BIOENGINEERING: THE ENGINEERING DISCIPLINE OF THE 21ST CENTURY?

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Simpson Endowed Chair in Bioengineering
Professor and Chair of Bioengineering
Professor of Electrical Engineering
Adjunct Professor of Computer Science & Engineering and Radiology
University of Washington
Seattle, WA  98195  U.S.A.
IEEE-EMBS President 2005-2006

October 18, 2005
Shun Hing Institute of Advanced Engineering
CUHK, Hong Kong
DOWNTOWN SEATTLE
DEPARTMENT OF BIOENGINEERING
UNIVERSITY OF WASHINGTON

- Was set up in 1967. Belongs to the College of Engineering and the School of Medicine
- Merges biology, engineering and medicine
- 19 tenure-track and 8 research faculty members
- 149 graduate and 104 undergraduate students
- 38 postdocs and 78 research staff & support personnel
- 5 thrust areas for integrated education/research
- Outstanding and talented faculty
- Ranked #1 in NIH funding ($20.1M in FY2004)
- Leader in UW in IP generation
- Long history in creating and working with industry
BS BIOE COURSE REQUIREMENTS

- Mathematics 25 cr.
- Natural Science 48 cr.
- Engineering Fundamentals 17 cr.
- Bioengineering Core 38 cr.
- Bioengineering Senior Electives 15 cr.
- Written & Oral Communication 8 cr.
- VLPA & I&S 24 cr.
- Approved Electives 5 cr.

- TOTAL 180 cr.
## CURRICULUM FOR BS DEGREE IN BIOENGINEERING

### Mathematics (25 credits)

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 124, 125, 126</td>
<td><em>Calculus with Analytic Geometry I, II, III</em></td>
<td>15</td>
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<tr>
<td>MATH 307</td>
<td><em>Introduction to Differential Equations</em></td>
<td>3</td>
</tr>
<tr>
<td>MATH 308</td>
<td><em>Linear Algebra with Applications</em></td>
<td>3</td>
</tr>
<tr>
<td>STAT 390</td>
<td><em>Probability and Statistics</em></td>
<td>4</td>
</tr>
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<td></td>
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### Natural Science (48 credits)

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<tr>
<th>Course</th>
<th>Topic</th>
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<tbody>
<tr>
<td>CHEM 142, 152, 162</td>
<td><em>General Chemistry</em></td>
<td>16</td>
</tr>
<tr>
<td>CHEM 223 or 237</td>
<td><em>Organic Chemistry</em></td>
<td>4</td>
</tr>
<tr>
<td>PHYS 121, 131</td>
<td><em>Mechanics with Labs</em></td>
<td>5</td>
</tr>
<tr>
<td>PHYS 122, 132</td>
<td><em>EM and Oscillatory Motion with Labs</em></td>
<td>5</td>
</tr>
<tr>
<td>PHYS 123, 133</td>
<td><em>Waves with Labs</em></td>
<td>5</td>
</tr>
<tr>
<td>BIOL 180, 200</td>
<td><em>Introductory Biology</em></td>
<td>10</td>
</tr>
<tr>
<td>BIOC 405</td>
<td><em>Introduction to Biochemistry</em></td>
<td>3</td>
</tr>
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### Engineering Fundamentals (17 credits)

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<th>Course</th>
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<tbody>
<tr>
<td>CSE 142</td>
<td>Programming for Engineers and Scientists</td>
<td>4</td>
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<tr>
<td>CSE 143</td>
<td>Advanced Programming</td>
<td>5</td>
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<tr>
<td>EE 215</td>
<td>Fund. Elec. Eng.</td>
<td>4</td>
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<tr>
<td>CHEM E 260</td>
<td>Thermodynamics</td>
<td>4</td>
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<td><strong>Total</strong></td>
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</table>

### Bioengineering Core (38 credits)

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>BIOEN 201</td>
<td>Bioengineering Laboratory</td>
<td>2</td>
</tr>
<tr>
<td>BIOEN 301</td>
<td>Bioengineering Systems Analysis</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 302</td>
<td>Introduction to Instrumentation</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 303</td>
<td>Bioengineering Signal Processing</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 304</td>
<td>Bioeng. Analysis of Physiological Systems</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 305</td>
<td>Bioeng. Analysis of Physiological Systems &amp; Transport</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 357</td>
<td>Intro Molecular Bioengineering</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 481</td>
<td>Research &amp; Design Fundamentals</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 482</td>
<td>Senior Capstone Research/Design</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>38</strong></td>
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</table>
Bioengineering Senior Electives (15 credits minimum from the following list. Graduate courses may be approved by advance petition.)

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>BIOEN 420</td>
<td>Medical Imaging</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 440</td>
<td>Biomechanics</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 455</td>
<td>BioMEMS</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 457</td>
<td>Advanced Molecular Bioengineering</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 467</td>
<td>Biochemical Engineering</td>
<td>3</td>
</tr>
<tr>
<td>BIOEN 470</td>
<td>Systems Engineering &amp; E-Medicine</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 485</td>
<td>Computational Bioengineering</td>
<td>4</td>
</tr>
<tr>
<td>BIOEN 490</td>
<td>Biomaterials</td>
<td>3</td>
</tr>
<tr>
<td>BIOEN 491</td>
<td>Controlled Release Systems</td>
<td>3</td>
</tr>
<tr>
<td>BIOEN 492</td>
<td>Surface Analysis</td>
<td>3</td>
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Written and Oral Communications (8 credits)

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<tr>
<th>Course</th>
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<tbody>
<tr>
<td>ENGL composition</td>
<td>Approved University Writing Course</td>
<td>5</td>
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<tr>
<td>TC 231</td>
<td>Introduction to Technical Writing</td>
<td>3</td>
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<tr>
<td>Total</td>
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<td>8</td>
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</tbody>
</table>

General Education: 24 credits in Visual, Literary & Performing Arts (VLPA) and Individuals and Societies (I&S) (minimum 10 credits in each category)
**Electives** (5 credits from the courses below or from Bioengineering Senior Electives. Other 200-level Engineering Fundamentals or upper division science and engineering courses may be approved by advance petition.)

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>AMATH 353</td>
<td>Fourier Analysis &amp; PDE</td>
<td>3</td>
</tr>
<tr>
<td>AMATH 422</td>
<td>Introduction to Mathematical Biology</td>
<td>3</td>
</tr>
<tr>
<td>AMATH 423</td>
<td>Mathematical Biology</td>
<td>3</td>
</tr>
<tr>
<td>AMATH 441</td>
<td>Introduction to Fluid Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>BIOC 406</td>
<td>Introduction to Biochemistry</td>
<td>3</td>
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<tr>
<td>BIOC 440, 441, 442</td>
<td>Biochemistry</td>
<td>4, 4, 4</td>
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<tr>
<td>BIOL 220</td>
<td>Introductory Biology</td>
<td>5</td>
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<tr>
<td>CHEM 224</td>
<td>Organic Chemistry</td>
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<td>CHEM 238, 239</td>
<td>Organic Chemistry</td>
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<td>CHEM 241, 242</td>
<td>Organic Chemistry Laboratory</td>
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<td>CHEM 455, 456, 457</td>
<td>Physical Chemistry</td>
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<td>CHEM E 310</td>
<td>Material and Energy Balance</td>
<td>4</td>
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<td>CHEM E 330</td>
<td>Transport Process</td>
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<tr>
<td>MICROM 411</td>
<td>Gene Action</td>
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<tr>
<td>CSE 373</td>
<td>Data Structures and Algorithms</td>
<td>3</td>
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<tr>
<td>CSE 415</td>
<td>Introduction to Artificial Intelligence</td>
<td>5</td>
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<tr>
<td>GENET 371</td>
<td>Introductory Genetics</td>
<td>5</td>
</tr>
<tr>
<td>GENET 372</td>
<td>Gene Structure and Function</td>
<td>5</td>
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<tr>
<td>PHYS 321, 322, 323</td>
<td>E&amp;M Theory</td>
<td>3, 3, 3</td>
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<tr>
<td>EE 341</td>
<td>Discrete Time Linear Systems</td>
<td>5</td>
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<tr>
<td>EE 442</td>
<td>Digital Signals and Filtering</td>
<td>3</td>
</tr>
<tr>
<td>EE 416</td>
<td>Communications</td>
<td>4</td>
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<tr>
<td>ME 333</td>
<td>Introduction to Fluid Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>ME 478</td>
<td>Finite Element Analysis</td>
<td>4</td>
</tr>
<tr>
<td>ME 431</td>
<td>Advanced Fluid Mechanics</td>
<td>4</td>
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</table>

Total: 5
INGREDIENTS FOR A HIGH-IMPACT ACADEMIC UNIT

• Outstanding faculty
• Well-trained future leaders in our students and postdocs
• Critical mass
• External research funding
• Research leadership and risk-taking
• Active in IP and technology transfer
• Mutually-beneficial relationship with industry
• Excellent facilities and infrastructure
• Support from government, institution, industry, and individuals
• Entrepreneurial and collaborative spirits
• Stable and innovative leadership, willing to make difficult decisions
UW BIOENGINEERING AND GENOME SCIENCES BUILDINGS

- 265k gsf (122k)
- 147k asf (68k)
- Construction began in Aug. 2003
- Ready for occupancy in Feb. 2006
- Opening Celebration on March 8, 2006
- $70M gift from Gates Foundation
- $10M gift from Whitaker Foundation
- $12M from federal government
- More gifts from individuals and corporations
THE BEGINNING OF MODERN ULTRASOUND: FIRST PRACTICAL TRANSCUTANEOUS DOPPLER FLOW DETECTOR (SUMMER 1964)
FIRST TECHNOLOGY TRANSFER & UW ULTRASOUND LEADERSHIP

• During the 1960s, UW Bioengineering researchers developed the first ultrasound instrument sold in the United States, called Dopotone®, by Smith-Kline Instrument Company

• Used primarily for detecting the heartbeat of an unborn fetus and measuring characteristics of the circulatory system

• In 1974, ATL launched medical ultrasound business based on UW Bioengineering technology

• In 1998, Philips Medical Systems acquired ATL for $800M

• Many other ultrasound companies, both diagnostic and therapeutic, have sprung up, making the Puget Sound area the leader in medical ultrasound
HIGHEST DEGREES BY UW BIOENGINEERING FACULTY

- 32 faculty including active emeritus faculty
- 6 MDs and 28 Ph.D.s
- 28 Ph.D.s from the following disciplines
  - 10 in Engineering
  - 4 in Cellular/Molecular Biology
  - 4 in Chemistry
  - 3 in Physics
  - 2 in Biochemistry
  - 2 in Physiology
  - 1 in Mathematics
  - 1 in Pharmacology
  - 1 in Psychology
<table>
<thead>
<tr>
<th>Rank</th>
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<th>Total Award</th>
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<tbody>
<tr>
<td>1</td>
<td>University of Washington</td>
<td>$20.06M</td>
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<tr>
<td>2</td>
<td>Georgia Tech/Emory</td>
<td>$13.30M</td>
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<tr>
<td>3</td>
<td>Johns Hopkins University</td>
<td>$12.38M</td>
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<tr>
<td>4</td>
<td>California Institute of Technology</td>
<td>$11.37M</td>
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<tr>
<td>5</td>
<td>Stanford University</td>
<td>$10.66M</td>
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<tr>
<td>6</td>
<td>University of Michigan</td>
<td>$10.50M</td>
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<td>7</td>
<td>Boston University</td>
<td>$10.30M</td>
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<td>8</td>
<td>UC San Diego</td>
<td>$10.20M</td>
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<tr>
<td>9</td>
<td>Duke University</td>
<td>$9.72M</td>
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<tr>
<td>10</td>
<td>Massachusetts Institute of Technology</td>
<td>$9.17M</td>
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<tr>
<td>11</td>
<td>Case Western Reserve University</td>
<td>$7.83M</td>
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<tr>
<td>12</td>
<td>University of Florida</td>
<td>$6.53M</td>
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<tr>
<td>13</td>
<td>University of Wisconsin Madison</td>
<td>$6.22M</td>
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<tr>
<td>14</td>
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<td>15</td>
<td>University of Utah</td>
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<td>16</td>
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<td>17</td>
<td>University of Southern California</td>
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<td>18</td>
<td>Cornell University</td>
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<td>University of Delaware</td>
<td>$4.22M</td>
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<tr>
<td>20</td>
<td>University of Pennsylvania</td>
<td>$4.17M</td>
</tr>
</tbody>
</table>
INNOVATION & TECHNOLOGY STAGES

- Basic research, discovery
- Valley of death
- Feasibility study, prototype
- Product design
- Product development
- FDA
- Clinical use
UW BIOENGINEERING
ENTREPRENEURIAL & IP ACTIVITIES

- 26 start-up companies (out of UW’s total of 185)
- 460 inventions disclosed (25 in 2004 out of 226)
- 170 patents issued (14 from 7/1/04 to 6/30/05) to UW Bioengineering faculty/staff/students
- From 7/1/04 to 6/30/05, 62 patents were issued to UW
- 57 commercial licenses
- Thousands of jobs created
- Multi million $ royalties and license fees
BIOENGINEERING THRUST AREAS

- Engineered Biomaterials & Tissue Eng.
- D₂H₂
- Mol. Bioe. & Nanotechnology
- Imaging
- Computational Bioengineering

CLINICAL USE
An NIH-funded program through the Department of Bioengineering

**BEAT** (BioEngineered Allograft/Autograft Tissue)

**Goal:** Years 1-5 - tissue engineer a chunk of living heart muscle

**Goal:** Years 6-10 - tissue engineer a living ventricle
FROM GENOME TO FUNCTION:
Integrating Biological Systems Knowledge

Organism → Health

Genes → Molecules & proteins → Cell → Tissue → Organ
TRADITIONAL HOUSE CALL

Photo from the 1962 Boston University Hub Yearbook
D$_2$H$_2$ (Distributed Diagnosis and Home Healthcare)

Where the patient is

- Home, nursing home, work or vacation
- Wearable or implanted instrumentation
- Physiological sensors incl. imaging
- Assay modules
- Handheld station
- 2-way audio/video link
- Emergency Room
- Databases/Applications/Web Server
- Primary Care Provider
- Other Specialists and Clinicians
- Clinics and Hospitals
- Intelligent Controller

INTERNET

2-way audio/video link
FORCES LEADING TO D₂H₂

PUSHING

- Aging population
- Overloaded healthcare system
- Centralized healthcare costly and inconvenient

PULLING

- Information technology
- Inexpensive point-of-care diagnostics, secure communications
- Continuous long-term monitoring improves outcomes
- Remote home monitoring and treatment economical and comfortable

Why D₂H₂?
On April 27, 2004, President George W. Bush

"To protect patients, improve care and reduce cost, we need a system where everyone has their own personal electronic medical record that they control and they can give to a doctor when they need to."

"These electronic health records will be designed to share information privately and securely among and between health care providers when authorized by the patient"

“Within 10 years, every American must have a personal electronic medical record.”
MOLECULAR DIAGNOSTICS

• Benefits
  – Early diagnosis (e.g., various type of cancer or heart disease)
  – Monitor the progress of treatment or disease
  – Facilitate clinical trials

• Biological markers
  – Rapid advances in DNA and RNA-based diagnostics
  – Myc gene predicts outcomes to therapy for childhood neuroblastoma
  – DNA markers for Barrett’s esophagus progressing to cancer, which allows patients under intensive surveillance for early detection
  – Protein diagnostics: proteins are much more dynamic and reflective of cellular physiology.
  – Protein biomarkers and molecular imaging: by tagging antibodies with contrast agent, we can see not only where but also what is going on
MICROFLUIDIC SENSOR IN A SINGLE DISPOSABLE FOR POINT-OF-CARE DIAGNOSTICS (Gates Foundation)

Micronics’ 7-layer Mylar laminate hematology cartridge---rapid prototyping and mass fabricability
MY AGING FROM 1971 to 2001
IN VIDEO CONFERENCING SYSTEM

POLYCOM® VSX™ 7000
IN SONY TV

- **Advanced Broadband Codec Processor (ABCP)**
  - Still photography, streaming video, and television broadcasts are quickly processed to enhance picture quality on plasma screen and palette display

- **Plasma WEGA with “Air-Tact” Palette**
  - All-in-One unit consisting of plasma display, media receiver, and hand-held palette display
  - “Air-Tact User Interface” enables still and streaming image transfers from plasma screen to hand-held palette screen (or vice versa) for a more powerful viewing experience
  - Hand-held palette display has Internet capability, functions as a remote for other AV components such as DVD, has Memory Stick for still image storage, and features access to streaming audio in addition to video
INTRODUCING NEW ULTRASOUND MACHINES
OPPORTUNITY RECOGNITION: INSIDE A COMMERCIAL ULTRASOUND MACHINE

• Ultrasound processing is computationally intensive operations
  - e.g., 31.3 billion operations per second for an ultrasound back-end
• Data flow is unique and data rates are high
• Hardwired circuit boards are typically used to perform these operations
• To upgrade or deploy new applications, many of these boards may need to be modified or redesigned
  - significant R&D expense
PROGRAMMABLE ULTRASOUND

• Disadvantages of a hardwired system
  – Hardwired systems are inflexible & expensive to modify
  – Difficult to adapt to new algorithms and applications
    • Ultrasound algorithms and applications are continually evolving
      – e.g., 3D, segmentation, panoramic imaging, strain imaging

• Programmable advantages:
  – Adaptable - Reduced system & R&D cost
  – Hardware reuse - Faster deployment of new ideas
  – Scalable - Software upgrades

• Start-up or licensing opportunity?
COMMERCIALIZATION BY SIEMENS

• In 1996, we developed the Programmable Ultrasound Image Processor (PUIP) using two TI TMS320C80 processors
  - Commercially known as Crescendo™ image processing system

• PUIP is capable of 4 billion operations per second (BOPS)

• PUIP is an integral part of the Siemens family of ultrasound systems
  - Initially integrated into the ELEGRA system.

• Enabled rapid prototyping and release of new clinically successful applications like 3D ultrasound imaging and panoramic imaging
2D SIESCAPE IMAGING
3D ULTRASOUND IMAGING (1998)
MEDIA ACCELERATED PROCESSOR (MAP)

- Hitachi approached UW in Sept. 1994
- UW, Hitachi, and several other local people worked together to architect a new high-performance processor in 1994-1996
- Equator Technologies Inc. (ETI) formed in Spring 1996
- Strong technical leadership and support from UW
- Funding from Hitachi, Canon, Sony and VCs
- First product introduced in 1999
- Being used in digital video, Internet TV, set-top boxes, machine vision, security, and many other imaging/video applications
- Popular mediaprocessor, but threatened by competitors
- Acquired by Pixelworks in April 2005 @$109M
INTRODUCING A NEW HMC ULTRASOUND MACHINE AT RSNA 2003

UW R&D
since FEB. 2000
BREAST EXAMINATION WITH TISSUE ELASTICITY

• Clinical Benefits
  – To visualize the tissue stiffness
  – To differentiate tumor from normal tissues
  – To increase detection rate and reduce unnecessary treatments

• Other Application Areas
  – Prostate, thyroid, and vessels …

Breast application
Invasive ductal carcinoma
Frame rate up to 30 fps
CORONARY ARTERY DISEASE: CLINICAL NEED

- Early stage detection of coronary artery disease (CAD) is critical
  - 50% of men and 64% of women who died suddenly from CAD did not have symptoms prior to a fatal heart attack\(^1\)
- Current methods for diagnosing CAD are inadequate due to low accuracy for detecting early-stage disease
  - 88% would be considered at low/moderate risk the day before their heart attack\(^2\)
  - Sensitivity of stress ECG may be as low as 30%\(^1\)
- Poor screening for expensive and invasive procedures
  - 20-30% of coronary angiograms are unnecessary
    - The average diagnostic angiogram costs $18,000\(^1\)
  - Huge financial burden
    - $400B/yr spent on heart disease, $142B/yr spent on CAD, in excess of $30B/yr spent on CAD diagnostics\(^1\)

1. American Heart Association (2005)
2. Association for Eradication of Heart Attacks
VIBRATIONS FROM STENOSIS

Vibration amplitude image

Wall vibration spectrum
FIRST CLINICAL TISSUE VIBRATION IMAGING SYSTEM

Engineered at the University of Washington

Hitachi HiVision 5500

Fully programmable in software
ONGOING CLINICAL STUDY

Goal: To investigate the presence of myocardial vibrations in patients with angiographically-confirmed CAD
HIGH-GRADE LAD STENOSIS

Nuclear stress test was negative
Stress echo was negative

85-90% lesion in mid LAD
THE VISION

Ease of use
Low cost

Phase I: CardioMax
(Software License)

Cardiology Clinics and Hospitals

Phase II: CardioScreen
(Hardware + Software)

GP’s Office
Addressable market:
$6B one-time device sales
$2B/yr recurring fee/use

Acceptance Time
Research in ultrasound imaging, long a strength of UW, has resulted in the commercialization of new technology that brings unprecedented imaging power to the point of care inside or outside the hospital.
SoundSeal: SEALING ARTERIAL PUNCTURES
WHAT DOES IT TAKE TO SUCCEED IN ACADEMIC ENTREPRENEURSHIP?

• Excellence and innovation in research
• Understand the needs (marketing) and competition
• Vision, risk-taking, and (realistic) optimism & high energy
• Leverage the existing strength and experience
• IP
• Passion, perseverance and patience
• Team building and planning
• Integrity, trust and fairness
• Good peoples and communications skills
• Close ties with industry, win-win-win
• External research funding and external/internal translational funding
TRANSLATIONAL RESEARCH FLOW

Basic Research, Tech Develop

Feasibility Study, Prototyping

Preclinical Study

Product Develop

Clinical Study

Routine Clinical Use

NIH
NSF
DoD
Foundations
Industry

TGIF
RRF
WRF

Coulter

Industry
VC/Start-up
BMGF
AMI+

VC/Start-up
BMGF
AMI+
HOW TO PROPEL SCIENCE & TECHNOLOGY R&D TO THE NEXT LEVEL OF EXCELLENCE

1. Promote, protect and reward excellence and risk-taking in R&D
2. Respect due process and make the best decisions rather than the most convenient. Balance between self and institutional interests
3. Value honesty and integrity and constructive competition
4. Accept individual differences and understand the value of diversity
5. Achieve synergy based on individual excellence via mutually beneficial collaboration. Lower barriers between disciplines
6. Internationalize R&D, recruit leaders and nurture junior faculty
7. Professional administration, fair decisions, balance of power
8. Maximize the efficiency of researchers
9. Long-term planning and consistent investment
10. Cultivate a new value system where an individual is valued based on how much he/she has contributed to the knowledge and understanding, institution, nation and mankind
CONCLUSION

• Bioengineering is the fastest growing engineering discipline
• Interdisciplinary research and collaboration culture is very important in exploring exciting frontiers in biology, engineering and medicine
• There are tremendous opportunities in life sciences and bioengineering
• Via collaboration and partnership, we can take a leadership role in transforming and revolutionizing future medicine and healthcare
• We need to produce a new generation of bioengineers
• Although there are many pitfalls in technology commercialization, we should do it and do it better due to not only our responsibility with taxpayers' monies supporting our research, but also for benefiting mankind
• Bioengineering is the engineering discipline of the 21\textsuperscript{st} century
ISSUES IN CONDUCTING TRANSLATIONAL RESEARCH IN ACADEMIA

• Faculty time
• Working with industry and intellectual properties
• Issues are getting more complex
• Risk avoidance and bureaucratic approach (and legalistic) rather than customer-oriented
• Too many offices and their lack of coordination
• University research services (OSP, TechTransfer, …) are underfunded
• The number of faculty members and administrators understanding the issues well is typically limited
• Lack of market analysis
• Lack of patience
IDEAL ATTRIBUTES OF GRADUATE STUDENTS

- Honesty & Integrity
- Dedicated
- Self-Motivated
- Hardworking
- Perseverance
- Innovative
- Independent Thinking
- Communication Skills
- Excel under Pressure & Ambiguity
- Confident
- Constructive

- Proactive
- Responsive & Responsible
- Unselfish
- Self-Control
- Open to Criticism
- Learn from Mistakes and Failures
- Team Player
- Interdisciplinary
- Multi-tasking
- Leadership
- Vision
IDEAL ATTRIBUTES OF FACULTY MEMBERS

- Outstanding Scholarship
- Personal and Professional Integrity
- Excellent Teacher
- Leadership
- High Energy
- Vision
- Strive for Excellence
- Communications Skills
- Able to Make Difficult Decisions
- Team Builder
- Patience
- Sensitivity
- Humility

- Selflessness
- Confidence
- Open-Minded and Open to Criticism
- Self-Motivated and Tenacious
- Multi-tasking and Multi-level
- Insightful
- Able to see a big picture
- Planning: Strategic, Financial, …
- Good recruiter
- Cheerleader and Supporter for Former Students
- Grantsmanship
- Business/Industry Relations
- Press Relations
FACULTY DIRECTIONS UNDER EFFECTIVE LEADERSHIP