2013 DOE Vehicle Technologies Program Review Presentation

Smith Electric Vehicles:
Advanced Vehicle Electrification + Transportation Sector Electrification

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SMITH™

OVERVIEW

Timeline
- Start: Apr 2010
- Completion: May 2015
- Completion status: @ April 22 2013
  - Vehicles supplied 82% of target.
  - Jobs created 58% of target.
  - Project spend 85% of target.

Budget
- Total Project Funding
  - DOE $32M.
  - SMITH US $37.5M
  - DOE funding received $27.3M

Barriers & Risks
- Finance.
- Supply chain.
- Customer Adoption.
- Service Support.

Partner & Collaborators
- SMITH Europe
- Customers
- Technical Partners
- Suppliers
- Institutions
- Other DOE Funded Projects

OBJECTIVES/RELEVANCE

Relevance to American Recovery and Reinvestment Act-

- Accelerate the development, production and acceptance of AEV's in the US commercial market to substantially reduce petroleum consumption, reduce vehicular emissions of greenhouse gases, increase energy security, and create US jobs.

Project Objectives-

- Supply to customers 510 medium duty commercial All Electric Vehicles (AEVs) operating different duties in different regions of the USA.
- Collect and submit to the National Renewable Energy Laboratory (NREL) 2 to 3 years of performance data .
- Develop Second Generation Smith Power, Smith Drive, Smith Link and Smith Charging to enhance performance and reduce costs.
- Develop an e-stripped chassis to support the introduction of- step van, school and shuttle bus configurations.
- Create 225 new jobs at Smith USA.

PROJECT MILESTONES

Milestone Title	Milestone Description	Planned Start Date	Planned End Date
Initial Customer Program Vehicle Build Complete for Project	Initial vehicle deliveries as part of the project	4/1/2010	4/30/2010
Installation of telemetry system on initial customer program vehicle	Vehicle data received on Smith Servers	9/1/2010	8/31/2013
Initial customer vehicle initial data capture and reporting to DOE	Send complete data set to DOE for initial vehicles	11/1/2010	5/31/2015
Customer vehicle final data capture and reporting to DOE	Final data receipt from vehicles and final report submission to the DOE	10/31/2010	5/31/2015
255 Vehicles Deployed under program	Halfway point of vehicle deployment	4/1/2010	1/31/2012
Vehicle Deployment Complete	Final Vehicle deployed under program	4/1/2010	8/31/2013

Project Slippage attributable to-
- Smith IPO.
- Supplier quality.
- Supplier commercial issues.

Milestones updated as of April 22, 2013.

Project Approach

- Maintain fund raising activity to support corporate goals.
- Complete knowledge transfer from Smith UK to Smith USA.
- Secure US purchase commitments and participation agreements to support the demonstration project-
  - 87% of the $32M DOE/ARRA Grant will be paid to AEV buyers participating in the DOE Electric Fleet Data Collection Program.
  - On order placement and completion of the participation agreement at the time the customer agrees to a two to three year data collection program.
  - The amount paid to each participating company is based upon the duration of participation and the value of the base vehicle.
  - The encrypted performance data is collected via Smith Link, held and processed on secure servers for transmission to NREL monthly.
  - The remaining 13% of the Grant is a 32% reimbursement of Project Development costs.
- Establish technical teams to-
  - Deliver Homologation approvals.
  - US Platform Development and Introduction.
  - Develop Second Generation Smith Power, Smith Drive and Smith Link systems.
  - Deliver Corporate cost down targets in line with project objectives.

Project Approach

- Establish US facilities.
- Establish Service and Training resource to support customer adoption.
- Achieve ISO accreditation.
- Achieved and maintain compliance:
    - NHTSA,
    - FMVSS and
    - NEPA.

2012/13 Technical Accomplishments

QTR2 2012- (Quarters are calendar)

- Planned introduction of the Newton AEV Shuttle bus - **Complete**
- First customer deliveries of the Newton Step Thru Van- **Complete**

QTR3/4 2012-

- Planned introduction of the Newton Based AEV School Bus- **Validation**
- Smith Drive – Commenced transition to volume supplier- **In Process**

QTR4 2012-

- Planned introduction of Smith's cell agnostic modular battery system. **Strategy delayed/ changed as a result of existing supplier quality and commercial issues.**
- Commenced re-development of Smith Power Battery strategy to accommodate an interim generation reducing the reliance on the previous supplier- **In Process.**

2013/14 Technical Targets

QTR1 2013- (Quarters are Calendar)

- Engineering of Smith Power Gen 1.75 system (Prismatic Cell).

QTR2 2013-

- Delivery of first AEV Shuttle Bus to Department of Defense installation (TARDEC).
- Initial operation of V-to-G system at TARDEC.
- Initial receipts of production level Smith Drive components from volume supplier.
- Engineering and validation of Smith Power Gen 1.75 system (Prismatic Cell).
- Engineering of Smith Power Gen 2 system (Pouch Cell).

QTR3 2013-

- Introduction of Smith Power Gen 1.75 system (Prismatic Cell).
- Completion of 510 vehicle fleet target.
- Engineering and validation of Smith Power Gen 2 system (Pouch Cell).

QTR4 2013-

- Completion of Smith Power Gen 2.0 battery system (Pouch Cell).

2012/13 Progress

Project Progress at 22nd April 2013-

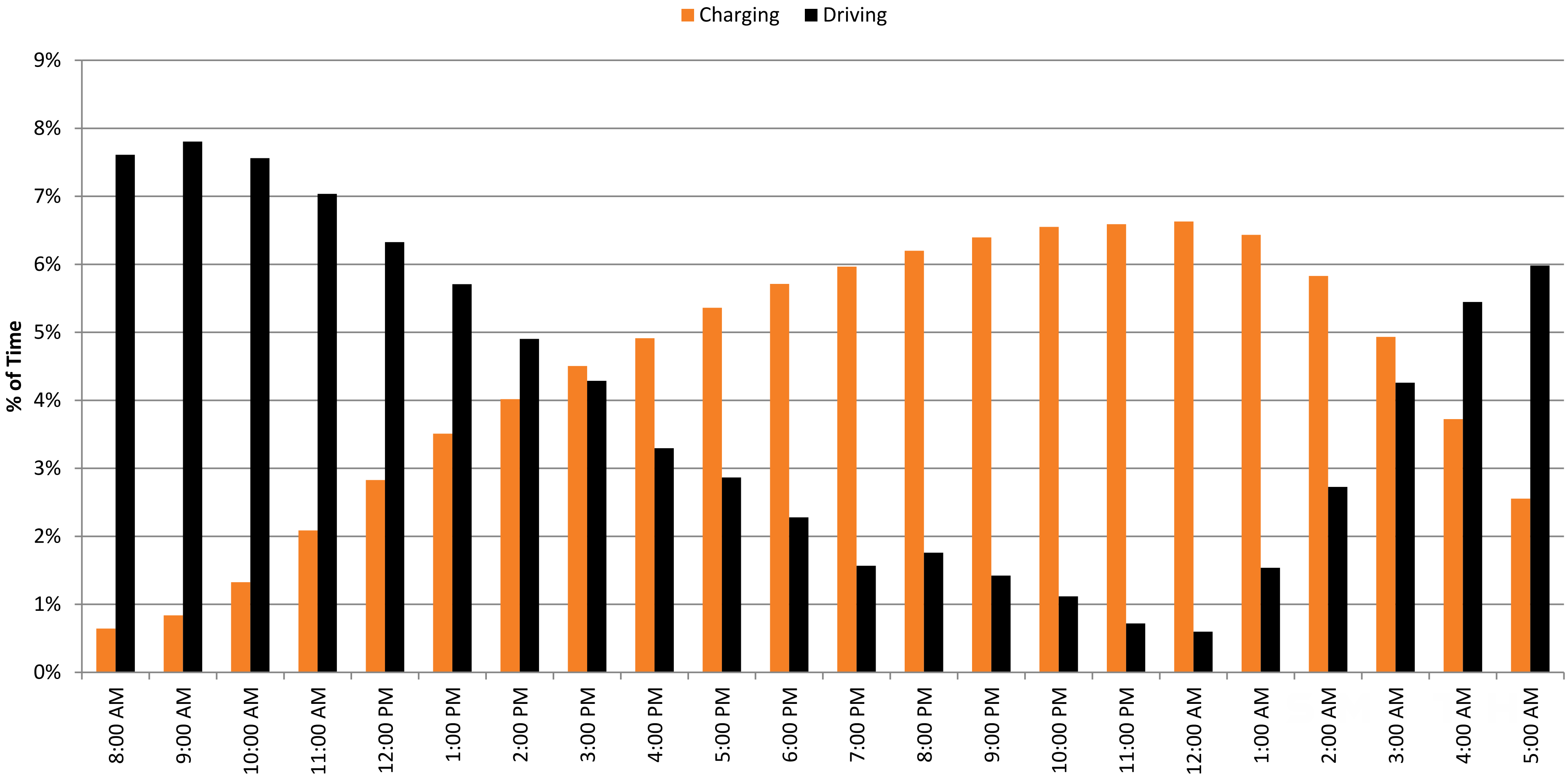
- 422 vehicles delivered.
- Order commitments for 88 additional vehicles against a target of 510 eligible vehicles under the program.
  - Fleet will include105 Newton Gen 2 Step-Thru Vans.
- Total Smith U.S. employees- 131.
- Gen 2 Smith Drive and Smith Power supply chain established.
- Cost down activity targeting 28% cost reduction by end of Q4 2013.

2012 DOE Funded Vehicle Statistics

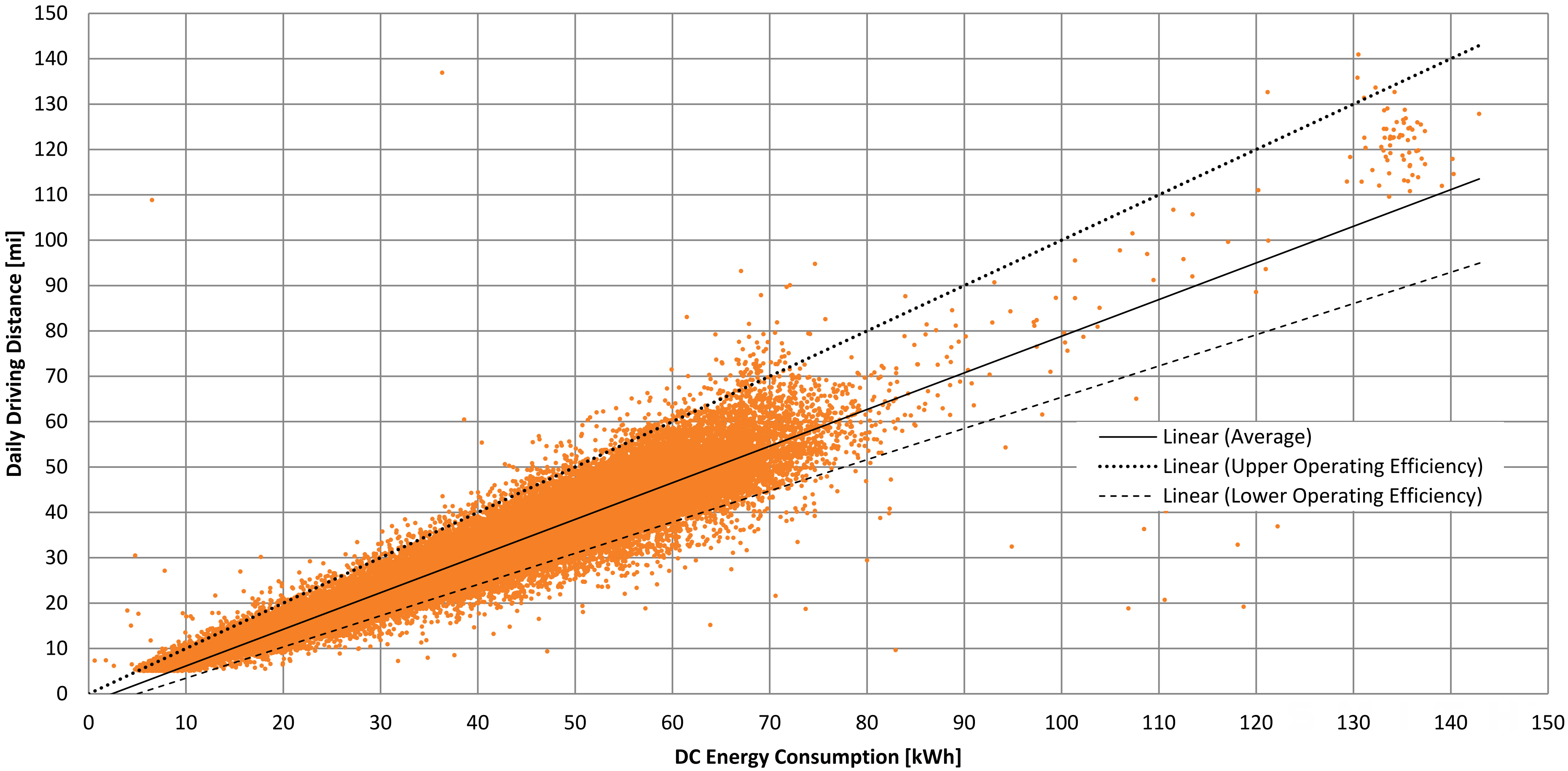
All Operational US Fleets	
Vehicles	422
Distance Traveled (2010 – 2012)	3,260,676 miles
Distance Traveled (2012)	1,751,104 miles
DC Energy Consumption (2010 – 2012)	4,401,331 kWh
DC Energy Consumption (2012)	2,304,362 kWh
DC Energy Regenerated (2010 – 2012)	518,260 kWh
DC Energy Regenerated (2012)	278,325 kWh

Areas of Smith Vehicle Operation United States

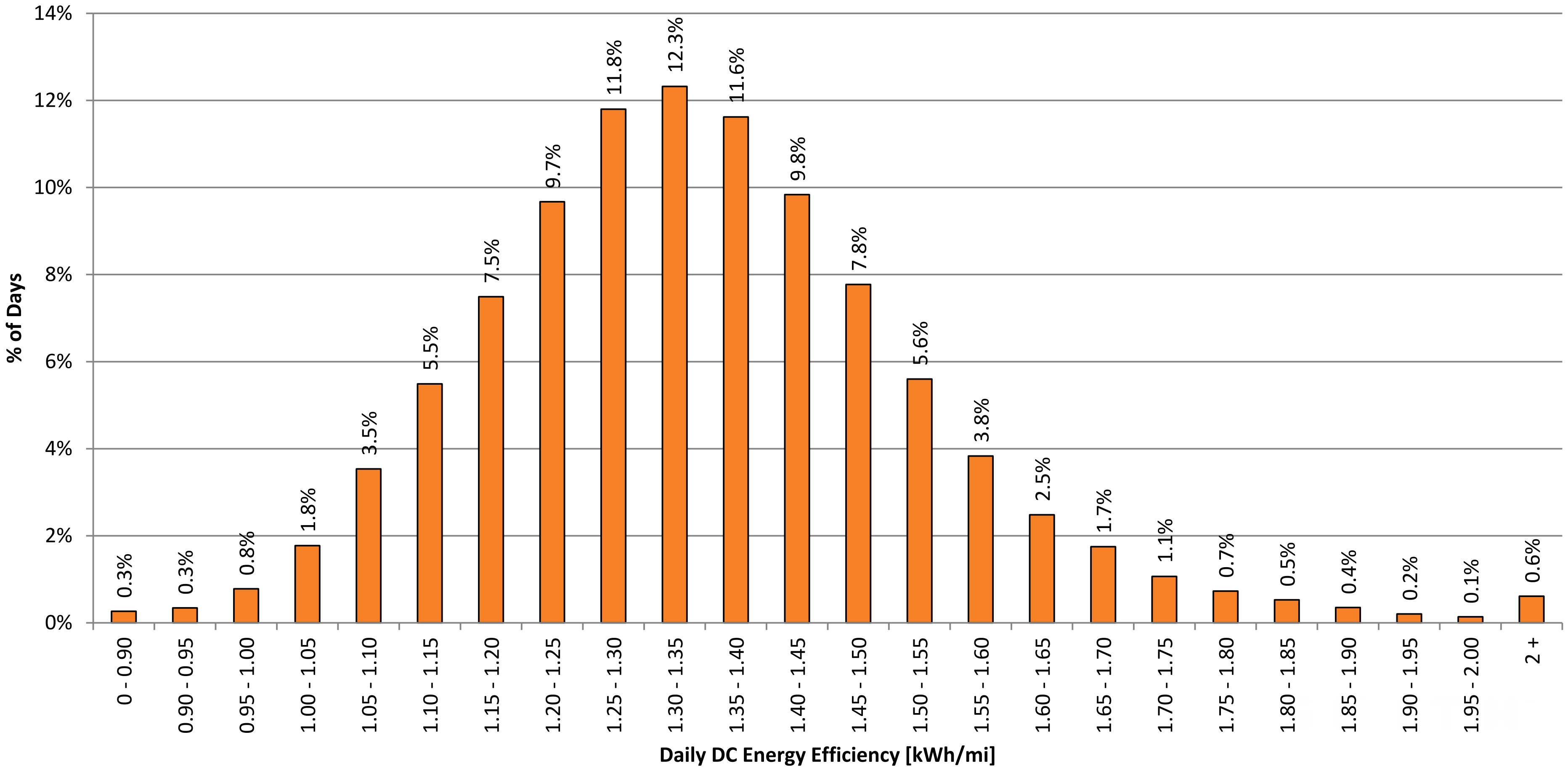
Daily Charging and Driving Profile



Distance and Energy Consumption

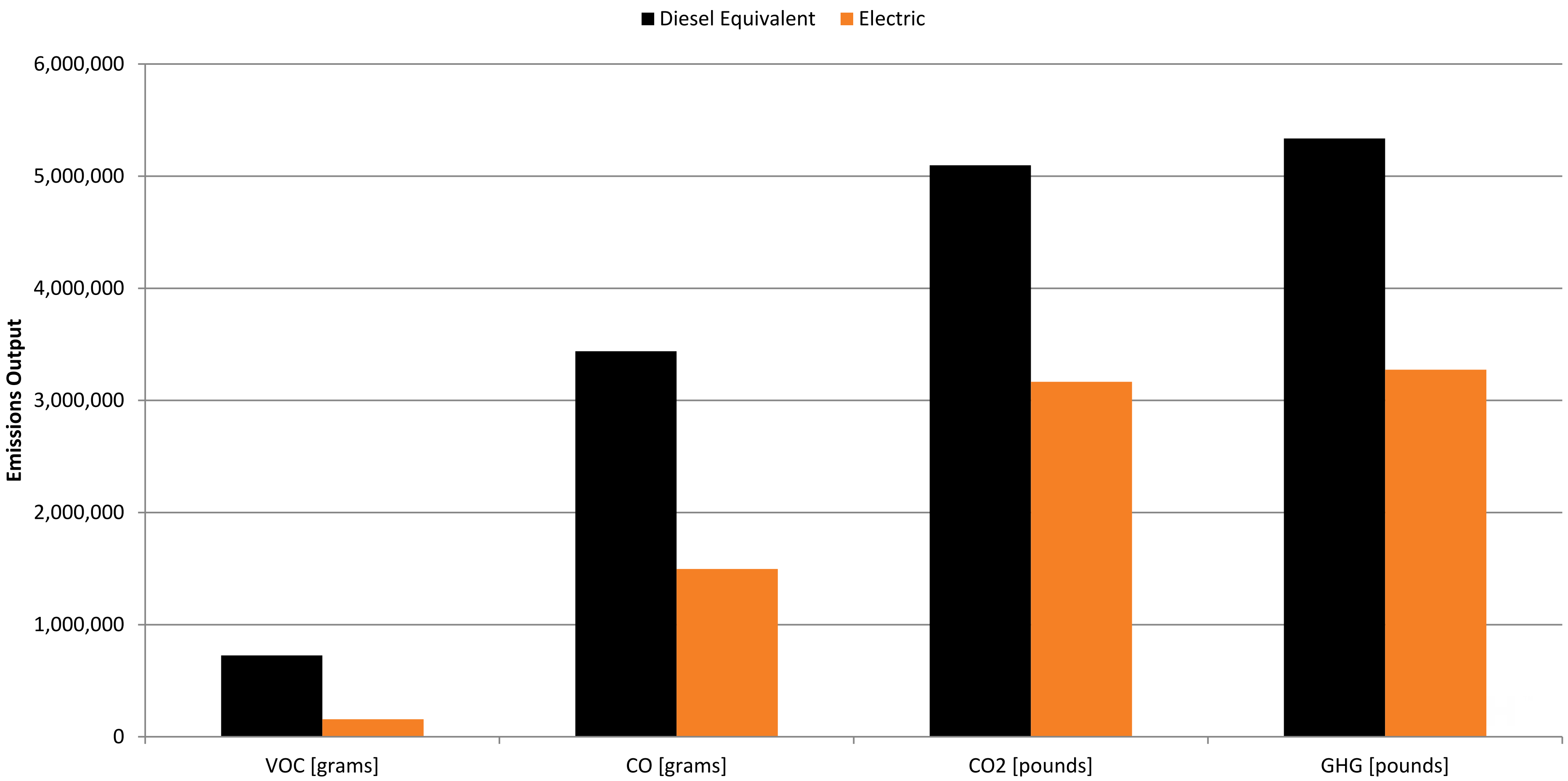


Daily Energy Efficiency Distribution



2012 Well to Wheel Emissions Comparison Overall Impact

Argonne's GREET fuel-cycle model is used to generate necessary petroleum use and GHG emission coefficients of key fuel production pathways and combustion fuel types.



2012 ELECTRIC VEHICLE IMPACT

Argonne's GREET fuel-cycle model is used to generate necessary petroleum use and GHG emission coefficients of key fuel production pathways and combustion fuel types.

Fuel and Energy Savings	
Diesel Fuel	206,012 gallons
Fuel Cost	$ 817,869
Electricity	2,304 MWh
Electricity Cost	$ 232,280
Total Fuel Savings	$ 585,589
Maintenance Savings	$ 262,665

Well to Wheel Savings	
CO	4,282 lbs
CO_2	1,931,310 lbs
VOC's	1,255 lbs
N_2O	127 lbs
Total HG	2,062,554 lbs

Pump to Tail Savings	
CO	6,879 lbs
CO_2	4,112,947 lbs
VOC's	1,123 lbs
N_2O	153 lbs
Total GHG	4,159,415 lbs

$848,254 Total Fuel and Maintenance Savings

Diesel: $3.97/gal 8.5 MPG, Electricity: $0.1008/kWh Maintenance Savings: $0.15/mile

23 Tanker Trucks of Diesel Fuel Offset

1,751,104 miles at 8.5 MPG

409 Hot Air Balloons Full of CO_2 Prevented

1 ton of CO_2 = 556.2 m^3 and 1 hot air balloon = 2,800 m^3

525 Forest Acres of Annual CO_2 Absorption

10-year-old red maples absorbing 11.2 lbs. CO_2 / year at 700/acre

Green House Gases Prevented Equivalent to weight of **24** Boeing 767's

Empty Boeing 767 = 176,000 lbs.

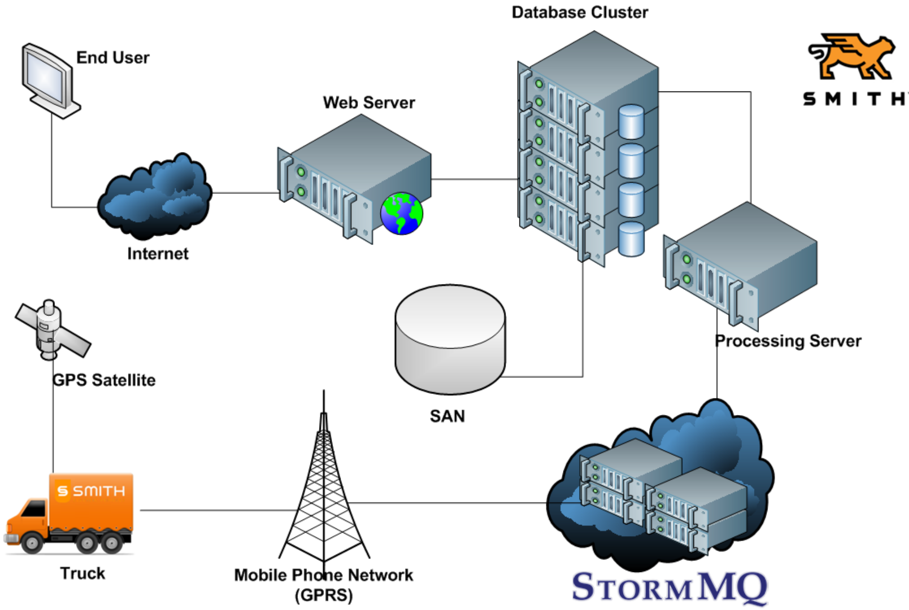
SMITH LINK

Developed specifically for the DOE project to collect real time performance data from customer vehicles participating in the project.

- Now utilized across all Smith Vehicles (USA and ROW).
- System metrics-
  - Approx 2500 data points collected per second per vehicle.
  - Approx 1.8 billion data points per day.
  - All data is encrypted.
  - All data consolidation and processing is carried out on secure Smith servers.
  - 22 Gb of data transmitted to NREL each month.
- Data utilized by the following-
  - Smith Service- support customer calls.
  - Smith Engineering- continuous improvement.
  - Smith Business Development- pre sales duty cycle analysis.
  - DOE- research and justification support.
  - Customers- Fleet performance.

SYSTEM OVERVIEW

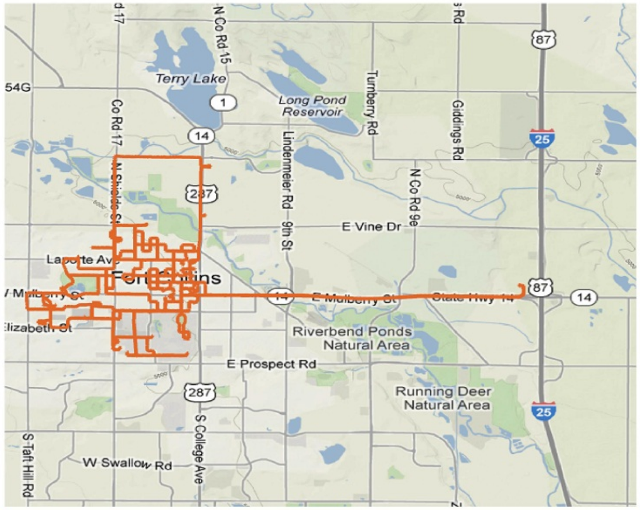
Data Points	
Per Vehicle	2,500 Per Second
Vehicles	~ 600
Per Second	1.5 Million
Per Day	1.8 Billion
Monthly	45 Trillion



Smith Link- Service Perspective

Smith Link- Duty Cycle analysis

Route 1 - Truck 239515 on 10/10/2012
Simulation - Energy Profile



Route Parameters and Information	
Base Weight	10,930 lbs (4,957 kg)
Payload Description	Constant 1,000 lbs
Key On Time	3.25 hours
Total Route Time	9.5 hours
Distance Covered	47 miles

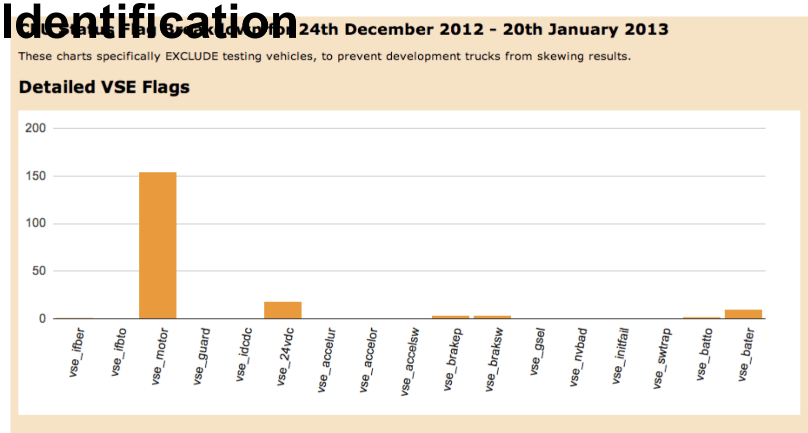
Route Duty Cycle Operational Efficiency		SOC at 47 miles	Energy Suitability
Ideal Operation	1.11 kWh/mile	30% - 35%	Yes
Typical Low Ancillary Load	1.24 kWh/mile	20% - 25%	Yes
Typical High Ancillary Load	1.37 kWh/mile	10% - 15%	Marginal
Severe Ancillary Load	1.37 kWh/mile	5% - 10%	Marginal

Route Energy Observations

Suitable for ideal and low load operating conditions.
May become marginal in extreme operating conditions.

SMITH-LINK: DIAGNOSTICS

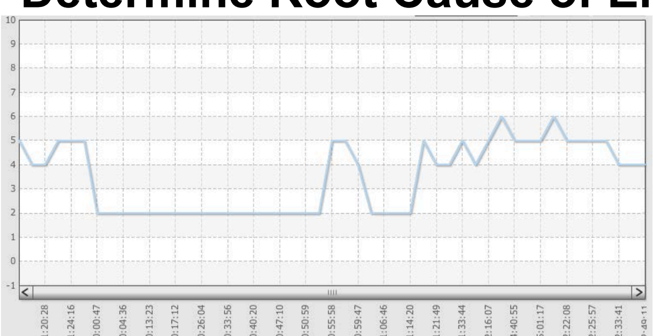
Step 1) High Level Fault Flag Identification



Step 2) Snapshot of Single Event

Fault 2 Undervoltage Event				16:26:02
	SBS1	SBS2	SBS3	SBS4
Voltage Low Error Flags	0	0	1	1
Temperature Low Diagnostic Flags	0	0	0	0
Voltage Low Diagnostic Flags	0	0	0	0
RPM	-			
Vehicle System State	-			
SOC SYS	0			
SOC	99	99	99	99
Cell Temperature Delta	1	0	0	0
Lowest Cell Temperatures	18	0	0	0
Average Cell Temperatures	18	0	0	0
Highest Cell Temperatures	19	0	0	0
Remote Device Ambient Temp	20			
Cell Voltage Delta	2	0	0	0
Lowest Cell Voltages	3292	0	0	0
Average Cell Voltages	3293	0	0	0
Highest Cell Voltages	3294	0	0	0
String Data Dump	SBS1	SBS2	SBS3	SBS4

Step 3) Deep-dive Data on a Per-Second Basis to Determine Root Cause of Error



Timestam	Battery_C	Battery_N	Battery_N	Battery_V	Battery_V	Battery_V	Battery_
0:19:07	0	27	0	343.5	343.4375	343.5	342
0:19:08	0	27	0	343.5	343.375	343.5	342
0:19:09	-4	27	0	343.5	343.375	343.5	342
0:19:10	-4	27	0	343.5	343.375	343.375	342
0:19:11	-5	27	0	343.5	343.375	343.375	342
0:19:12	-6	27	0	343.375	343.375	343.375	342
0:19:13	-6	27	0	343.375	343.3125	343.375	342
0:19:14	-7	27	0	343.3125	343.3125	343.375	342
0:19:15	-7	27	0	343.3125	343.3125	343.3125	342
0:19:16	-7	27	0	343.3125	343.3125	343.3125	342
0:19:17	-7	27	0	343.3125	343.3125	343.3125	342
0:19:18	-7	27	0	343.3125	343.3125	343.3125	342
0:19:19	-7	27	0	343.3125	343.3125	343.3125	342
0:19:20	-7	27	0	343.3125	343.3125	343.25	342
0:19:21	-7	27	0	343.3125	343.3125	343.3125	342
0:19:22	-7	27	0	343.3125	343.3125	343.3125	342
0:19:23	-7	27	0	343.3125	343.3125	343.3125	342
0:19:24	-7	27	0	343.3125	343.3125	343.3125	342
0:19:25	-7	27	0	343.3125	343.3125	343.3125	342
0:19:26	-6	27	0	343.3125	343.3125	343.25	342

SMITH LINK- CUSTOMER PERSPECTIVE

SMITH LINK

ROSS COONEY

PERFORMANCE | FLEET REPORT

Smith Link ➔ Customer area ➔ Performance report

PERFORMANCE REPORT

Performance Summary: 1st Apr 2012 - 1st May 2012	
Statistics	
Distance	104558 miles
% over 40mph	50%
Cumulative Energy Draw	152131kWh
Total Regenerative Braking Energy	12503kWh
Regenerative Energy Per Mile	0.12kWh/mile
Regenerative Energy Ratio	8%
Efficiency	0.7488 miles/kWh 1.3354 kWh/mile
Vehicle key-on time	5057:43:34
Vehicle drive time	3474:04:49
A/C Usage (hours)	612:48:09
Heater Usage (hours)	426:29:37
Carbon offset details (*Estimated*)	
Carbon cost for journey	9415.4700000001Kg
Typical cost for journey using diesel truck	21969.26Kg
Carbon saving	12553.79Kg

Details
1st Apr 2012
2nd Apr 2012
3rd Apr 2012
4th Apr 2012
5th Apr 2012
6th Apr 2012
7th Apr 2012
8th Apr 2012
9th Apr 2012
10th Apr 2012
11th Apr 2012
12th Apr 2012
13th Apr 2012
14th Apr 2012
15th Apr 2012
16th Apr 2012
17th Apr 2012

SMITH DRIVE

Project Delivery- QTR2 2013

Objectives of Project-

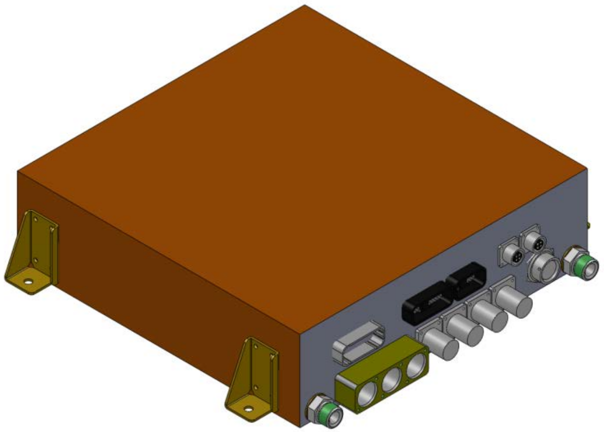
Continuous Improvement Initiative, cost down and scalable production-

- Technological-Keep pace with drive train developments.
- Commercial- Support value management and Cost Down.
- Quality- Improve specification, design, validation, manufacture.

Project Features and Benefits-

- Technology-
  - PM Machine- Support Energy Efficiency, and Weight out.
  - Greater Power- Improved acceleration.
  - Greater Torque- Improved launch feel.
  - Greater Max RPM- Support future proofing, Vmax.
  - Modular Motor/Gearbox- Support future proofing, Vmax, Gradeability.
  - Operational Environment -20 Deg to +50 Deg C.

SMITH DRIVE



Drive Controller-

- Function is to manage the energy and power flows to the driveline, domestic and aux systems.
- Process all I/O's from the driver.
- Process all communication between the other vehicle systems like the battery, and driver display.

Cooling-

- Water/Glycol cold plate.

Fully integrated with Smith Link and Smith Power.

SMITH POWER

Project delivery - Qtr 3 2013 Gen 1.75- Qtr 4 2013 Gen 2.0

Objectives of Project-

Continuous Improvement Initiative-

- Technology - Keep pace with cell and integration developments.
- Commercial- Reduce reliance on a single cell provider – capability to compete the market on price and market.
- Quality- Influence specification, design, validation, manufacture.

Project Features and Benefits-

- Transition from Cylindrical cells to Prismatic and Pouch configurations.
- Development of Smith cell agnostic Battery Management Systems and components.
- Mechanical integration strategy for Smith Module to accommodate both Prismatic and Pouch cell.
- Modular pack sizing to meet customer duty cycles.

COLLABORATIONS/PARTNERSHIPS

- •Duty Cycle Forecast Model- Kansas University Center for Research.
- •E-Van- Ultra Efficient System development UK DFT TSB funded program-
  - High Efficiency Drive Train- Bristol University (UK).
  - Controller programming Leicester University (UK).
- •QM Power on an ARPA-E project to develop electric motors using non-rare earth magnets.
- •Smith, DOE, NREL & GM joint project to demonstrate a hydrogen fuel cell range extender on an AEV.
- •Partnership with Trans Tech to deliver AEV School Buses to school districts.
- •Partnership with NREL, Burns & McDonald, Schneider Electric, TARDEC to develop Vehicle-to-Grid charging systems.
- •TARDEC V2G Performance Analysis - Missouri University of Science &Technology.

FUTURE WORK

- Finalize the 510 vehicle deployment milestone of August 31, 2013 with delivery of the final 88 vehicles.

Smith Link-

- System data efficiency improvements.
- Bi -Directional data transfer.
- Load sensing.
- Prognostics.

Smith Drive-

- Complete the transition to high volume manufacturer.
- The development and introduction of both a Light and Medium duty multispeed transmission.

Smith Power-

- Development of cell agnostic Smith Power Gen 1.75 and Gen 2.0.
- Development of active thermal management.
- Continued development and optimization of the Smith BMS.

SUMMARY

•**Objectives/Relevance-** Manufacture and sell 500+ commercial all electric vehicles, and deliver to the NREL 2 to 3 years of operating data in order to accelerate the development and production of electric drive vehicle systems in the US to reduce petroleum consumption, reduce vehicular emissions of greenhouse gases, promote US energy security, and create new US jobs.

•**Approach-** Utilize existing Smith UK technology and systems to develop a Smith US DOT-compliant all electric commercial vehicle for various industries in several geographical regions of the United States.

•**Technical Accomplishments-** Developed and improved GPS-based operational monitoring system; Gen 2 AEV drive and battery systems; created 131 new US jobs; cost reduction strategy in place.

•**Collaborations/Partnerships-** NREL, DOE, KUCR, Bristol University, Leicester University, General Motors, QM Power, Trans Tech, TARDEC, Missouri University of Science & Technology, Burns & McDonnell, Schneider Electric.

•**Future Work-** Hire and train 95 new US workers; meet delivery milestones for the 510 vehicle demonstration fleet; further improve the Gen 2 products and secure intellectual property; drive down purchase and manufacturing costs of primary and secondary components; continuously strive to improve quality.

TECHNICAL BACKUP SLIDES

SMITH DRIVE

Motor: Manage HV electrical energy and produce useful work at the wheels
Type: Permanent Magnet
Cooling: Water/Glycol jacket cooled
Weight: 97Kg
Torque: PEAK 600 Nm, CONT 400 Nm
Power: PEAK 150 kW, CONT 80 kW
Efficiency: 93%

Gearbox: Torque multiplication, prop speed reduction
Type: Single ratio (3.4:1) , parallel shaft, helical cut
Lubrication: Oil, Splash lubricated
Mating Flange: Supports Stock Avia
Tachograph Supported: Yes

Smith Power

Gen I,

- 40 KWh String
- 40 80 120 Configurations.
- 24 Mod / String
- 320 VDC Nominal
- 1 string per charger
- Fuse/controls in Battery Pod
- Master/Slave Battery Pod
- Manually intensive sealed box
- No Interlock Pins for HVDC
- Common power cables
- Pre-charge circuit in Batt Pod
- Battery Supplier BMS

Gen II,

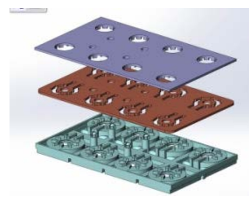
- 20 KWh String
- 40 60 80 100 120 KWh Conf
- 4 Mod / String
- 346 VDC Nominal
- 2 strings per charger unit
- JB- Accessible fusing/controls
- Master Distribution Box
- Full gasket sealed ox
- Interlock-Pins for HVDC
- Power Shielded cables/ferrites
- Pre-charge circuit in CEU
- Smith BMS

Smith Power – Gen 1.75 and Gen 2.0 Concepts

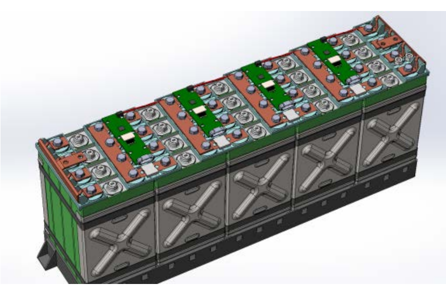
Gen 1.75

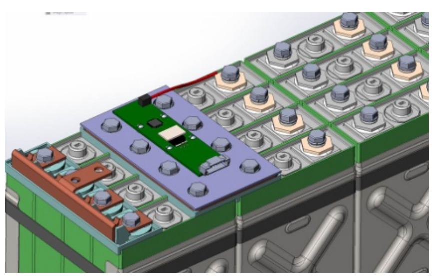
Module

Fusing and Measurement Concept



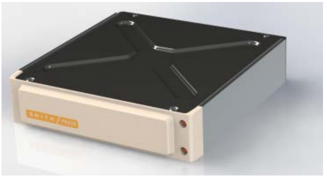
Stacking Concept



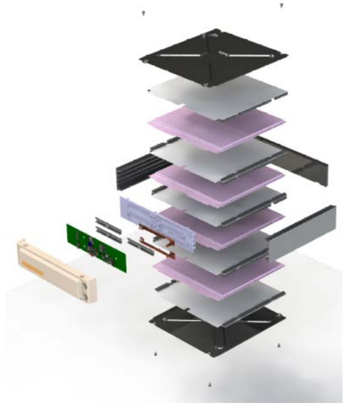


Gen 2.0

Module



Exploded View



Stacking Concept

Technical Backup Slides

Smith Newton Shuttle Bus

Technical Backup Slides

Smith Newton School Bus

Smith Newton Step Van