally and on a stand at a near vertical (~75°) position**
- **In each position, each tablet tested**
  - without any fire extinguishment (FE)
  - with FE following the SAFO guidance
- **In each test, a single cell was forced into thermal runaway with a thin-film heater.**
  - Once thermal runaway occurred, heating is disabled
- **Temperatures of each cell, the screen and back surface of each tablet were monitored**

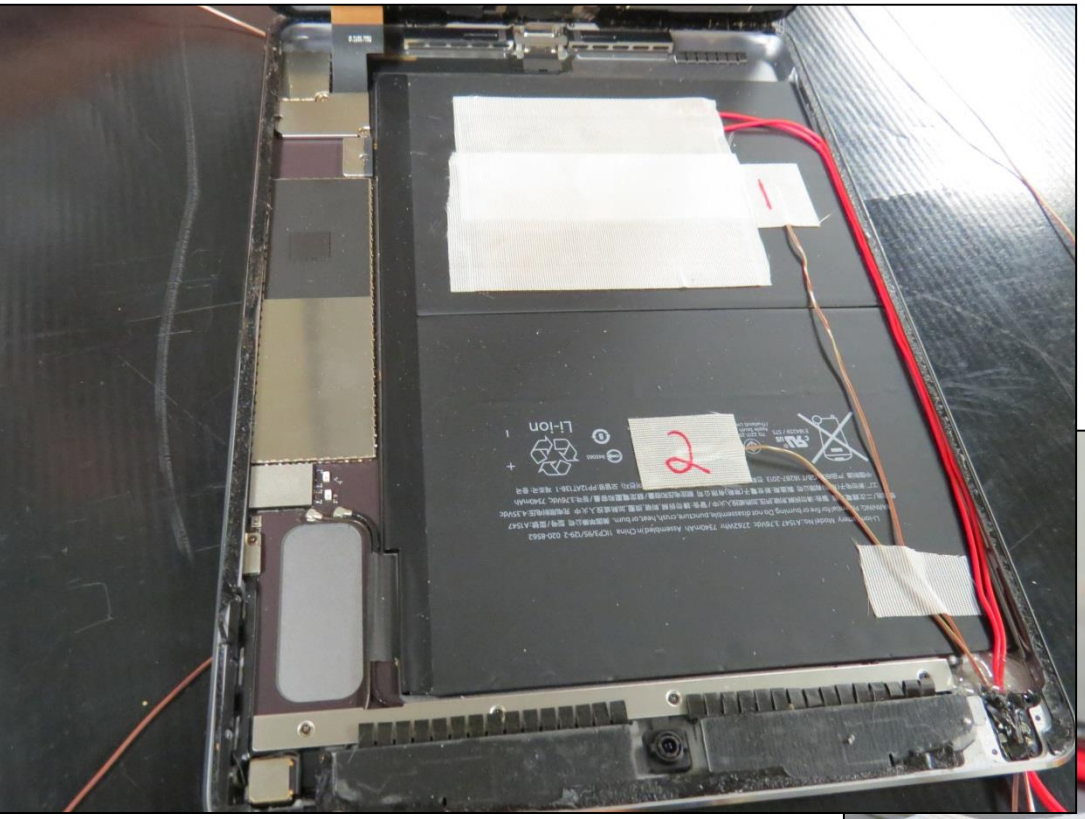
Thermal Runaway Initiation

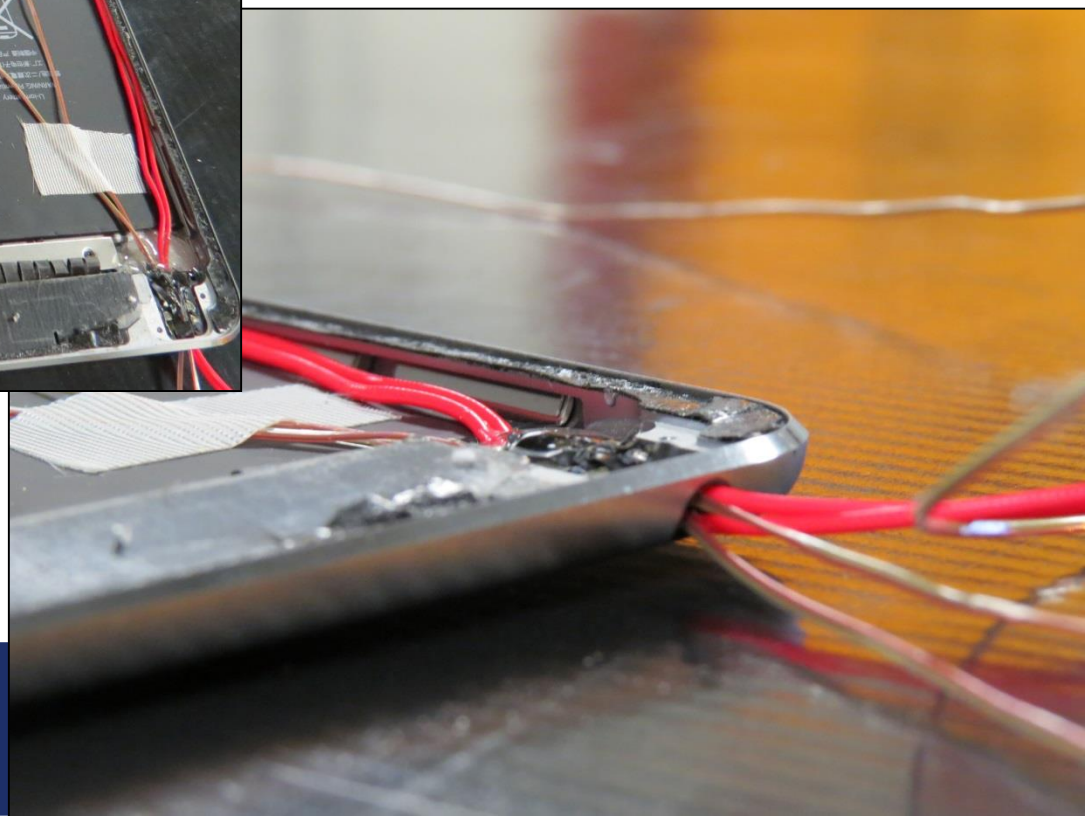
- **Objectives in our TR initiation method were:**
  - Keep the tablet as close to its original condition as possible
  - Ensure all cells were fully charged
  - Initiate TR in only a single cell
  - Monitor temperatures of all cells

Thermal Runaway Initiation

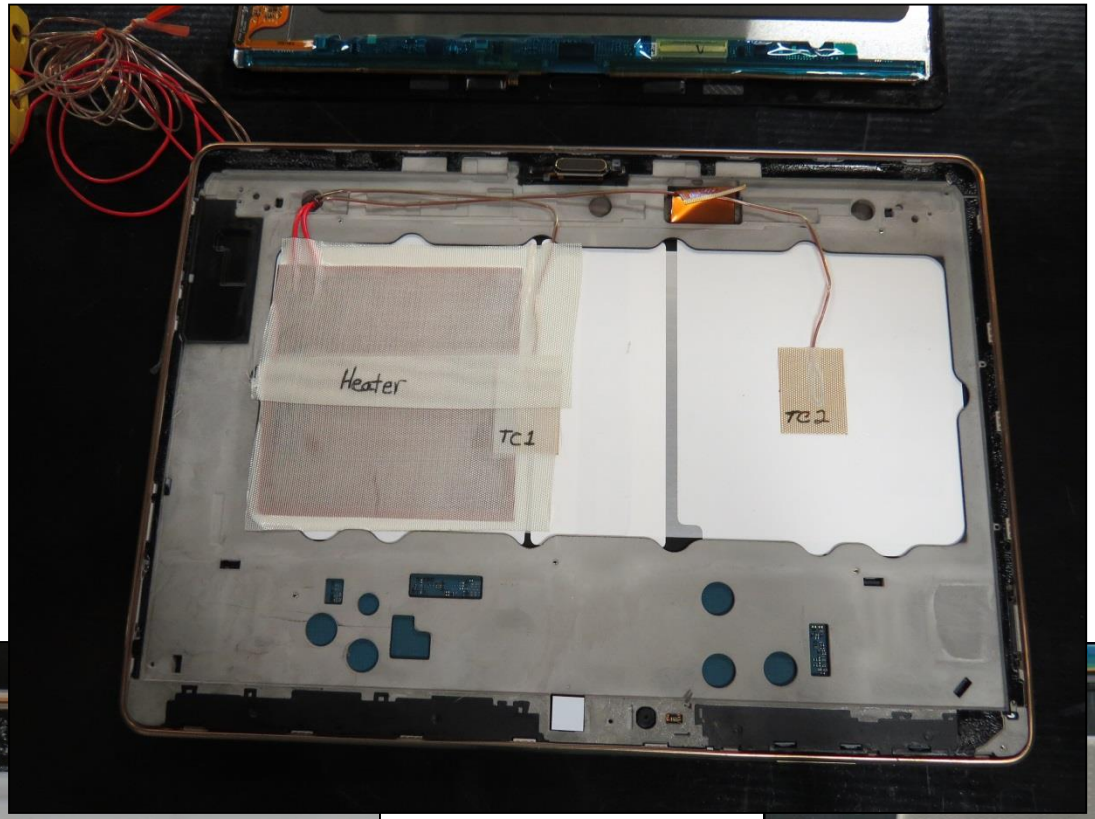
- **In order to achieve this:**
  - Each tablet was carefully opened by removing its screen
  - A 10 W/in^2, thin film polyimide heater was installed on a cell
  - Self-adhesive, surface mount thermocouples installed on each cell
  - All wiring was carefully routed through
    - Existing tablet vent ports
    - Removal of the headphone jack (remaining hole sealed back up with epoxy)
    - Small hole drilled through back of device (sealed back up with epoxy)
  - Each tablet was then sealed back up by re-activating the factory adhesive
  - All tablets remained in full functioning condition and were subsequently charged

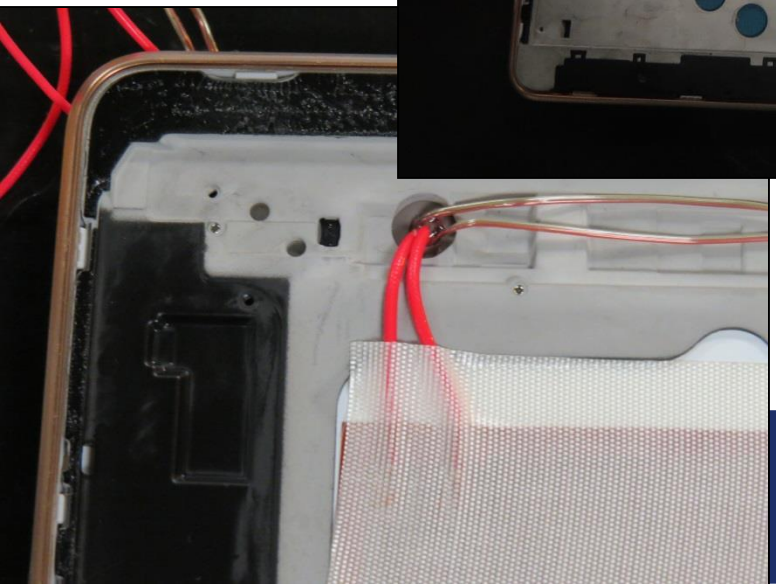
TR Initiation – Tablet Type 1



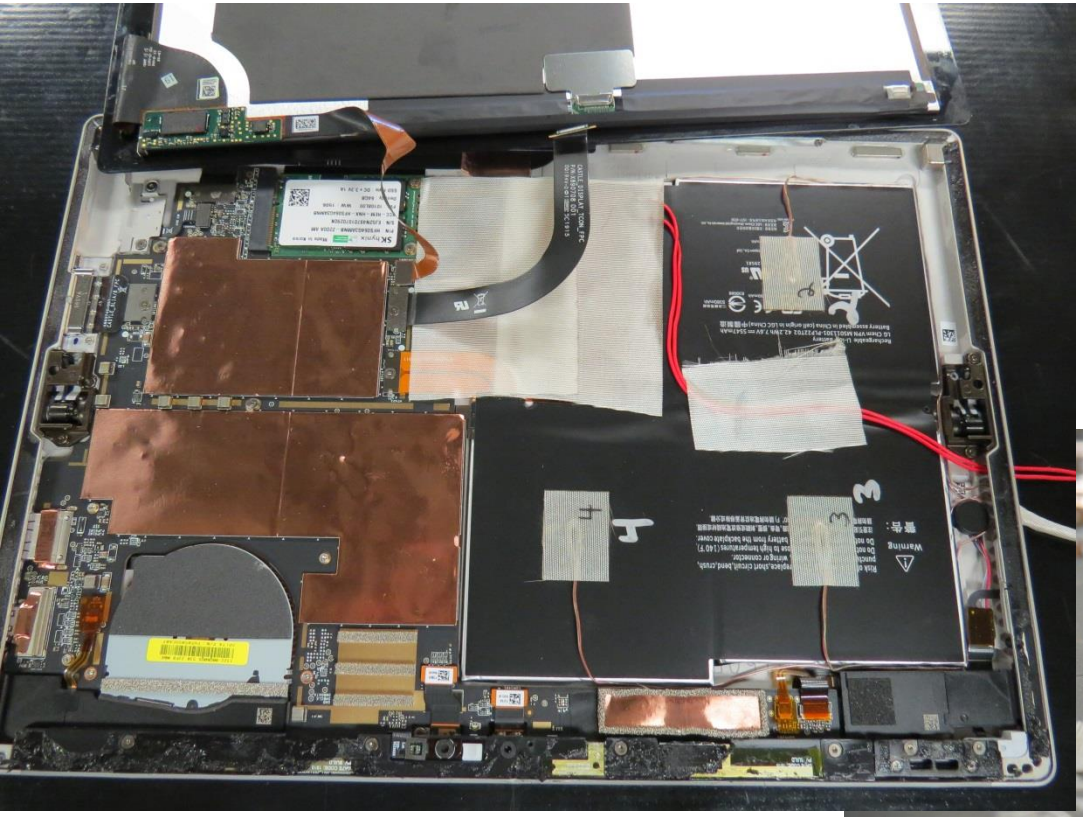


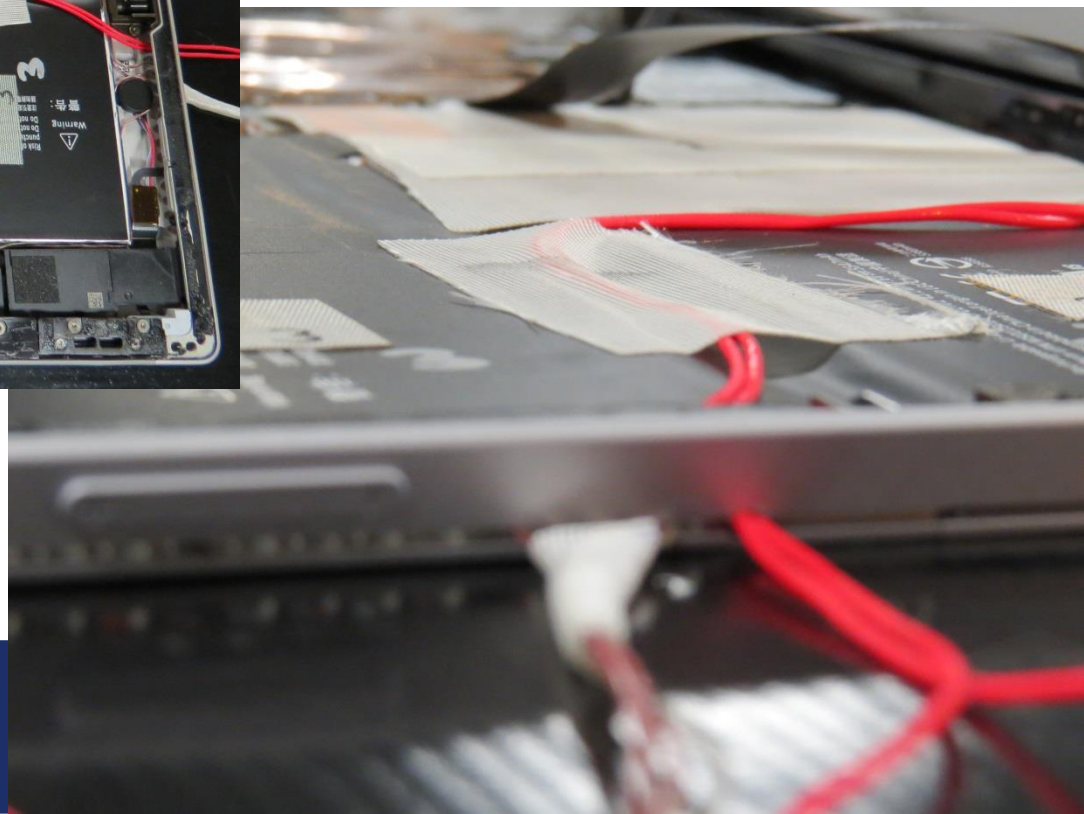
TR Initiation – Tablet Type 2





TR Initiation – Tablet Type 3





Extinguishment Methods

- **Halon extinguisher on hand to knock down any flames (not necessary on any of the tests)**
- **Water applied through two different methods:**
  - Two 16 oz drinking water bottles.
  - Two 16 oz chemistry wash bottles which allowed for water to be directed into any openings of the tablet
- **Two additional bottles of each on hand for each test**

Summary – General Observations

- **Initial TR observed through forceful release of smoke with varying intensity**
- **Flaming/burning only occurred during 1 of 16 tests**
- **Propagation occurred in only 2 of 16 tests**
  - Occurred rapidly (4-8 seconds after initial TR)
- **Magnesium surface of Tablet Type 3 did not ignite and instead acted as a heat sink**

Summary – Extinghuisment

- **Horizontal Position**
  - Dousing tablets with water per current SAFO 09013 procedures had virtually no effect

- **Vertical Position**
  - Dousing tablets with water per current SAFO 09013 procedures had some measurable effect, but temperatures had a tendency to rebound.
  - Directing the water into openings formed during TR had a sustained effect of cooling all cell and surface temperatures.

Thermal Runaway Event Guidance

- **Philosophy of SAFO 09013 still holds:**
  - Extinguish any flames
  - Cool the device to prevent propagation
- **However, based on the current testing, some additional guidance could be provided:**
  - The most effective cooling is achieved by ensuring the liquid gets *inside* the device. This may require discharging liquids into any openings formed by the separation of the screen from the unit.
  - During TR, external temperatures of the device could exceed 500F – Extreme caution should be exercised in handling of the device.
  - Though tablet devices may have a lower probability of propagation of the event to other battery cells, they should be treated as though there is a risk of additional TR events until the device is adequately cooled.