

NASDAQ: BLDP | TSX: BLD

Fuel Cells for Rail Applications

May 15th , 2017
Brussels



BALLARD POWER SYSTEMS

PUTTING FUEL CELLS TO **WORK**

The Power of Fuel Cells, Simply Delivered

BALLARD®

WWW.BALLARD.COM

Key Messages



- **Electrification of the railway network is high on the agenda of the EU**
 - Currently, only 60% of the track in EU is electrified and it is much less in the East European member nations
- **Fuel cell technology is able to address powertrain electrification in the domains of rail propulsion, both for regional trains and shunt locomotives**
- **Electrification with fuel cells is an innovative and less capital intensive option than batteries**
- **Fuel cell powered shunt locomotives and trams have already been tested and demonstrated**

We Are Ballard Power Systems

BALLARD®

Making a meaningful difference with our fuel cell technology that will continue long into the future...

- 38 years of experience
- 22 years listed on NASDAQ
- 500 employees
- 2,000 patents/applications
- 320MW of fuel cell products shipped
- 3 million MEAs manufactured
- 3,000 stationary systems delivered
- >10 million kilometers in revenue service by Ballard fuel cell buses
- 85 M US\$ Revenues in 2016 , 50 % growth y-o-y



*Ballard HQ facility
Vancouver, B.C., Canada*

 **Protonex®**
a Ballard® company

Power Products for Sustainable Mobility

BALLARD®

- Mission:** Meet customers' power needs through delivery of high value fuel cell products that provide zero emission motive power trains

PRODUCTS

Fuel Cell Stacks



Air-cooled FCgen®-1020ACS
Liquid cooled FCvelocity®-9SSL

Motive Modules



FCveloCity®-MD
(30kW)



FCveloCity®-HD
(60kW-100kW)



FCveloCity®-XD
(up to 200kW)

MARKETS



Material Handling



Medium Duty Truck



Transit Bus



Light Rail

FCveloCity[®] Motive Module Product Line

BALLARD[®]

The FCveloCity[®] motive module product line is designed to meet all motive application power requirements from 30kW to 200kW.



Product Series	FCveloCity [®] -MD	FCveloCity [®] -HD	FCveloCity [®] -XD
Net Power Levels	30kW	60kW, 85kW, 100kW	100kW, 200kW
Application	8 to 10 meter buses, battery hybrid range extenders	10 to 25 meter hybrid fuel cell buses	Rail and Marine
Availability	Available now	Available now	Available now / Under development

- Optimized for fuel cell hybrid drives
- Modular design
- High performance
- Easy installation/integration
- Safety features
- Cost reduction

Ballard FCveloCity® Motive Modules

BALLARD®

- **Modular design** to facilitate integration and enhance serviceability
- **High temperature operation** to improve overall vehicle fuel economy
- **Humidification** to maximize system performances and durability
- **Climate protection** to ensure operation in extreme climates
- **High pressure system** to prevent degradation and increase efficiency
- **Remote diagnostics** for preventive maintenance

Ballard's Rail Experience

Fuel Cell Technology for Rail Propulsion



- **Applications include shunting locomotives, trams, auxiliary power units and stationary railway signaling**
- **Elements of the value proposition:**
 - **Zero-emission operation**
 - Reduces atmospheric greenhouse-gas emissions in urban centres and at railyards
 - Meets new emission regulations and goals
 - **Quiet operation**
 - Reduces noise pollution
 - Avoids citizens complaints due to noise of shunting operations
 - **Improved infrastructure**
 - No requirement for overhead catenary infrastructure
 - Central hydrogen refueling avoids cost of electricity-generation plant, transformers, and transmission lines

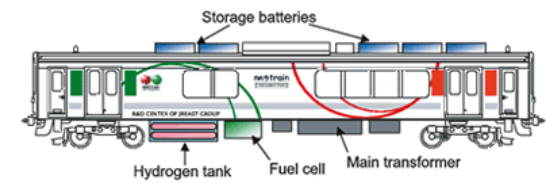
**Fuel cell propulsion offers the environmental benefits of electric
with the lower infrastructure cost of diesel**

Fuel Cell Rail – Ballard Experience

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Ballard has participated in a number of rail fuel cell applications:

- **USA**
 - 1st shunt locomotive delivered with 2 x P5 bus units to BNSF (240 kW net fuel cell)
- **South Africa**
 - 6 mine locomotives powered by FCvelocity-9SSL fuel cell stacks (17 kW gross fuel cell)
- **India**
 - 2 shunt locomotives fitted with 2 kW APUs
 - Another 20 APUs delivered and under integration
 - Indian Railway has issued a tender for 2 fuel cell powered shunt locomotives. Tender under evaluation
- **Japan**
 - JR East integrated and evaluated a commuter train
- **China**
 - 2 Fuel Cell Tram Projects being deployed



Fuel Cell Powered Shunt Locomotives

BNSF Railway Demonstration

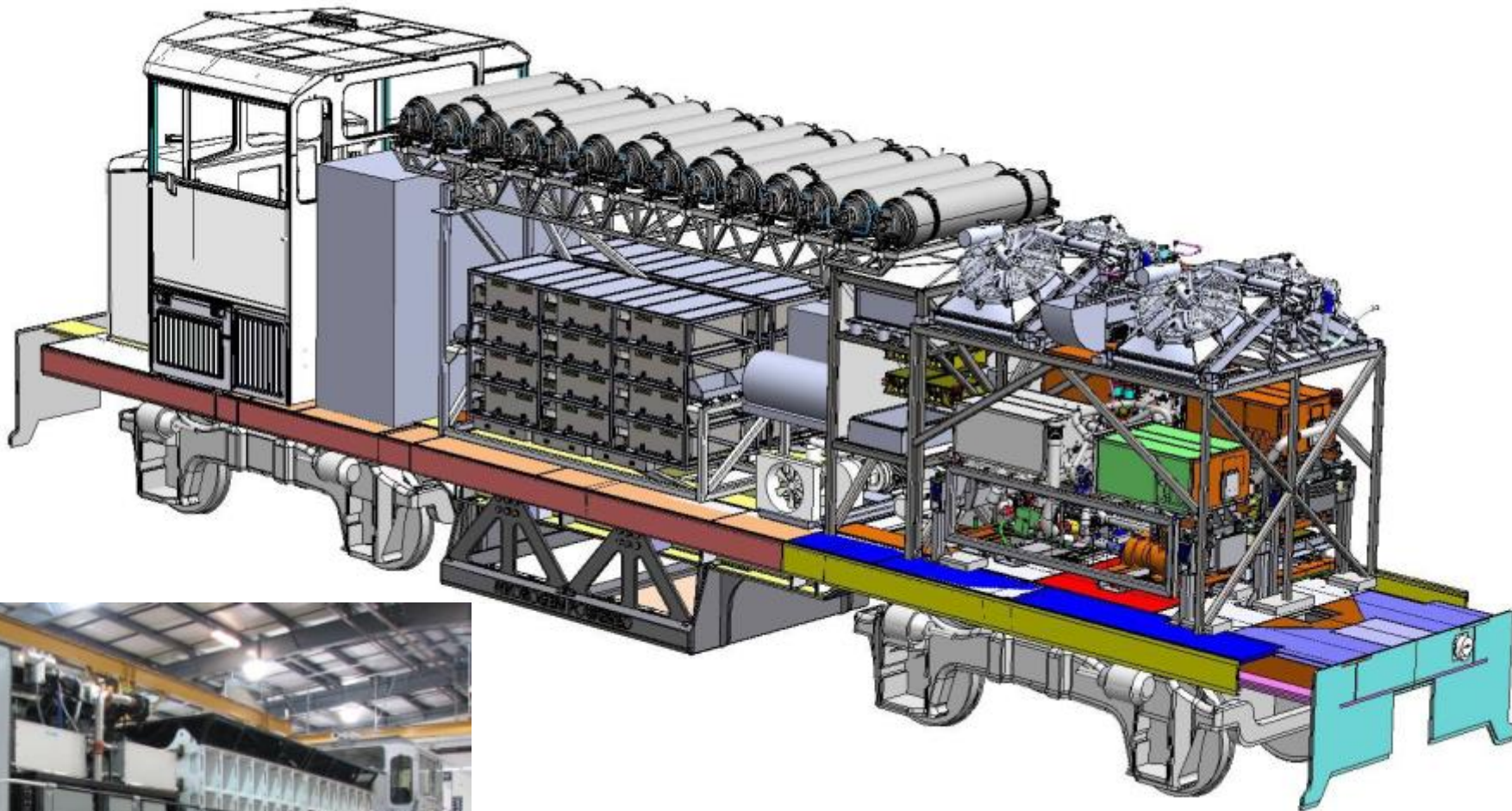
BALLARD®

- Development of a prototype fuel cell powered shunt locomotive for urban rail applications
- A public-private project partnership comprised of
 - Vehicle Projects Inc
 - BNSF Railway Company
 - The U.S. Army Corps of Engineers
 - Ballard Power Systems



Operational fuel cell locomotive prototype developed by BNSF

Typical Shunt Locomotive Layout

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Shunt Locomotive Performance

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- **Gross Power** 300 – 500 kW
- **Mean observed power** 85 – 150 kW
- **Mean fuel usage** 5.6 to 8 kg per hour
- **On board H2 storage** 60 kg at 350 bar
- **Mean power plant efficiency** 52%

Shunt Locomotive – Future Projects



- **Ballard has signed a MoU in August 2016 with Latvia Railways to support a pilot project to refurbish 3 Shunt Locos with fuel cells**
 - Project timing 2017 - 2019
- **Further interest in Germany , Austria and Eastern European Countries, India – currently under discussion**

Fuel Cell Tram Projects in China

Major Partners & Programs in China

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Ballard has announced contracts with China bus and light rail OEM's to produce fuel cell mass transit systems in large volumes

Active fuel cell buses	<24
Fuel cell buses in development	>300



Nantong



Foshan / Yunfu



Yancheng

XINGBANG



Foshan



Tangshan



Tram Projects

Foshan-Yunfu

CRRC Qingdao Sifang / Gaoming District Tram Project

BALLARD®

- **World's first commercial fuel cell tram line in Gaoming district of Foshan**
 - 10 units of Ballard FCveloCity®-XD-200 modules to be delivered in 2017
 - Operations to begin late 2017 to early 2018
 - Preliminary specifications
 - Maximum speed = 70km/h
 - Refill time = 3 minutes
 - Range = 100km



CRRC Sifang – World's first light rail tram, powered by a Ballard fuel cell module



Video of the tram

https://youtu.be/o9QAV_orYsc

Project with CRRC Tangshan Railway

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- Customized 200kW fuel cell module for ground transport vehicle prototype
- First successful demonstration in May 2016



Tram powered by a hybrid system with fuel cells and supercapacitors

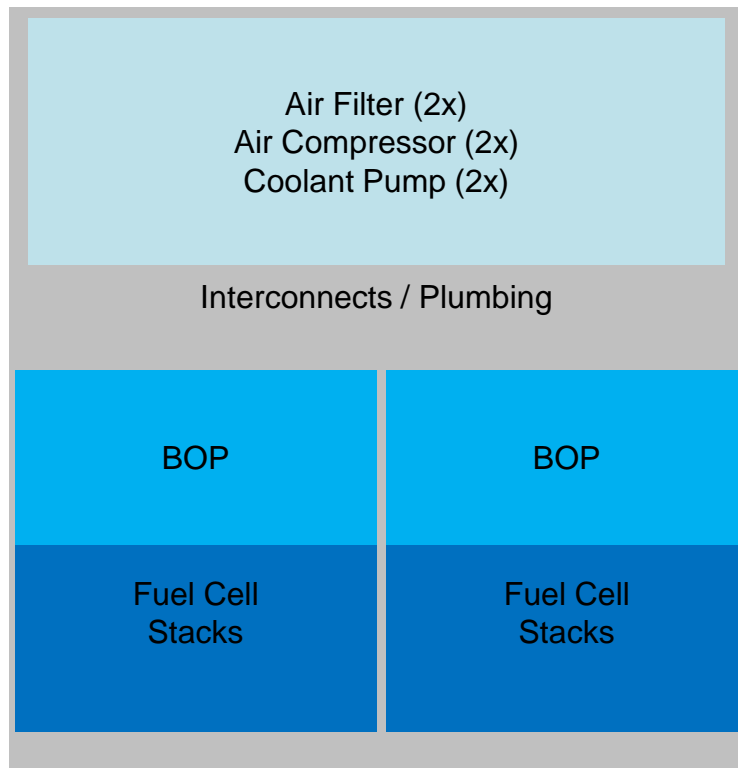
System Architecture

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- Leverage common technology platform for two different architectures

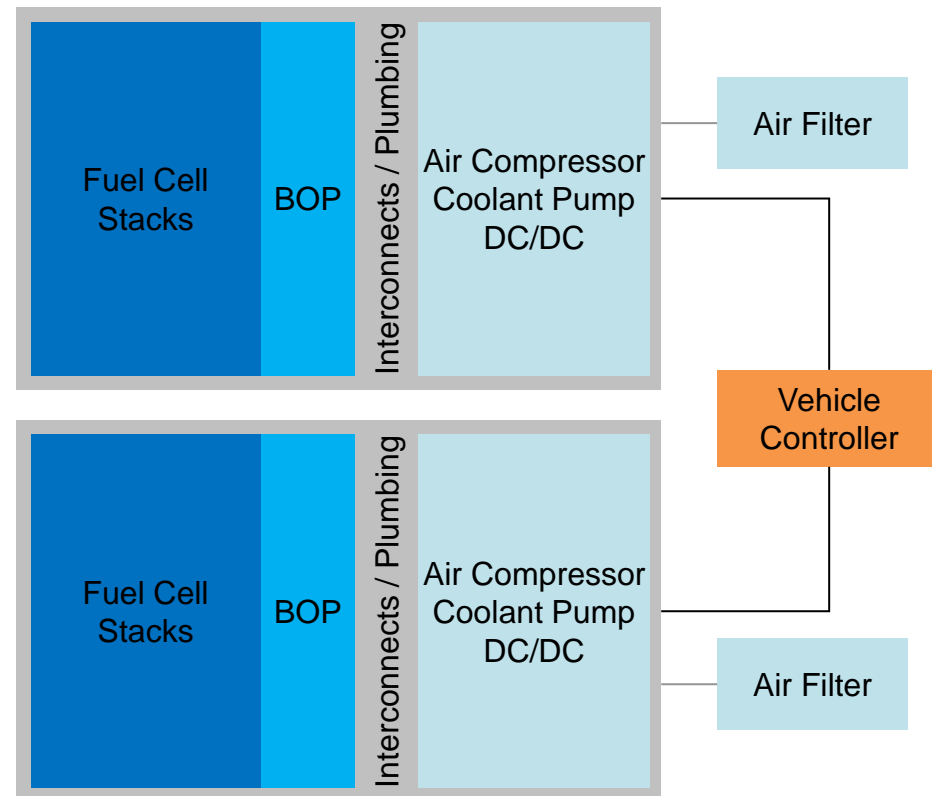
FCveloCity 200 kW

- Single integrated systems (200 kW)
- Roof mountable enclosure
- Includes air filter in enclosure



FcveloCity 100 kW

- Two discrete integrated systems (100kW each)
- Roof mountable enclosure
- Includes DC/DC converter in each enclosure



Design Standards



ISO11452-4:2011	Road vehicles -- Component test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 4: Harness excitation methods
ISO11451-1:2015	Road vehicles -- Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy -- Part 1: General principles and terminology
2004/104/EC	...relating to the radio interference (electromagnetic compatibility) of vehicles...
ECE/TRANS/180/Add. 13	Global technical regulation on hydrogen and fuel cell vehicles
ISO23273:2013	Fuel cell road vehicles -- Safety specifications -- Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen
IEC60664-1	Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests
IS 6469-2:2009	Electrically propelled road vehicles -- Safety specifications -- Part 2: Vehicle operational safety means and protection against failures
ISO6469-3:2011 Voltage Class B	Electrically propelled road vehicles -- Safety specifications -- Part 3: Protection of persons against electric shock
IEC61373-2010	Railway application—rolling stock equipment---shock and vibration tests
EN50125-2-2002	Railway Applications — Environmental Conditions For Equipment — Part 2: Installation Of Fixed Devices
ISO3744-2010	Acoustics - Determination Of Sound Power Levels Of Noise Sources Using Sound Pressure - Engineering Method in an Essentially Free Field Over a Reflecting Plane
EN50124-1-2001	Railway Applications — Insulation Coordination - Part 1: Basic Requirements — Clearance And Creepage Distance For Electrotechnical And Electronic Devices
EN50124-2-2001	Railway Applications - Insulation Coordination- Part 2: Overvoltages And Related Protection
DIN5510-2-2009	Preventive Fire Protection for Railway Vehicles – Part 2: Fire Behaviour and Fire Side Effects Of Materials and Parts – Classification, Requirements and Testing Methods
EN50343-2014	Rules for the Cabling of Railway Vehicles
EN50264-1-2008	Railway Applications — Railway Rolling Stock Cable with Special Fireproof Function - Standard Outer Wall - Part 1: Basic Requirements
EN50306-1-2002	Railway Applications — Railway Rolling Stock Cables Having Special Fireproof Function - Thin Wall
EN50121-3-2-2015	Railway Applications — Electromagnetic Compatibility Part 3-2: Railway Rolling Stock -- Apparatus
IEC61375-3-3-2012	Electronic Railway Equipment – Train Communication Network (TCN) – Part 3-3: CANOpen Consist Network (CCN)
EN12663-1-2010	Railway Applications ---Structural Requirements Of Railway Vehicle Bodies Part 1: Locomotives and Passenger Rolling Stock
DIN30646-2006	Self-Adhesive Signs - Technical Delivery Conditions For Signs Made Of Plastic Film, Aluminum Foil And Paper
EN15085-1~5-2007	Railway Applications — Welding Of Railway Vehicles and Components of Vehicles
IEC61287-1-2005	Railway Applications –Power Convertors Installed on Board Locomotives – Part 1: Characteristics and Testing Methods
IEC60529-2001	Degrees Of Protection Provided by Enclosures (IP Code)

Summary

BALLARD®

- Ballard will provide the engineering resources to help integrate fuel cell and associated system into Tram/Train/Loco platforms
- Ballard will meet the rail safety & certification standards for the fuel cell modules
- Full lifetime support for the fuel cell systems will be offered
- Ballard FCveloCity® heavy duty power modules continue to lead the industry in performance, durability, cost, and overall road experience

Flexible Platform	Proven Durability
Technology Leadership	High Performance
Manufacturing Expertise	Tier 1 Customers



BALLARD®

**FUEL CELL POWERED
ZERO EMISSION**

HEAVY DUTY MOTIVE MODULES



Thank you