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Lithium Ion Batteries: Assessment and Investigation

November 15, 2005

Jan Swart*

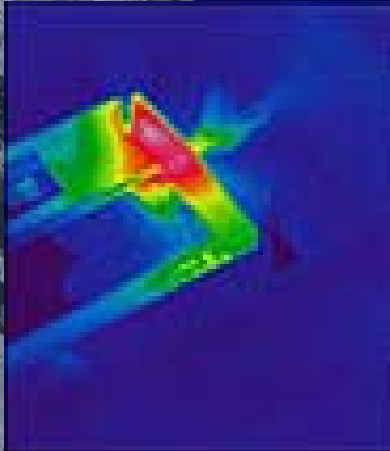
Celina Mikolajczak, P.E.*

Marcus Megerle

Troy Hayes, Ph.D., P.E.

Daren Slee, P.E.

Ming Wu, Ph.D., P.E.



Lithium Ion Batteries: Assessment and Investigation

- **Introduction**
- **Part 1: Developing a company specific product safety evaluation process**
 - Presented by Jan Swart
- **Part 2: Determining the cause of a battery failure**
 - Presented by Celina Mikolajczak, P.E.

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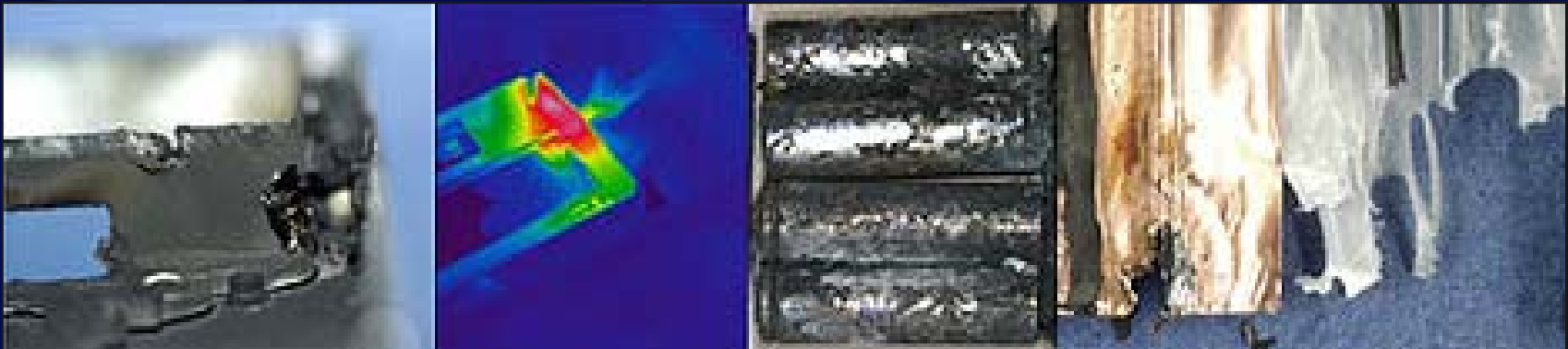
Washington, D.C.

Lithium Ion Batteries: Assessment and Investigation

Part 2: Determining the cause of a battery failure

A Scientific Methodology for Investigation of a Lithium Ion Product Failure

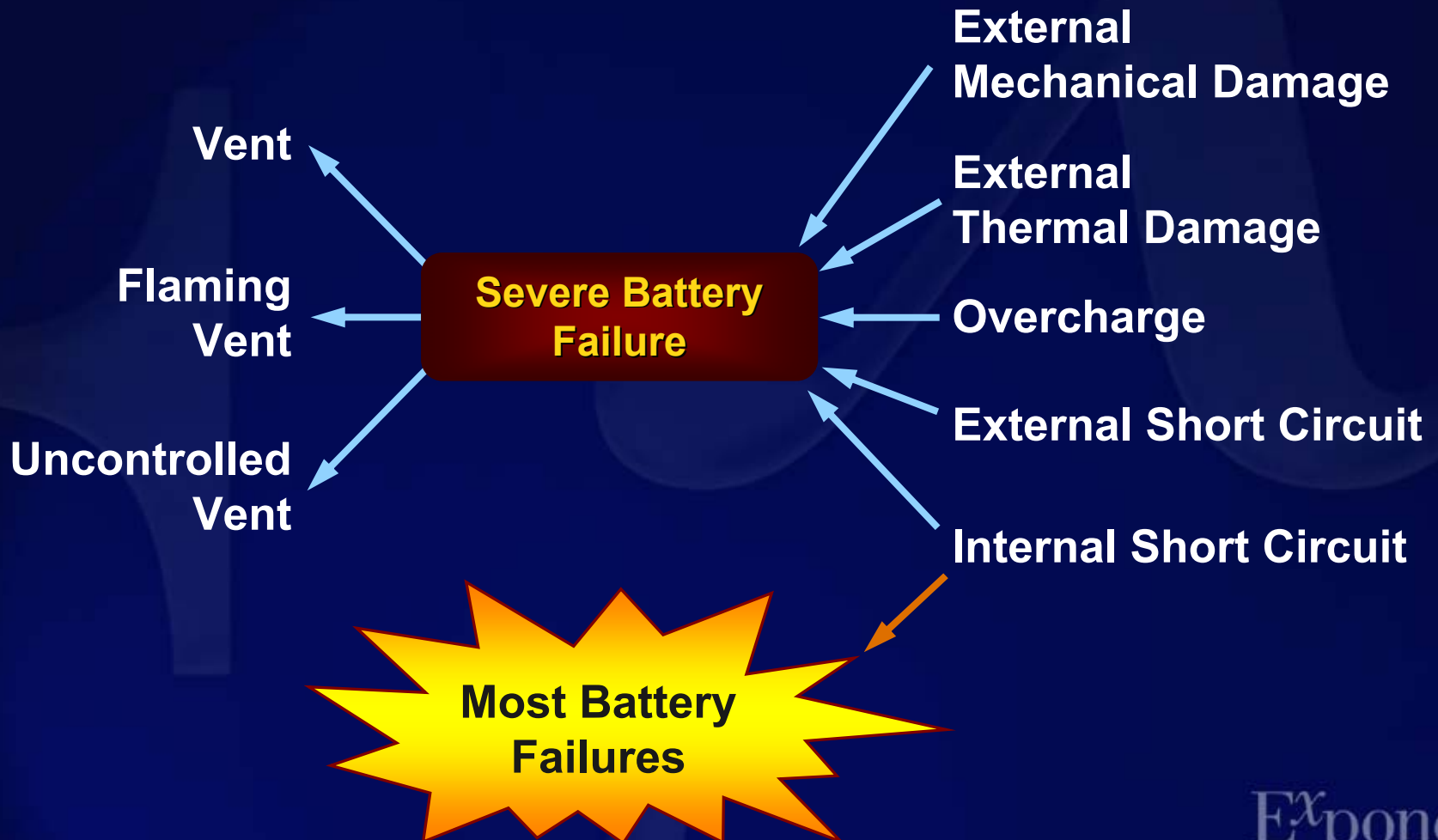
- Lithium-ion batteries, on occasion, fail in a manner that includes:
 - Overheating
 - Case rupture
 - Combustion



A Scientific Methodology for Investigation of a Lithium Ion Product Failure

- How can the causes of these failures be identified?

Fault Tree



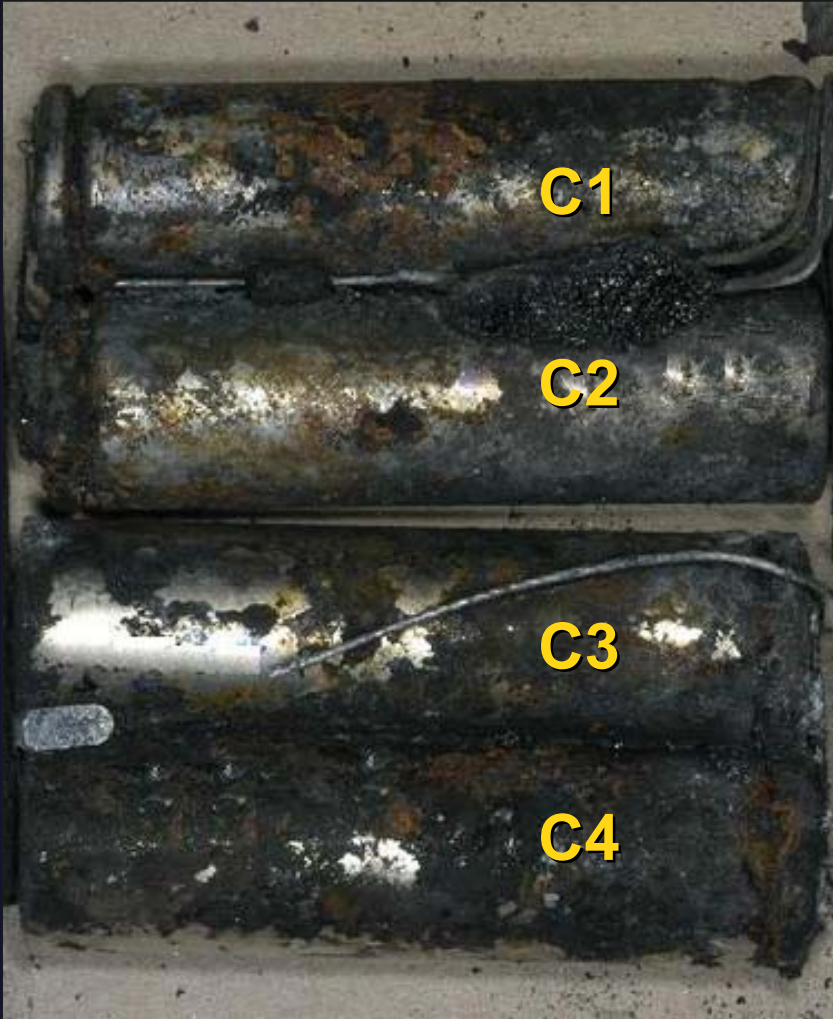
**Case Study:
Notebook Computer Battery Failure
with 18650 Li-Ion Cells**

Step 1 – Photograph System

Incident System

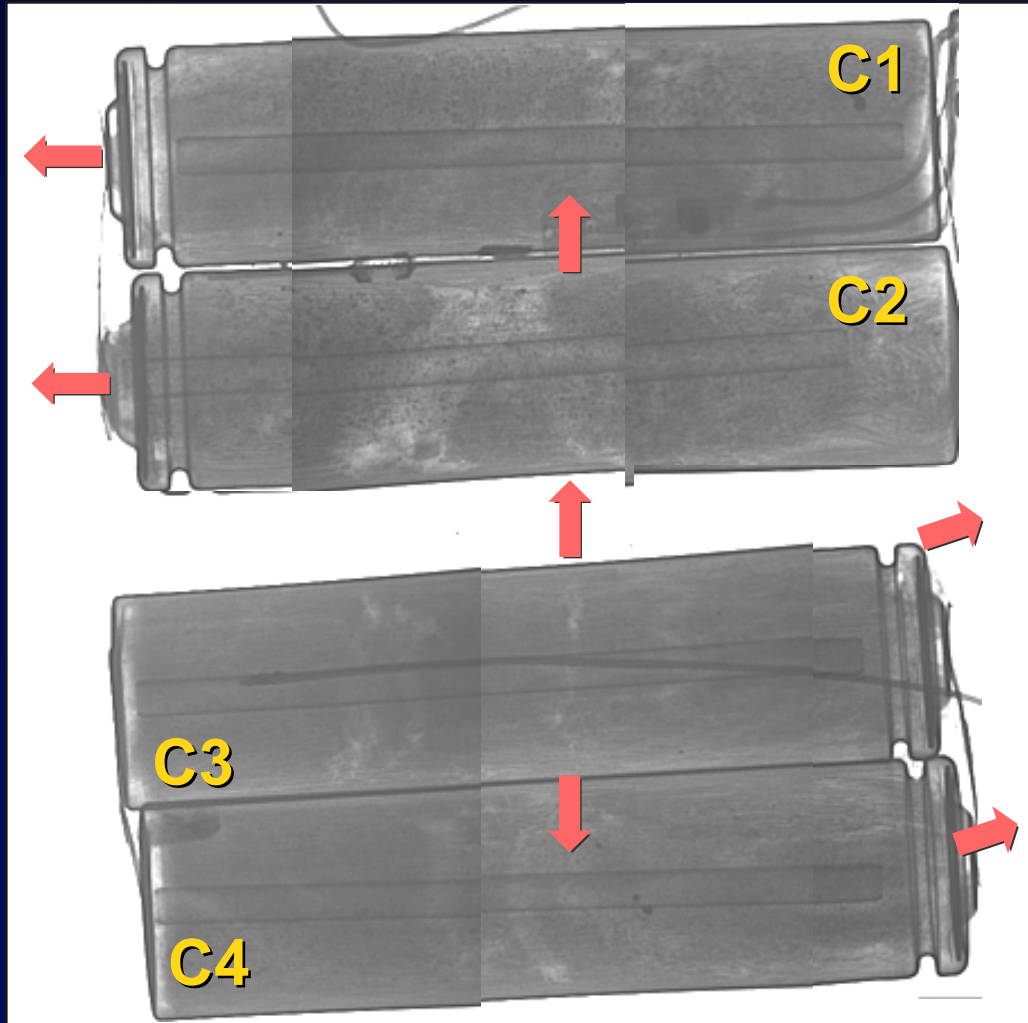


Failed Battery Pack

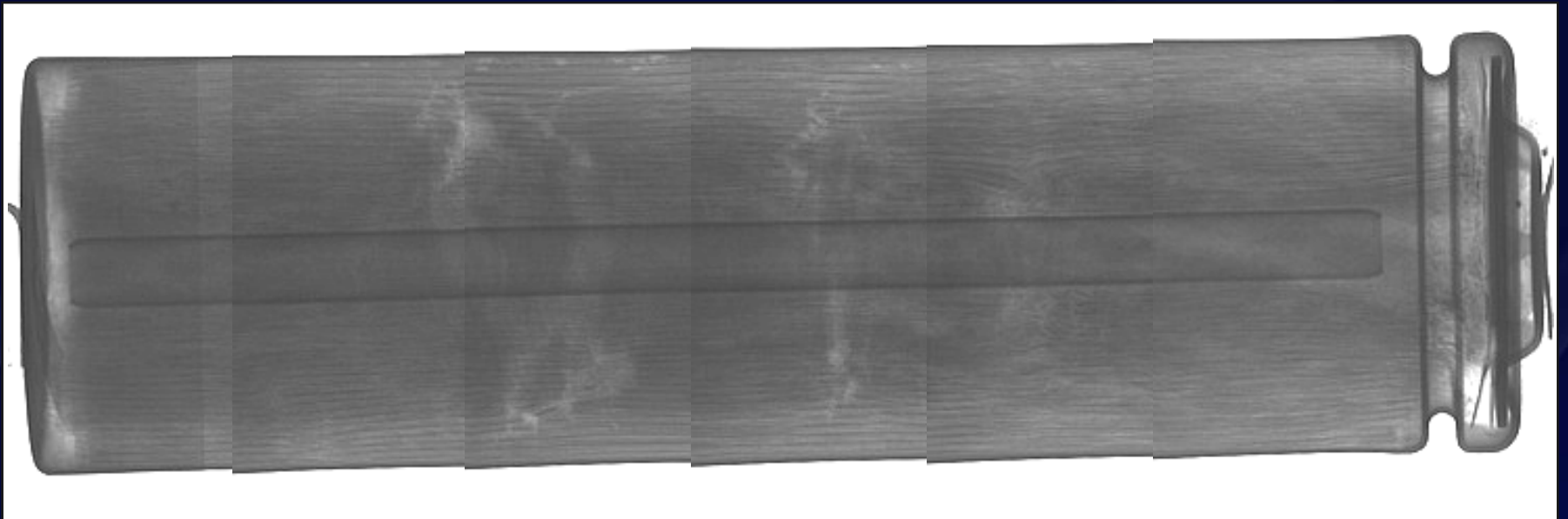


Step 2 – X-Ray Pack and Cells

Likely Fault Propagation Sequence

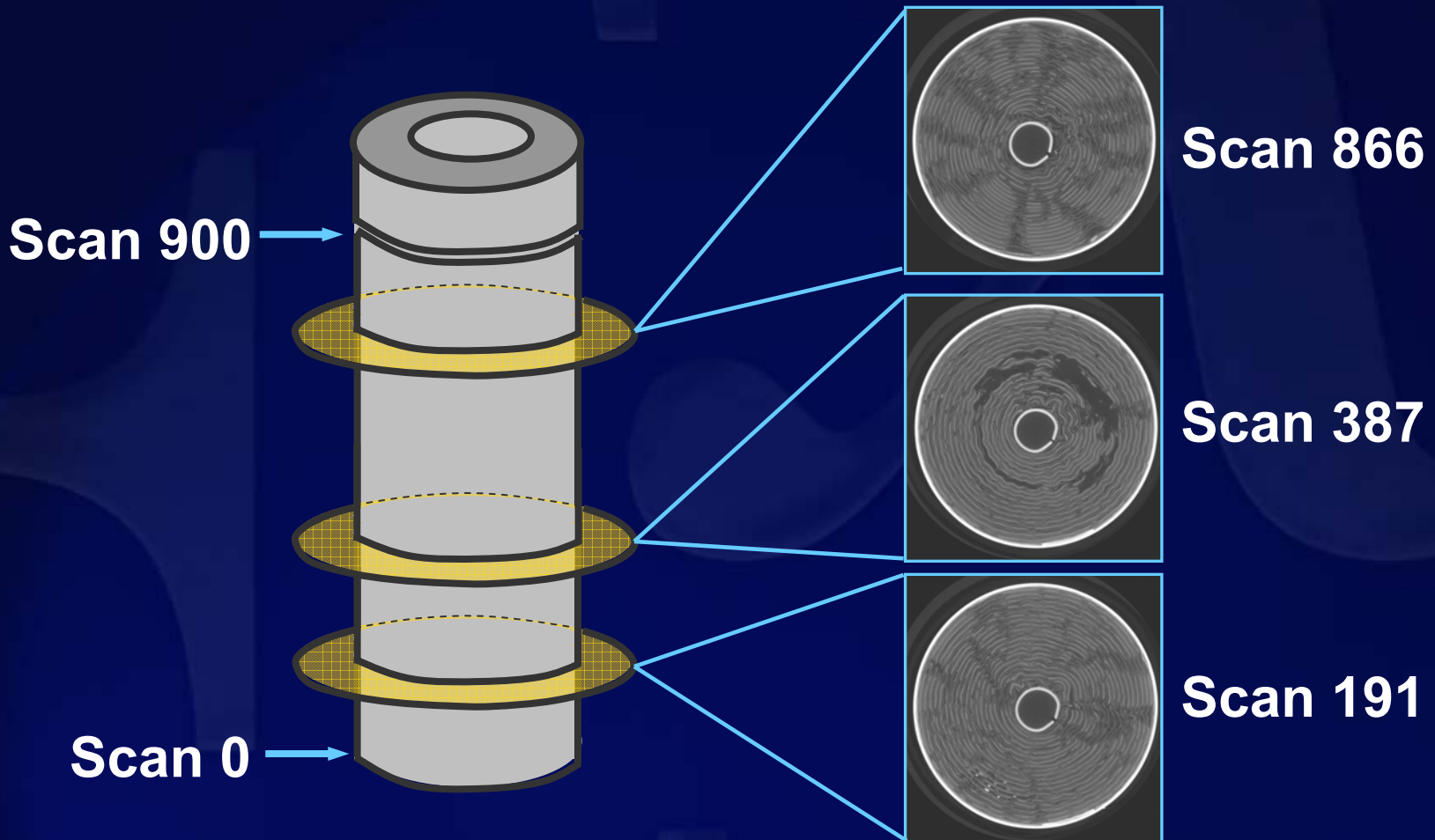


Cell C3 X-Ray Detail

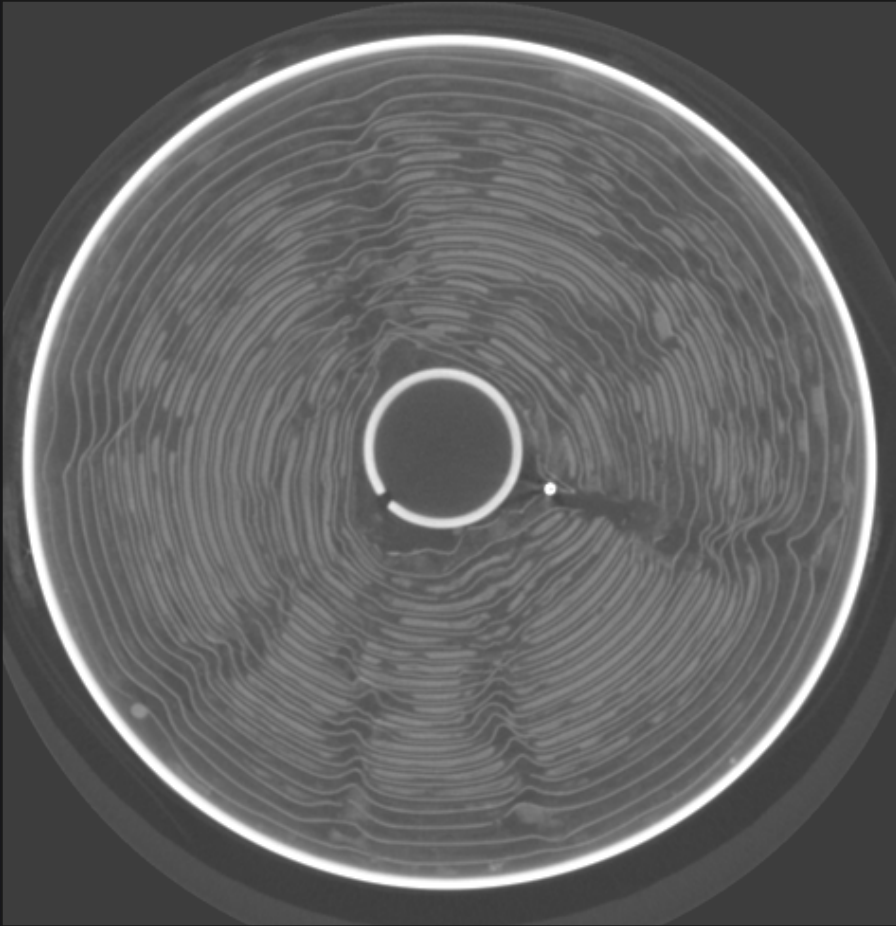


Step 3 – CT Scan Cells

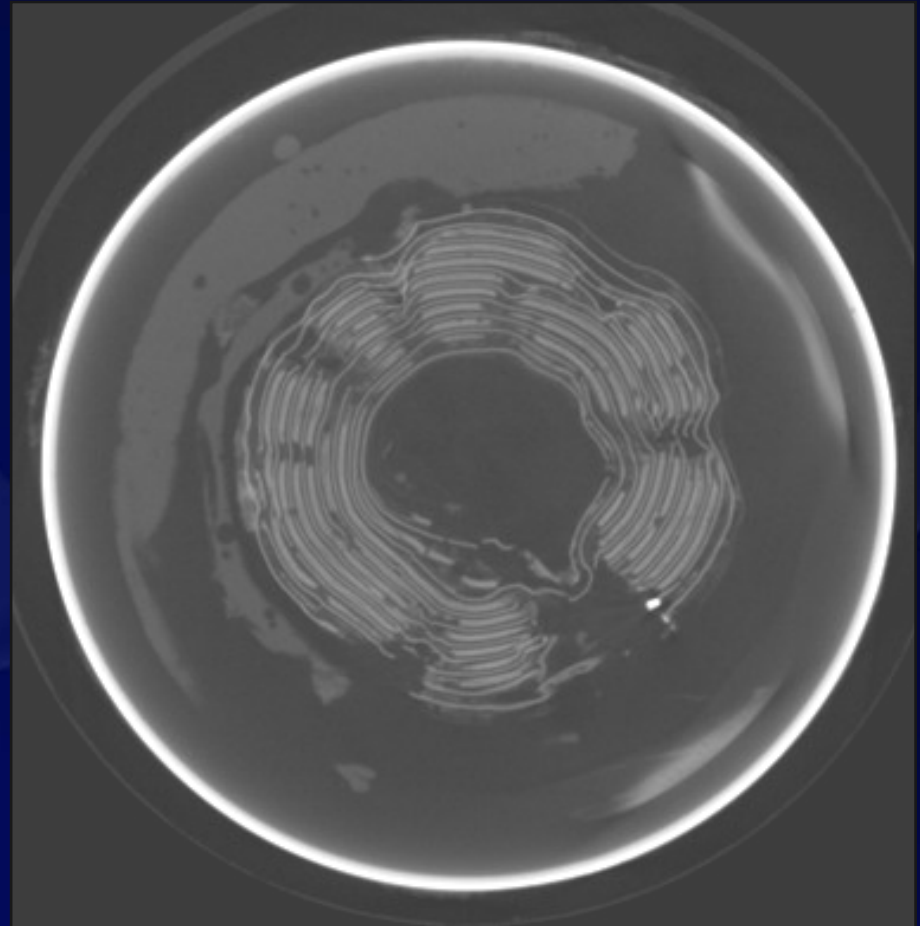
CT Scan



Cell C3 CT Scan Detail



Scan 936

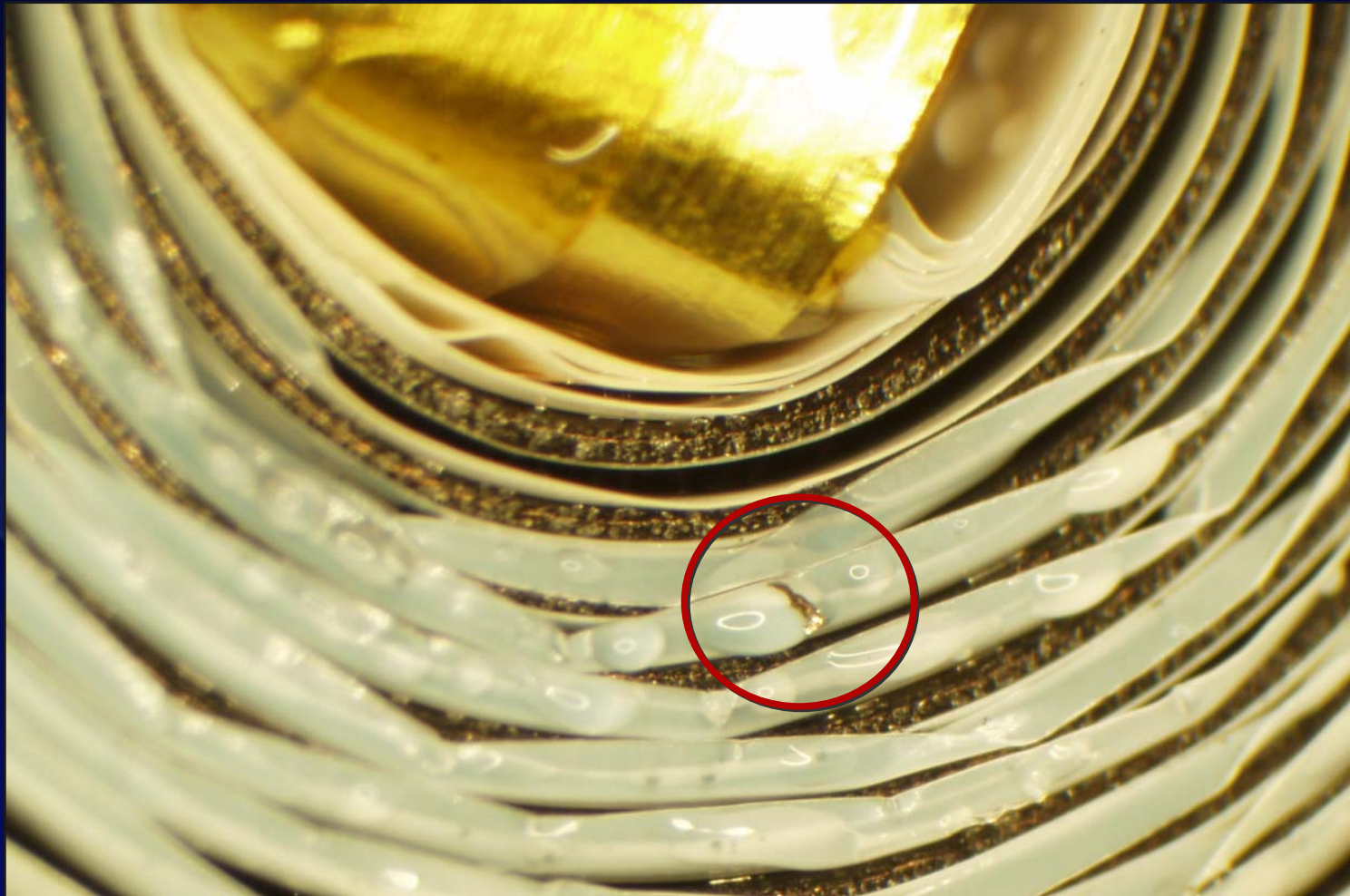


Scan 957

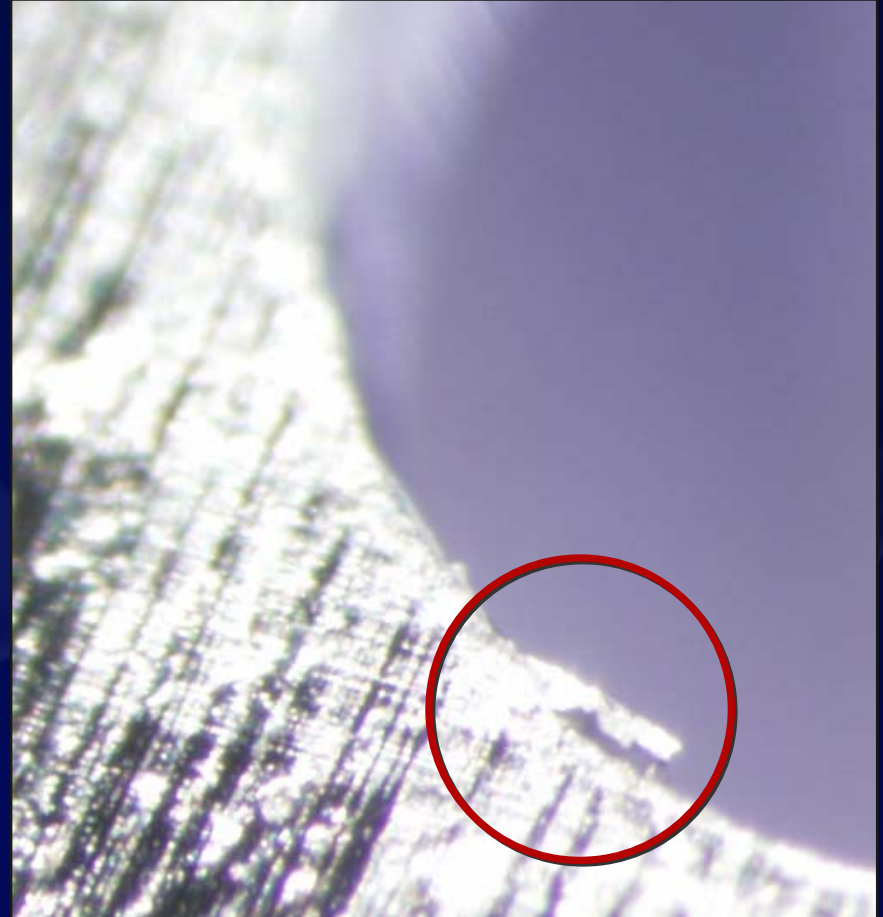
Step 4 – Examine Production Cells

**Now that we know the fault location,
we need to find the source**

Particle Contamination on Top of Cell Windings

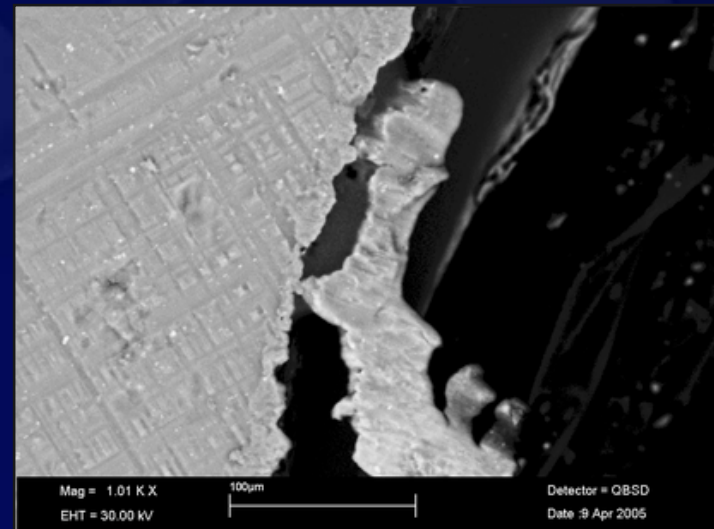
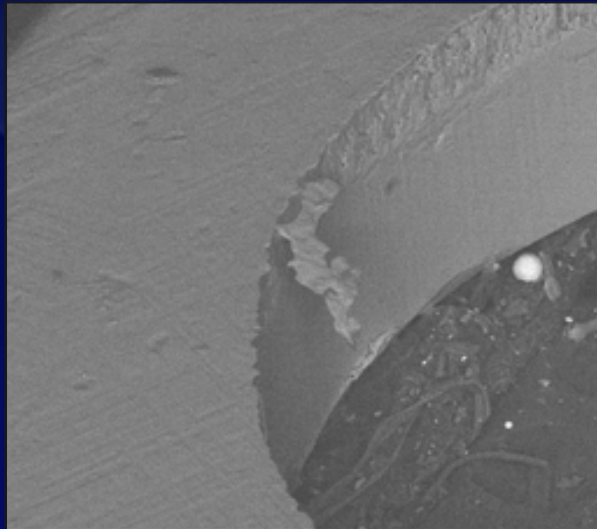


Possible Source: Burrs on CID

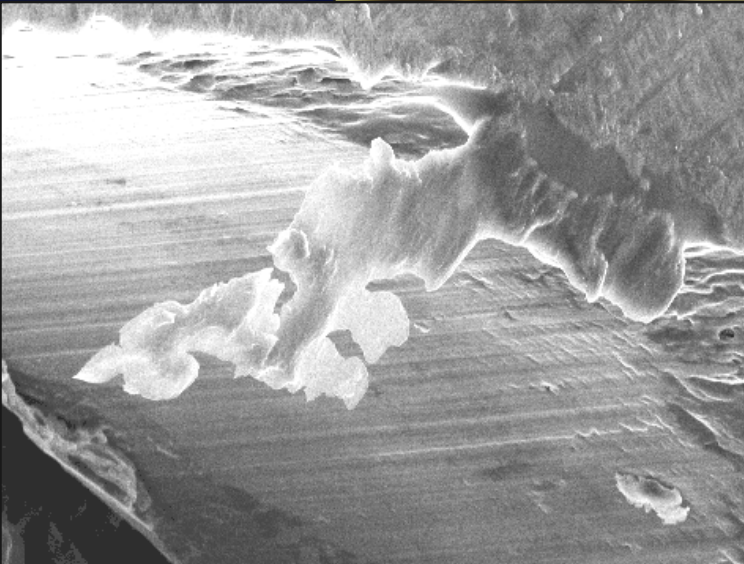
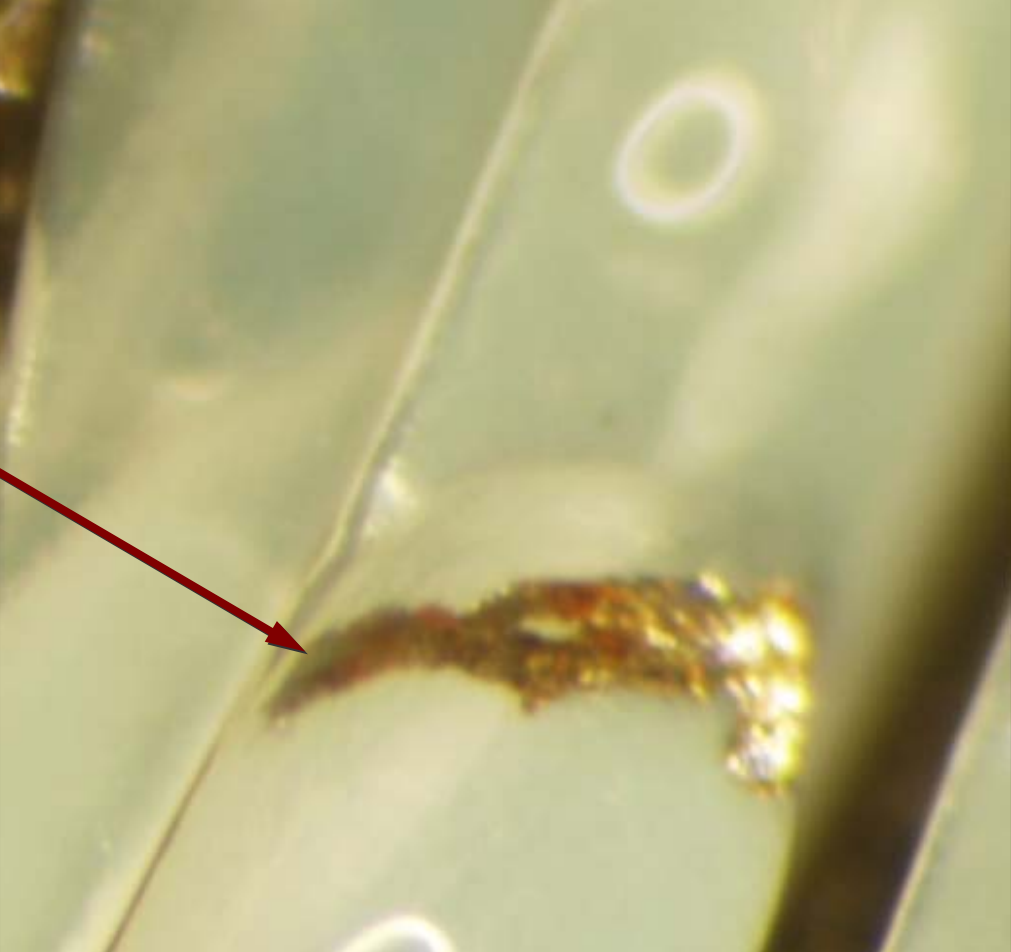
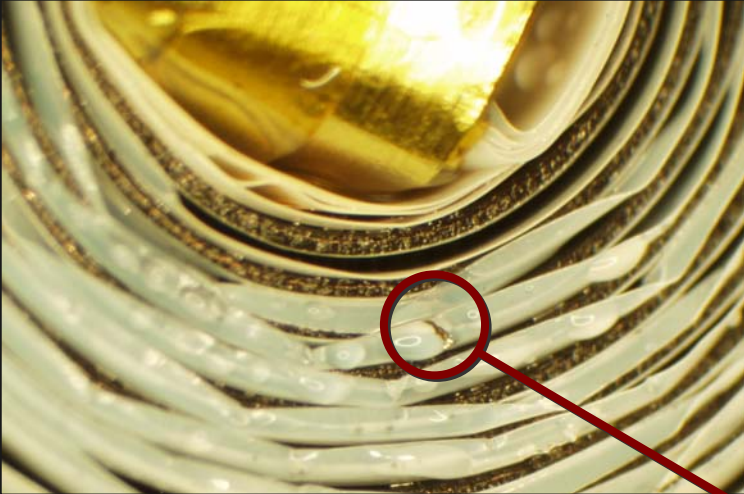


Partially Detached CID Burr

This burr is approximately 330 μm long and is barely attached to the CID.



Particle Contamination on Top of Cell Windings



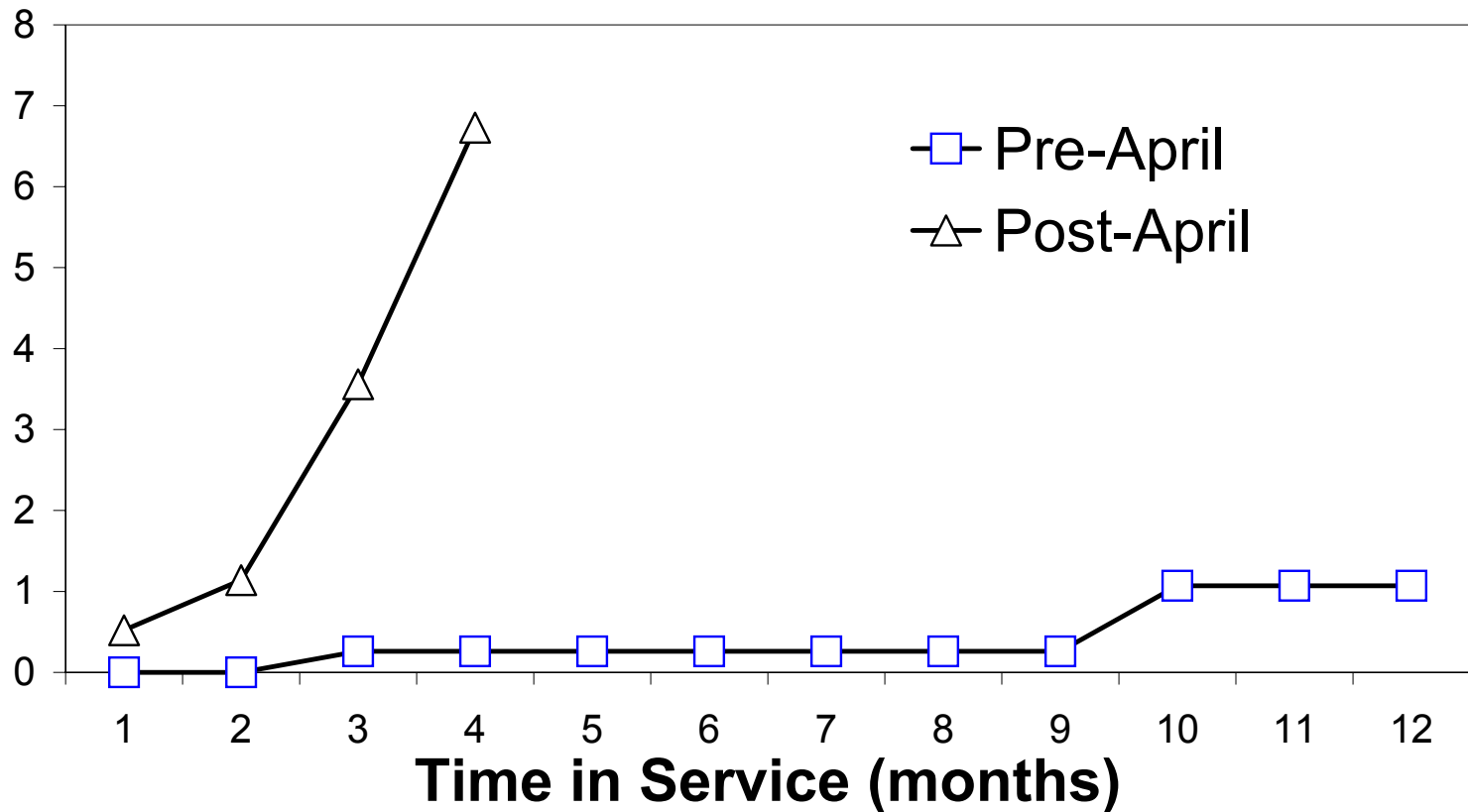
Step 5 – Statistical Analysis

Now that we know the problem, we need to find out what production time frames are affected

Statistical Analysis

Distribution of Cell Failures by Time

Expected Number of Failures
per Million Cells



Summary - Internal Cell Fault Investigation

- **Determine the initiating cell**
 - Visual examination (photography, microscopy)
 - X-rays of cells
- **Determine the location of the initiating fault within the cell**
 - X-rays and CT scans
- **Examine production cells for clues to processes that may have contributed to the fault**
- **Statistical analysis**
 - Estimate rates or counts of incidents over the life of the product
 - Identify production lots potentially susceptible to the fault

Exponent Failure Analysis Associates

149 Commonwealth Drive

Menlo Park, California 94025

U.S.A.

1 (800) 627 – 3245

email: info@exponent.com

www.exponent.com/industries/battery