

Ground Support Equipment Demonstration

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MT011



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Today's Fuel Cells for proven, reliable power.

OVERVIEW



Timeline

- Project start – January 2013
- Project end – December 2015
- Kickoff meeting – 3/27/13

Budget

- Total project funding - \$5.0M
 - DOE - \$2.5M
 - Partners - \$2.5M
 - Status: 4% Complete

Barriers

- Barriers addressed:
 - Power upsizing for BTT app
 - Outdoor operation
 - Run time

Partners

- FedEx Express
- Charlotte
- Nuvera
- Memphis International Airport
- Oakland International

RELEVANCE

- **DOE Fuel Cell Technologies Objectives Over Project Life**
 - To create a hydrogen fuel cell-based solution as a **cost-competitive and more energy-efficient baggage tow tractors (airport vehicle)** compared to the incumbent internal combustion engine-powered vehicles.
 - To enable airport end users to accomplish their daily tasks with a hydrogen fuel cell solution while **reducing consumption of gasoline and diesel fuels**, reducing U.S. demand for petroleum.
 - To demonstrate **lower carbon emissions** with the fuel cell solution
 - To demonstrate a value proposition that shows **decreased energy expenditures** when compared to diesel-powered airport vehicles
- **Specific Project Objectives During 2013**
 - Plug Power develops the 80V fuel cell product for baggage tow tractor
 - Testing with Charlotte CT5E baggage tow tractor
 - Factory Acceptance Test to demo equivalent operation as battery / ICE
 - Nuvera conducts site planning to install hydrogen at 2 locations

RELEVANCE

- **Specific Project Objectives and Expectations**

| DOE Project Objectives | Plug Power-FedEx Project Expectations |
|---|--|
| Reduce petroleum consumption | Each BTT uses ~2 gal/hr. Total BTT run time of 15 BTT's over 2 years will be upwards of 175,200 gallons of diesel fuel reduced. |
| Reduce emissions at airports | AT 9.8 kg CO2 per gal of diesel, there will be upwards of 1717 metric tonnes of CO2 eliminated at airports. |
| Operate 10 hrs/day & 5,000+ hours | BTT operation occurs during two shifts: day (11 AM-3 PM) and night (10 PM-2 AM). The total clock day is 11AM-2PM (15 hours). Actual BTT activity is 8 hours per day. Total run time of 15 BTT's over 2 years will be upwards of 87,600 fleet hours. |
| Towing capability of 3,000 to 6,000 lbs. | The BTT will be able to tow 4 FedEx containers each weighing 40,000 lbs. The corresponding drawbar capacity of the fuel cell-powered BTT is 5,000 lbs. |
| Accelerated development of FC-powered GSE | Fleet of 15 80V fuel cell systems in real world application in 2013 gaining significant field experience while allowing a premier BTT end user to evaluate for larger deployments. |

APPROACH

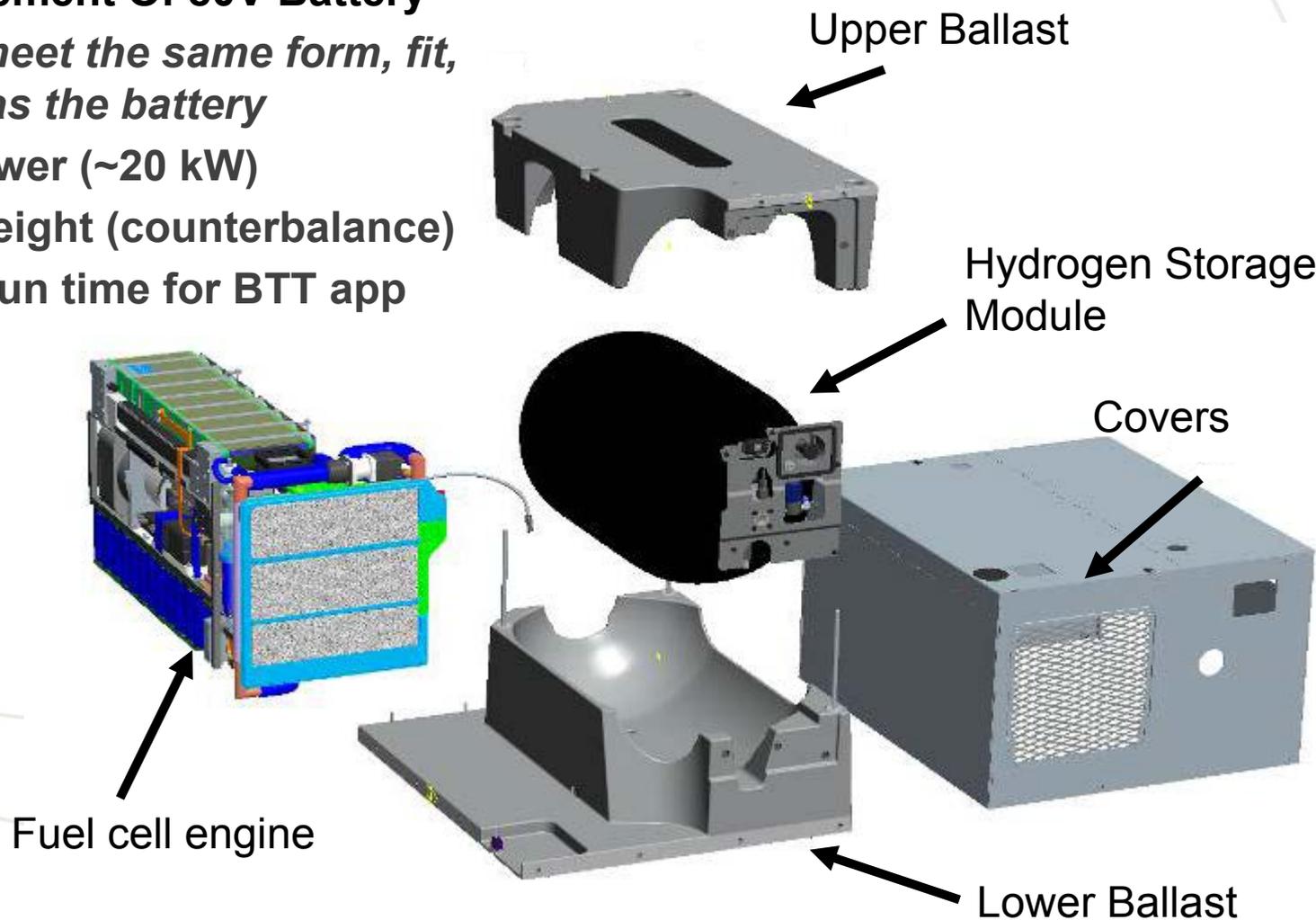
- **Deployment of 15 FC-powered units for two years at two national airports.**
 - **Ten BTTs at Memphis, TN (fleet of 1383 BTTs to manage 270 flights / day)**
 - **Five BTTs at Oakland, CA (fleet of 122 BTTs to manage 40 flights / day)**
 - **Sites were selected to gain operational experience for different:**
 - **Geographies**
 - **Different scale operation**
 - **Duty cycles**
 - **Weather**
 - **Environment (heat, humidity)**
- **The project is planned for two phases:**
 - **Phase 1: one-year development phase where Plug Power develops, builds and tests the 80V (~20 kW) fuel cell system for the BTT application**
 - **Phase 2: two-year demo where a fleet of BTTs are integrated into electric tow tractors and deployed at the locations under real world conditions**
 - **The two fuel cell fleets will be fueled by onsite hydrogen production and CSD (compression, storage, and dispensing) solution at each site**

APPROACH: 80V Fuel Cells

Direct Replacement Of 80V Battery

Designed to meet the same form, fit, and function as the battery

- Stack – power (~20 kW)
- Ballast - weight (counterbalance)
- H2 Tank - run time for BTT app



APPROACH: Hydrogen

Nuvera H2 Production and Dispensing

- Fueling Pressure: 350 bar
- Refueling time: 1 kg/min
- H2 Capacity: 50 kg/day
- H2 Storage: 60 kg
- Refueling nozzle is proven, simple and safe – breakaway hose includes hydrogen safety shutoff valve

POWERTAP™

a complete hydrogen generation and refueling solution for vehicle fleets



Nuvera and their onsite hydrogen generation solution provides the most economical hydrogen supply for the proposed demonstration.

APPROACH: Integration in Baggage Tow Tractor

Charlatte CTE5 BTT

- Plug visited Charlatte to discuss integration, specifically for FedEx app
- 80V GenDrive meets the battery requirements of CT5E (developed for FedEx's application)

Plug Power GenDrive 80V Fuel Cell

- Stack sized for necessary power
- Ballast sized for weight (traction)
- H2 Tank sized for long run time



| Electric Baggage Tow Tractor | | | | | |
|------------------------------|-------------|---------------|--------|------------|----------|
| OEM | Model | Drawbar (lbs) | Power | hp (comp.) | Voltage |
| Charlatte | CT5E | 5000 | 22.1 | 30 | 80 |
| TUG | MZ | 4500 | 17.7 | 24 | 80 |
| Toyota | 2TE18 | 4000 | 16.4 | 22.3 | 80 |
| Eagle | MTT | 5000 | 18.4 | 25 | 80 |
| Harlan | Charger HLE | 5000 | 30.9 | 42 | 80 |
| OEM | L | W | H | GVW | Batt Wgt |
| Charlatte | 45" | 27.5" | 31.25" | 4,824 | 4,000 |
| TUG | 36 | 26.125" | Open | 3,550 | 3,500 |
| Toyota | | | | 4,960 | 2,535 |
| Eagle | | | | 5,600 | 3,400 |
| Harlan | 47.5" | 31" | 28" | 4,200 | |

APPROACH

Partners \$2.5 M pays for:

Contribution in Kind:

- Fed Ex: Operator Labor
- Plug Power: Engineering
- Plug Power: Program Mgmt
- Plug Power: Service Personnel

DOE's \$2.5 M pays for:

- Hydrogen Infrastructure
 - 2 Nuvera Units for 2 years
- Fuel Cell Systems
- Plug Power: Engineering
- Plug Power: Program Mgmt
- Plug Power: Service Personnel
- Subcontract for stacks

Outside Budget:

- Fed Ex: 15 Charlotte BTTs ($\$32k * 15 = \$480k$ per sites, 2 sites)
- Fed Ex: Utilities to produce hydrogen ($\sim \$2.50/kg$) – *cheaper than diesel*
- Plug Power: Partial payment for stack development and stack purchases

APPROACH: Scope of Work

Budget Period 1

- **Task 1: Definition of Requirements**
- **Task 2: Alpha Prototype (milestone: Detailed Design Review)**
- **Task 3: BTT Beta Builds (milestone: Build of 15 units)**
- **Task 4: BTT Testing and Certification (milestone: see below)**

Go/No Go Decision (Testing of Alpha prototype fuel cell system)

- **Criteria: Does the Beta system fuel cell meet the same form, fit, and function as the 80V battery?**
 - **Voltage output: 72-80V continuous output**
 - **Maximum dimensions: 45" L x 27.5" W x 31.25" H**
 - **Weight (traction): 4,000 lbs.**
 - **Drawbar capacity: 5,000 lbs.**
 - **Speed rating: 10 mph**

Desired Result: Achieve OEM certification

APPROACH: Scope of Work

Budget Period 2

- **Task 5: Site Preparation (milestone: H2 installation, receipt of units)**
- **Task 6: Commissioning (milestone: commissioning of units)**
- **Task 7A: Demonstration During Budget Period 2**
- **Task 8: Assessment after Year 1 (milestone: see below)**

Go/No Go Decision (Performance Assessment)

- **Criteria: Does the fuel cell meet customer requirements**
 - **Power: Capable of 5,000 lbs. drawbar capacity**
 - **Availability: > 80%**
 - **Run time: > 1 shift**
 - **Reliability (MTBF – Mean Time Between Failures): > 100 hours**
 - **Speed rating: 10 mph**
 - **Outdoor operation: no non-recoverable issues**
 - **Hydrogen Fills: 350 bar**

Desired Result: Continued operation for 2nd year

APPROACH: Scope of Work

Budget Period 3

- **Task 7B: Demonstration during Budget Period 3**
- **Task 9: Assessment after Year 2**
 - Final Milestone:**
 - **Financial & Technical Assessments, Lessons Learned**
 - **Decision to continue in commercial application or decommission**

ACCOMPLISHMENTS

As of the submission of this presentation, there has been ~2 months of work:

- **Systems Engineering - Collection of Requirements**
 - Data logging of CT5E in FedEx Express application (Ontario, CA)
 - Sharing of information with BTT OEM
- **Component Requirements and Supply Chain Discussions**
 - Identification of stack characterization and requirements for larger power (ex. pressure drop, polarization curve)
 - Identification of products with current component model lines
- **System Modeling → Module / Component Input-Output Charts**
- **Coordination with FedEx Express Sites for Hydrogen Prep / Permits**
- **Kickoff meeting with DOE and Partners in Latham on 3/27/13**
- **Receipt of Charlotte CT5E at Plug Power for weatherproofing and interconnect design**

COLLABORATIONS

Project Team



Program Management



Fuel Cell System Integrator



BTT OEM



Airport BTT End User

Onsite H2 Supply



Airport Authority



FUTURE WORK

Focus in 2013 will be on building and validating the 80V fuel cell system

Budget Period 1

- Task 1: Definition of Requirements – *already in process*
- Task 2: Alpha Prototype – **Q2 testing / Q3 design improvements**
- Task 3: BTT Beta Builds – **Q4 demo builds**
- Task 4: BTT Testing and Certification – **by end of year**

Budget Period 2

- Task 5: Site Preparation
- Task 6: Commissioning
- Task 7A: Demonstration During Budget Period 2
- Task 8: Assessment after Year 1

Budget Period 3

- Task 7B: Demonstration during Budget Period 3
- Task 9: Assessment after Year 2

SUMMARY

- **Objectives**
 - Fuel cell development versus diesel incumbent
 - Cost-competitive
 - More energy-efficient
 - Reduce consumption of gasoline and diesel fuels
 - Lower carbon emissions
 - Decreased energy expenditures
 - Validate value proposition
- **Major Contributions by Partners**
 - Plug Power: develop 80V fuel cell product for BTT
 - Charlatte: testing with Charlatte CT5E baggage tow tractor
 - Nuvera: onsite hydrogen production
 - FedEx Express: end user evaluation

SUMMARY

Work on the project began in January 2013

Fuel Cell Development

- 80V prototype is planned for testing in Q2/Q3.
- Demo builds and certification in BTT by YE 2013

Onsite Hydrogen Production

- Site planning in Q2 2013
- Installation in Q4 2013

Start of Commercial Demonstration – Start of 2014

- FedEx Express – 10 units in Memphis, TN
- FedEx Express – 5 units in Oakland, CA