Jean Botti
Chief Technologist
Delphi - Dynamics & Propulsion
Delphi Overview

- World leader in mobile electronics, transportation components & systems
  - Fortune 40 company
  - Global Presence
  - Expertise in gasoline & diesel engine systems

- Leader in technology and electronics integration
  - Customer differentiating products
  - Diverse product line now seeking a diversified customer base

- Growth opportunities:
  - Automotive:
    » Progression of IC Engine driven transportation to lower levels of harmful emissions and higher levels of performance.
    » Hybrid powertrains with IC Engines and alternate power sources
  - Non-Automotive:
    » Stationary Power & Mobile Power
    » Medical Accessories - Use of automotive technologies applicable to the non-automotive market
# Extensive Global Presence

As of December 2000

<table>
<thead>
<tr>
<th>Region</th>
<th>Manufacturing sites</th>
<th>Employment</th>
<th>Joint ventures</th>
<th>Technical centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Delphi</td>
<td>190</td>
<td>211,400</td>
<td>44</td>
<td>31</td>
</tr>
<tr>
<td>U.S. &amp; Canada</td>
<td>51</td>
<td>73,100</td>
<td>8</td>
<td>14</td>
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<tr>
<td>Europe &amp; Middle East</td>
<td>75</td>
<td>48,000</td>
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<td>10</td>
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<tr>
<td>Mexico &amp; South America</td>
<td>46</td>
<td>83,300</td>
<td>8</td>
<td>4</td>
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<tr>
<td>Asia Pacific</td>
<td>18</td>
<td>7,000</td>
<td>20</td>
<td>3</td>
</tr>
</tbody>
</table>
Delphi Sectors

- Dynamics & Propulsion: 2001 Sales: $12.6 Billion
- Safety, Thermal & Electrical Architecture: 2001 Sales: $9.0 Billion
- Electronics & Mobile Communication: 2001 Sales: $4.8 Billion

2001 Sales: $26.1\(^{(1)}\) Billion

(1) Includes inter-sector eliminations.
Current Product Portfolio

Fuel Cell related Systems & Components

**Dynamics & Propulsion**
- Air/Fuel Systems
- Ignition Systems
- Exhaust Aftertreatment Systems
- Fuel Handling & Evaporative System
- Energy Storage & Conversion
- Valve Train Products

**Sensors & Solenoids**
- Chassis Systems & Modules
- Intelligent Chassis Control Systems
- Complete Brake Systems
- Wheel Brake Components
- Brake Apply Components
- Gen III Wheel Bearing Modules
- Suspension Dampers & Damper Modules

**Vehicle Control Systems**
- Electric Power Steering, Steering Columns, Power Steering Pumps & Hoses, Steering Gears, Driveline Systems, QUADRASTEER
- Half Shafts, CV Joints

**Electronics & Mobile Communication**
- Sensors & Power Modules
- Powertrain Controllers
- Body & Chassis Electronics
- Electronic Control Units
- Supplemental Inflatable Restraint Electronics
- FOREWARN Collision Warning Systems
- Audio Systems
- Communications Systems
- Navigation Systems
- Driver Information & Controls

**Safety, Thermal & Electrical Architecture**
- Instrument Panels
- Airbag Systems
- Steering Wheels
- Power Products
- Door Hardware & Trim Modules
- Latching Systems
- Modular Doors
- Climate Control Systems
- HVAC Modules, Condensers, Compressors, Accumulator Dehydrators, Thermal Management Systems
- Powertrain Cooling Systems
- Radiators, Oil Coolers, Engine Cooling Modules

**Power & Signal Distribution Systems**
- Connection Systems
- Switch Products
- Sensors
- Electronic Products
- Fiber Optic Lighting/Data
- Electrical/Electronic Centers
- Ignition Wiring Systems
- Modular Cockpits
Delphi’s Core Competencies

- Application of skills to the commercialization of Fuel Cells for Automotive and other markets
  - Automotive Market access and experience
  - Systems integration expertise
    - Engine Management Systems
    - Fuel Systems Integration and Air-Fuel Management
    - Emission System Control and Diagnostics
    - Regulatory Compliance
  - Complementary technology expertise
  - Electronic Controls and Power Electronics in relatively harsh environments

- High Volume Low Cost Manufacturing
  - Decades of automotive experience in this very competitive market have honed skills of high reliability, low cost manufacturing
Fuel Cells
A Means to Realize Delphi’s Vision

◆ Following our customers’ needs
  – Help reduce fuel consumption
  – Reduce harmful emissions
  – Use combination of fossil and renewable energy sources

◆ Duty as a Corporate Citizen
  – Use our expertise and established manufacturing base to support national imperatives
  – Support SECA by providing Auxiliary Power Units and 21st Century Truck Initiative with Essential Power Units
  – Help establish alternate energy sources for transportation and stationary power
  – Look after our stakeholders’ interests by ensuring future growth
Fuel Cells
Fuels To Applications

Hydrogen Storage

OR

Fuel Reformer
Converts fuel to hydrogen rich gas

Fuel Cell
Converts hydrogen and oxidant to power

Balance of Plant

Propulsion

PEM FC

Electric Power

Electrical Accessories

SOFC

Stationary applications

SOFC / PEM

Fuels = gasoline, diesel, natural gas
Reformer Complexity - SOFC vs PEM

PEM

PEM reformer + stack run at very different temperatures. A complex, multi-stage reformer system must be carefully thermally managed at each step.

SOFC

SOFC reformer and stack run at similar temperatures and can be closely coupled.

- **Autothermal / Steam Reformer**: > 900 °C
- **Partial Oxidation Reformer**: 800 °C
- **High Temperature Shift Reactor**: 800 °C
- **Low Temperature Shift Reactor**: 700-1000 °C
- **Solid Oxide Fuel Cell Stack**: 700-1000 °C
- ** Preferential Oxidation (CO clean-up)**: 80 °C
- **PEM Fuel cell stack**: 80 °C
SOFC APU Applications

- **SOFC SYSTEM as an AUXILIARY POWER UNIT (APU).**
  - Markets: trucks, passenger automobiles, recreational vehicles, stationary applications, military.

Gasoline APU for passenger automobiles

Diesel Truck APU

Stationary applications - Natural gas or diesel
Increased Electrical Power needs are being driven by advanced IC Engines for enhanced performance, emission controls, and creature comforts:

- Electrical Power Steering
- Direct Injection
- Electrically Heated Catalyst
- Electrical Water Pump
- Electro-magnetic Valvetrain
- Engine Cooling Fan
- Electric AC Compressor
- Heated Windshield, Seats

These requirements are beyond the capabilities of the Lundell type generator and require supplemental Electrical generation, such as from an SOFC APU.
Hotel Loads
- Supply electrical power for cabin needs with vehicle engine off: air conditioning/heating, mobile office, microwave, etc.

Reduce emissions by reduction of load or total run time of the engine
- Allow the shutdown of engine during extended idle or overnight operation
- Reduce parasitic loads on the engine through electrification of accessory drives, i.e. water and oil pumps, hydraulic drives, cooling fans

Technology enabler for additional electrical/electronic devices
Distributed Generation (DG) is the production of power at or near the point of use.

Key advantages of Distributed Generation are:

- The ability to add generation capacity in smaller increments
- The ability to avoid installation of additional electrical power transmission capacity
- The ability to cogenerate heat at the point of use
- An ability to develop either a microgrid of several DG units or work the DG units in conjunction with the traditional grid in order to provide higher reliability

DG is an emerging market and is not as clearly defined as the transportation market - particularly with respect to distribution channels.
SOFC Auxiliary Power Unit
Development Status

Proof of Concept (PoC) APU

Size reduction:
PoC: 152 Liters
Gen. 2: 50 Liters

Mass reduction:
PoC: 200 kg
Gen. 2: 50 kg
In addition to the large reduction in system size and weight, the Delphi-Battelle cell and stack is designed to be thermally cycled.

Thermal cycle requirements depend on application:

- 2004 development goal: 100 cycles
- Stationary market entry: 500 cycles
- Stationary market mature: 2000 cycles
- HD Automotive market entry: 3000 cycles
- HD Automotive mature: 5000 cycles
- LD Automotive market entry: 5000 cycles
- LD Automotive mature: 10000 cycles
System Cost Targets
- by application

System cost targets

- Military
  - Current technology: 3000 $/kW
  - SECA supported 2nd generation SOFC technology: 800 $/kW
  - Highly integrated 3rd generation technology

- Premium Stationary
  - Distributed Generation / Niche Automotive: 600 $/kW
  - High Volume Automotive: 400 $/kW

- Military
  - 3000 $/kW

- Current technology
  - 800 $/kW

- SECA supported 2nd generation SOFC technology
  - 600 $/kW

- Highly integrated 3rd generation technology
  - 400 $/kW

- Military
  - 150 $/kW

Jean Botti, Delphi
Learning curve and incremental product and process innovations are likely to drive large cost reductions.

Disruptive changes in materials, product and processes are also required to meet high volume automotive goals:
- less use of premium materials (thinner layers)
- lower temperature operation
- new metallic alloys and low cost processing techniques
- highly integrated reformer/stack/heat exchange
- simplified balance of plant
- integrated controls and power electronics
- model based controls

High volume potential of automotive applications may accelerate cost reduction and result in higher volume stationary applications which will accelerate cost reduction further.
Synergies with Delphi’s SOFC program: Hydrogen Enrichment / SULEV ICE

Strategies:

Start: Nearly zero HC and NOx

(1) Extremely low emission cold start on reformate (only fuel to engine on start)

(2) Accelerated catalyst heating (reformate added to lean engine exhaust)

Run: Low NOx – lean or extreme EGR modes

(3) High dilution (with EGR or lean) with partial reformate and partial gasoline fuel to engine

Super low emission gasoline engine EMS with a fast light-off micro-reformer

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Fast-startup reformer:

- This video shows the start-up of a prototype reformer in < 10 s. The project goal for SULEV ICE applications is < 2 s.
- SOFC and SOFC/ICE systems will contain this type of device.
Summary

◆ Delphi is a Leading Global Systems and Component Supplier

◆ Delphi Provides Solutions to Customer Needs
  - Quality Focused
  - Evolving Manufacturing Footprint
  - Expanding Technical Resources
  - Customer Focused Marketing
  - Global Presence

◆ We believe that SOFC is a technology with promise that offers advantages over other power systems - especially in the 1 - 10 kW size range.

◆ Delphi intends to use both existing competencies and new technology to target the growing market for SOFC systems in stationary and automotive applications.
Driving Tomorrow’s Technology