Engineering the Life Sciences

Darlene J.S. Solomon, Ph.D.
Senior Vice President and Chief Technology Officer
Agilent Technologies
Multidisciplinary Contributions

- Critical to the World and Agilent
- Successful Examples
- Moving Forward
Drivers of Global Dilemmas

- Economic Health
  - Resources Management
  - Transportation
  - Communications
  - Geographic consumer requirements
  - Global Culture Shift

- Globalization
  - Infectious Diseases

- Environmental Health
  - Energy Management
  - Global Warming
  - Waste Management
  - Environmentalism
  - Water
  - Novel Energy Sources
  - Public Infrastructure

- Demographics
  - Human Health

March 26, 2012
2012 ECEDHA Annual Conference
“The evolution of ... electrical and computer engineering demands a new breed of ECE graduates with a broad set of competencies that cannot be ... constrained by traditional boundaries.”

“Electrical and Computer Engineering for a New Generation”
By T.E. Schlesinger and B. Krogh
ECEDHA Source, Issue 4, Spring 2010

Biomedical Engineer – the fastest growing job, a relatively new specialty that bridges medical and engineering disciplines such as math, chemistry, physics, biology and engineering

“Top 10 List: Where the Jobs Are”
by Cecilia Simon
New York Times, April 13, 2011
Historic Discrete Measurements

- **Optical characteristics**
- **Size, shape, structure**
- **Chemical mixture**
- **Biological make-up**

- **PHYSICAL**
- **ELECTRICAL**
- **CHEMICAL**
- **BIOLOGICAL**
Current Converging Measurements

- Biological make-up
- Drug delivery
- Disease detection
- Chemical mixtures
  - Coatings
  - Catalysts
- Energy
  - Semiconductors
  - RF/Microwave
- Electrical characteristics
  - Size, shape, structure
  - < 100 nm
- Optical characteristics
  - Fluorescent markers
- Nanotechnology

Agilent Technologies
2012 ECEDHA Annual Conference
March 26, 2012
Electronics / Biology Convergence

Engineering at the Nanoscale

Graphene Quantum Dot Device
University of Manchester
20nm

Integration & Miniaturization

Complexity

Electronics

Scaling down to reach nanoscale

Nanotechnology

Biology

Scaling up to reach nanoscale

Graphene Quantum Dot Device

Graphene Quantum Dot Device

Nanomotor: ATP Synthase
Boris A. Feniouk, www.atpsynthase.info

10nm

20nm
Science & Measurement Are Inextricably Linked

Advances in Fundamental Knowledge

Measurement Advances

Technology Improvements

Image: Bacterial culture of aeromonas hydrophila
## Agilent’s Businesses

Opportunities for Multidisciplinary Teamwork

<table>
<thead>
<tr>
<th>Business Group</th>
<th>FY11 Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Measurement Group</td>
<td>$3.3B</td>
</tr>
<tr>
<td>Chemical Analysis Group</td>
<td>$1.5B</td>
</tr>
<tr>
<td>Life Sciences Group</td>
<td>$1.8B</td>
</tr>
<tr>
<td><strong>Agilent Research Laboratories</strong></td>
<td><strong>$6.6 B</strong></td>
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Enabling technology breakthroughs and synergies across Agilent

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**FY11 Revenue:**
- Electronic Measurement Group: $3.3B
- Chemical Analysis Group: $1.5B
- Life Sciences Group: $1.8B
- Agilent Research Laboratories: $6.6 B
Measurement: Agilent’s Core Contribution

Digital Fundamentals Apply Across Multiple Businesses

Application Specific

Sample
- Physical Analog Measurement

Detect/Acquire
- Signal Conditioning and Data Conversion

Analyze
- (What is that signal?)

Integrate
- (What is it doing?)

Interpret
- (What does it mean?)

Digital Signal Processing and Signal Correlation

Measurement Science in System Context

Data Management, Visualization and Decision Analysis

National Cancer Institute, Pathology Histology Breast Cancer
iStock Photo, Circuit Board
### Agilent Technologies

**Addressing Critical Measurement Challenges**

<table>
<thead>
<tr>
<th>Electronic Measurement</th>
<th>Chemical Analysis</th>
<th>Life Sciences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wireless technologies</td>
<td>Food safety, quality</td>
<td>Pharmaceutical research and manufacturing</td>
</tr>
<tr>
<td>Mobile phone R&amp;D and manufacturing</td>
<td>Energy research, production</td>
<td>Genomics, proteomics, metabolomics tools for disease research</td>
</tr>
<tr>
<td>Aerospace/defense</td>
<td>Quality of air, water, soil</td>
<td></td>
</tr>
<tr>
<td>Low-cost instrumentation</td>
<td>Forensics, drugs of abuse</td>
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March 26, 2012

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## Agilent Research Laboratories

### Competitive Advantage Through Technology

<table>
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<th><strong>Applied</strong> research</th>
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<td><strong>Breakthrough</strong> technologies</td>
</tr>
<tr>
<td><strong>Measurement</strong> synergies</td>
</tr>
<tr>
<td><strong>World-class research teams</strong> across interdisciplinary, global organization</td>
</tr>
<tr>
<td><strong>Collaboration</strong> with leading academic, government &amp; industrial researchers</td>
</tr>
</tbody>
</table>

### Partners to Agilent’s businesses in R&D commercialization
A Diversity of Research Disciplines

Biology
- Molecular
- Cellular
- Computational
- Micro
  - Material Science
  - Separation Science
  - Measurement Science
  - Micro/Nano-Fabrication and Fluidics
  - Business

Engineering
- Mechanical
- Electrical
- Chemical
- Biological
  - Physics
  - Optics
  - Mathematics
  - Chemistry
  - Computer Science

Software
- Signal Processing
- Connectivity and Control
- Modeling & Design
- Visualization and Analysis
Key Innovation Partners
About 100 Active University Collaborations Annually

Life Sciences
Chemical Analysis
Electronics

Johns Hopkins
Yale
CU Boulder
UNICAMP, Brazil
U of Illinois
U of Michigan
U of Texas
UCSF
Arizona State
UC Berkeley
UC San Diego
Baylor U
U of Hawaii
Stanford
UC Davis

Karolinska Inst., Sweden
Karlsruhe U, Germany
Maastricht U, NL
U of Twente, NL
Charles U, Czech Republic
NIBRT, Ireland
U of Kent, UK
U of Oviedo, Spain
Technion, Israel

Tsinghua U, China
Tohoku U, Japan
Southeast U, China
National U. of Singapore
Monash U, AU
Macquarie U, AU
Multidisciplinary Contributions

• Critical to the World and Agilent
• Successful Examples
• Moving Forward
Synergy: two or more components working together to produce a result not obtainable by any of the components independently.
Agilent: Seven Decades of Innovation Across Boundaries
2000s: Electronic Data Converter ICs
Speed Mass Spectrometers

Accurate-Mass Time-of-Flight Mass Spectrometer

• 1970: Entered mass spectrometry business with quadrupole mass filters
• Today Agilent mass spec systems lead in performance and leverage our high-speed oscilloscope platform
• Both are critically dependent on high-speed data conversion and digital signal processing.
• Agilent is the only mass spectrometry company not limited to data converters available commercially
• Improved analysis of complex proteomic and metabolomic samples and biomarker discovery

Agilent 6550 iFunnel Quadrupole Time-of-Flight Liquid Chromatography Mass Spectrometry System

The most sensitive instrument in its class…
pushes the limits of detection and identification to new, unprecedented levels
Electronic Research Aids Bioanalytical Customers

Faster Digitization Leads to Unambiguous Molecular Analysis

Molecules are hard to identify with slow speed (1 GSa/s), low resolution time of flight mass spectrometers.

One broad peak with 4 possible molecular formulas:
- $C_{10}H_{10}O_4$
- $C_{11}H_{14}O_3$
- $C_{14}H_{10}O$
- $C_{15}H_{14}$

High-speed (4 GSa/s), high resolution time of flight mass spectrometers separate molecules and identify their masses accurately.

Two distinct peaks with unambiguous molecular masses.

Mass (m/z)
Keeping water clean requires ability to identify and quantify pollutants.

Thousands of chemical substances have been found in sewage and reclaimed water for irrigation:
- antibiotics
- cosmetics
- pain killers
- over-the-counter drugs

Very low concentrations aren’t considered dangerous short term, but no one knows the long-term human and ecological effects.

Research and government agencies use Agilent instruments to investigate and develop effective strategies to remove these pollutants.
Synergy 14: DNA Microarrays
2000s: Inkjet Printing Meets Nucleic Acids

DNA Microarrays

- Agilent’s expertise in DNA biochemistry, image analysis and inkjet printing (from HP) was key to development of DNA microarrays for genomic analysis.
- Inkjet synthesis of 60-200mer length probes \textit{in situ} provide superior performance
- Virtual grid of up to 1,000,000 features on a standard slide; any format, any density, any sequence on demand.
- Agilent continues to advance technology and create new research applications and businesses; RNA therapeutic manufacturing and target enrichment for DNA sequencing.

*Advancing sophisticated tools for examining the genomic aspects of cancers and other illnesses*
Researchers can study structures and functions of chromosomes with high accuracy and resolution.

Analysis of genomic changes advances research for Down syndrome, autism and cancer.

Research goals: to understand cell function and diagnose genetic disorders more precisely.
2012: “See” RNA, DNA in cells
2011: Detect copy number and copy-neutral aberrations
2010: Study 49,000-year-old Neandertal DNA
2009: Sequence specific genomic areas
    Microarrays include up to 1M probes
    Arrays to study human Copy Number Variation
2007: Agilent microarray is first to gain FDA approval
    Profile human microRNAs
2005: Microarray for human comparative genomic hybridization
2004: Locate genetic alterations related to cancer and developmental disorders
    Microarray to study whole human genome
2000: Agilent ships first DNA microarrays
1992: DNA microarray research begins in Labs
Multidisciplinary Contributions

• Critical to the World and Agilent

• Successful Examples

• Moving Forward
Driving the Future of Measurement

Multidisciplinary Contribution Will Be Increasingly Pervasive

- Energy and the Environment
- Advancing High Growth Economies
- Portable, Mobile and Out-of-Lab
- Nanotechnology
- Food Safety
- Personalized Medicine
- Single Cells and Microbiome
- Synthetic Biology
The Next Frontier: Synthetic Biology

- Transform research practices and manufacturing processes within the $100B industrial biotechnology and biomedical markets

- “Engineer” biological systems
  - Bacteria
  - Fungi
  - Cell-lines
  - Plants, Algae

- Manufacture useful products and high-value intermediates
  - Pharmaceuticals
  - Chemicals
  - Biofuels

- Greener, more sustainable alternatives to traditional methodologies

3D rendering of bacteria that could be genetically altered or engineered
Synthetic Biology: Next Electronics Industry?

The redesign of biological systems and their component parts for useful and practical purposes

- Standardized integrated electronic parts & devices
- Integrated circuit
- Tools for IC Fab
- Well developed for maturing industry

- Standardized integrated biological parts & devices
- Synthetic genome
- Tools for SynBio
- Requires revolutionary technologies

Design & model

Healthcare Environment

Validate

Fabricate

Scale
Innovation Challenges

For Technology Educators and Leaders

Teamwork
- Days of the lone inventor working heroically are diminishing
- Innovations often part of complex systems and solutions
- Our connected world and competition are moving faster than ever

Multiple disciplines
- Excellence in each of many areas
- Communication across disciplines

Supportive environment
- A culture that challenges the status quo
- A culture that tolerates failure; freedom from fear

Enlightened leadership
- Leaders can command obedience, not passion
- Trust, patience and commitment to diversity
Technology Innovation is Not Enough
For Meaningful Product Contribution

What will sustain a business?

From Hugh Dubberly, AIGA Journal of Design for the Network Economy, 2001
Multidisciplinary Contribution

Opportunities to Address Problems That Matter

- Climate Change
  - Energy Management
  - Global Warming
  - Waste Management
  - Environmentalism
  - Water
  - Novel Energy Sources

- Economic Health
  - Resources Management
  - Transportation
  - Communications
  - Geographic consumer requirements
  - Safety
  - Global Culture Shift
  - Infectious Diseases

- Environmental Health
  - Public Infrastructure

- Globalization
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- Demographics
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