May 2018

Maxwell® TECHNOLOGIES

Enabling Energy's Future™

Ultra-Capacitor Energy Storage

A Mature and Powerful Technology

International Workshop on Super capacitors and Energy Storage 2018

Eng. Jan-Hendrik Ernst I Key Account Manager

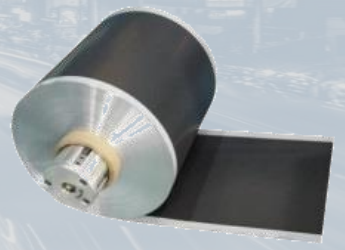
Maxwell Technologies – At a Glance

Business Highlights

Overview

- Founded 1965; IPO 1983 (NASDAQ: MXWL)
- Energy storage & power delivery solutions
- Headquarters: San Diego, CA
- Locations: U.S.A., Switzerland, China, South Korea, Germany
- Employees: 456

Products & Markets

High Voltage	Energy Storage	Dry Battery Electrode
		
Circuit Breakers • Metering • Converters	Automotive • Grid • Rail • Industrial	Lithium-Ion Battery

Financial Highlights

- 2017 Revenue: $130M
- 2017 Adjusted EBITDA: ($9.6M)
- FYE 2017 Cash Balance: $50M

Headquarters

Corporate: San Diego, CA USA


High Voltage: Rossens, Switzerland

*Revenue from external customers in ROW does not individually comprise of more than 12% of total
*See Appendix for GAAP to non-GAAP reconciliation of EBITDA

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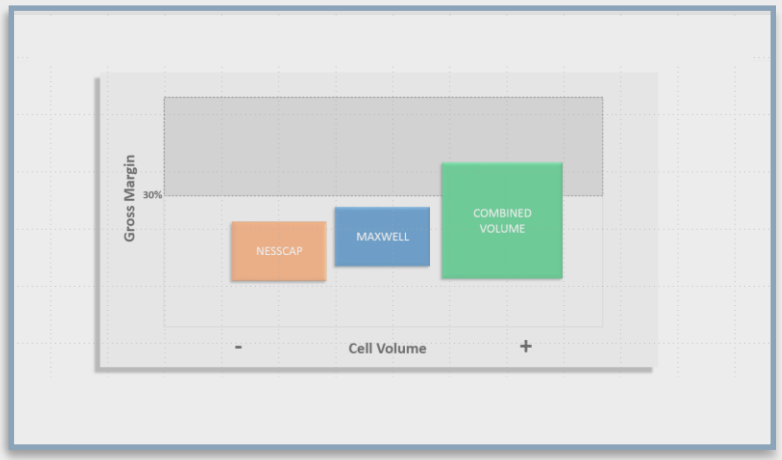
Nesscap: Leveraging Key Synergies to Extend Market Leadership

Maxwell TECHNOLOGIES + NESSCAP ULTRACAPACITORS

Optimize Portfolio

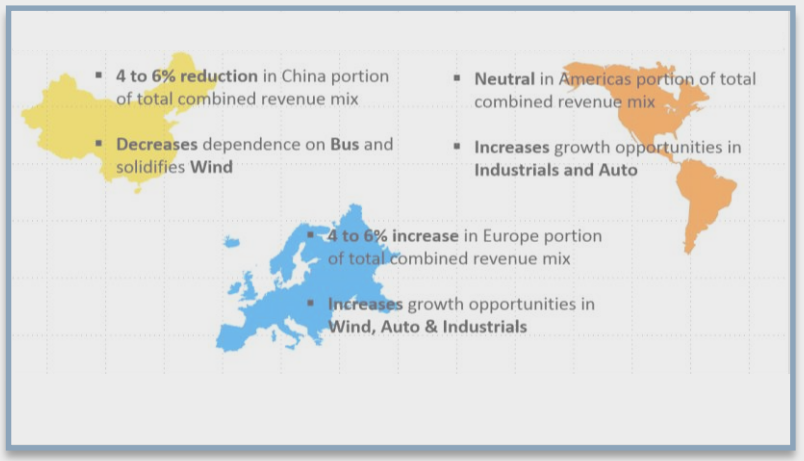
More New Products & Technologies, Faster

Streamline Operations



Increases Scale for **volume Expansion**

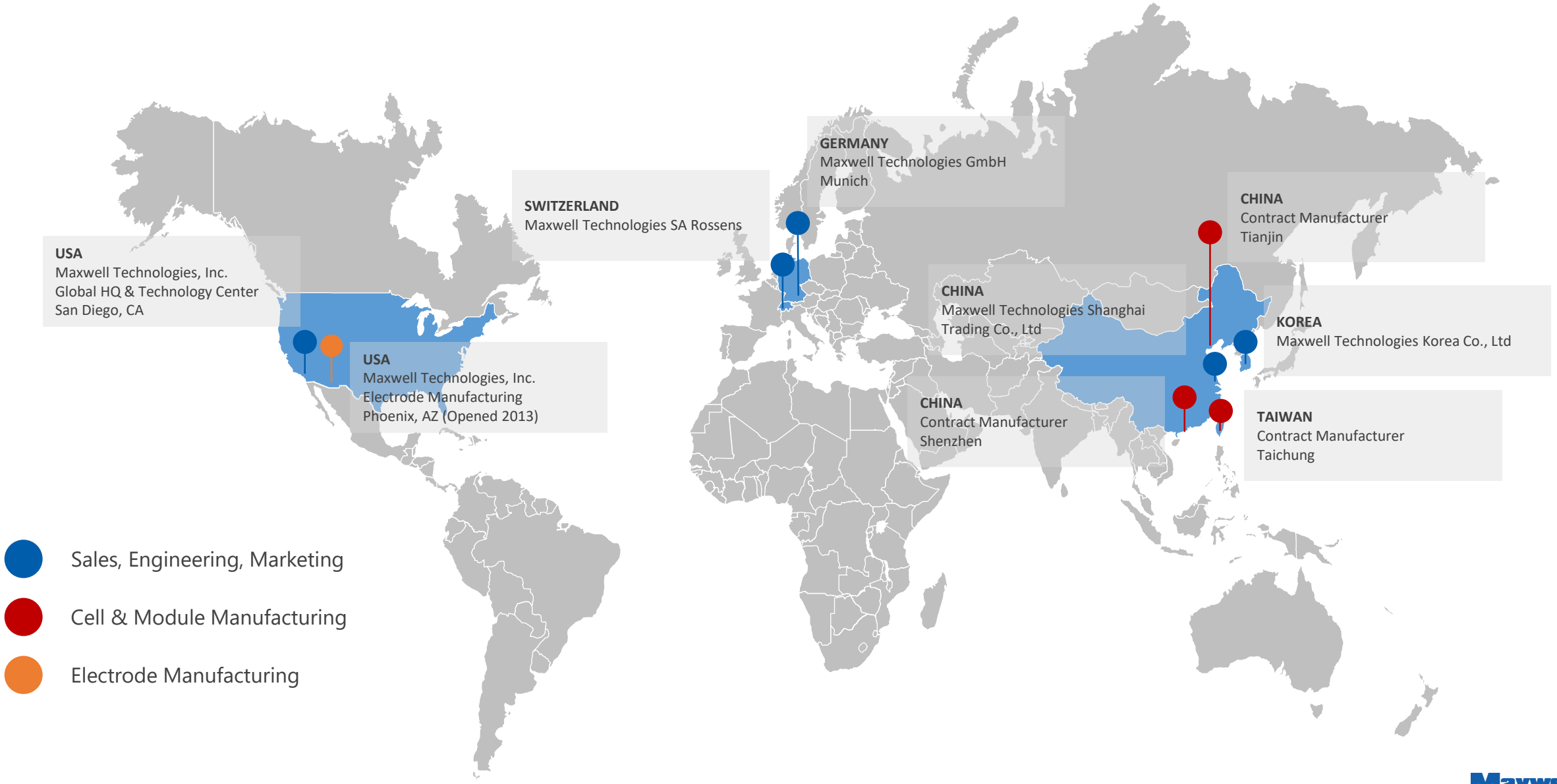
Solidify Leadership



Expands Markets & Diversifies Revenue Streams

Nesscap Acquisition Strengthens Leadership, Progressing to Market Inflection Points; Accelerates Growth

Maxwell Technologies – Global Reach



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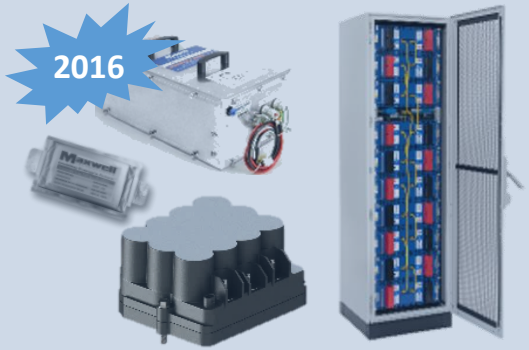
Ultracapacitor Energy Storage:

Technology Differentiation & Competitive Advantages

Fundamental IP	Core Product Line	Value Add Solutions	Partner Integration
2004 	2004 	2016 	2018 
Dry Electrode	Cells & Subsystems	Intelligent Systems	Complex Solutions
Core Technology		**Value Extension**	

- Proprietary Dry Electrode Fabrication & Differentiated Ultracapacitors - Significant Cost & Performance Advantages
- Industry's Most Extensive, Best-in-Class Portfolio of Technology, Protected IP, & Value Added Solutions
- Expanding Strategic Partnerships & Customer Relationships to Develop Differentiating Platforms & Accelerate Adoption

Building on Strong Foundation of Core Competencies; Increasing Value Creation & Differentiation in the Commercial Ecosystem

Product Trends

Ultra High Capacity

Easy Integration

Multiple Service Storage

State of the Art	Cells (W)	Modules (kW)	Systems (kW-MW)
Voltage	2,7 V / 2.85 V	12V to 160 Volt	Up to 1300V
Capacitance	From 1F to 3400F	6F to 500F	7,1 F
Temperature	65°C	65°C	65°C
Monitoring	x	Analog / Digital	Digital (optical)
Balancing	x	Pseudo Active	Active

Trends	Cells (W)	Modules (kW)	Systems (kW-MW)
Voltage	2,7 V/ 2.85 V / **3V**	12V to **480Volt**	Up to **1300V**
Capacitance	From 1F to 3400 F	6F to 500F	7,1 F
Temperature	**85°C**	65°C/**85°C**	65°C
Monitoring	x	~~Analog /~~ Digital	Digital
Balancing	x	~~Pseudo~~ Active	Active



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Ultra-Capacitor Success Story

Transportation

Maxwell Designed into 2M+ vehicles since 2011

1 FUEL ECONOMY / CO_2 REDUCTION

AERODYNAMICS	VEHICLE MASS	ICE TECHNOLOGY	TRANSMISSION	POWER MGMT
Drag coefficient	**Lightweight material**	GDI	Improved control of automatic transmission	**Switching from mechanical to electrical subsystems**
Tires	Manufacturing technologies	**Engine Downsizing + Turbocharging**	Continuously variable transmission	Optimization of accessories electricity consumption
	Downsizing	VVT	Dual clutch	**Regenerative power**
		Cylinder Deactivation		**Boardnet stabilization**
		Micro, Mild, and Full Hybrids		
		HCCI Technology		

Ultracapacitor opportunity

Advanced Evaluation

In Production: Micro Hybrid

In Production: Active Suspension

In Production: Back-Up Module for AD

2 PRODUCT INNOVATION

ENHANCED SAFETY	NEW FEATURES
Collision mitigation	**Active suspension (12V + 48V)**
E-Call systems	**E-Steering**
Post-Crash Backup-Systems	**(12V+ 48V)**
	Autonomous Driving (Back-Up)
	GPS
	Other

Continental

PSA PEUGEOT CITROËN

PEUGEOT CITROËN

GM

Not public

Not public

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Automotive: Vehicle Electrification Driving Adoption

Internal Combustion Engine

Hybrid Electric

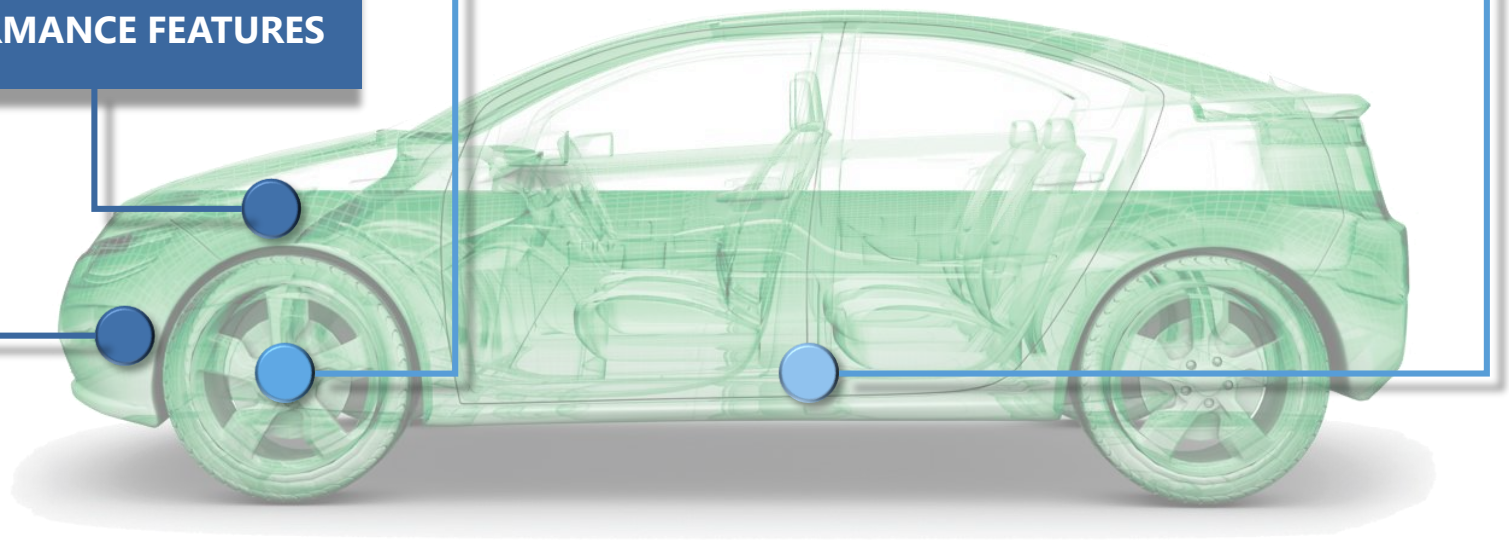
Plug In Hybrid/EV

BACKUP POWER & ENERGY STORAGE

MILD HYBRID & BRAKING REGENERATION

ENGINE DOWNSIZING & PERFORMANCE FEATURES

ELECTRICAL SYSTEM STABILIZATION



Continental

PSA PEUGEOT CITROËN

GM

Cadillac

2017

2022

Automotive: Challenges and Support factors

- Long design in phases (5 years)
- Long business cycles (7 years)
- Customer highly integrated into designing process

- Automotive is one of the industries with the most challenging qualification processes

  - Robustness
  - Reliability
  - Safety
  - **COST!**
  - Financial stability
  - Secure supply chain

- ISO/ISO 16949 Automotive certification
- Fulfilling most demanding shock and vibe profiles

Official Design-Wins by Maxwell

Maxwell signs $100m ultracapacitor deal with Volvo maker

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Adoption of Success in to Transportation

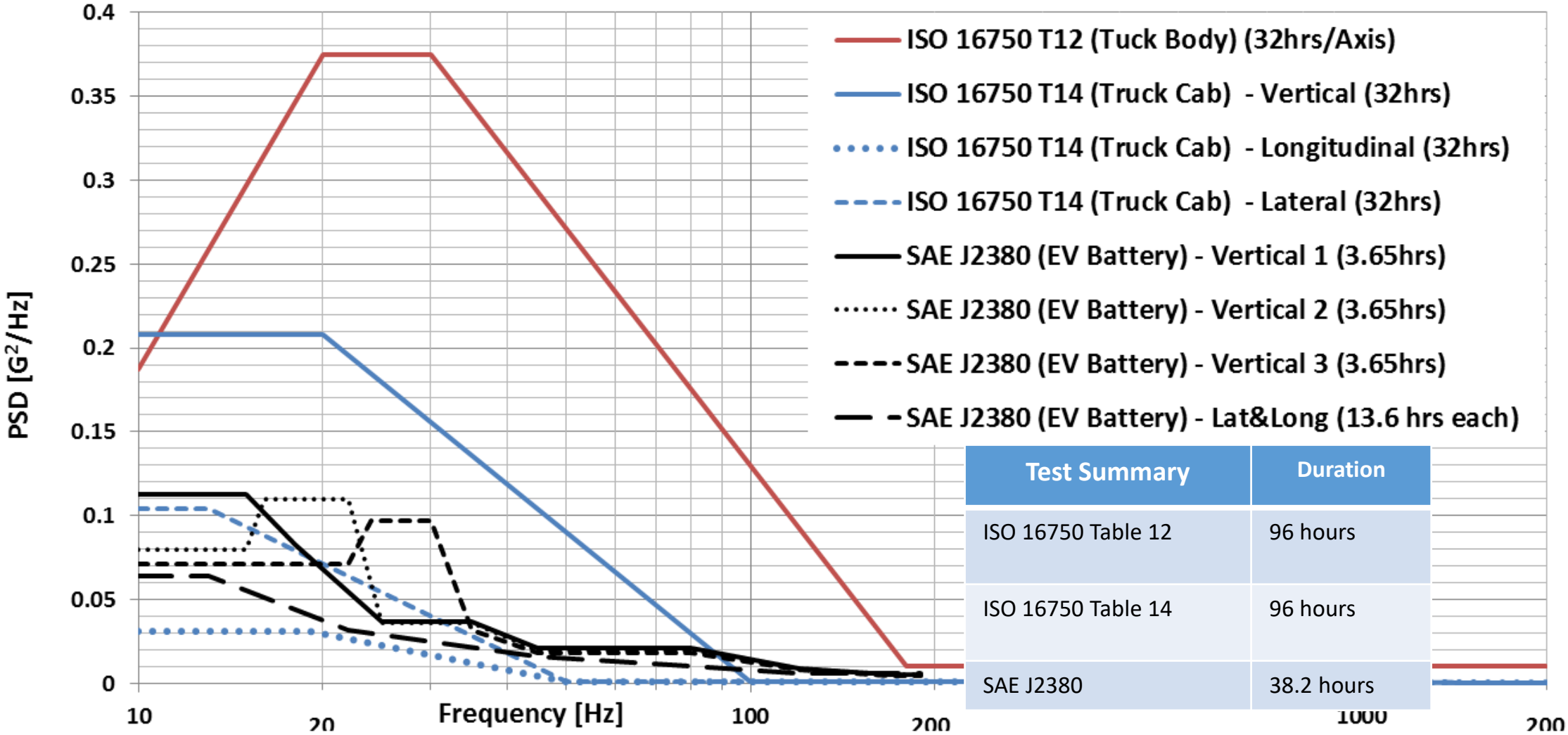
Automotive qualification allows adoption of high quality and reliability into other industries

F.e.:
- Rail onboard
- Rail wayside
- Hybrid bus
- Aviation

Key Requirements:
- Sustainability @ Increased temperatures
- Good performance @ vibration-, shock environments
- Low weight
- Long life
- High reliability
- Low maintenance

Todays State of the Art Ultracapacitors Meet These Requirements

Vibration Test Qualification Comparison



Test Summary	Duration
ISO 16750 Table 12	96 hours
ISO 16750 Table 14	96 hours
SAE J2380	38.2 hours



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Ultra-Capacitor Success Story

Grid

Maxwell Grid and Microgrid Applications – High Power, Fast Response

Energy Production

Traditional Power Generation

- Fast Frequency Regulation
- Voltage Stabilization
- Bridging and Ramping
- Power Stabilization
- Peak Shaving

Renewables Integration

- Voltage Stabilization
- Solar and Wind Intermittency Smoothing
- Synthetic Inertia
- Wind Pitch Control Backup Power

Energy Delivery

Transmission and Distribution

- Fast Frequency Regulation
- Synthetic Inertia
- Voltage Stabilization
- Power Stabilization
- Peak Shaving

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Energy Consumption

Rail to Utility – Wayside ESS

- Braking energy recovery fed to grid
- Power stabilization
- Frequency regulation

C&I

- Voltage sag mitigation
- Power Quality
- UPS
- Bridging Power
- Smart Meters

Since 1999, Maxwell has shipped > 8M ultracapacitors into grid applications globally

Grid Cell Pack

Specification Overview

- 64V 141F Open Cell Pack for Stationary Grid Market
- 24 x 2.7V 3,400F Cells
- Stored Energy: 80 Wh
- Max Operating Current: 1,900A
- Weight: 14.7 kg
- Smart CMS 3.1 balancing and cell monitoring
- String Voltage Rating to 1,500VDC (>400 MΩ IR)

Grid Energy Storage System

Ultracapacitor Module

Cabinet Controller/Gateway

Example 19” rack configuration (1.3MW)

Example 20” Containerized Solution)

Key Applications (MW – 100’s MW)

- Voltage support
- Frequency response
- Solar and wind firming
- Bridging power
- Stacked services
- Continuous, pulsed power and/or transient applications

Differentiating Features/ Benefits

- Up to 1,000,000 duty cycles, 10 year DC life*
- 19” standard rack mountable
- Use of CMS 3.1 balancing and monitoring using internal proprietary CANbus communication
- Wide DC Bus voltage
- Rated to 2,000V basic & 1,350V reinforced insulation
- Cabinet Controller to enable integration of many UCAP modules into large control systems
- External Field bus interface, ProfiNet IRT Fiber Optic (DC-10), Modbus (DC-11)

*Results may vary. Additional terms and conditions, including the limited warranty, apply at the time of purchase. See the warranty details for applicable operating and use requirements.

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Thank You!

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