Fuel Cells for Mobile Products

Micro Nano Breakthrough Conference

July 26, 2005

www.neahpower.com

Fuel Cells Can Be The Next Generation Power Source For Mobile Products

- **Enormous demand for better portable power sources**
  - ✓ Proliferation of electronic devices
  - ✓ Increased usage, especially in mobile environments
  - ✓ Improvements in battery technology are limited
  - ✓ End-user desire for convenience of use
- **Fuel cells combine fuel (Methanol) with oxygen in chemical reaction to generate electricity**
  - ✓ Generate electricity continuously if fuel and oxygen are supplied
  - ✓ "Refueled" instantly by replacing a small fuel cartridge
- **Enable long run-time with small, light spare cartridges not extra batteries**

Electronic Product Markets Provide Huge Volume Opportunity for Fuel Cells

Worldwide Annual Unit Volume (millions)

	2003	2009	Δ%
Notebook PCs	41	85	+107%
Tablet PCs	0.6	4.1	+592%
Military	0.3	0.6	+79%
PDAs	15	29	+93%
"Smart" Phones	14	78	+446%
Camcorders	20	41	+101%
Digital Cameras	31	76	+146%
Music Players	12	44	+266%
All Other	9.6	29	+201%
Total (14 markets)	144	387	+168%

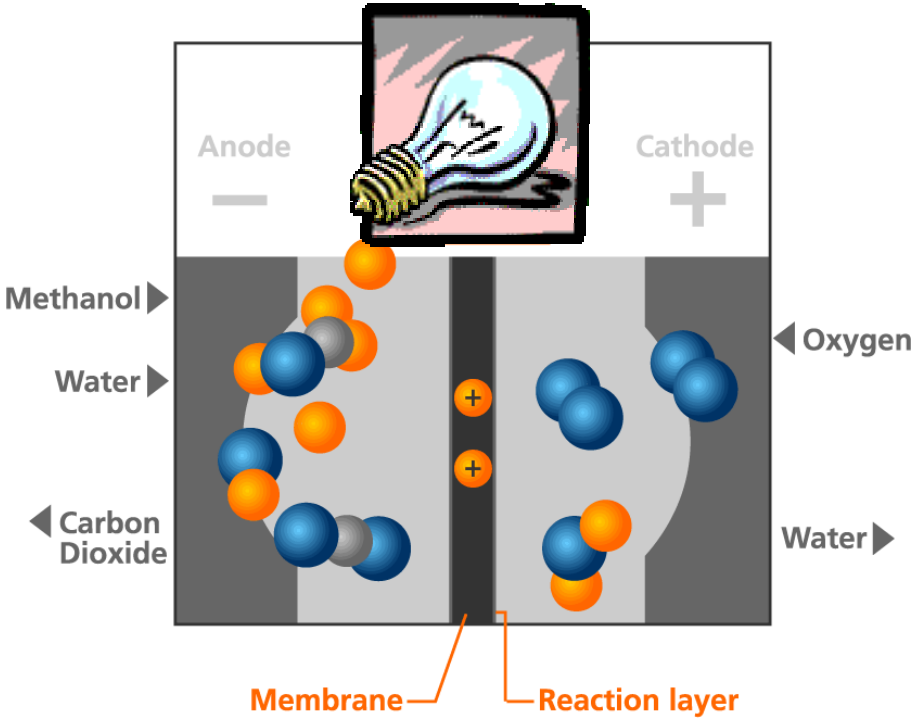
Sources: IDC, Bear Stearns, Morgan Stanley, ABI, CEA, etc.

NEAH power systems

Design Limitations Have Hindered Application of Direct Methanol Fuel Cells (DMFCs)

- **Chemical reaction only where fuel, catalyst, and electrolyte in direct contact**
  - ✓ Thin, 2D reaction zone
- **High power requires large surface area**
- **PEM fuel cells challenged by:**
  - ✓ Efficiency (typically 20 - 25%)
  - ✓ Reliability
  - ✓ Miniaturization
  - ✓ Cost

Traditional PEM-Based Design



PEM Fuel Cells Over-sized and Under-Powered for Portable Electronic Devices

Fuel Cell Charger for Notebook PC (prototype)

Fuel Cell for PDA (prototype)

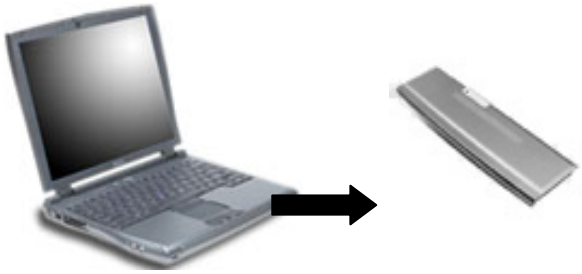
Fuel Cell for Notebook PC (prototype)

NEAH power systems

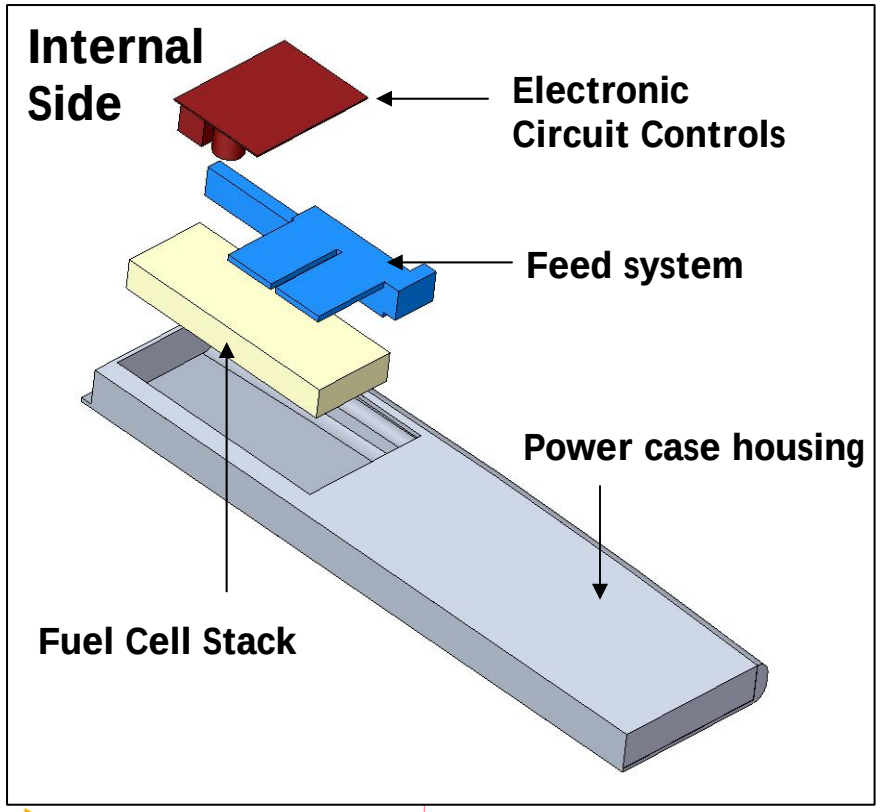
Neah Power Founded to Develop Improved DMFCs for Mobile Electronic Devices

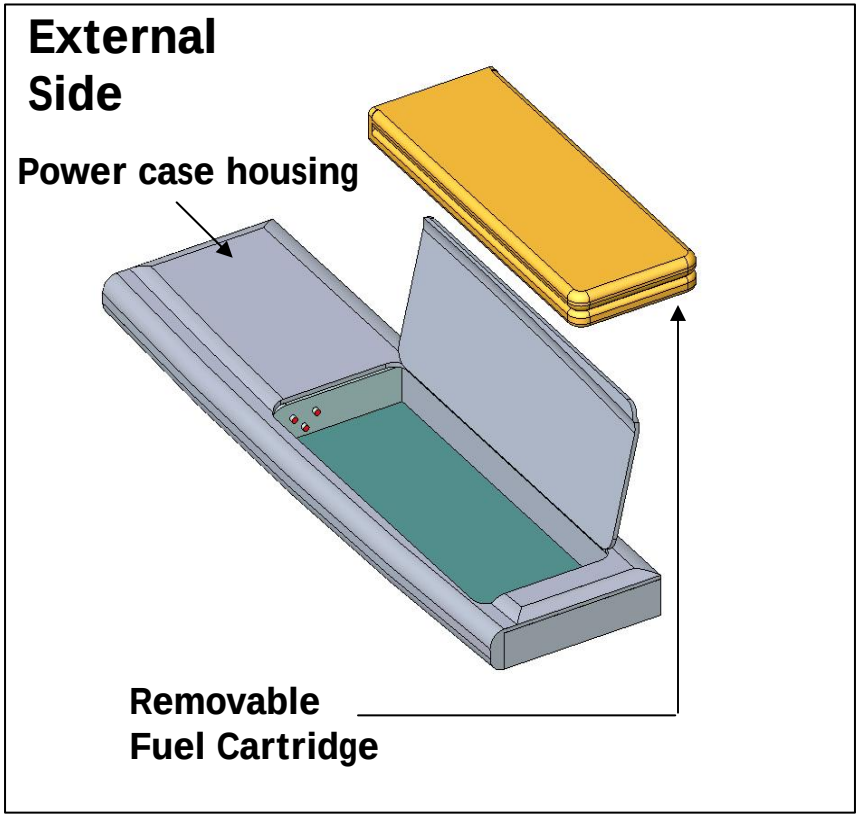
- **Founded in 1999**
  - ✓ Venture Capital funded
  - ✓ Frazier, Alta, Intel Capital, Castile & WestAM
- **2000-2003:**
  - ✓ Identified and proved early technical concepts, filed patents
  - ✓ Expanded management team, tested prototypes, received NIST/ATP funding, granted key patent
- **2004-2005**
  - ✓ Agreement with military OEM, strategic relationship with silicon processing company, reducing concepts to practice, developing fuel cell prototypes
- **2006-2007**
  - ✓ Develop product designs, scale-up low volume production, initiate product shipments, expand OEM customer base

Neah's Goal: DMFC with 2 Times Energy Storage in the Size of Current Batteries



Two Components: Fuel Cell and Fuel Cartridge

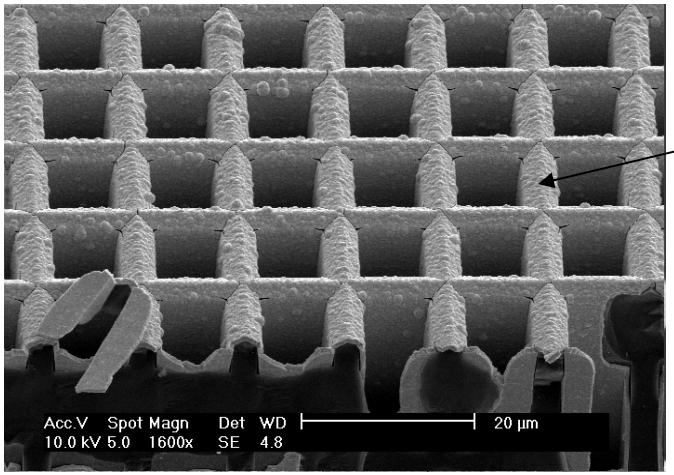




Silicon Electrodes With Liquid Electrolyte and Oxidant Eliminate PEM and Enable New Design Alternatives

Fuel Cell Component	Typical DMFC	Neah Fuel Cell	Differentiating Benefits
Electrode Catalyst Support	Carbon	Porous Silicon	• Higher surface area & many morphologies • Leverage silicon coating & adhesion technology • Silicon more durable material enabling liquid electrolyte and oxidant
Electrolyte	Polymer Electrolyte (PEM)	Flowing Liquids (Sulfuric Acid)	• Higher catalyst utilization on anode • Minimizes fuel crossover • Higher proton conductivity
Oxygen Source	Oxygen from Air	On-board Oxidant (Nitric Acid w/ Peroxide or Air)	• Higher catalyst utilization on cathode • Non-Pt catalyst resistant to methanol crossover
Reaction By-Products	Vented into Air	Captured in BOP & Fuel Cartridge	• No water vapor released • Operate under harsh field conditions • Highly reliable and durable

Porous Silicon Enables Unique "3D" Electrode Architecture

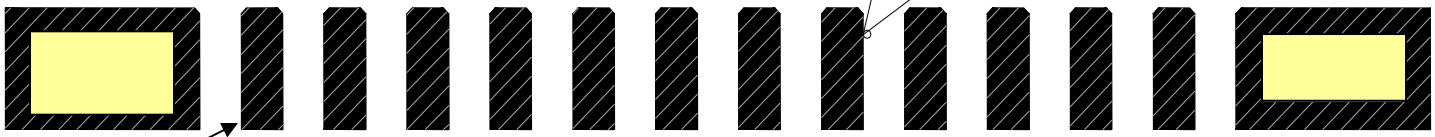


Electrode With 10 Micron Pores

Catalyst Particles

Conductive Film

Bulk Silicon

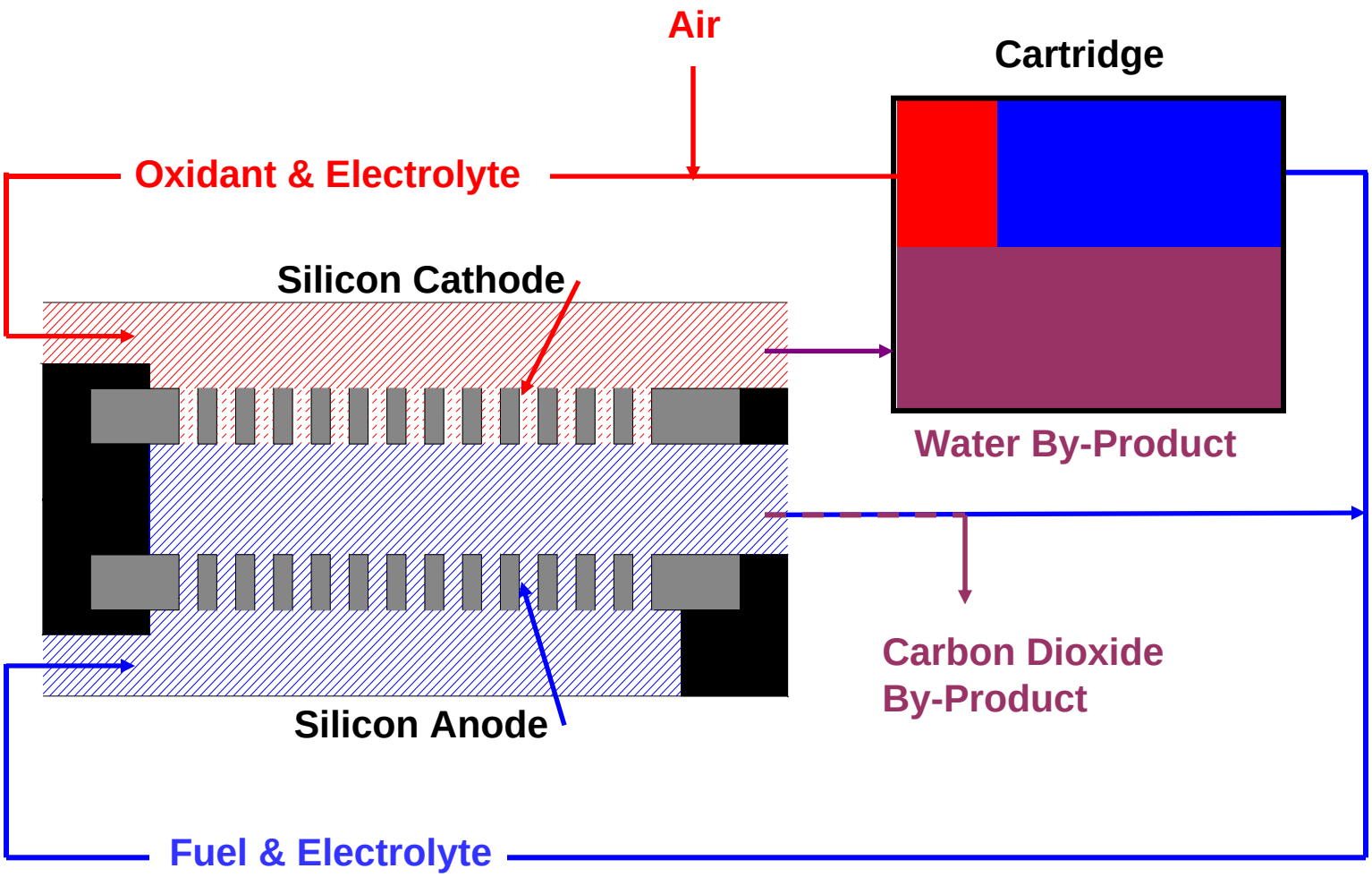


400 Microns

Bulk Silicon

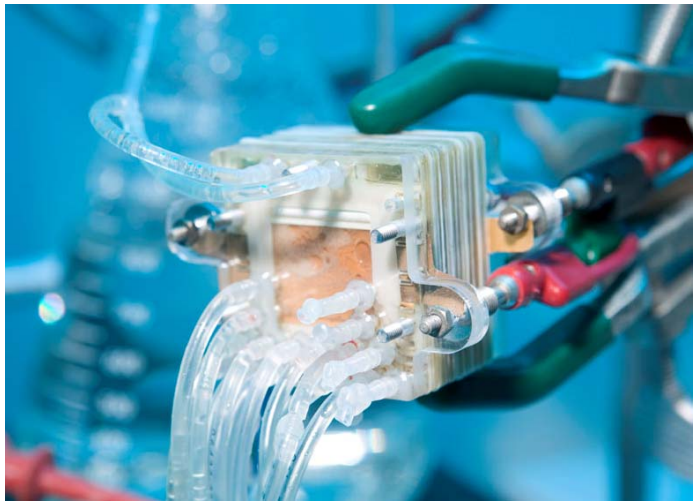
3-D structure provides significant increase in reaction zone thickness

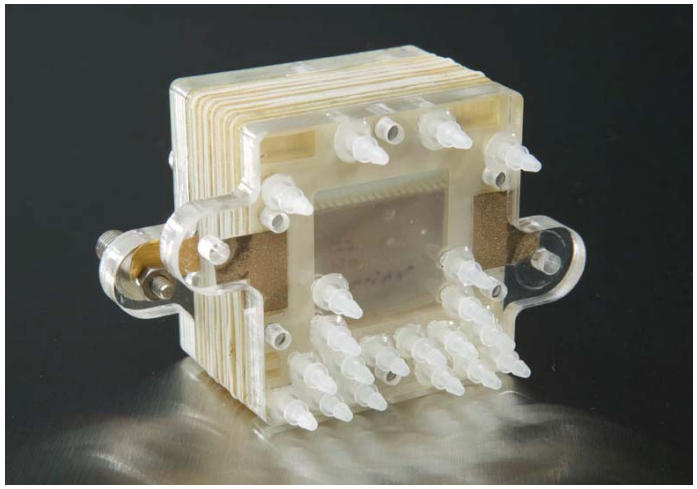
Reactants Pumped Through Electrodes and Water By-Product Collected in Cartridge

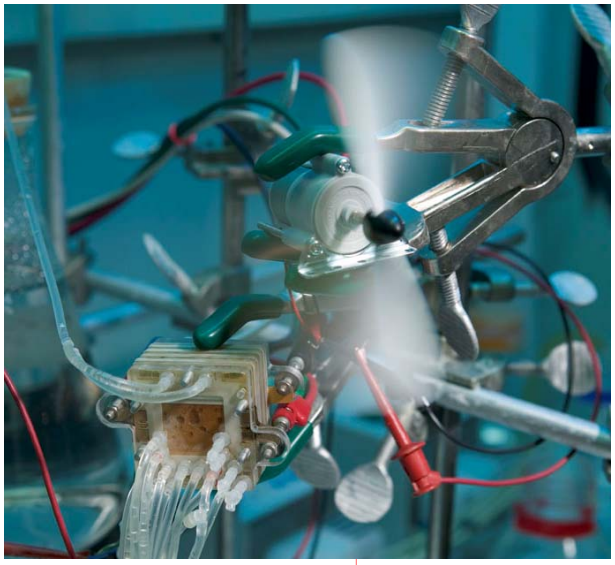


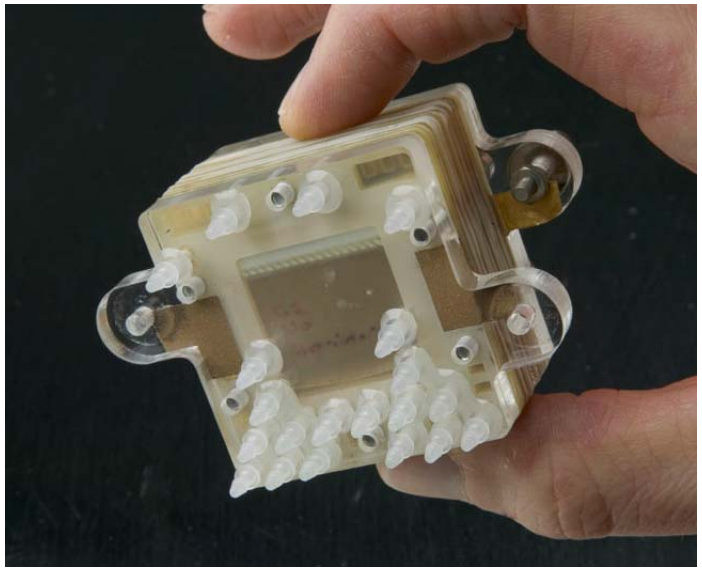
Note: A simple schematic for illustrative purposes only

Neah Power Fuel Cell Stacks Operated in April 2005



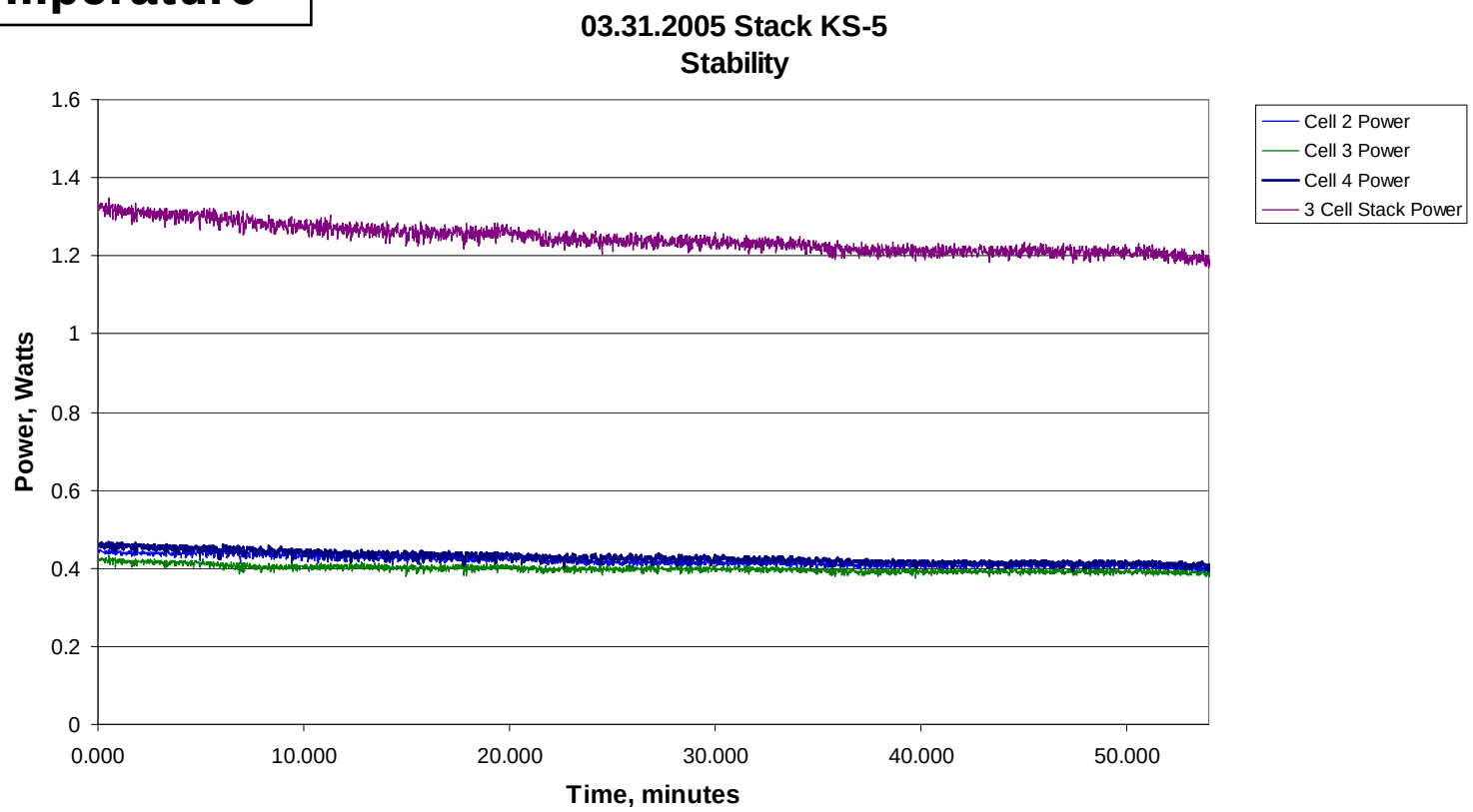




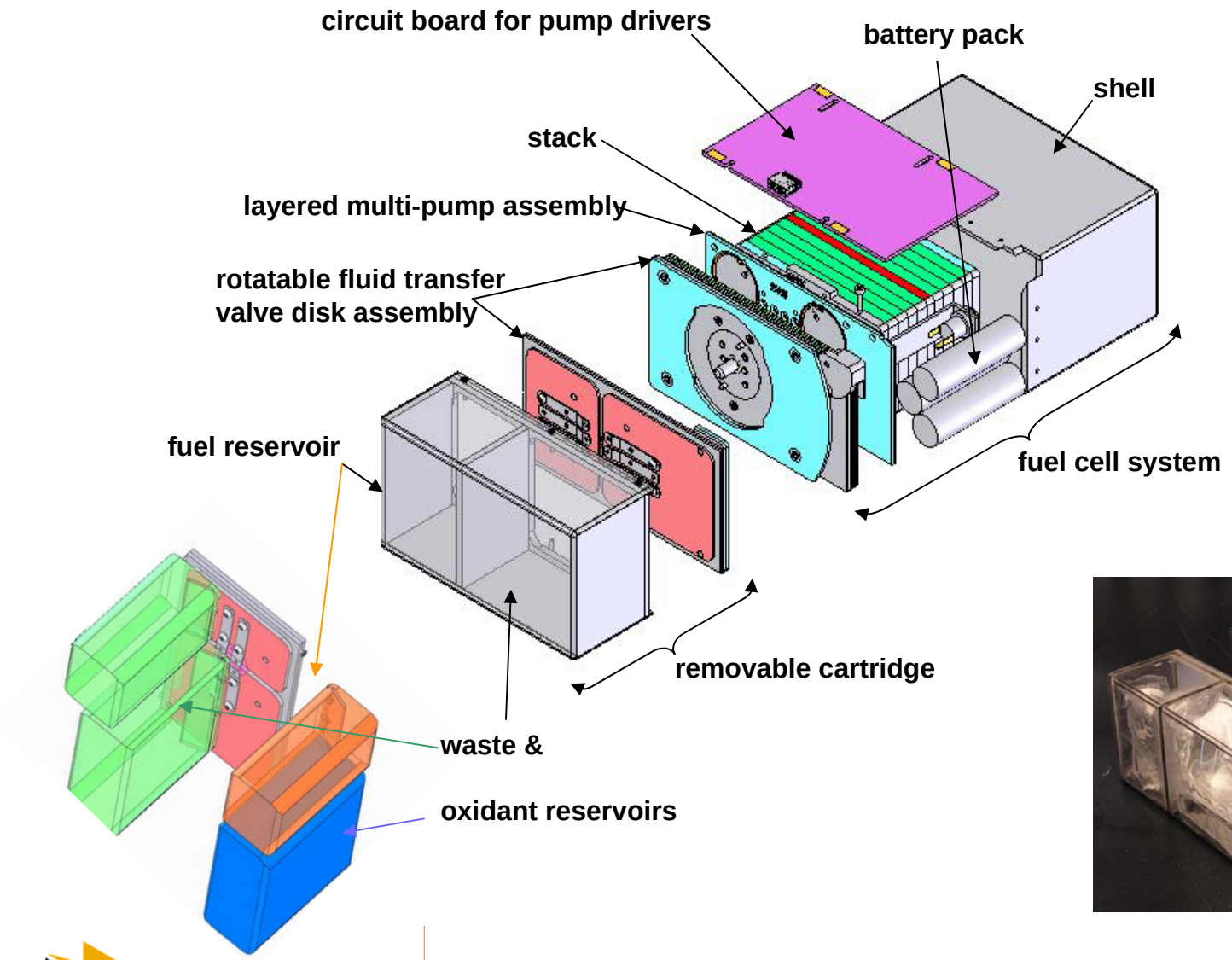


Stack Prototype at 80 mW/cm2 Out Performs Typical PEM Systems

Tested at Room Temperature



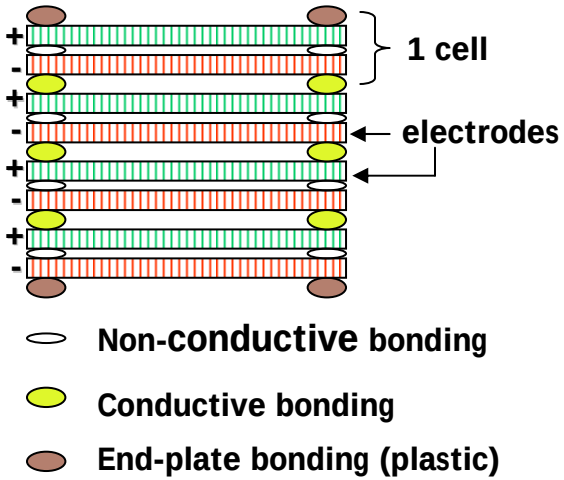
Components Have Been Developed for Use in Complete System Prototypes in 2005



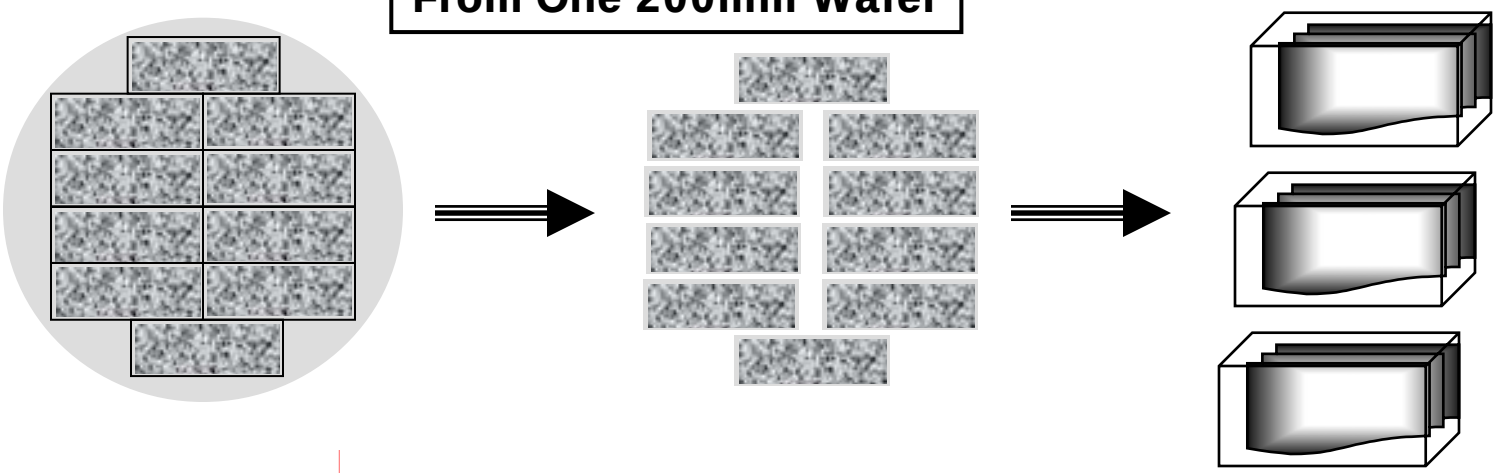
Multiple Fuel Cells From One Silicon Wafer Can Yield Costs Similar to Current Batteries

"Scalability" of Silicon

- Utilize known Silicon processing technology
- Etch and catalyze
- Dice wafer into multiple electrodes
- Bond electrodes into fuel cell stacks
- Size stack for device power needs



Multiple Fuel Cell Stacks From One 200mm Wafer



Enable Long Run-Time With Small, Light Spare Cartridges Not Extra Batteries

Penetrate Military & Commercial Markets First

Military Electronics

Logistics / Scanning

Public Safety Radios

Use Validations in Military & Commercial Products to Enter Consumer Markets

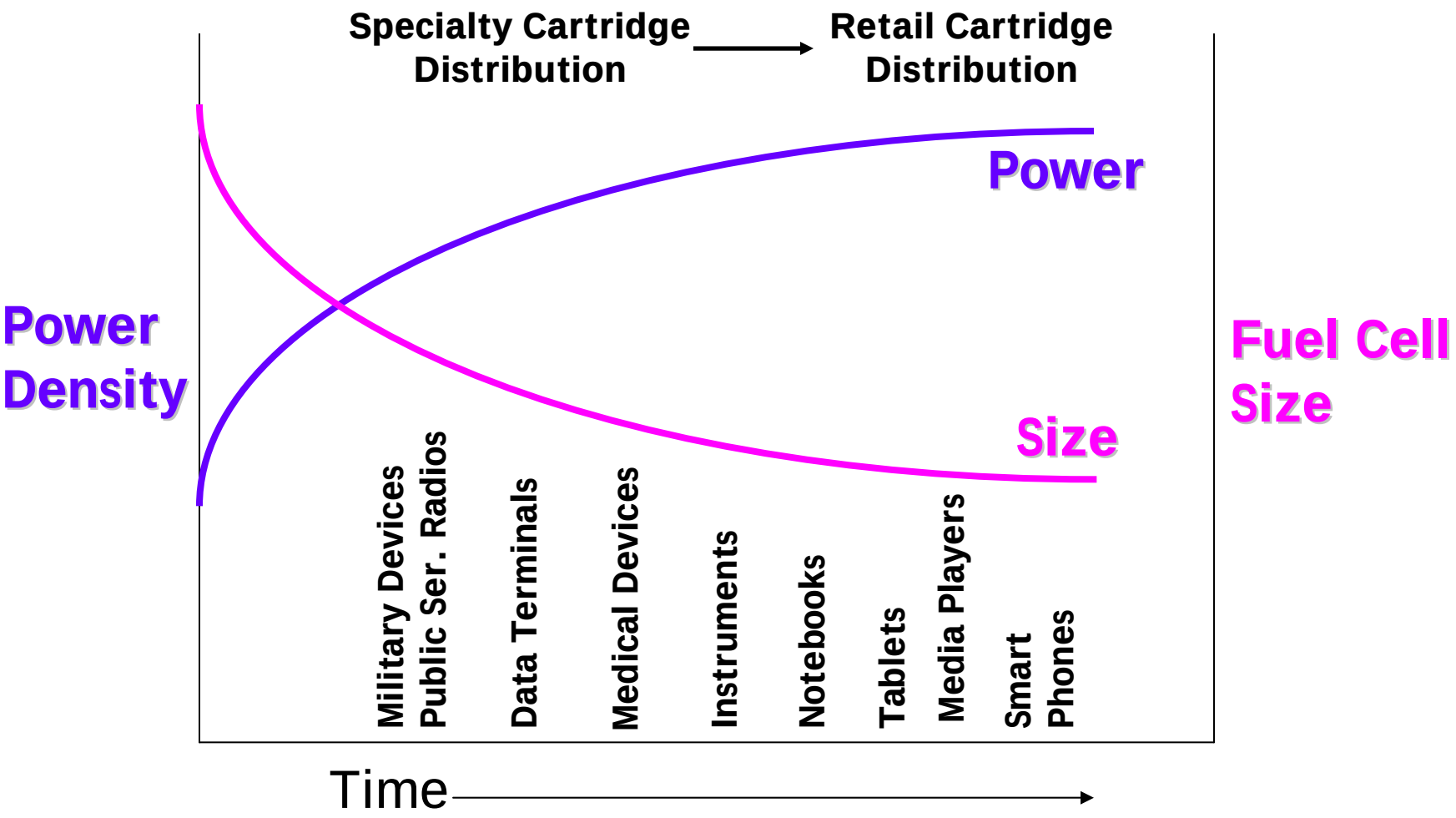
Corridor Warriors

Road Warriors

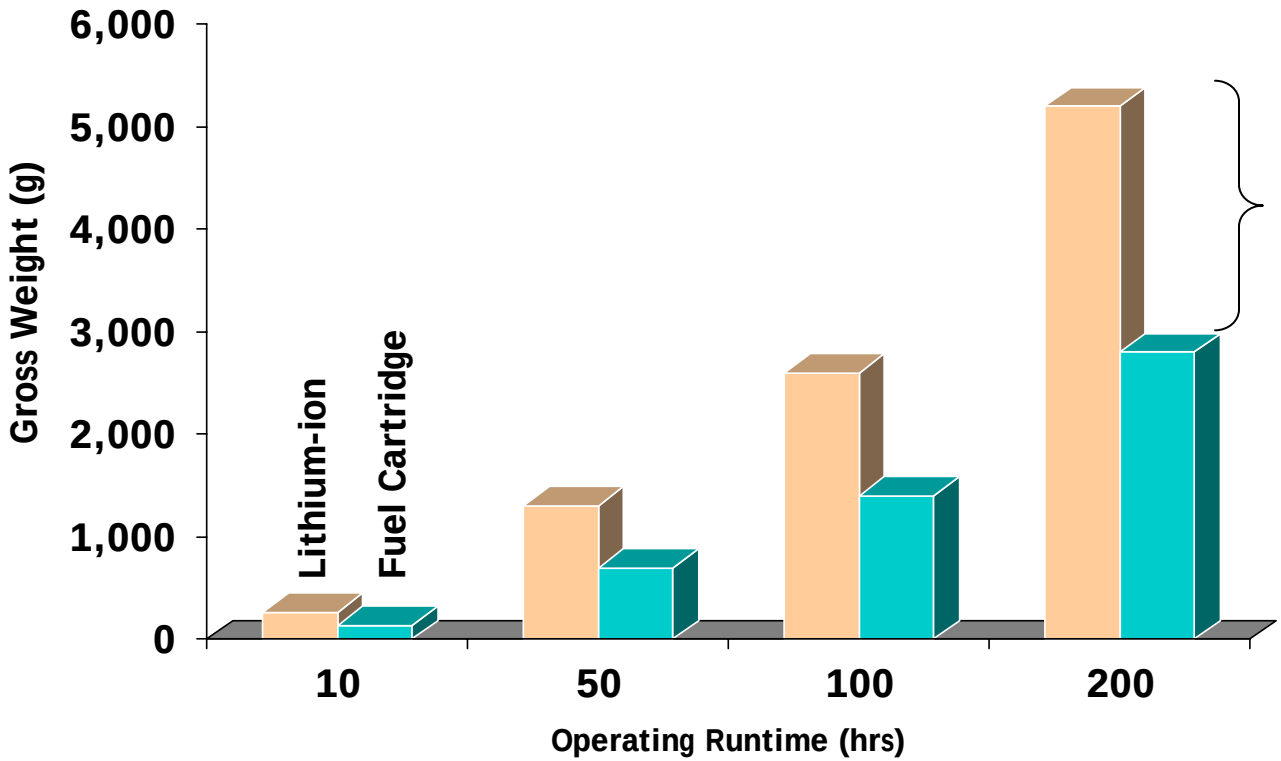
Entertainment

NEAH power systems

Use Increased Power Density to Reduce Fuel Cell Size and Expand Application Base



Fuel Cartridges Lighten the Load for Soldiers Compared to Extra Batteries



- 58% less weight

- 200 hour mission, save 2.4kg (over 5 lbs) in weight
- Longer the mission, greater the weight reduction

Wide Range of Relationships Exhibited in Early Partnership Activities

- **Received NIST/ATP grant Sept. 2003**
  - ✓ $2.0 million over 2 years
- **Wacker supplying Silicon wafers**
  - ✓ Developing specifications for low cost Silicon wafers for fuel cells
- **Company in semiconductor processing industry supporting electrode design and process development**
  - ✓ Equity investment of $2.5 million
  - ✓ CTO on Neah Board
  - ✓ 2-plus people dedicated to technical effort
- **Military OEM funding development of fuel cell for mobile, military communication devices**
  - ✓ Initiated $1.7 million program Jan. 2004
  - ✓ First phase is prototype demonstration in “BA-5590” form factor
  - ✓ Can reduce soldier battery weight by 50 to 60%
- **Congressman Inslee secures Neah $3.5 million in 2006 DoD appropriations bill**
- **Intel willing to promote fuel cell reference deigns to OEMs**
  - ✓ Insert fuel cell in removable DVD slot in notebook computer
  - ✓ Could achieve 12 to 14 hour runtime

Fuel Cell Market Potential in 2009
Measured in Billions of $

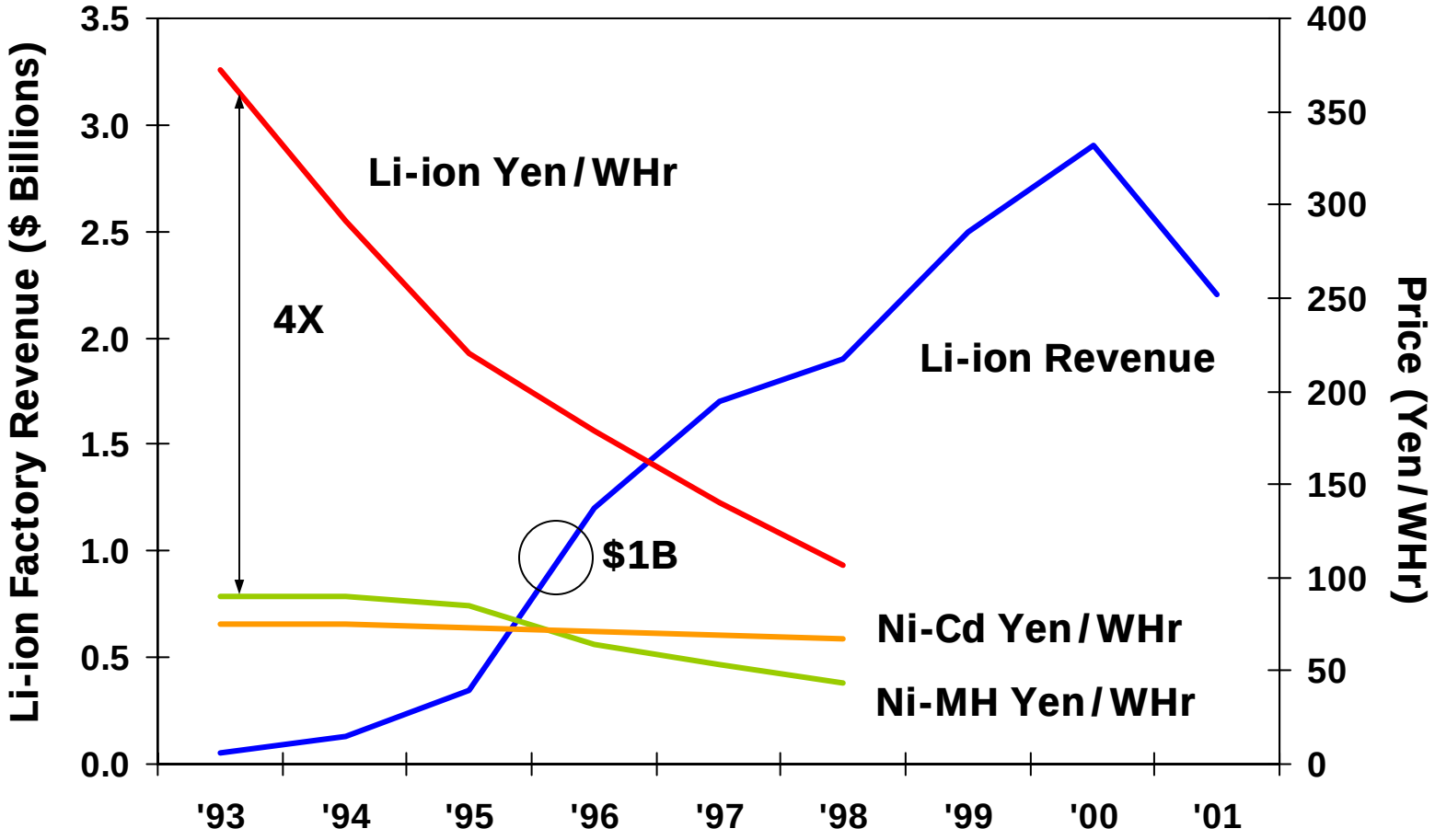
Worldwide Producer Forecast - 2009

Scenario	No. Of Mkts	Notebook Penetration	Notebook Cartridges Units/user/yr	Fuel Cell Units (MM)	Cartridge Units (MM)	Total Revenue ($MM)
All Markets/ Conservative Estimate	14	5.0%	21.0	14.6	336	$1,048
All Markets/ Aggressive Estimate	14	15.0%	60.0	38.1	1526	$3,022

Key Assumptions:

- ✓ 2009 fuel cell selling prices similar to current Li-ion prices
- ✓ Producer price for cartridges under $1.00

Rapid Growth of Li-ion Supports Potential for Fuel Cell Growth



User willingness to pay for performance created rapid penetration of notebooks

Source: Nomura Research Institute, Advanced Rechargeable Battery Industry Report, '97/'98; Takeshita, Institute of Information Technology, 9/2000

Neah Technology Can Revolutionize Micro-Fuel Cell Industry

- **Capitalizing on "Scalability" of Silicon-based electrodes**
  - ✓ Scale to high power density with 3D structure
  - ✓ Scale to cost effective production
- **Target 2 times increase in energy storage in Li-ion sizes**
  - ✓ Low cost potential allows pricing similar to Li-ion prices
- **5 U.S. patents issued and 10 U.S. patent applications filed**
  - ✓ Silicon electrode patent #6,641,948 issued Nov. 2003
- **Achievements allow development of full system prototypes**
  - ✓ Pilot production for porous Silicon and electrodes
  - ✓ Demonstrated stable stack operation
- **Establishing strategic relationships to support commercialization**
  - ✓ $2.0 million NIST/ATP grant
  - ✓ $1.7 million military OEM development project
  - ✓ $2.5 million investment from Silicon processing company
  - ✓ $3.5 million in 2006 DoD appropriations bill