



BACKUP/PEAK-SHAVING FUEL CELLS

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Plug Power
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Project ID # GO13097

Clean, Reliable On-site Energy

This presentation does not contain any proprietary or confidential information

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Timeline

Project Start Date:	August 2003
Project End Date:	April 2007
Percent Complete:	95%

Budget

Total Project Funding	\$ 7,201,881
DOE Share	\$ 3,600,940
Plug Power Share	\$ 3,600,941
Funding Received in FY05	\$ 2,762,242
Funding for FY06	\$ 149,251

Barriers

Barriers Addressed:

- ❖ DOE Technical Barriers for Distributed Generation Systems
 - E. Durability
 - G. Power Electronics
 - H. Startup Time
- ❖ DOE Technical Barriers for Fuel Cell Components
 - O. Stack Material and Manufacturing Cost
 - P. Durability
 - R. Thermal and Water Management

Partners

Bell South

Telcordia Labs

Airgas

Argonne National Labs (Test Site)

FAA (Test Site)

High Level Objective

Develop new generation of commercially viable, stationary, backup/peak-shaving fuel cell systems.

- ❖ Develop, build and test three fuel cell backup systems and field test at three sites including an industry host (BellSouth)
- ❖ Identify technical barriers and objectives
- ❖ Develop a cost-reduced, proton electrolyte membrane (PEM) fuel cell stack tailored to hydrogen fuel use in back-up applications
- ❖ Develop a modular, scalable power conditioning system tailored to market requirements
- ❖ Design a scaled-down, cost-reduced balance of plant (BOP)
- ❖ Certify the design to Network Equipment Building Standards (NEBS) and Underwriters Laboratories (UL)

	PHASE I	PHASE II	PHASE III
Objective	Technology Assessment	Product Design and Validation	Field Demonstration
Status	Complete	Complete	In-Process
Key Activities	<ul style="list-style-type: none"> ❖ Develop system requirements with Bell South ❖ Technologies Assessed <ul style="list-style-type: none"> • Dry Cathode Operation • GenSys Stack Integration • H2 Regeneration Options • Power Conditioning Platform • Advanced Electrical Energy Storage • System Water Balance • Advanced H2 Storage • Scale System • GenSys Stack 	<ul style="list-style-type: none"> ❖ Develop Design ❖ Validate Design ❖ UL certification of system to FC-1 ❖ Certify system to NEBS <ul style="list-style-type: none"> •GR 487 •GR 63 •GR 1089 	<ul style="list-style-type: none"> ❖ Test one system at Bell South to validate customer requirements ❖ Test one unit at ANL to baseline system performance ❖ Field trial on unit at FAA (Tentative)

2003/2004 Recap

- ❖ In 2003 and 2004, the Program executed a broad-based initiative to determine requirements for the platform's commercial design, collecting data by:
 - Extensive laboratory testing at Plug Power
 - Field testing of the GenCore[®] prototype system (13 systems)
 - Certifying the prototype to UL and NEBS requirements
 - Developing a Backup Power Fuel Cell System Requirements Document (SRD) with BellSouth

- ❖ Additionally, the Program evaluated ten enabling technologies and selected six for inclusion in the commercial design

- ❖ Finally, the Program began the new product development of the commercial product design, combining the technical, certification and customer requirements with the feasible technology initiatives in the design of the next-generation platform

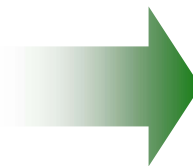
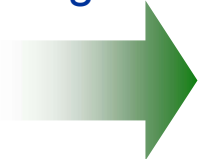
Technology Go/No Go Results Summary

<u>Enabling Technology</u>	<u>Go/No Go</u>	<u>Comments</u>
2.1 Dry Cathode Operation	No Go	Will not yield in program timeframe
2.2 GenSys® Stack Integration	No Go	Will not yield in program timeframe
2.3. Power Scalable Stack	Go	In final design
2.4. H2 Regeneration Options	Go	In final design - Advanced Exhaust Gas Recirculation (EGR) Option. No electrolyzer.
2.5. Power Conditioning Platform	Go	In final design
2.6. Advanced Electrical Energy Storage	Go	In final design - Non-lead acid solution in place
2.7. System Water Balance	No Go	Will not yield in program timeframe
2.8. Advanced H2 Storage	No Go	Will not yield in program timeframe
2.9. Scale System	Go	In final design
2.10. GenSys Stack	No Go	Will not yield in program timeframe – Key technology initiatives incorporated into GenCore Stack

TECHNICAL ACCOMPLISHMENTS – PRODUCT DESIGN



Start of
DOE
Program



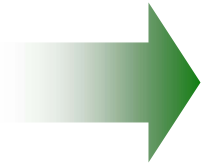
	UPS -1	Prototype	Final Design
Life	800 Hours	1500 Hours	1500 Hours
Coolant	Paralux	Propylene Glycol	Propylene Glycol
H2 management	Purge	Blower EGR	Venturi EGR
Energy Storage	Batteries	Batteries	Ultra Caps
Stack Cells (Relative)	100%	79%	71%
Humidifier	Enthalpy Wheel	Membrane	Membrane

POWER SCALABLE STACK



UPS-1

Key
Changes



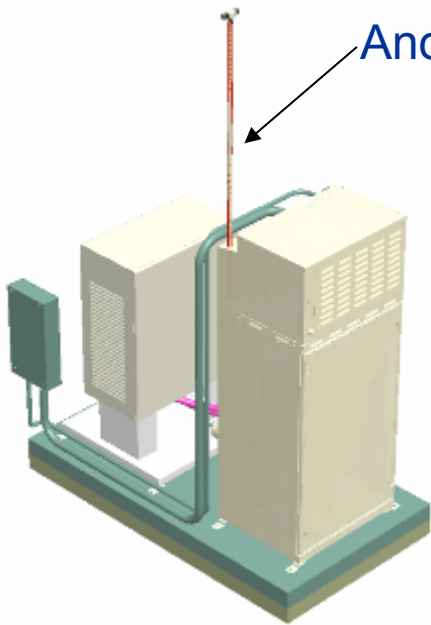
- Cast End Hardware
- Cost Reduced MEA
- Thinner Plates
- Improved Scanner Cards



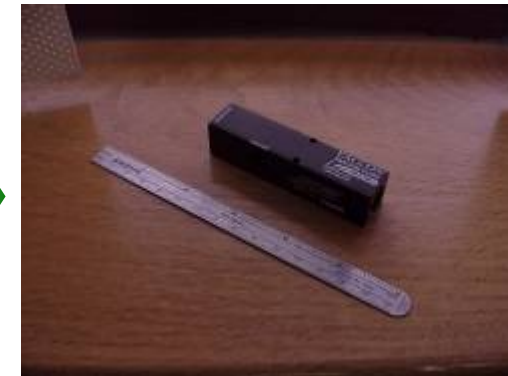
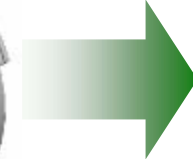
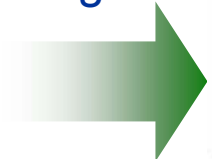
Final Design

	UPS –1	Prototype	Final Design
Volume (L)	70	53	53
Weight (Lbs)	~100	~60	~60
Stack Cells (Relative)	100%	79%	71%

H2 EXHAUST GAS RECIRCULATION OPTIONS



Start of
DOE
Program



UPS-1

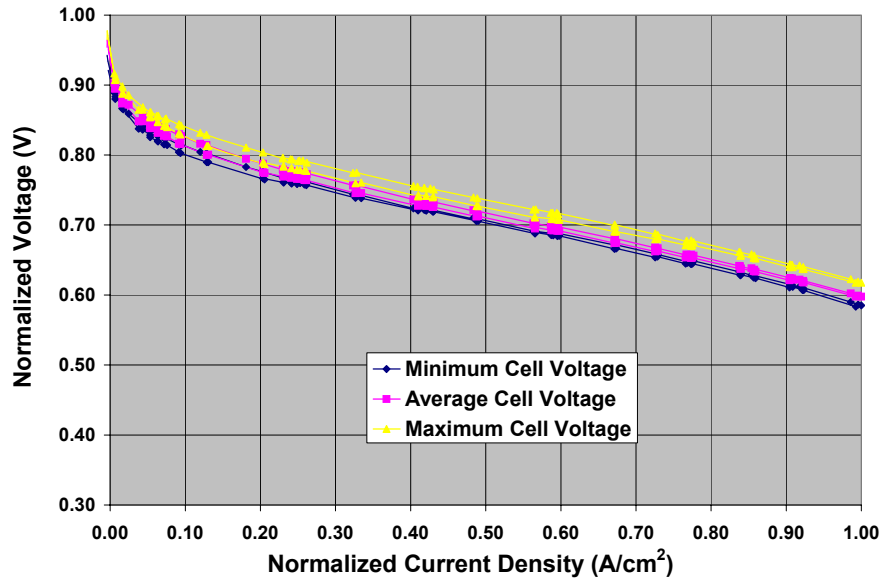
Prototype

Final Design

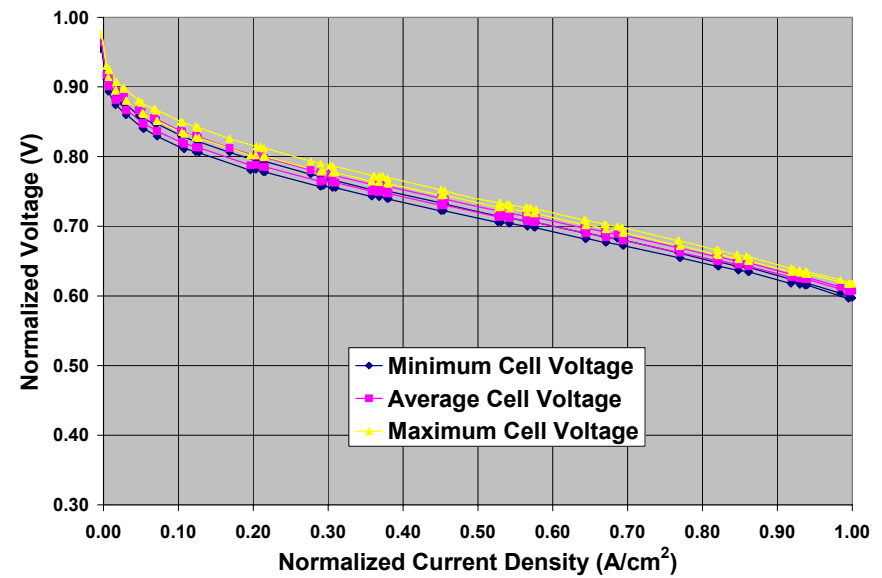
	UPS –1	Prototype	Final Design
Technology	Purge	Blower EGR	Venturi EGR
Siting/H2 Exhaust	70 SLM, 30sec purge	< 1000 ppm	< 1000 ppm

VENTURI VS. BLOWER EGR 350 HOUR TEST

Blower EGR



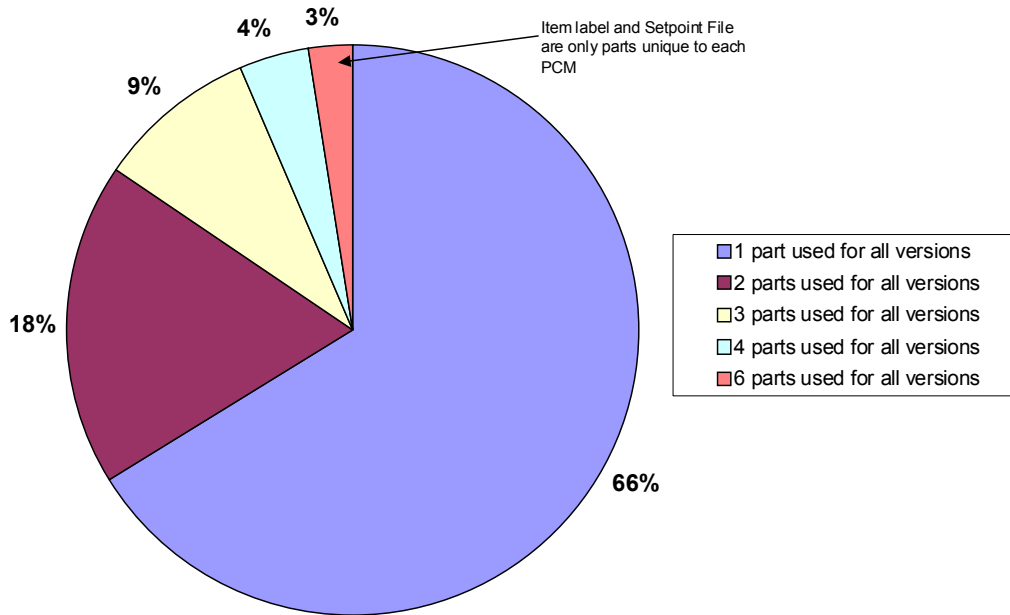
Venturi EGR



Results showed similar stack performance after 350 hour test

POWER CONDITIONING PLATFORM

Overall DC-DC Converter - Common Parts Used

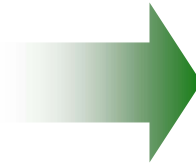


GenCore DC/DC Converter

- ❖ DC/DC was developed to be easily modified to accommodate different voltage ranges
- ❖ 66% of the DC/DC converter parts are common across the platform
- ❖ Only 3% of the parts are unique to on every converter

	24V	48 V Positive Ground	48V Negative Ground	120V
Main Output	6000 W	5000 W	5000 W	5000 W
24V Aux. Output	None	900W	900W	900W
Topology	Buck	Buck-Boost	Buck-Boost	Boost
Main Efficiency @ full power	>96.5%	>97%	>97%	>95%
Aux. Efficiency @ full power	NA	>87%	>92%	>92%

ADVANCED ELECTRICAL ENERGY STORAGE



UPS-1

Final Design

	UPS-1	FINAL DESIGN
Technology	Batteries	UltraCaps
Energy Storage	3 MJ (5kW for 10 minutes)	150 kJ (5kW for 30 Seconds)
Weight	108 lbs	44 lbs

ADVANCED ELECTRICAL ENERGY STORAGE



- ❖ Ultra Caps are ideally suited to the GenCore application due to the short start up time (<30s)
- ❖ Ultra Caps will last the life of the system (10 years) while the batteries will need to be replaced every three years.
- ❖ Ultra Caps are currently approximately 4 times more expensive than batteries.
- ❖ Ultra Caps are more tolerant to ambient temperature ranges (-40 to 46 C)

Scale System

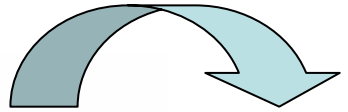
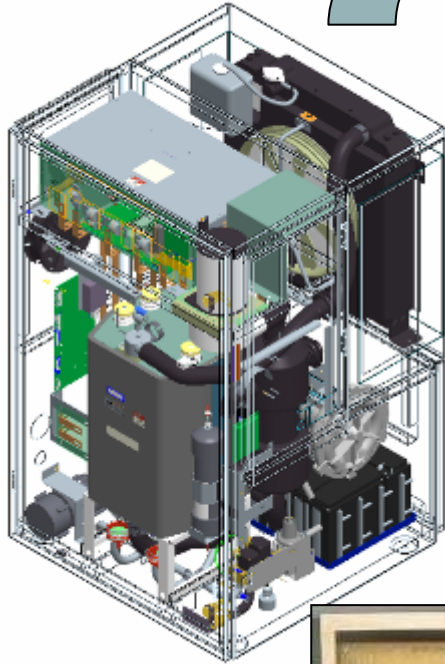


PRODUCT CHARACTERISTICS

- Re-packaging incorporates several years of design learning from original GenCore
- Component count is significantly reduced, improving reliability by reducing opportunities for failure
- Re-packaging improves manufacturability and servicability

TECHNICAL ACCOMPLISHMENTS – PRODUCT DESIGN

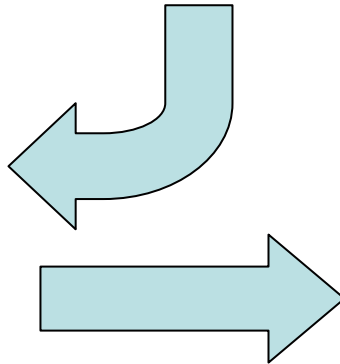
Pro/Engineer



Foam Core



Wood "Buck"

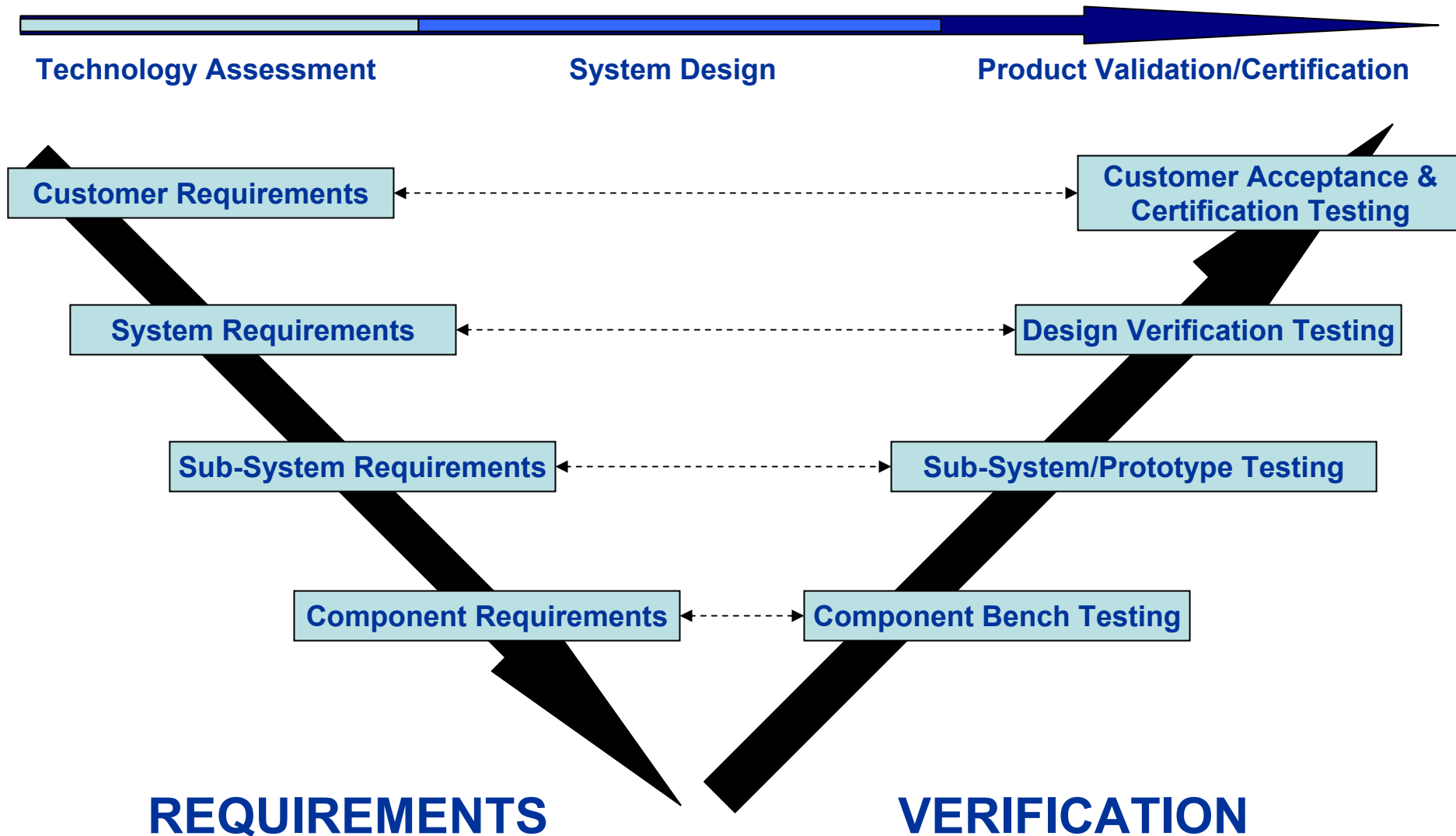


FINAL DESIGN EVOLUTION



Functional Hardware

Product Development and Design Verification Cycle



TECHNICAL ACCOMPLISHMENTS – DESIGN VALIDATION

GR 1089 - Electromagnetic Compatibility (EMC) and Electrical Safety

- ❖ System-level Electrostatic Discharge (ESD)
- ❖ Electromagnetic Interference (EMI)
- ❖ Lightning and AC Power Faults
- ❖ Steady-state Power Induction
- ❖ Electrical Safety
- ❖ Bonding and Grounding



GR-63: Network Equipment Building Systems (NEBS) Requirements for Physical Protection




- ❖ Temperature and humidity
- ❖ Altitude
- ❖ Flammability
- ❖ Earthquake
- ❖ Vibrations
- ❖ Airborne contaminants
- ❖ Acoustic noise
- ❖ Illumination.

GR-487: Generic Requirements for Electronic Equipment Cabinets

- | | |
|--------------------------------|-------------------------------------|
| ❖ Water and Dust Intrusion | ❖ Fire Resistance |
| ❖ Wind Driven Rain | ❖ Corrosion Resistance |
| ❖ Rain Intrusion | ❖ Shock and Vibration |
| ❖ Lawn Sprinklers | ❖ Transportation Shock |
| ❖ Weathertightness | ❖ Transportation Rail |
| ❖ Acoustical Noise Suppression | ❖ Transportation Vibration |
| ❖ Wind Resistance | ❖ Installation Shock |
| ❖ Impact Resistance | ❖ Environmentally Induced Vibration |
| ❖ Firearms Resistance | ❖ Earthquake Resistance (Zone 4) |



TECHNICAL ACCOMPLISHMENTS – FIELD DEMONSTRATIONS

Partner	Scope	Status
	Validate system meets customer requirements	❖ System shipped on 3/3/06
	Perform baseline performance testing	❖ System shipped on 3/15 ❖ System installed ❖ Test plan developed ❖ Testing has begun
	In application field demonstration	❖ System will ship in August 2006 ❖ Testing will complete in February 2007

- ❖ The program is scheduled to be complete by April 2007. The following items activities will be completed:
 - Validation of customer requirements at BellSouth
 - Completion of baseline testing at Argonne National Laboratory
 - Completion of field trial at FAA

- ❖ The program has completed all of the objective of this program except the field demonstrations which have been scheduled.
- ❖ All activities will be completed within the original program budget
- ❖ 5 of 10 technology initiative proved feasible and are incorporated into the final design
- ❖ A cost-reduced, proton electrolyte membrane (PEM) fuel cell stack tailored to hydrogen fuel use in back-up applications was developed
- ❖ A modular, scalable power conditioning system tailored to market requirements was developed
- ❖ A scaled-down, cost-reduced balance of plant (BOP) was incorporated into the final design
- ❖ The final design was certified to the Network Equipment Building Standards (NEBS) and FC-1 by Underwriters Laboratories (UL)

BACK-UP SLIDES

- ❖ “Argonne National Laboratory; Bell Labs, etc. are potential demonstration partners not collaborators.”
 - BellSouth provided customer requirements which were incorporated into the design requirements

- ❖ ‘No future “research” is planned. Future plans include engineering and packaging systems for the demonstration.’
 - Plug Power continues corporate research and development on fundamental fuel cell topics this and several other product opportunities. As this program is a demonstration, final tasks under this program are only related to the field demonstration.

- ❖ W.D. Ernst, Small Scale Distributed Stationary Systems – A Status Report. 9th Grove Conference. Westminster, England, October 2005.
- ❖ Bin Du, Qunhui Guo, Richard Pollard, Daniel Rodriguez, Christopher Smith, and John Elter, "Proton Exchange Membrane Fuel Cells (PEMFCs): Technology Status and Challenges for Commercial Stationary Power Applications". JOM is Journal of The Minerals, Metals & Materials Society, Volume 58, Issue 5, May, 2006

PLUG POWER. PLUG WILL.



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