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where energy meets environment

Lithium Ion Battery Offgas Monitoring

Marine Hi-Power Battery Workshop

December 15, 2016

Overview

- Nexceris Introduction
- Li-ion Battery Safety Problem
- Why Off-Gassing is important
- Capability
- Product Development Status
- Acknowledgements

About Nexceris

Nexceris, LLC

- **Founded in 1994, privately held**
- **Technology Developer**
  - advanced ceramics, electrochemical devices
- **Product Developer**
  - fuel cells, catalysts, sensors and monitors
- **Manufacturer/Distributor**
  - fuel cells and related products, sensors
- **ISO 9001:2008 certification**
  - covers all products and operations
- **Changed name from NexTech Materials to Nexceris on October 1, 2015**

www.nexceris.com

About Nexceris

Our Vision

Nexceris focuses its materials science expertise on creating innovative products that improve the quality, efficiency, and safety of energy and environmental systems, while providing maximum value to our customers.

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Our Brands

NTM Sensors
we sense a green future

NTM Sensors provides gas sensors and monitors for hydrogen gas safety

FCM
fuelcellmaterials.com
PERFORMANCE AND QUALITY DELIVERED

fuelcellmaterials.com is our sales division to supplying high quality fuel cell and battery materials, coatings, and related materials for R&D and OEM markets.

Problem Statement

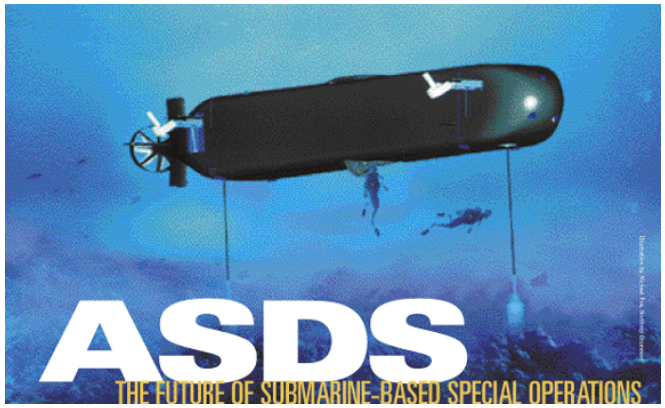
Lithium Ion Battery Safety

- Lithium-ion batteries are concentrated energy sources that can cause catastrophic events when abused
- In rare cases, batteries can cause catastrophic events even when not subjected to improper conditions
- The desire for safer battery systems is not only the ability to isolate these events when they do occur, but also the ability predict and, ideally, avoid them altogether

Lithium Ion Battery Incidents

High Profile Examples

- NHTSA initiated $8.75M study after lithium ion battery related car fires (2012)
- FAA grounds Boeing 787 after issues with lithium ion batteries (2013)
- Battery fire ended the Navy's Advanced Seal Delivery System Program (2008)
- Samsung recalls millions of Galaxy Note 7 phones (2016)



Military Applications

High energy density batteries are essential for modern military systems:

Navy/Marines: Direct energy weapons, auxiliary power on ships, unmanned underwater vehicles, battery storage/transport

Air Force: Auxiliary power on aircraft, unmanned aerial systems

Army: Soldier power systems, target acquisition systems, UAVs and UGVs

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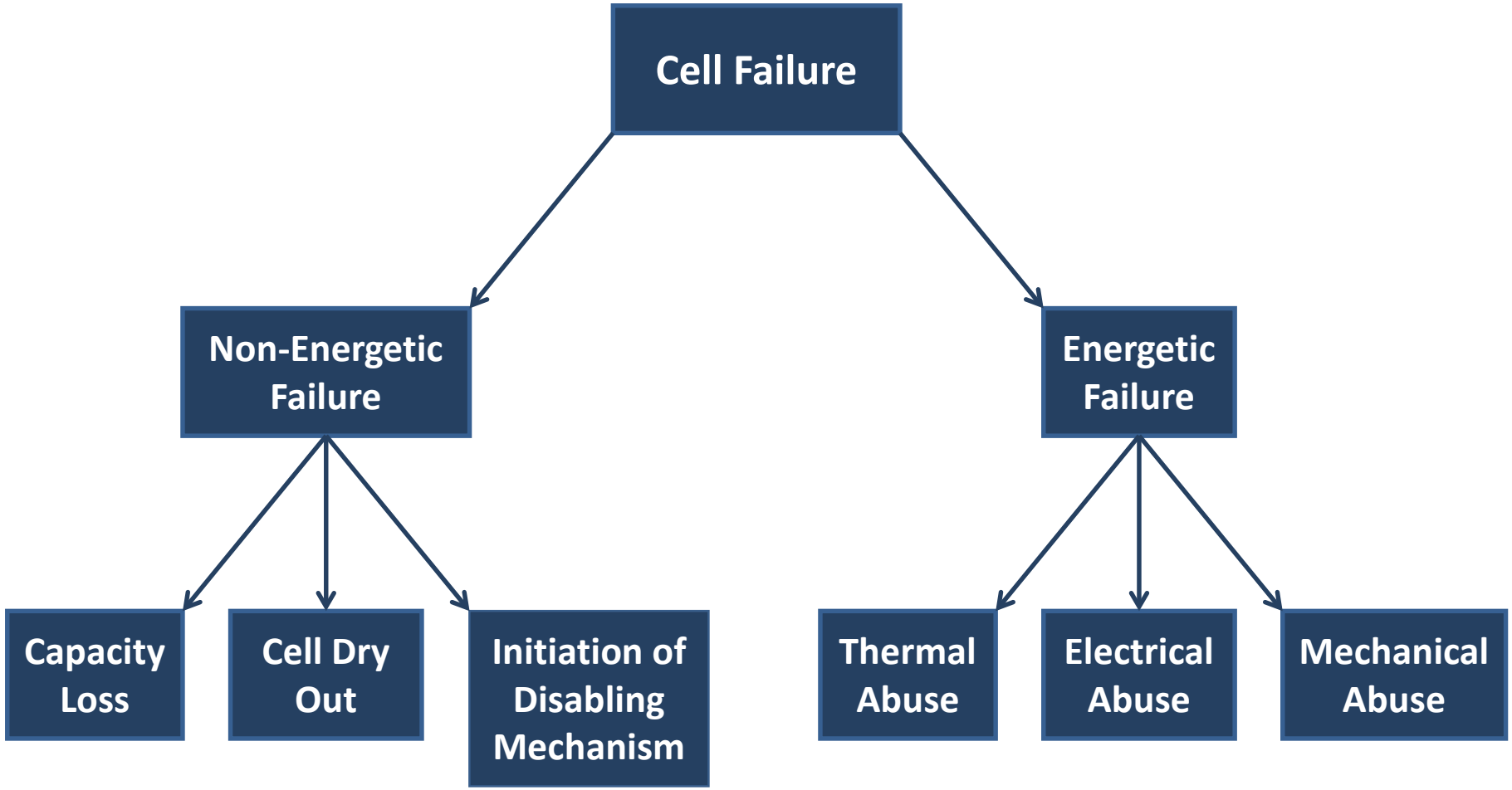
Failure Modes



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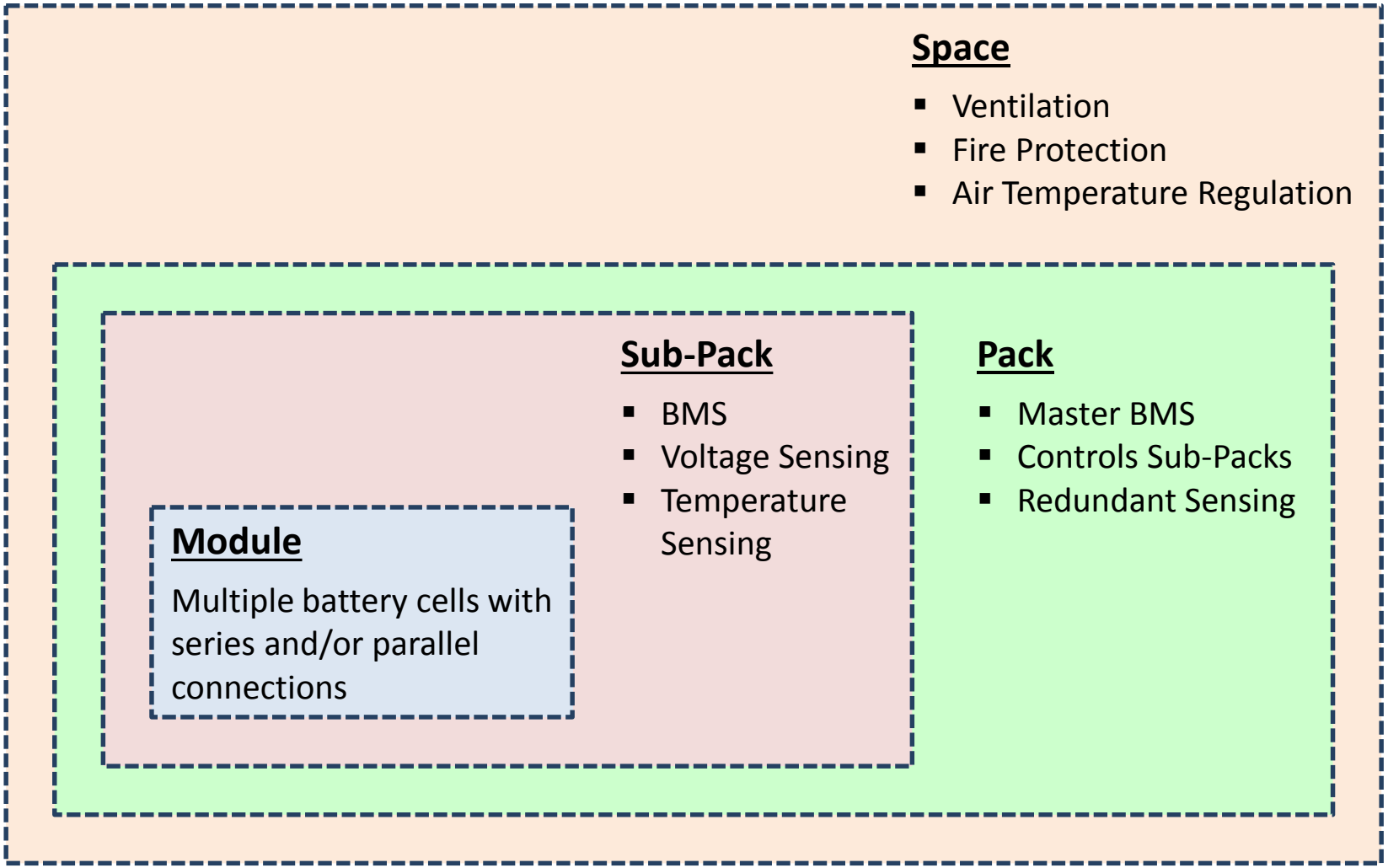
Critical Safety Concerns

- **Short Circuit:** Rapid release of heat and gas
- **Thermal Runaway with Active Materials:** Material decomposition, gas evolution, electrolyte combustion
- **Electrolyte Degradation, Gas Generation and Flammability:** Overpressure and cell venting, flammable electrolyte ejection
- **Propagation:** Failure is not contained to one cell

Battery Safety Approaches



Battery Safety Approaches

Cell Level

- Burst Disk/CID
- Separator Materials

Module Level

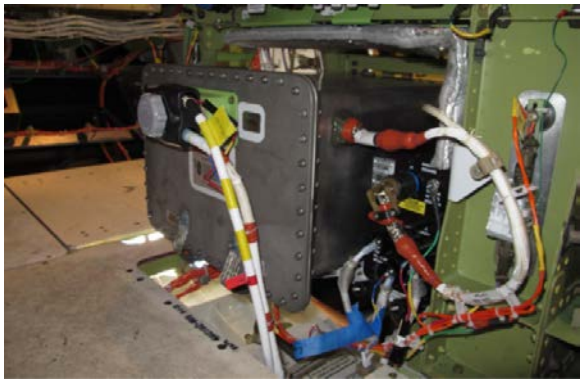
- Thermal Management
- Battery Management Systems (BMS)
- Robust Design of Enclosure

Pack Level

- Master BMS
- Redundant Sensor Systems

Space Level

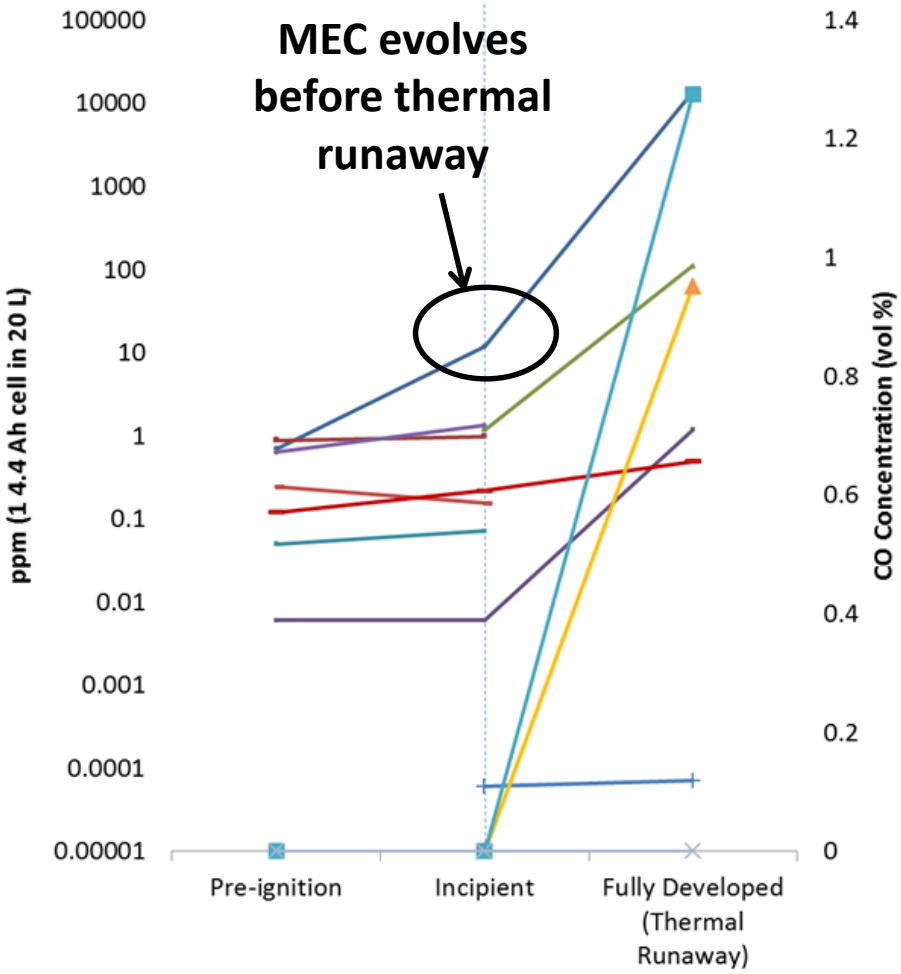
- Fire Suppression
- Temperature Regulation

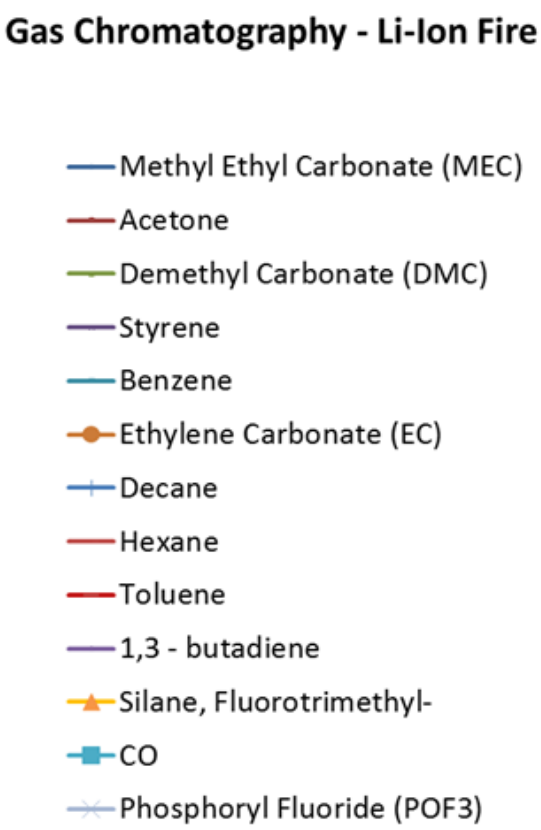


Lithium-ion battery reliability and safety is generally considered a function of the entirety of the cell, pack, system design, and manufacture

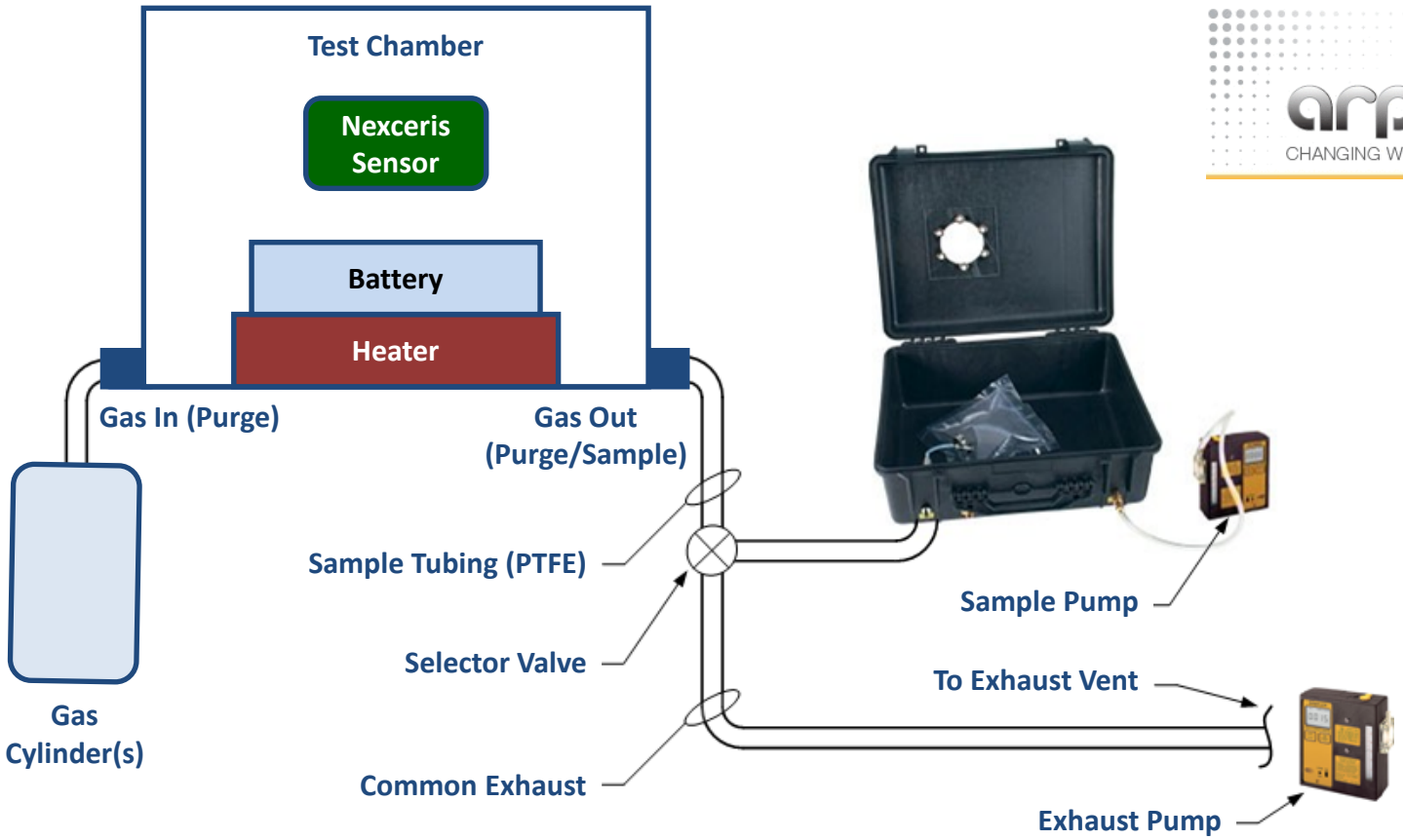
Nexceris approach uses early detection of off-gassing to prevent failure

Off-Gassing Characteristics





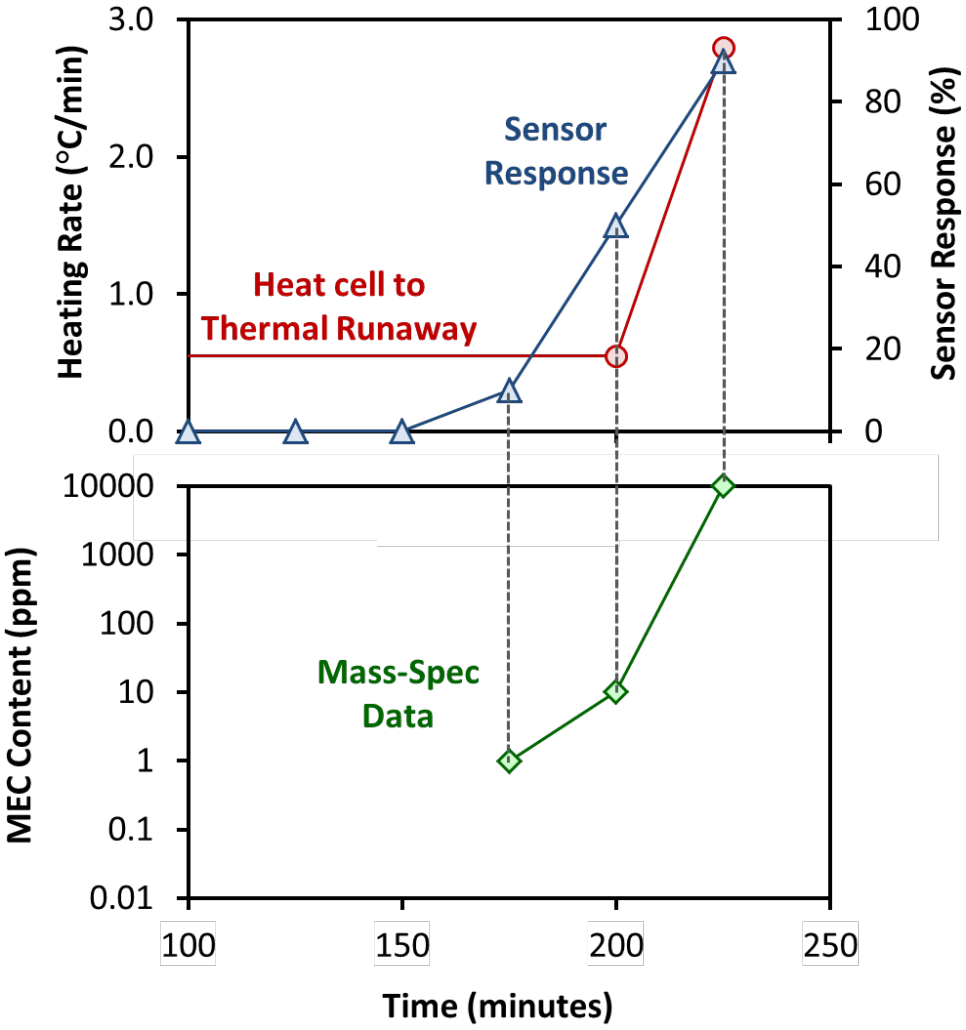
Thermal Abuse Testing



- Chamber is designed to monitor battery off-gas during abuse testing.
- Pump allows for bag samples to be collected for third party analysis.

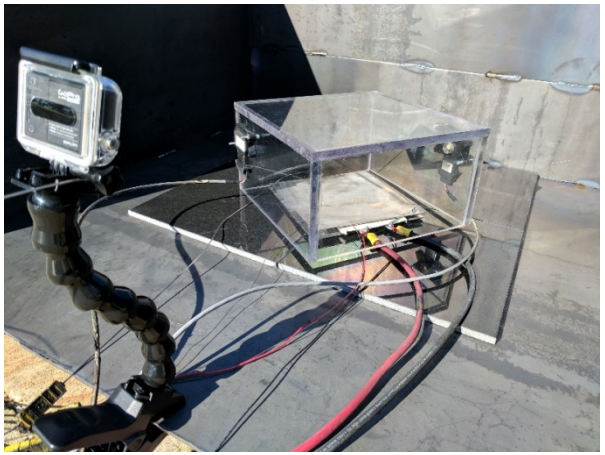
Thermal Abuse Testing

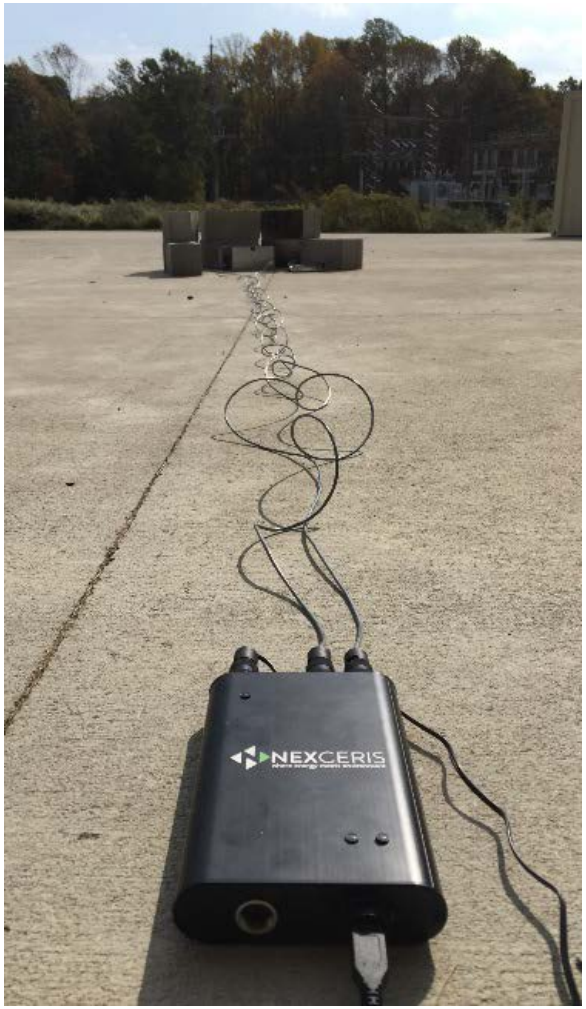
Sensor responded prior to temperature spike by 10-20 minutes under thermal runaway test conditions. Confirmed gas species with bag sample analysis.



Battery Failure Testing

- Nexceris has built capabilities for characterizing failing batteries and designing systems around prevention of catastrophic events
- Enables understanding of off-gassing characteristics of all lithium ion battery cell form factors and chemistries
- Nexceris has tested cylindrical, pouch, and prismatic cells and continues to characterize off-gassing mechanisms for battery safety stakeholders





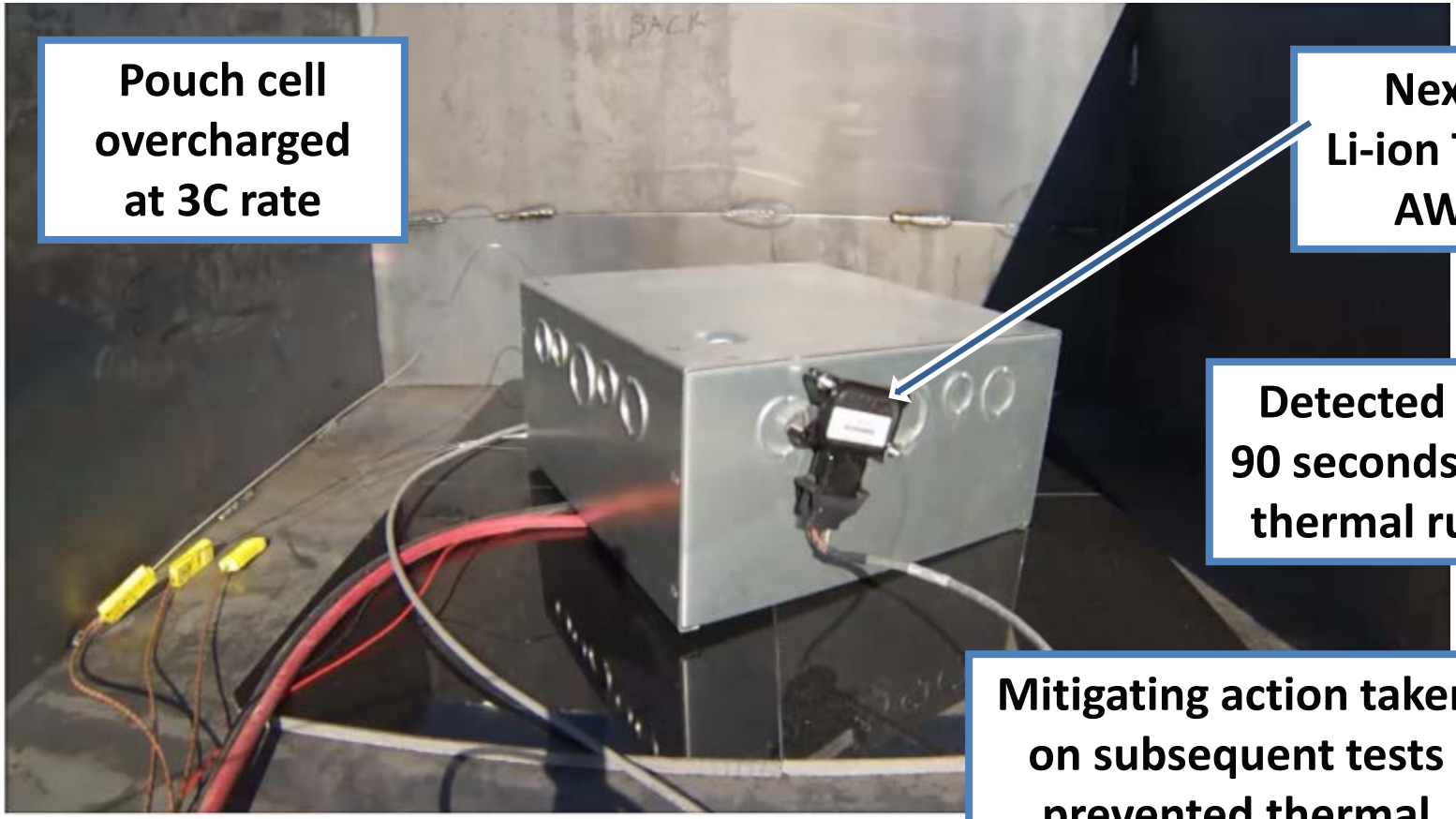
Battery Failure Testing

A lithium ion pouch cell was abused with overcharge to induce failure

An enclosure was created to contain the test and simulate a battery module

Testing performed with support from Battery Innovation Center

Early Detection of Thermal Runaway



Pouch cell overcharged at 3C rate

Nexceris Li-ion Tamer™ AWARE

Detected off-gas 90 seconds prior to thermal runaway

Mitigating action taken on subsequent tests prevented thermal runaway

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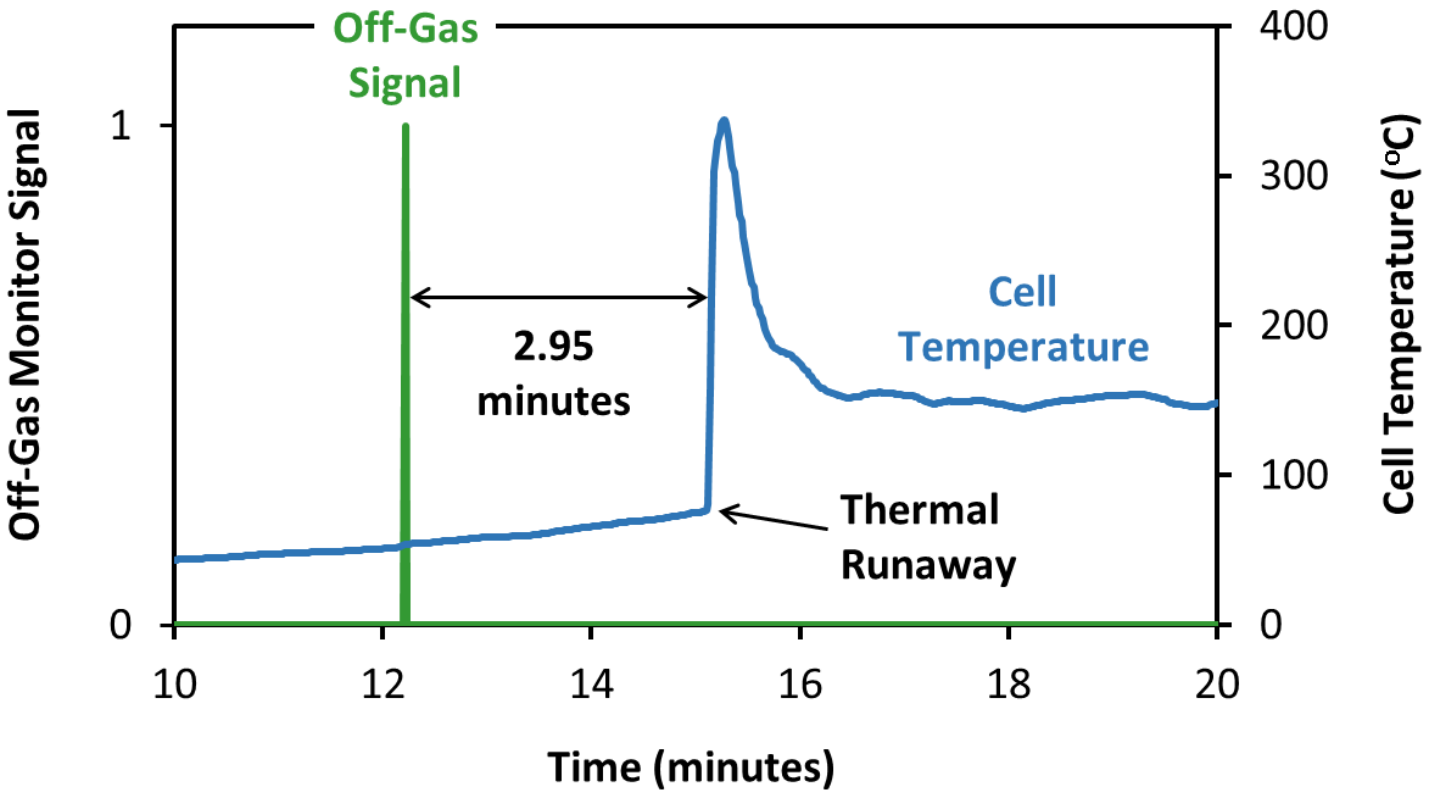
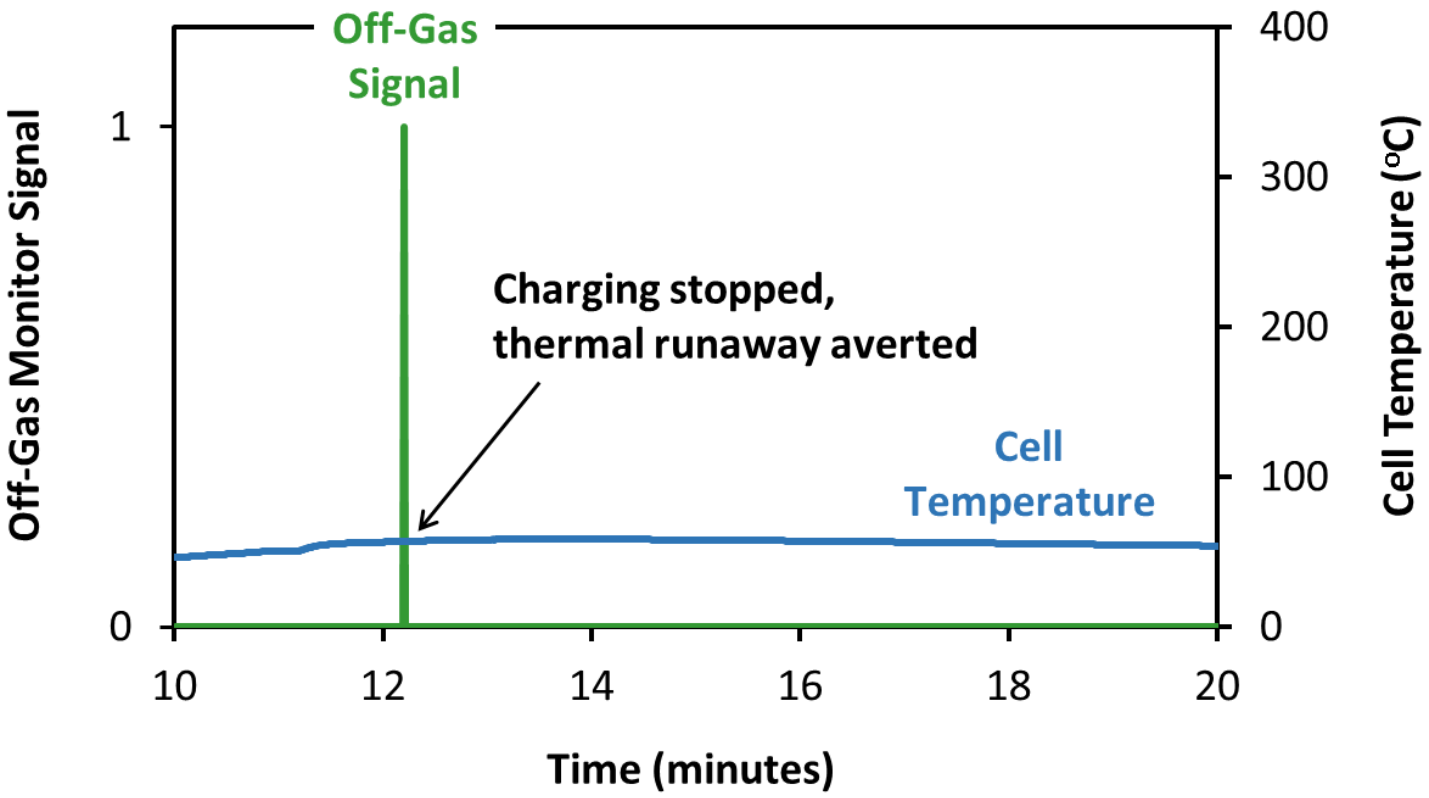
Early Detection of Thermal Runaway



Overcharge failure test (5C charge rate)

Off-gas detected 2.95 minutes in advance of thermal runaway

Mitigation of Thermal Runaway



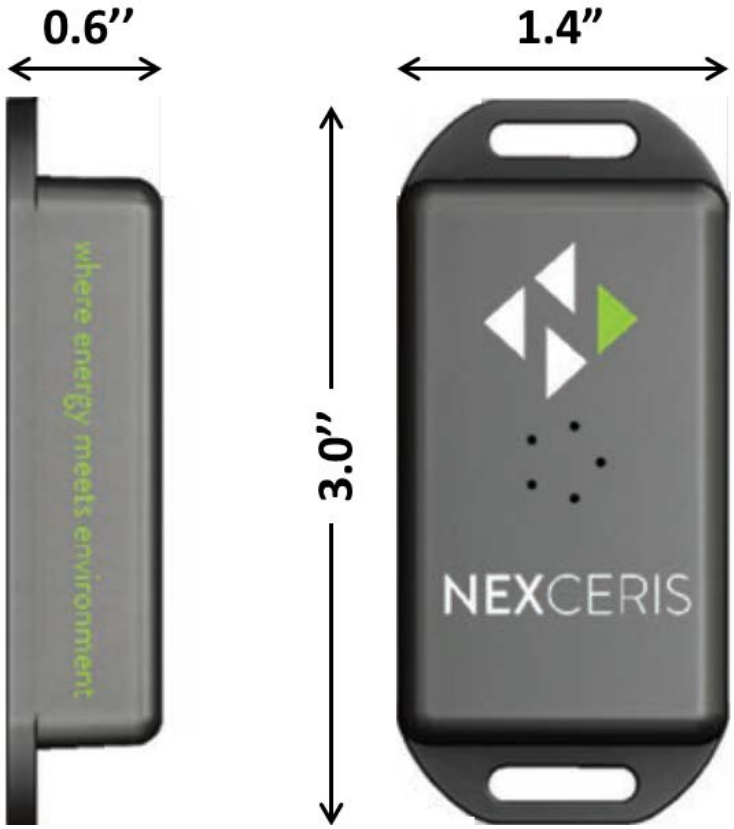
Overcharge failure test (5C charge rate)
Charging suspended when off-gas detected
Thermal runaway avoided

Li-Ion Tamer Aware™

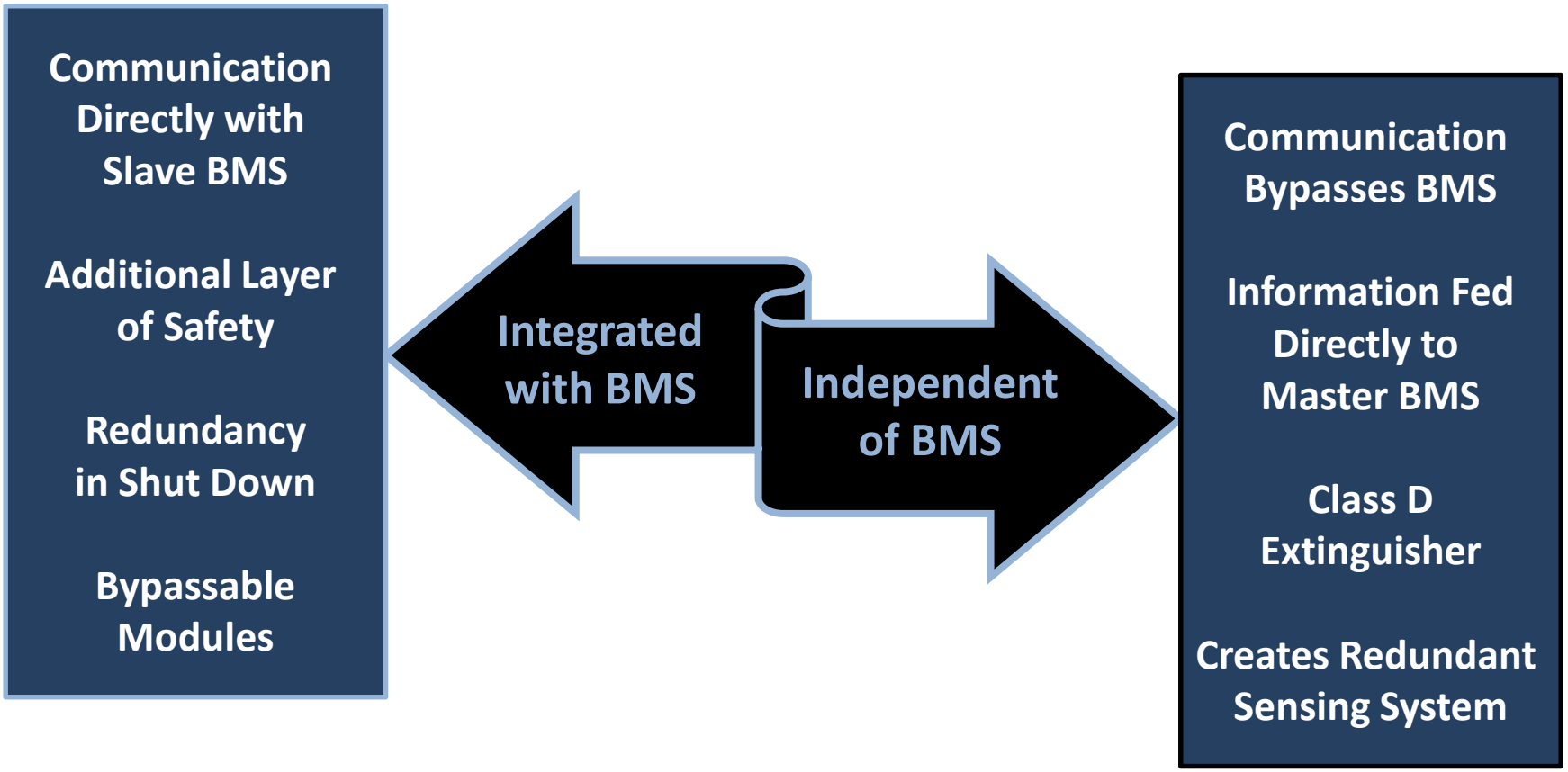
Li-ion Tamer™ AWARE Battery Off Gas Monitor

- Product release in Q2 2017
- Integrated with BMS – plug and play design
- Early warning signal for shut-down or other mitigation
- One monitor per battery module
- Added layer of safety

ISO 9001 Certified
International Organization for Standardization



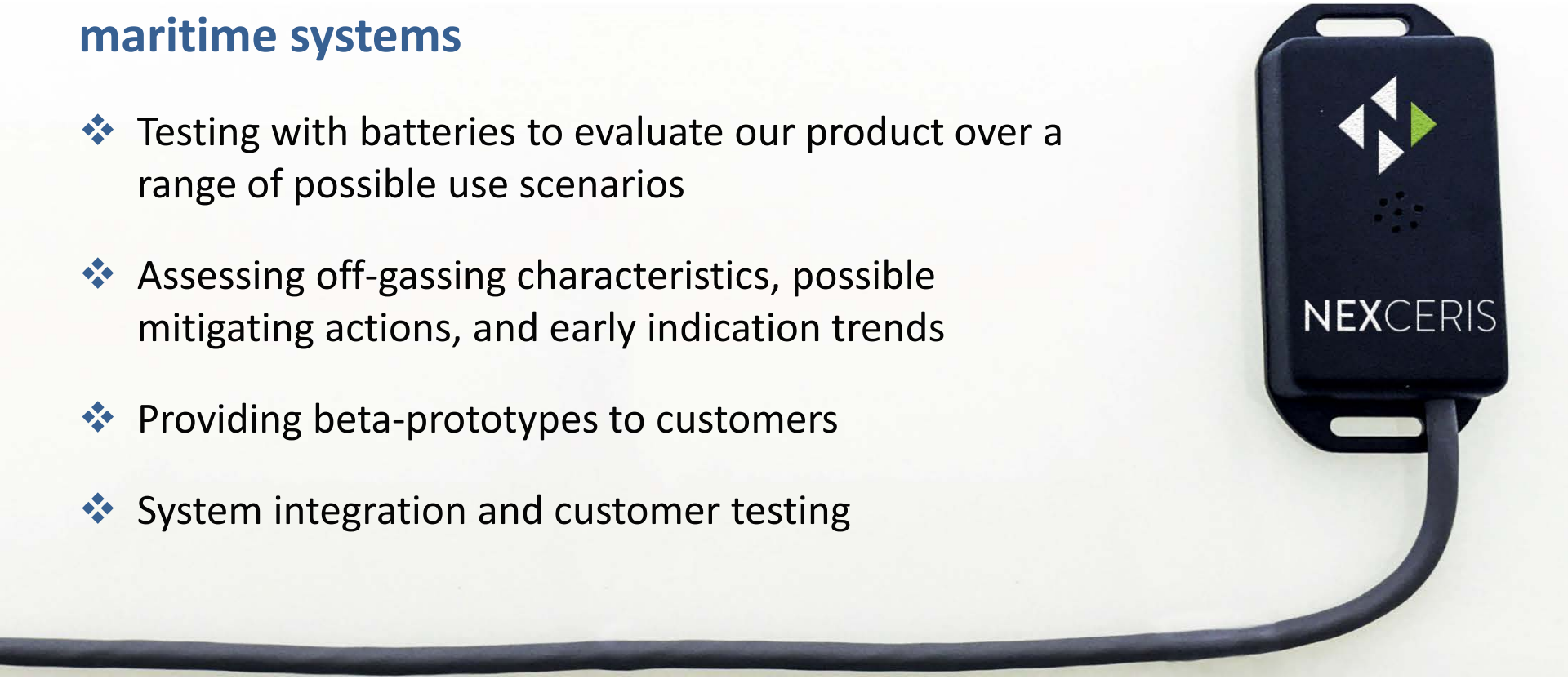
Possible Use Scenarios



Product Development Status

We are looking to design our product into next generation military, packaging, laboratory, and maritime systems

- Testing with batteries to evaluate our product over a range of possible use scenarios
- Assessing off-gassing characteristics, possible mitigating actions, and early indication trends
- Providing beta-prototypes to customers
- System integration and customer testing



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Li-ion Tamer Product Team

- Steve Cummings
- Nick Frank
- Bill Dawson
- Scott Swartz

Acknowledgements

NAVSEA
NAVAL SEA SYSTEMS COMMAND
DNV
arpa·e
CHANGING WHAT'S POSSIBLE
BIC