FastCap®
Ultracapacitors
A Nanoramic® Labs Technology

# Advanced FastCap Capacitors For Military and Space Electronics And Embedded Solutions

# FastCap Ultracapacitors Story

**Headquarters**

- Greater Boston, MA

**Key Figures**

- Employees: >10
- Founded: 2009

**Key Investors**

HALLIBURTON

MARUBUN CORPORATION

Niterra

FORTISTAR

SAFAR PARTNERS

WINDSAIL CAPITAL GROUP

**Supported By**

arpa·e ENERGY

NASA

AFWERX

*Developer the only ultracapacitors capable of operating in extreme environments, such as temperatures up to 150C and under conditions of high shock and vibration, and the first reflow solderable chip cap*

## Overview

- Founded by MIT graduates in 2009 following a DOE ARPA-E award
- Developed and commercialized the world's first harsh environment supercapacitors in Oil & Gas drilling
- Established rapid commercialization business model, expanded product lines
- Repeated successes in product licenses and business line exits
- Transferred core innovations to Lithium-ion Batteries in 2019
- Spin off FastCap Ultracapacitors in 2024

## Technology

- Neocarbonix® at the Core 3D nanocarbon electrode
- Advanced electrolytes especially designed for harsh environments
- Unique ultracapacitor designs

## Business Model & Commercialization

- Capital light, Low and mid volume mfg, IP licensing business model
- Focus: Rapid commercialization
- Over 140+ granted and pending patents worldwide

# FastCap Core Team

**Christopher Deane**

Chief Operating Officer

**John Hyde**

Chief Technology Officer

**Tatyana Movchan, Ph.D.**

VP Business Development

**Alex Germain**

Director of Product Introduction

**Lito Mahaira**

Associate General Counsel

Boston University, Duracell

>13 years tenure with FastCap/Nanoramic
>20 years of industry experience

Northeastern University, WPI

>8 years tenure with FastCap/Nanoramic

IPCP RAS, P&G, Ultralife, Duracell

>6 with FastCap/Nanoramic
>30 years of industry experience

University of Virginia, Sikorsky

~ 7 years with FastCap/Nanoramic
>14 years of industry experience

University of London, Donovan Hatem LLP

>5 years tenure with FastCap/Nanoramic

# Nanoramic Executive Team Members

**John Cooley, Ph.D**

CEO, Founder
Nanoramic

**Nicolò Brambilla**

CTO
Nanoramic

**Matt Fenselau, Ph.D.**

Chief Licensing Officer & General Counsel
Nanoramic

**Julie Ross**

CFO
Nanoramic

**Eli Cohen**

**EVP Corporate** Development **Nanoramic**

MIT, Politecnico Milano 1863, Les Supélec, Thales

Boston College, Foley & Lardner LLP, Yale University

PwC, Bentley University

Rabobank, McGill University

# FastCap Ultracapacitors Intellectual Property

***Generation Next Supercapacitors for Generation Next Applications***

## High Performance Ultracapacitors


- Extreme Temperature Advanced Electrolytes
- Neocarbonix EDLC Electrode
- Advanced Cell Designs
- Surface-Mount Technology

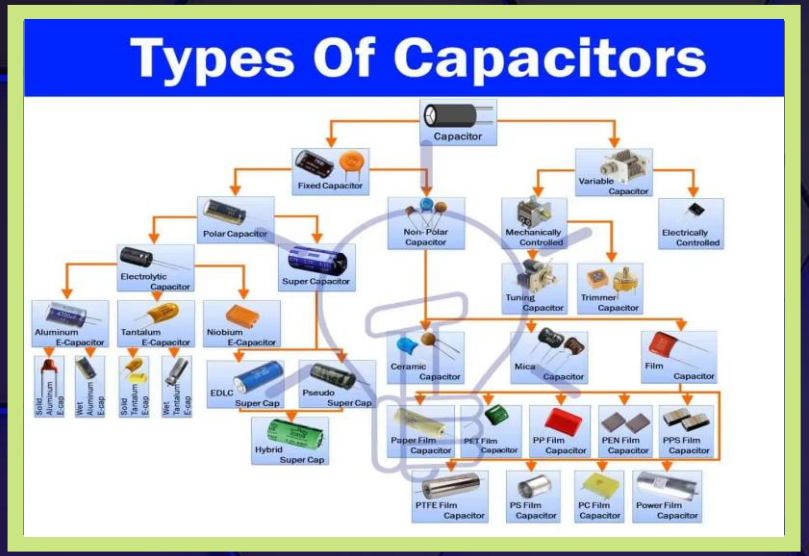
**IP Protection**

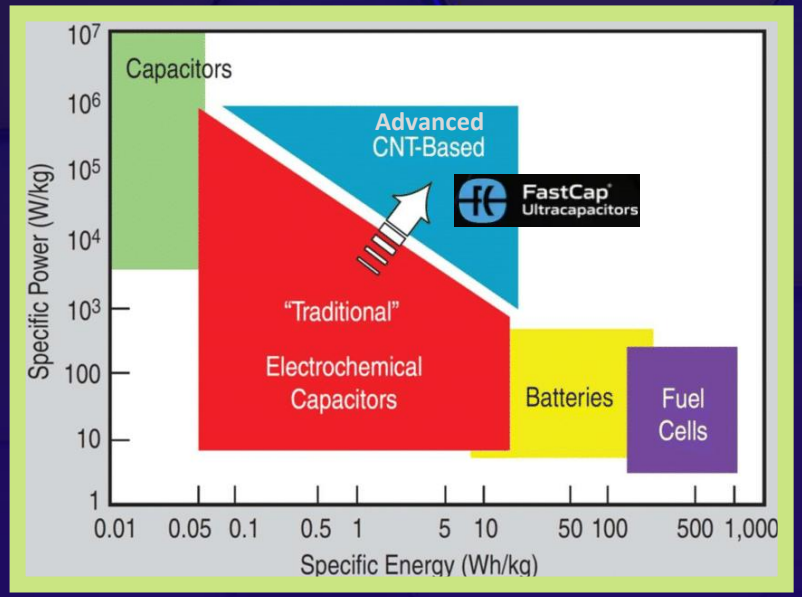
| Patent Portfolio Summary | |
|---|---|
| **Patents Granted** | **Total: 55**<br>**US: 31** |
| **Applications Pending** | **Total: 89**<br>**US: 18** |

***144 Total Patents Granted and Pending Globally***

# EDLC CAPACITORS ADVANTAGES

- High Power Density – can deliver significantly higher power than batteries
- Fast Charge/Discharge Rates: they can charge and discharge almost instantaneously, making them ideal for applications requiring quick energy bursts
- Long Service Life: EDLCs have a much longer lifespan than batteries, with some models lasting up to 15 years
- Wide operating temperature range - can maintain their performance even at low and high temperatures
- Compact and Lightweight: EDLCs are generally smaller and lighter than batteries, making them suitable for space-constrained applications.



# Capacitors Requirements for Defense & Aerospace Applications

## Ruggedized

- High Vibration: withstand up to 80 g
- Wide Temperature Range:
  - Low to -55 °C
  - High up to 200 °C
- High Altitude: ≥ 80,00 ft (vacuum)

## High Reliability, Long Life

- Stability over a wide range of operating conditions
- Hermetic or near hermetic package
- Reliability and Safety
- Low ESR
- Low leakage current

## Compactibility

- High energy density
- Low weight
- Low volume
- Low-profile

## Application Versatility

- Surface mounted designs
- Reflowable designs

# FASTCAP CAPACITORS FOR EXTREME APPLICATIONS


## FastCap®
## Chip Ultracapacitor
## -Charlie-

Reflowable – Survives 260°C Soldering

Higher Energy Density than Tantalum – replaces > 10 Tantalum

Data Centers
Consumer/IoT
Energy Harvesting
Aerospace/Defense


## FastCap®
## High Temperature
## Ultracapacitor
## -Delta-

Commercial Product for 150°C Operation

Prototypes up to +300°C

Better Power Delivery

Oil & Gas Drilling
Aerospace & Defense
Stational Storage
Medical

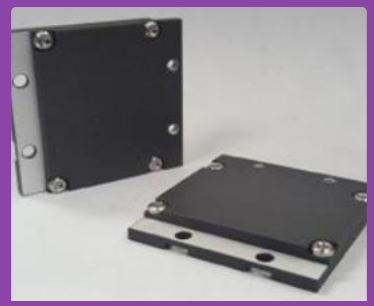

## FastCap®
## Low Temperature
## Ultracapacitor
## -Lima-

Commercial Product for -55°C Operation

Prototypes to -100°C

High Altitude Capable

Flight Data Recorder
Aerospace & Defense
Transportation/Auto

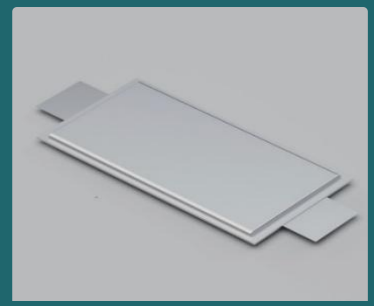


## FastCap®
## Structural
## Ultracapacitors
## -Sierra-

Combination of Cube Satellite Wall & Energy Storage

High Power Density

Cube satellites
Aerospace & Defense
Transportation/Auto
Energy Storage



## FastCap®
## LiC Capacitor
## -Yankee-

Better Energy Density than Ultracapacitors

Better cycle life than Batteries

Super High-Power Density

Transportation/Auto
Aerospace & Defense
Consumer/IoT

COMPLIANT · COMPLIANT
ROHS
Pb
lead-free

# FASTCAP DEFENSE AND AEROSPACE INTERACTIONS

FastCAP® Ultracapacitors have been tested and validated by numerous organizations, including NASA and the United States Army. The technology has also been recognized with several awards and grants, including a grant from the National Science Foundation and the NASA Tech Briefs "Create the Future" Design Contest Grand Prize

LEONARDO DRS

LOCKHEED MARTIN

Department of Defense

Sandia National Laboratories

VISHAY

NASA

Missile Defense Agency

L3HARRIS™ FAST. FORWARD.

United States Army

Others?

# DELTA HIGH TEMPERATURE EDLC CAPACITORS

- Rigidized design
- Hermetically welded shut to <10^-8 cc/sec of He
- Able to withstand shocks up to 1,000G or continuous operation at 20Grms
- Broad operation temperature down to -40°C, highest as rated by Model Name. EE100, EE125, EE150 represents 100°C, 125°C, and 150°C respectively
- Prototypes to up to 300 °C
- Stainless Steel terminals
- Eco-friendly
- Commercially available for Oil and Gas Drilling

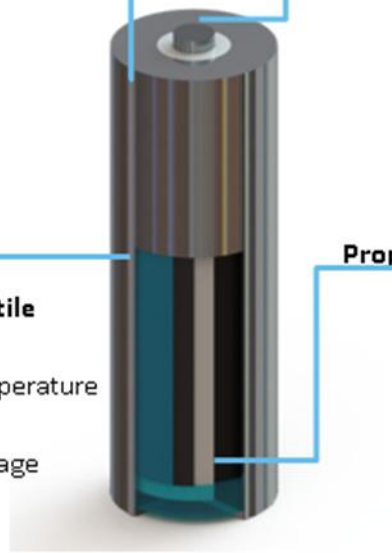

# DELTA CAPACITORS ATTRIBUTES

**Shock and vibration resistance technology**
- Engineered internal connections to withstand shock and vibrations

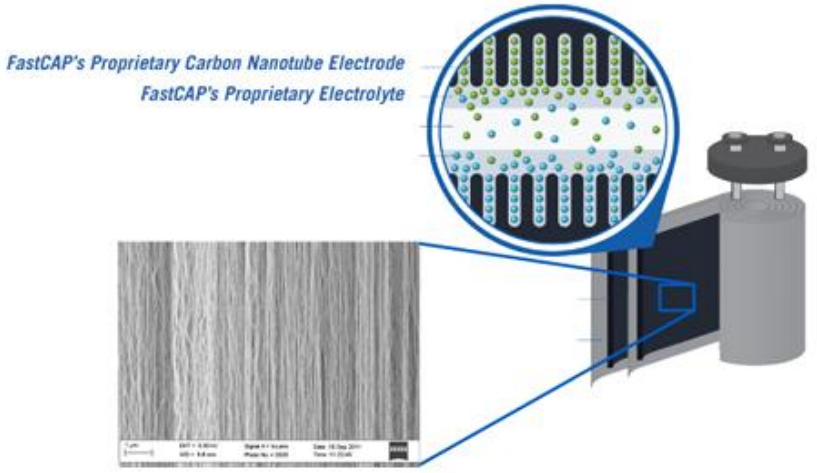
**Laser welded & hermetic package**
- Operation in vacuum and at high temperatures

**Proprietary non-volatile electrolyte**
- Wide temperature range
- Wide voltage window

**Proprietary electrodes**
- High temperature capabilities
- Great cycleability



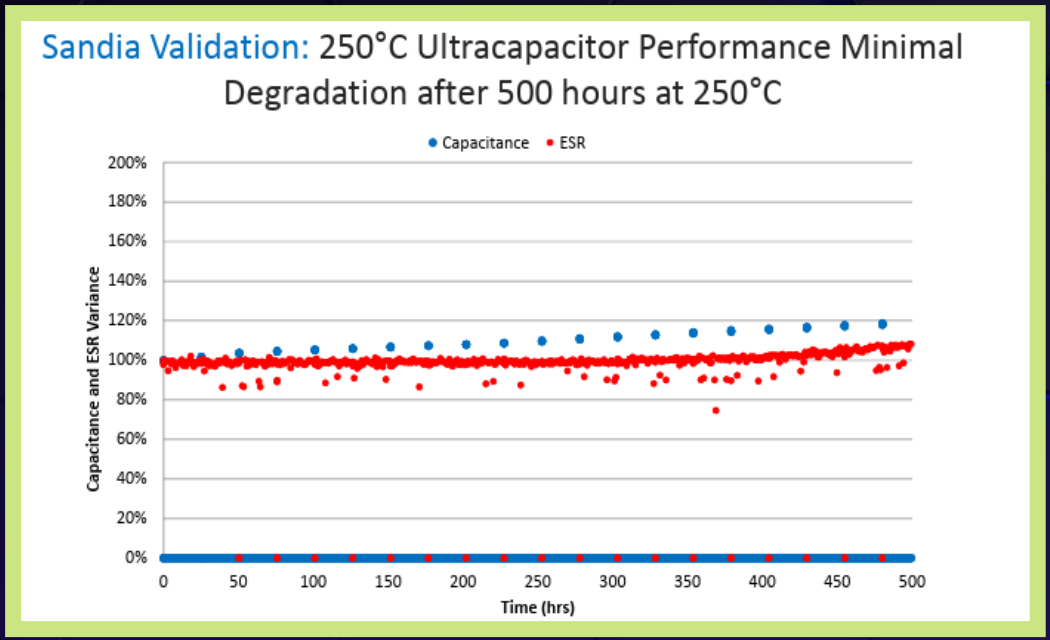
## Nanoramic's Core Technology: CNT Ucaps

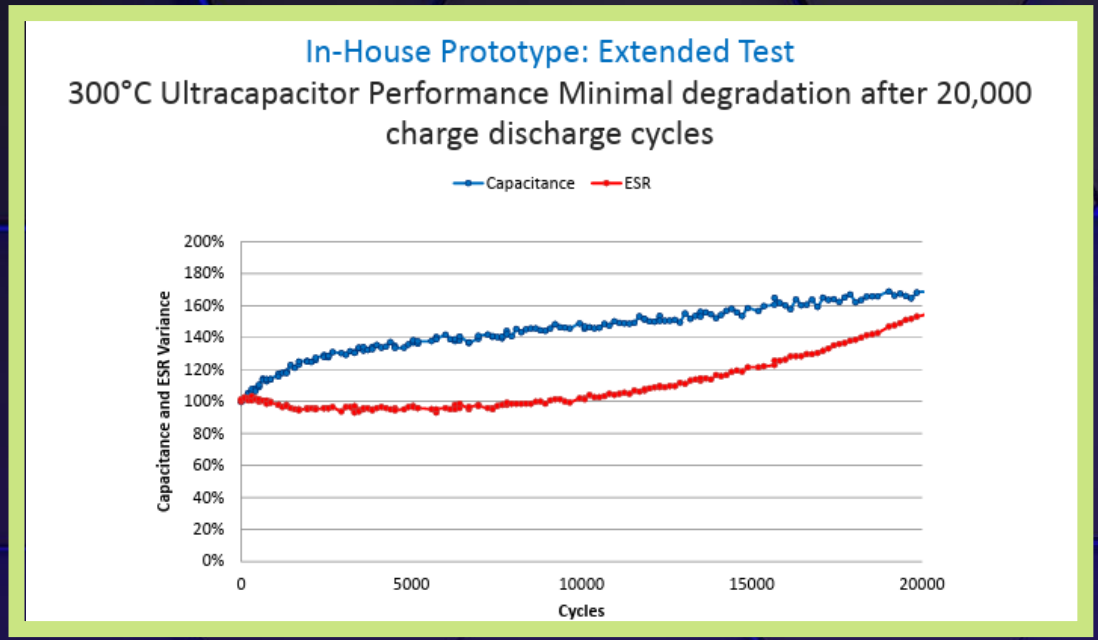


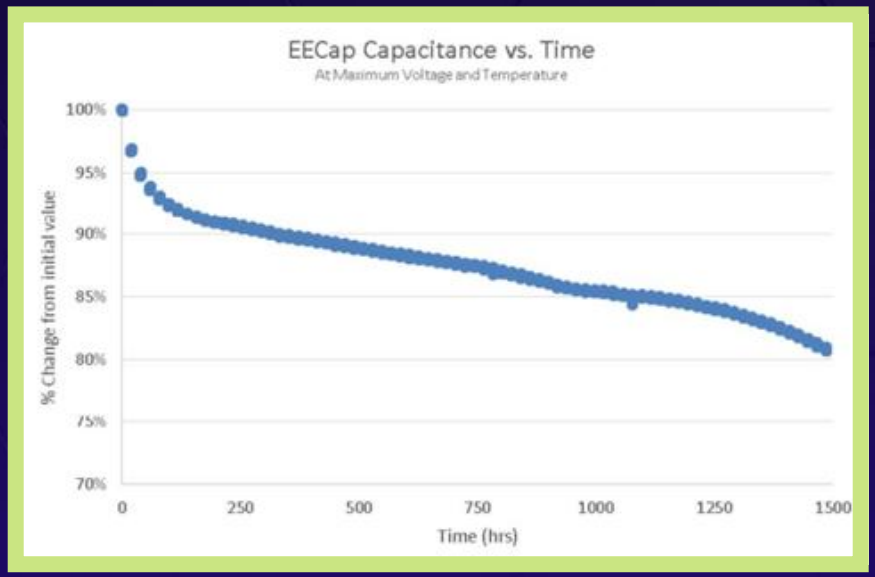

Notable attributes:

- Proprietary carbon nanotube electrode with high surface area
- Proprietary electrolyte for high stability at high temperature
- 10x the power density of incumbent ultracapacitors
- 3x energy density

# DELTA CAPACITORS PERFORMANCE TESTING




The resistance is measured by performing a 100mA pulse train on the capacitor while it is at maximum voltage. Resistance will be lower and capacitance higher at elevated temperatures. The plot below shows an example of this.

# DELTA CAPACITORS SAFETY & ABUSE TESTING

## Downhole Ultracapacitor Safety and Abuse

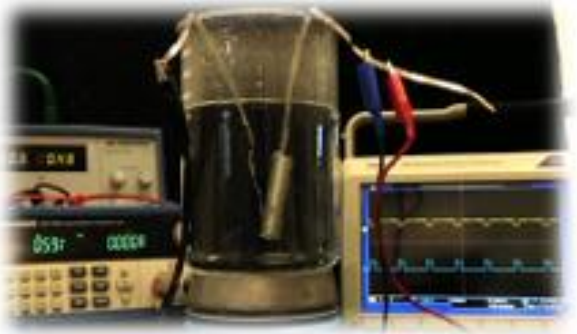
Extensive abuse tests performed on FastCAP's ultracaps:

- Sawed in half while charged and cycling
- Punctured and shocked while charged and cycling
- Crushed while charged and cycling
- Boiled while charged and cycling
- Blow torched (1000C) while charged and cycling

Puncture while charged and cycling

Blow Torch Test while charged and cycling

Cut in half while charged and cycling



Freeze to boil while charged and cycling

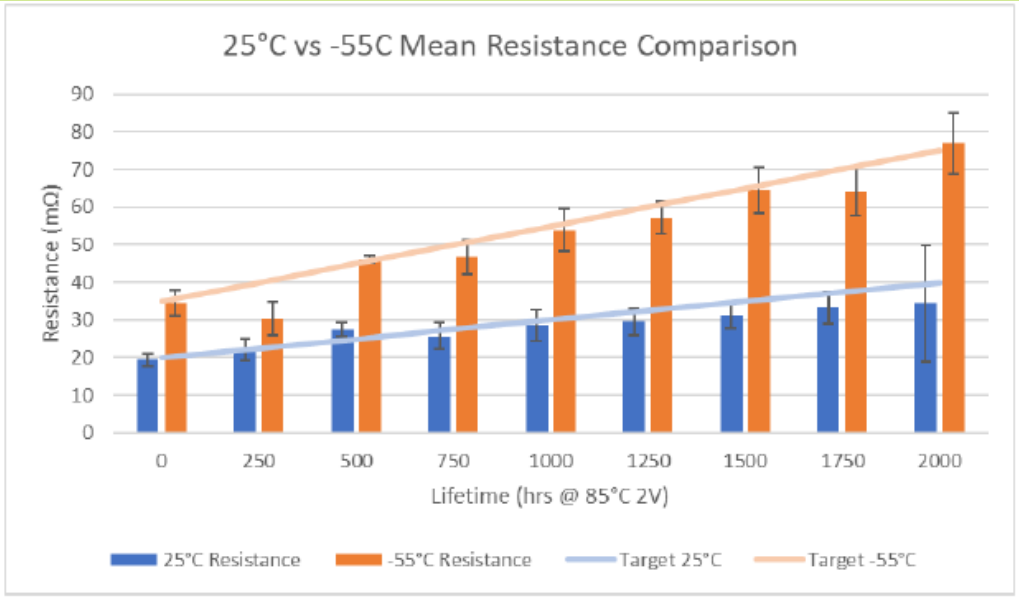
# DELTA CAPACITORS APPLICATIONS

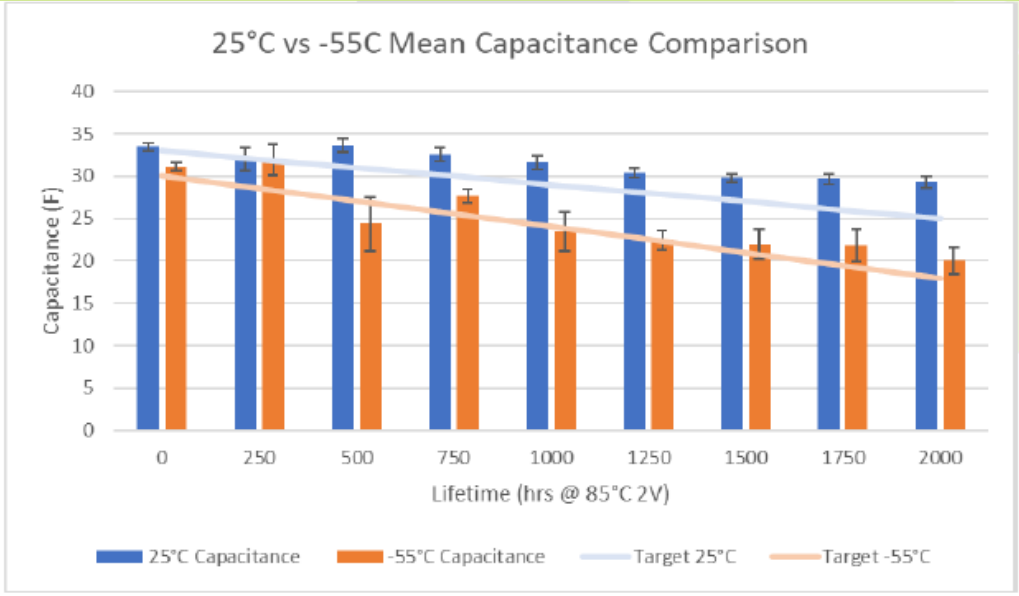
- Instant energy release – “firing” lasers, electromagnetically accelerated projectiles (rail guns), catapults
- Electromobility - vehicle drive trains
- Others

# LOW TEMPERATURE LIMA EDLC CAPACITORS

- Rigidized design
  - Vibration  resistance: 20 gRMS
  - Shock resistance: 500 g
  - Hermicity: 100,000ft altitude
  - Operating temperature: -55°C to 85 °C
  - Storage temperature: -65°C - 100°C
  - Hermetically sealed
- Designed to maintain high capacitance and low resistance throughout entire operable temperature r

# LIMA PERFORMANCE CHARACTERISTICS

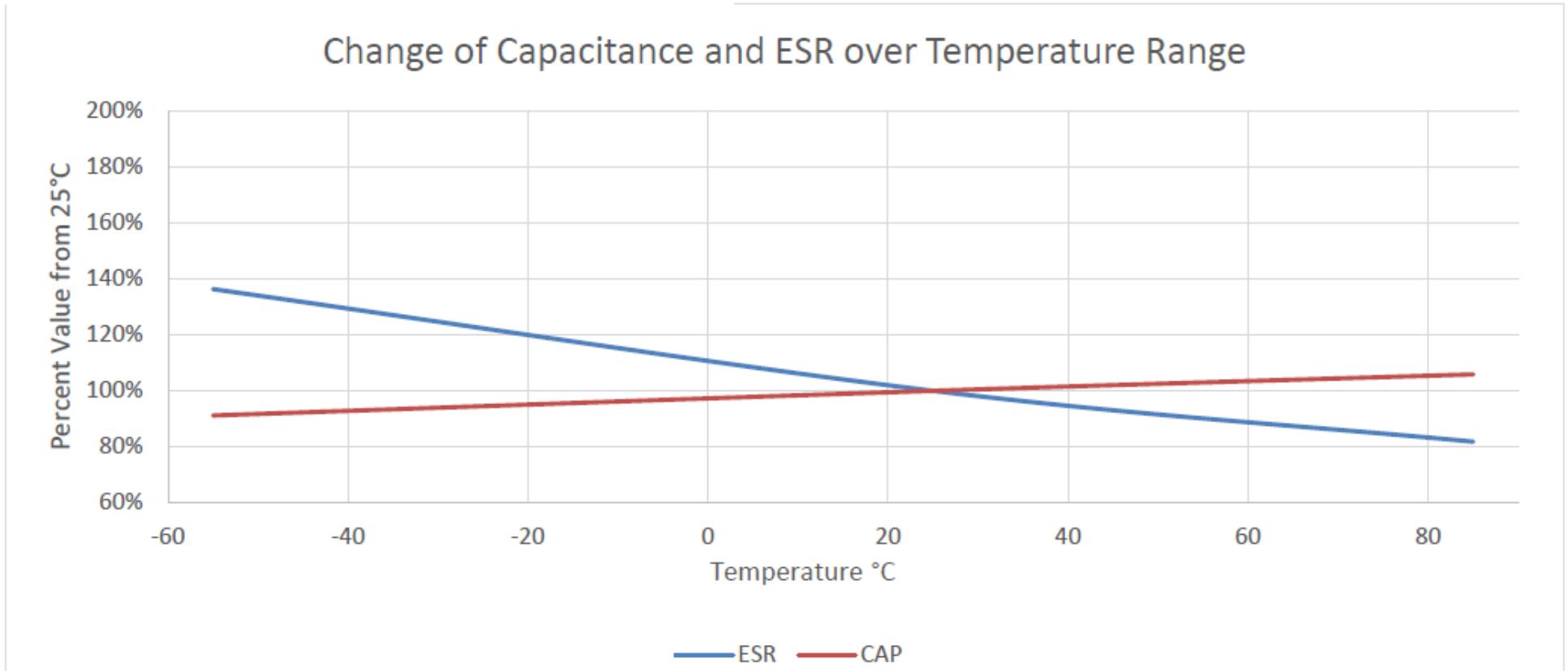



- Less than 50% room temperature ESR degradation after 2000 hours of lifetime at 85°C.
- Less than 100% -55°C ESR degradation after 2000 hours of lifetime at 85°C.

- Less than 15% room temperature capacity degradation after 2000 hours of lifetime at 85°C.
- Less than 40% -55°C capacity degradation after 2000 hours of lifetime at 85°C.

# LIMA PERFORMANCE CHARACTERISTICS



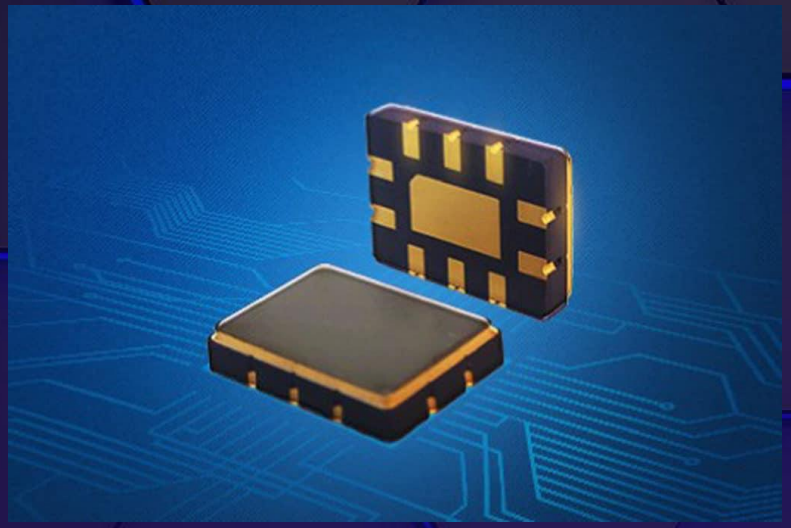

- Initial capacity rating within 10% of room temperature rating between -55°C and 85°C
- Initial ESR rating within 40% of room temperature rating between -55°C and 85°C

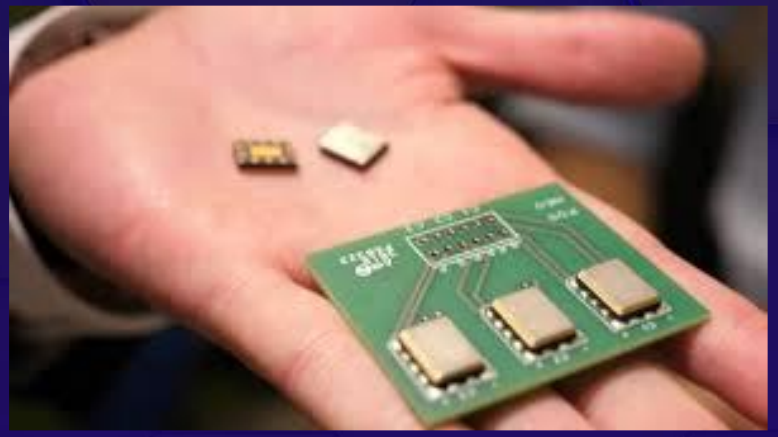
# LIMA CAPACITORS APPLICATIONS

- Flight data recorders
- Deployable recorders
- High-altitude distributed power buffering
- In-flight sensors

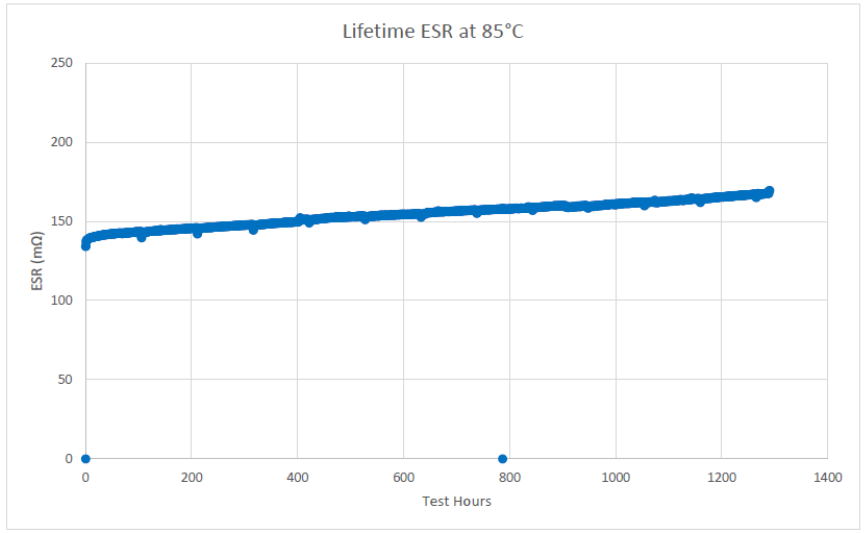
# CHIPCAP REFLOWABLE CHARLIE ULTRACAPACITORS

- Rigidized design
- Chip cap passes IEC60068 random vibration stress test
- Wide Operating Temperature -20°C to +85°C
- The only low ESR reflowable ultracapacitor (wistands high temperature solder process)
- Sealed ceramic package – great for air sensitive applications
- 10X more energy density vas tantalum capacitors
- Low ESR and leakage current
- Tolerates high ripple current (3 A vs. ~ 0.4-0.5 mA industry standard)
- Light weight, small footprint, high energy density

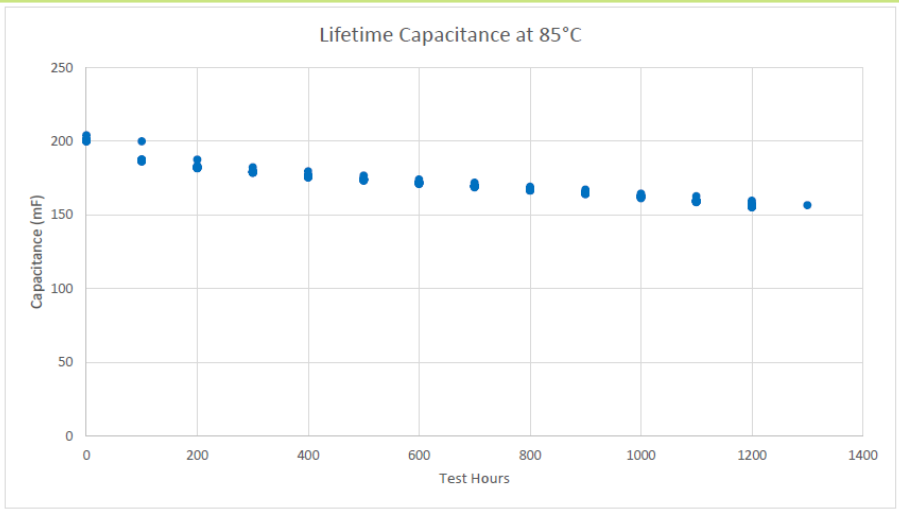




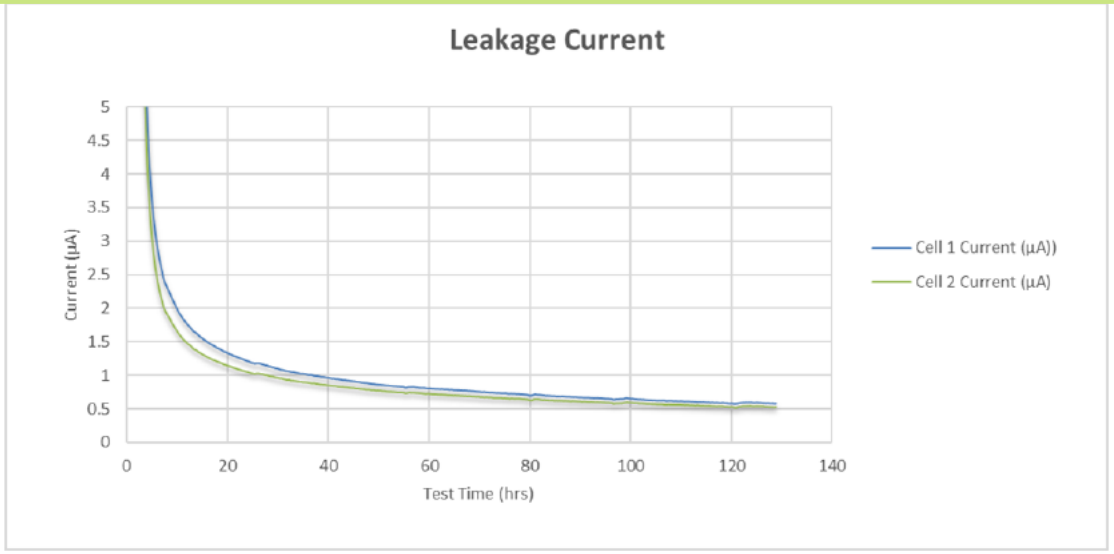
# CHARLIE PERFORMANCE CHARACTERISTICS



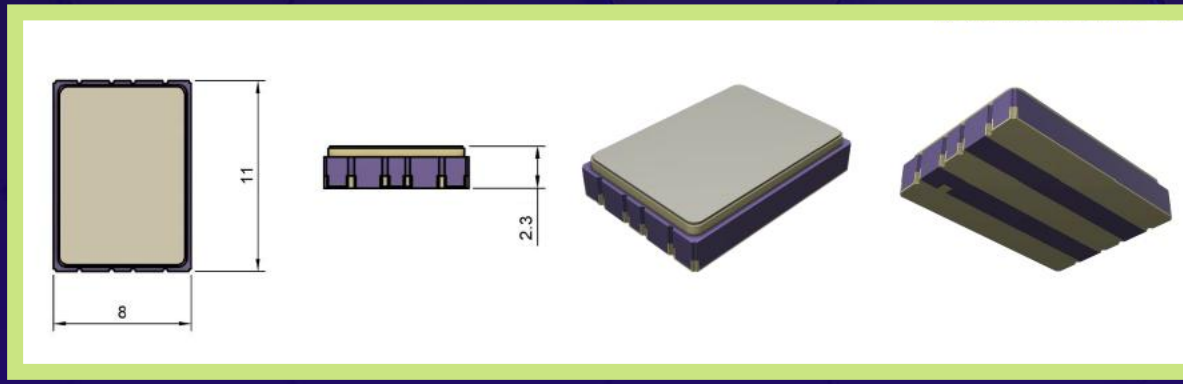

Average ESR increase is 14% after 1,000 hours at 85°C. ESR measured with 4-point Arbin measurement at test temperature. Arbin measurement is the average voltage drop over 10 pulses of 100mA at a frequency of 1kHz. Consult the Arbin manual for more detail.



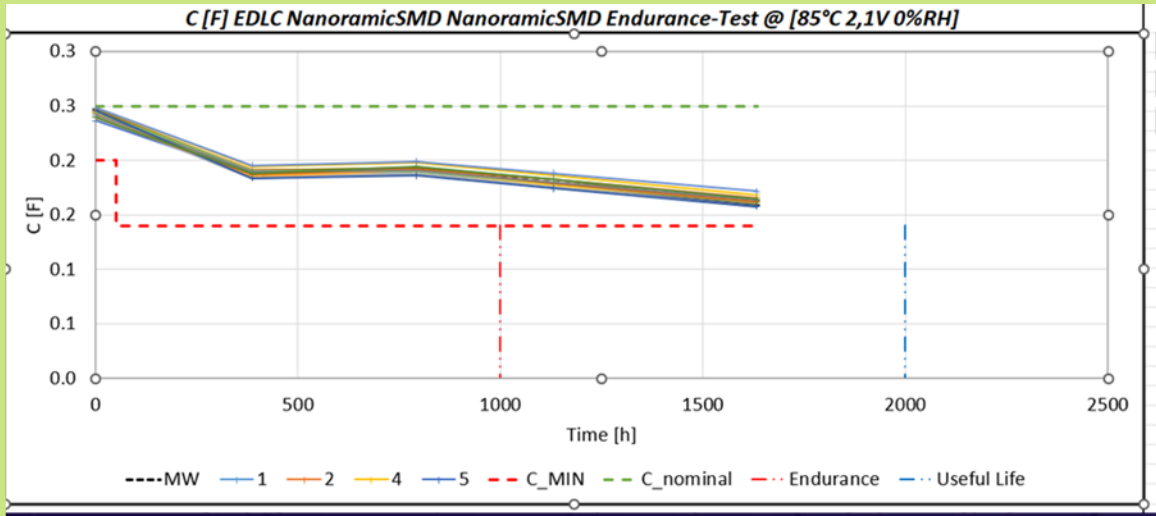

Average capacitance retention is 80% after 1,000 hours at 85°C. Capacitance measured on 100mA discharge. Cells are cycled 20 times every 100 hours at test temperature.

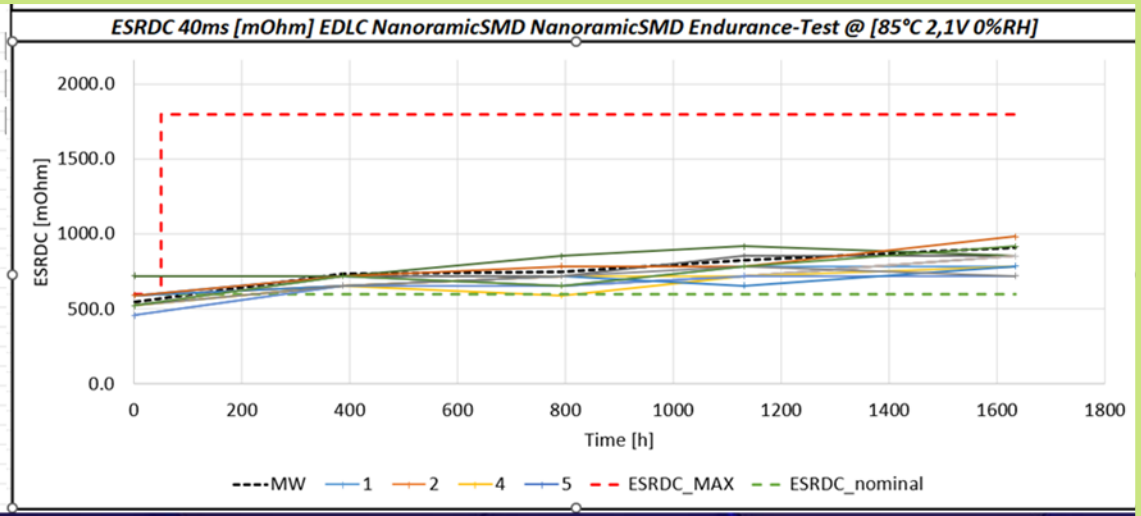


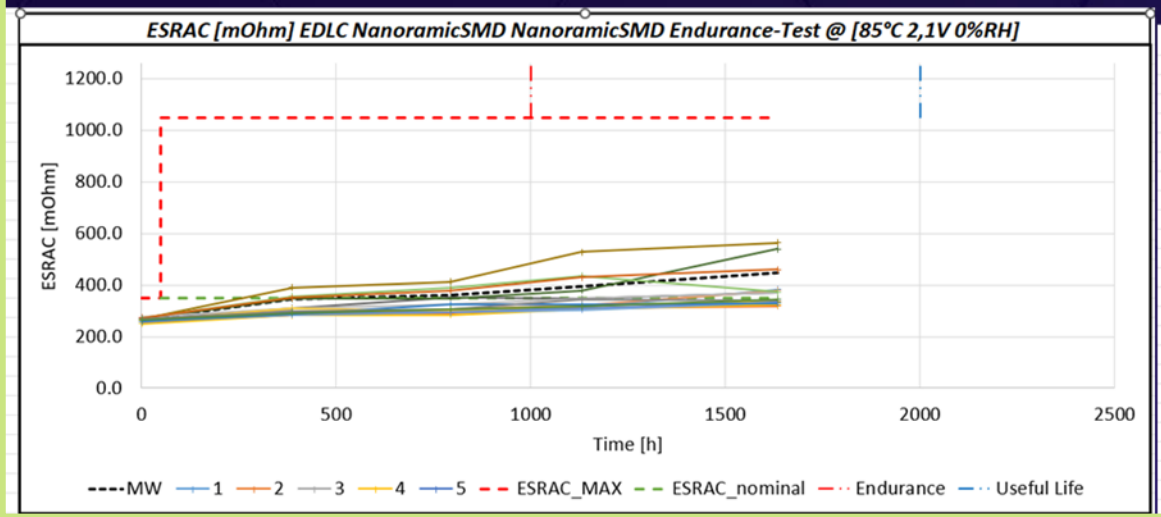

Leakage current readings taken during 25°C 2.1V hold. Minimum current of 550nA reached after 130 hours, current of <750nA reached at 96hours.

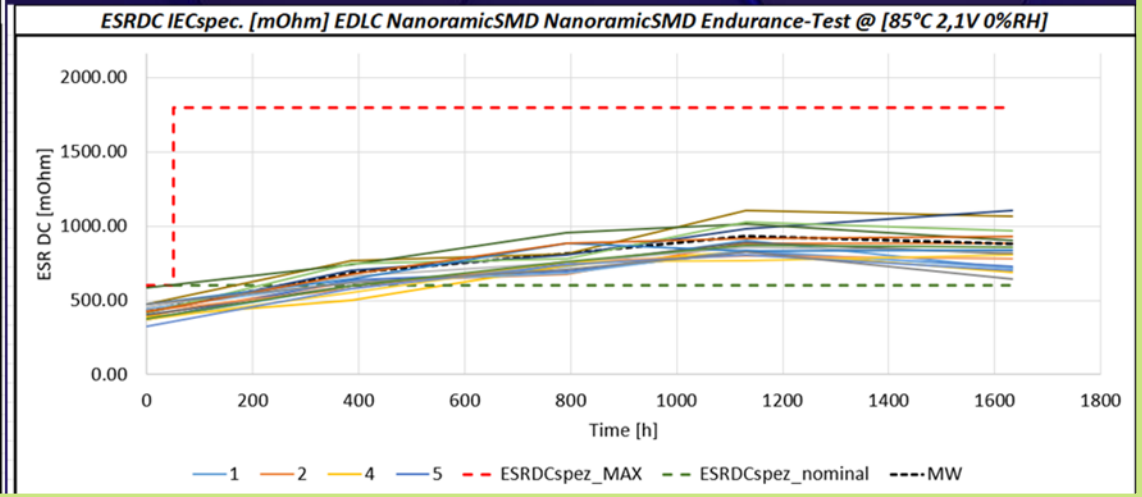


# 85C/2.1V LIFETIME TESTING – 3RD PARTY TESTING

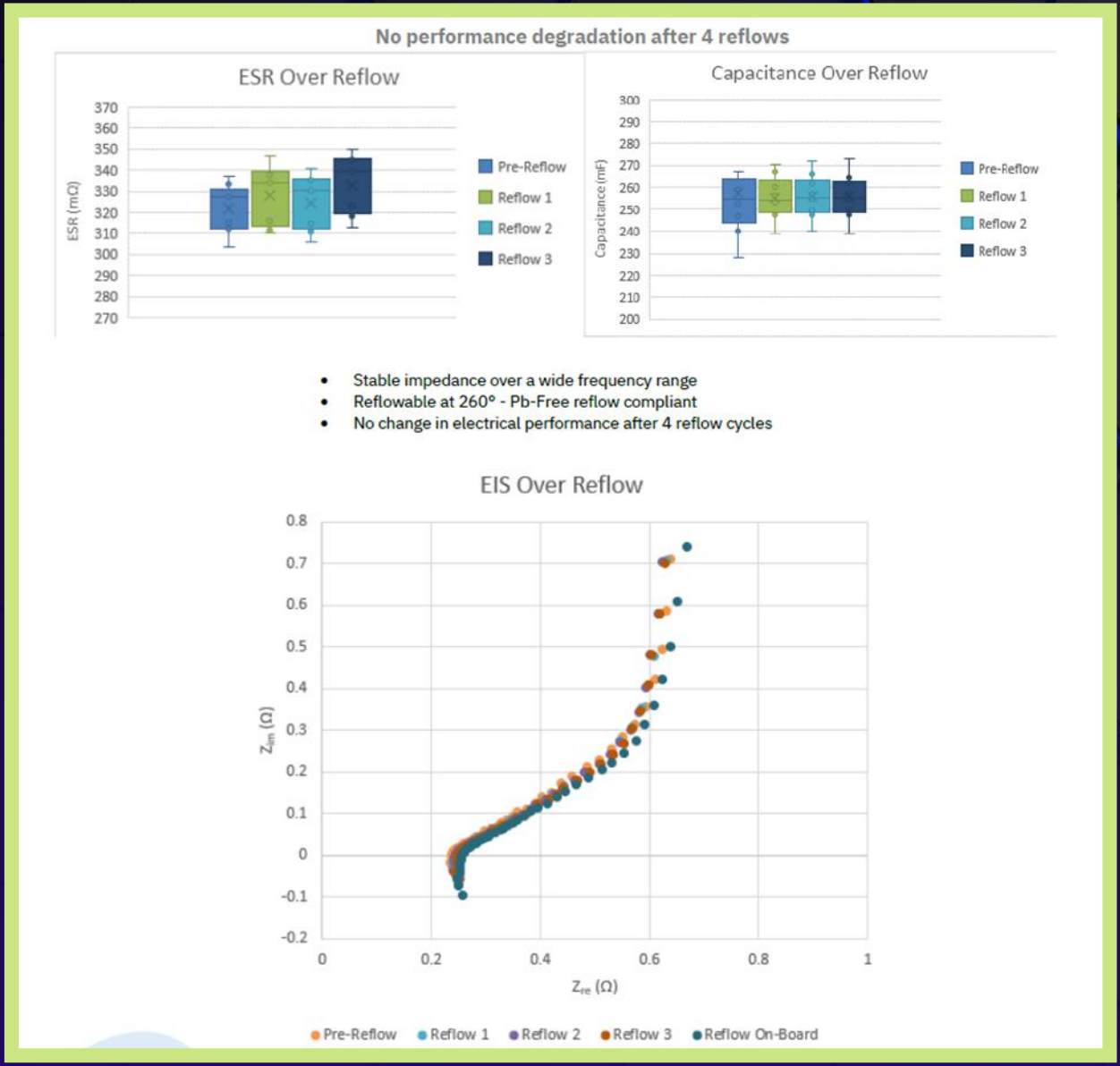


# REFLOW PERFORMANCE



# CHIPCAP CAPACITORS APPLICATIONS

- IoT for Military Asset Managements
- Ground-based power
- Communication systems
- Backup Power
- Radars
- Field Medical
- Edge Computing

# FASTCAP CAPABILITIES

- Unique expertise in designing capacitors for extreme environments, including military, aerospace, medical, oil & gas
- Wide-range of applications, form factors, extreme environments
- Customized design options
- Advanced electrical and physical testing and analytical techniques
- Advanced modeling and machine learning

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A Nanoramic® Labs Technology

# THANK YOU

Christofer Deane
Chief Operating Officer
chris@fastcapsystems.com
857-226-4366

Contact Us:

Tatyana Movchan, Ph. D.
VP of Business Development
tatyana@fastcapsystems.com
857-226-4366

# EXTRA SLIDES