

***Progress Report on Arizona  
Bioengineering Research Platform  
Strategic Plan***

*Updated September 2003*



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## ***I. Strategic Vision and Focus for Bioengineering Platform***

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### **STRATEGIC VISION**

Over the next five years, the formation of the Arizona Bioengineering Institute will serve as a catalyst, resource and facilitator that will enable Arizona to make pioneering advances in three major application areas of biosciences—neural engineering, rehabilitation engineering and regenerative medicine—and rapidly translate innovations to tangible solutions, working in partnership with clinicians and industry. These application areas will draw upon key enabling strengths found in Arizona, namely biomaterials, biosensors and actuators and bioimaging.

Concomitantly, the Institute will support the training of the next generation workforce in the multidisciplinary skills that these areas require.

These goals will be realized through a world class staff working in state-of-the-art laboratories with leading edge, one of a kind equipment, distributed strategically throughout the state, yet networked into a “collaboratory” that is open to all qualified users, from university, research institutes, hospitals and industry.

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### **IDENTIFIED FOCUS AREAS FOR BIOENGINEERING DEVELOPMENT**

Bioengineering stands at the intersection of the revolution that is taking place in advanced medical treatments involving the convergence of non-bioscience technologies to advance biomedical applications. It is concerned with applying principles and methods from engineering to understand, define, and solve problems in medicine, physiology, and biology. As might be expected, bioengineering is a broad and emerging field that impacts drug delivery, surgery, diagnosis, prevention, and treatment. A key to success of the platform

will be the “translational research” necessary to move the basic science and innovations effectively from the laboratory to the clinic and/or the marketplace.

The medical device industry is the largest non-clinical care bioscience industry in Arizona, and already today draws strength from the overall technology base found across universities and other research organizations in the state. For Arizona to achieve a nationally recognized leadership role in bioengineering, however, it must build upon its areas of

strength and find competitive advantage in how it organizes its activities into new product development and improved health care.

***Three related areas stand out as major bioengineering application areas in Arizona:***

These are linked thematically in that they focus on developing materials, devices or systems to replace diseased or damaged body parts, or enhance the capabilities and improve the quality of life for individuals with physical and cognitive impairments. These three are the target “Centers of Excellence” that will make Arizona’s bioengineering reputation.

**Neural engineering** is an interdisciplinary area with the common goal of analyzing the function of the nervous system; developing methods to restore damaged neurological function; and creating artificial neuronal systems by integrating physical, chemical, mathematical and engineering tools. Key efforts found in Arizona include restoring motor function after stroke and spinal cord injury; prediction and control of epileptic seizures; interfacing the central nervous system to artificial devices to replace lost senses, missing limbs or paralyzed limbs and to control robotic assistive devices; and applying signal processing techniques to diagnosis and control brain dynamics and to control robotic assistive devices.


**Regenerative medicine** is an emerging field that approaches the repair or replacement of tissues and organs impaired by disease, trauma or congenital abnormalities by incorporating the use of cells, genes or other biological building blocks along with bioengineered materials and technologies. The scope of this field includes tissue engineering, cellular therapies, biosurgery and artificial and biohybrid organ

devices. Key activities in Arizona include development of tissue-engineered blood vessels, heart valves, soft tissue augmentation devices, and glaucoma shunts, and neural tissue regeneration.

**Rehabilitation engineering** is an expanding field that uses integrative and multifaceted research efforts to counteract the effects of disability and disease. It utilizes advances in key enabling technologies, such as biosensors and actuators, biomaterials, biocomputing and bioimaging, to improve the quality of life for individuals with physical/cognitive disabilities as well as cardiac, pulmonary and metabolic diseases. It also seeks to understand the mechanisms that underlie the broad and long-term impact of disability and disease on the individual and society. Key efforts in Arizona include development of assistive devices to enhance functional capabilities of people with physical disabilities, therapies to improve neuromotor control after neurotraumatic events, and exercise technology that will enable people with physical disabilities and “exercise intolerant” individuals (cardiac, pulmonary and metabolic diseases) to achieve improved health and wellness.

***Key enabling areas of strength found in Arizona that support these major application areas include:***

**Biomaterials**, which are key for implantable medical implants, tissue engineering and drug delivery systems, where materials come in contact with the tissues of patients. Research covers basic science and engineering aspects of biomaterials, including their mechanical, physical, chemical and biological properties, relevant design and production characteristics of devices constructed of these materials, and their clinical performance. Arizona has particular strengths in biopolymers, biosurfaces and surface coatings, and processes



for self-assembling of biomolecules and the preservation of biomaterials.

**Biosensors and Actuators**, which are systems critical to making measurements for medical diagnosis and controlling therapeutic devices, as well as environmental measurements critical for pollution and homeland security applications. A particular application of biosensors and actuators is that of bioMEMS devices, which are nanoscale and microscale systems that perform key biological-related processes and are often embedded in medical devices.

**Bioimaging** involves the application of image science and signal processing technology to a broad range of biological problems from imaging single cells to the entire human or animal body. Areas of emphasis found in Arizona include magnetic resonance imaging and spectroscopy to identify

tissue abnormalities, optical imaging from cell to organism, positron emission tomography and single photon emission computed tomography, two radiotracer techniques, used for studying central nervous system function, and image quality enhancement involving the development of new algorithms and detector systems across imaging modalities.

Supporting the development of the strategic plan for Bioengineering were two analyses. One was the development of an inventory of assets, namely facilities, equipment and expert staff identified through the efforts of the Technology Platform members and reported at the scientific retreat. The other was a peer analysis conducted by Battelle, which was used to validate the strategic plan approaches identified by the Technology Platform committee. These two analyses are included as Appendices B and C.

## ***II. Identified Resource Gaps and Collaborative Opportunities for Advancing the Bioengineering Research Platform***

Based on the guidance of the Bioengineering Platform committee, resource gaps and collaborative opportunities were identified as areas for enhancement to enable Arizona to position its bioengineering research activities for national excellence. Below we summarize a number of these key enhancements.

Across the bioengineering platform a number of key resource gaps were identified:

- An organizational structure to “tease out” real world problems and provide therapeutic solutions in a systematic way.
- Application and prototype development focus, involving micro-fabrication, biomaterials characterization, and packaging technologies.
- Investments in animal facilities with a broad range of animal species, including primates, pigs and transgenic mice, in at least two locations in the state to enable easy access.
- Linking of animal facilities with hospital settings to enable testing of surgical implants.
- Clinicians with research expertise and interest. Need financial incentives and changes in medical training.

- Lack of small animal research bioimaging facility in the Phoenix area.
- Research support staff – technicians, grant writers, etc. Low salaries cause high turnover or unfilled positions.
- No resources available to take pre-clinical successes through to clinical trials.
- Lack of adequate research space.

More specific gaps in technology competencies were also identified, including:

- Genomic and proteomic approaches to understand implant acceptance/rejection, and tissue responses to preservation/storage, injury and regeneration of tissue.
- Facilities for design, synthesis and testing of novel biomaterials.
- Long term transient neural functional monitoring using electrical and magnetic activity recordings
- While there is lots of activity in use of imaging for diagnostics, going from cell to body, there is a need for dynamic imaging—taking real-time images over time.
- Arizona has engineered tissue developed in the lab like many others, but it is not clear if there is much depth in manufacturing processes to make substantial quantities of tissue. Arizona could take a national leadership position

by designing a manufacturing process that works, then developing an effective means of long-term storage and transport of tissue-engineered products.

- BioMEMs capabilities are not lodged within the bioengineering efforts. Existing facilities tend to be silicon based for semi-conductor needs and are not conducive to interaction with biological systems. Equipment cannot be easily recalibrated for other uses, e.g., tests in aqueous environments.
- Opportunity to build micro-electronics labs for bioengineering applications, but requires investments for equipment and more electrical engineering partners.
- Cell-based sensors is a big area in Arizona, but is not well represented in the bioengineering activities.

Key collaborative opportunities identified by the bioengineering platform committee included:

- Ensure easy access for clinicians to available resources in the state. Doctors do not know about the extensive bioengineering research and technology base. A “one stop shop” website would be helpful.
- Encourage physicians to work in university environments and vice versa.
- Resolve issues with technology transfer and commercialization that hold back collaboration—IP policies, cost sharing and liability all act as barriers.
- Provide seed funds to encourage collaborative projects.
- Create “go to” facilities that can harness the power of Arizona in bioengineering, which lies in the sum of the parts.

Our concept for a statewide Bioengineering Institute, responds to these gaps, needs and opportunities either through facilities, equipment and people, or management and operating mechanisms.

### **III. Proposed Structure and Organization of the Bioengineering Research Platform**

Bioengineering research in Arizona is a highly fragmented effort involving as many as 200 faculty members working across universities, research institutes and hospitals in the state. Unlike other regions of the nation, there is no centralized “go to” facility and mechanism for collaboration. This fragmentation hinders collaborations and reduces the effectiveness of the researchers to partner with clinicians and with industry.

Approaching development of the bioengineering platform on an institution-by-institution approach will fall short of addressing the infrastructure challenges holistically. To realize major advances in technology and overall program growth, it is evident that a new approach is needed to undertake bioengineering research in Arizona. The potential is apparent, but the research staff is operating in a sub-optimal manner, given the current infrastructure.

Accordingly, we are proposing a radical departure from current plans, namely a statewide “Bioengineering Research and Development Collaboratory” that will engage university researchers, hospitals and institutes, and small and large industry, in the process of innovation, taking new technologies from laboratory to application in the shortest possible time.

To advance bioengineering research in Arizona calls for the establishment of an Arizona Biosciences Institute described as following.

#### **Critical Success Factors**

In order to gain acceptance by the various stakeholder groups and obtain the necessary funding and support for this unique statewide initiative, the following key factors must be addressed:

- The new Institute must fit the broader Bioscience business plan for Arizona, and, while leading the state Bioengineering revolution, also complement, not compete with initiatives such as Arizona Biodesign Institute and The Translational Genomics Research Institute (TGen).
- A cultural shift must occur in universities, medical institutes and hospitals to encourage researchers and clinicians to translate their research into real applications. Mechanisms must be introduced to identify and engage “clinician researchers” throughout the state, not just those in the universities and institutes.
- The focus for hiring the best and brightest researchers must shift to those interested and skilled in “translational research,” that is the movement of research from the laboratory to the clinic and/or marketplace. University hiring practices and promotion and tenure policies must be changed to achieve this.
- Facilities and equipment infrastructure must include enabling capabilities, as well as “marquee” equipment.

Often, the rate-controlling step in transferring technology is the lack of manufacturing and test labs, material characterization labs, or cell culture facilities.

- User facilities must be maximized to the extent practicable, so that one-of-a-kind, expensive facilities are available to all researchers.
- The “distance factor” must be overcome through use of high speed internet connections between satellite sites; laboratory software that enables interactions between researchers as if they were just down the hall; user friendly, fast transportation; and “user housing.”
- Sustained funding is needed to promote and enhance collaborations between sites; the power of this Institute is in the interdisciplinary, systems approach it can bring to complex problems.
- A sustained source of funds is needed to ensure the rapid development and deployment of novel technologies. Together with these funds, the requisite product development, business and market skills must be readily accessible for technology transfer to be effective.

### Key Features

The key features of the Arizona Bioengineering Institute are built around Arizona’s key application and enabling areas of bioengineering research strength. The three application areas of Neural Engineering, Regenerative Medicine and Rehabilitation Engineering are linked thematically in that they focus on developing materials, devices or systems to replace diseased or damaged parts, or enhance the capabilities and improve the quality of life for individuals with physical and cognitive impairments. These three

application areas are the target “Centers of Excellence” that will make Arizona’s bioengineering reputation.

The enabling technical areas that are critical for the success of these three centers include biomaterials, biosensors and actuators, and bioimaging. In addition, to complete the bioengineering infrastructure, facilities for animal models, clinical studies, scientific computing, genetics/genomics and prototype development, manufacture and testing are required. Finally, the management and operations of this “collaboratory” will be addressed.

### *Centers of Excellence*

All or parts of these facilities exist at the universities, primarily Arizona State University (ASU) and University of Arizona (UA), but they are *not* co-located, nor are they optimally sized and outfitted for the achievement of “center of excellence” status. It is proposed that these three centers be housed in a single, multi-storey building or building complex in Tempe/Phoenix and Tucson, adopting the hub and node (satellite) model.

- **Neural Engineering Center** – including center specific labs, such as neuromuscular control, neural microsystems, neurobotics, neural dynamics and neural signal processing.
- **Regenerative Medicine Center** – including center-specific labs such as molecular, cellular and tissue engineering; cell cultures—bioreactors, 3D CAD printing, production, sorting, characterization; tissue preservation; sterilization and packaging; advanced tissue microscopy.
- **Rehabilitation Engineering Center** – including center specific labs such as motor control, motor development

and learning, therapeutic implanted stimulators (e.g., heart pacemakers, brain pacemakers), physiology/exercise and biomechanics.

### *Cross-cutting, Enabling Technologies*

State of the art laboratory suites for the following are essential and must be in close proximity to the Centers:

- **Biomaterials** – Synthesis of ceramics, polymers, biomimetic materials (wet labs, dry labs); testing (ie. physical, mechanical, chemical); characterization, particular surface properties (ie. chemical analysis, microscopy); biological surface modifications
- **Biosensors and Actuators** – Clean room environments, Class 100 to 1000 for MEMS, bio-MEMs, electronics—sensor systems/devices; and bio-nanomaterial sensors
- **Bioimaging** – This area has been identified by the other two platforms as critical to their success also, so it is likely that a Bioscience Core “User Facility” could service all three platforms (see later). While the Phoenix area has human imaging capabilities in the hospitals, they are devoted to patient care, not research. There is no substantial animal imaging facility in the Phoenix area. Tucson has both human and animal imaging capabilities but both need enhancements.

The core user facility would have two separate components/divisions, human research imaging and animal imaging, together with a central biosignal processing center.

- Human Research Imaging Center, to include the range of MRI, FMRI, PET, SPECT, ultrasound, and CT scans
- Animal Model Imaging Center, to include cell to whole animal imaging capabilities for a range of different

animals, primates to rodents—confocal microscopy, optical coherence tomography, small animal MRI, FMRI, micro PET and SPECT, tissue spectroscopy

### *Completing the Bioengineering Research Infrastructure*

Five important capability sets are needed to complete the bioengineering infrastructure. These may be included in the Bioengineering Institute facilities or provided by other organizations as a “just in time” service.

- **Animal Facilities.** Complete facilities in at least two locations, Phoenix and Tucson, have been identified as a need for all three platforms. Animals would include primates, pigs and transgenic mice, SCID mice, rats, dogs and sheep. Fully equipped surgical suites are an important part of this capability also. It would be cost effective if the Bioengineering Institute could buy this service. ASU and BNI maintain an ALAAC approved surgical unit. The University of Arizona maintains an ALAAC approved large animal surgical suite with two full operating rooms, which are GLP compliant and would be accessible by investigators performing preclinical studies for submission to FDA.
- **Clinical Research Support.** A central clearinghouse for patient groups, supported by all the state’s hospitals, would be extremely advantageous and would give Arizona a competitive edge. Its diverse population provides for some unique patient groups/disease states. The Bioengineering Institute should buy this service if it can be made available.
- **Scientific Computing.** Bioengineering requires large-scale scientific computing in a number of areas—designing biomaterials (termed “materials by design”),

neurocomputation, signal processing, large data set analysis/pattern recognition/visualization, 2D and 3D modeling of musculoskeletal and cardiovascular systems, genetic basis for implant rejection, and bioimage enhancements to name just a few challenges. A central large-scale computing facility, accessible by all researchers, and supported by a cadre of expert hardware/software engineers would be a good investment. Alternatively, a computing-on-demand service provided by companies such as IBM and HP might be acceptable.

- **Genomics.** The genetic basis for the body's acceptance or rejection is an important aspect of bioengineering whether it be neuroprostheses, artificial tissue or organs, or artificial bone implants. The Bioengineering Institute will need a functional genomics core, but it will be integrated with TGen to ensure effective use of facilities, databases and experts.
- **Prototype Development, Manufacture and Testing.** Much of the innovation from bioengineering will be materials, systems and devices that must be designed, manufactured and tested. This is a critical part of the Bioengineering Institute's infrastructure and therefore it is preferable that such capabilities be under the Institute's direct control, assigned to the centers of excellence. However, such a facility should be a "user facility" that encourages and supports product teams, comprised of university researchers and industry engineers, to accelerate productization and commercialization. A new university-industry relations model, perhaps based on value sharing, will be needed to realize this. Basic equipment in such application centers might include CAD/CAM, electronics (MEMs, ASIC's, embedded

systems), metal shop, glass shop, and a range of test equipment. Incubator space for spin-out companies should be included.

### *Management and Operations*

As has been mentioned several times, the key to success of the statewide Bioengineering Institute is that it is managed and operated as a system, where the facilities and researchers are located for maximum productivity, but are networked together as if they are "just down the corridor." A number of key actions can be taken to achieve this goal, as follows:

- Single Institute Director (CEO), Chief Scientist/Technologist (CTO), Center Directors and Board of Advisors.
- A common set of systems for lab management and operations (e.g., QA, ES&H, setting and sharing indirect costs, IP management and sharing, training, security, etc.) to ensure transparency to the research staff.
- Joint appointments between universities, institutes and hospitals to strengthen partnerships. A target of 10–15 such appointments should be set at senior and junior levels.
- As many facilities as possible operate as "user facilities," supplied with one-of-a kind-equipment and trained technicians, who will either perform the tests etc. for the researchers or support them. Availability of "user housing" at the key sites will be essential to provide for efficient operations.
- Use of collaboratory software that links researchers together. Hardware and software is now available that can enable researchers to interact with their colleagues, access instrumentation, share data and computation

resources, and access information in digital libraries. By providing access to instruments, data, and computer display sharing, the Collaboratory would enable researchers in different geographical locations to interact as closely as if they were just down the hall.

- Create and finance formal Technical Networks around the three Centers and three enabling technologies. The value to participants includes the expansion of their knowledge base, access to resources not available in their home institutions, and increased opportunities for collaborative R&D funding. The Collaboratory environment discussed above would be very useful in enabling the networks.

#### *Technology Commercialization.*

Several aspects of this process should be “housed” in the Institute, or be readily accessible, to ensure timely movement of inventions to practice. These include:

- Adequate funding for patent protection, including a system to capture the IP, and evaluate its market potential.
- A discretionary proof of principle pre-prototype development fund to ascertain whether there is value from the research for commercial applications.
- Access to business management expertise such as market analysis, business plan preparation and business management.
- Flexible licensing agreements that properly address the state of the technology and the market, and the industry partner needs (i.e., one size does not fit all).
- Freedom to bundle IP with other universities or research institutions to create a competitive package for

commercialization. An Arizona-wide system for bundling IP will be critical to the success of the Bioengineering platform.

- Mechanisms to engage the private sector on a regular basis. Industry needs regular exposure to the science and technology opportunities; venture capitalists need to be exposed to business investment opportunities.

#### *Application Centers*

With the development of physical facilities, the Arizona Bioengineering Institute will be able to emphasize the establishment of Application Centers to:

- Operate as a “User Facility,” shared by both research institutions and private industry offering access to one-of-a-kind equipment or facilities.
- Focus on translational research, i.e., activities undertaken to increase the commercial value of innovations.
- Emphasize the development of products that will support the growth of emerging markets and the creation of brand new markets.
- Leverage and influence federal investments in research and development.
- Be networked to institutions conducting basic science research and the companies that are the end users of the technology being developed.
- Provide demonstration and test-bed facilities as well as testing and evaluation services.
- Allow for the manufacture of limited quantities of prototypes for testing, and further development.

- Have a computer-aided design facility to provide software development and simulation.
- Accommodate startup companies in incubator space.

**Example: Application Center for Rehabilitation Engineering**

This space would include laboratory space for design shops that specialize in designing and developing prototypes and to streamline the technology transfer and commercialization processes. The application center would include two or three small lab spaces that are GLP compliant. Some of these lab spaces would be for human subject research, others for animal model system research. These labs would be made available to different projects on a rotating basis to complete

studies that require a GLP environment. There would also be five additional lab incubator spaces to be leased at reduced rates to companies formed by researchers affiliated with the Center. Each of these spaces would provide either a dry lab space (for the engineering projects), or a wet-lab space with general chemistry bench space, or a lab with a sterile fume hood. Also available will be high-speed internet access and phone lines. The Application Center would provide a shared use pre-equipped office facility, a meeting room and access to Institute library resources. Investigators could run their SBIR/STTR type proposals or venture capital funded projects for up to three years through his incubator space, at which point they would be required to “graduate.”

## IV. Specific Investment Requirements for Bioengineering Research

The Bioengineering Research Platform committee identified a detailed program of investments to develop the Arizona Bioengineering Institute. Below, the investment components

for the Arizona Bioscience Institute are set out, followed by cost estimates over the next five years.

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### INVESTMENT PROGRAM

Underlying the Arizona Bioengineering Institute are several key assumptions:

- The Bioengineering Institute will occupy new buildings in Phoenix/Tempe and Tucson; there will be a new building or space for the Institute for Integrative Biotechnology Research and Education in Flagstaff. Total space requirements will be derived from faculty research and support needs (i.e., bottoms up approach).
- The Institute will adopt the Hub-Node (satellite) Model with the focus on three world class “Centers of Excellence”
  - Neural Engineering Center: hub in Tempe; satellite in Tucson
  - Regenerative Medicine Center: hub in Tucson; satellite in Tempe
  - Rehabilitation Engineering Center: hub in Tempe; satellites in Tucson and Flagstaff
- All existing, relevant university laboratories, equipment and staff will be moved to the new buildings. Investments will only deal with:
  - Upgrading existing laboratory equipment;
  - Hiring new staff and furnishing new laboratories for them; and
  - Creating “Signature” facilities that will “put Arizona” on the map.
- Dedicated laboratory suites for biomaterials and biosensors/actuators will be at Tempe, Tucson and Flagstaff locations.
- We will have central Bioimaging “User Facilities” in Tempe/Phoenix and Tucson for both human research and animal models.
- We will have comprehensive animal model testing facilities in Tempe/Phoenix and Tucson, which will include surgical suites and facilities for long-term tests, and an upgrade of an existing facility in Flagstaff.

- We will have access to “on demand” scientific computing for all three sites.
- We will create a dedicated bioengineering genomics core at UA, Tucson, with satellites at TGen, ASU and Northern Arizona University (NAU).
- Application centers for prototype development, manufacture and testing will be co-located with the centers. Incubator space for early stage spin-out companies will be included.
- Staffing of the Centers and support facilities will include adequate numbers of technicians, engineers, and administrative staff to ensure smooth operation of all laboratories, user facilities and support for proposals, projects and general management.
- Faculty hiring will focus on recruiting stars to build the Institute’s reputation, but will also include adequate numbers of younger faculty and graduate students. Joint appointments between institutions will be emphasized for new hires.
- The procurement of collaboratory software will include dedicated support staff to ensure user-friendly operations.

- Dedicated technology transfer professionals will be included in the Institute’s Administrative budget.

The specific investment requirements to make the Bioengineering Institute a reality include the following (more detailed cost data are provided in Appendix A):

### **Neural Engineering Center**

With the base of expertise already existing in Arizona universities, institutes and hospitals, the enhancements proposed to create this center of excellence will result in new methods to diagnose and treat a variety of neurological disorders ranging from Parkinson’s disease, epilepsy, and paralysis to blindness, deafness, and learning disabilities. In close collaboration with the Neurosciences Platform, these treatments will extend from advanced, high-tech interventions—for example, deep brain stimulation and pallidotomy for the treatment of Parkinson’s disease, implanted brain stimulators and just-in-time administration of anti-epileptic drugs for the treatment of epilepsy, and cochlear implants for the treatment of deafness—to more molecular and cellular approaches involving neural regeneration and gene therapy. The center will be positioned to contribute broadly in this rapidly growing field.

## Enhancements Summary

Location	Faculty and Staff	Facilities and Equipment	Enabling Initiatives
<b>Hub at ASU</b>	Star faculty to lead “Signature” Labs Senior level faculty/researchers Junior level faculty Post docs PhD Grad students Res. Technicians Engineers Administrative staff	General <ul style="list-style-type: none"> <li>• Histology Lab</li> </ul> “Signature” Facilities <ul style="list-style-type: none"> <li>• Primate Research Lab</li> <li>• Bio-Signal Processing and Dynamics Lab</li> <li>• BioResponsive and Intelligent Neural Interfaces Lab</li> </ul>	<ul style="list-style-type: none"> <li>• Collaboratory network</li> <li>• Bioengineering Genomics</li> <li>• Bioimaging Center</li> <li>• Animal test facilities</li> <li>• Application Centers</li> <li>• Technology Transfer</li> </ul>
<b>Satellite at UA</b>	New faculty members in areas of prosthetic design and construction and computer modeling.	Three laboratories: <ul style="list-style-type: none"> <li>• Design and fabrication for development of prosthetics and robots.</li> <li>• Computer engineering</li> <li>• Human study</li> </ul>	

### Regenerative Medicine Center

The Center of Excellence for Regenerative Medicine will facilitate and expedite the movement of regenerative medicine technologies into clinical practice. Its focus is cutting edge research and advanced clinical methods related to molecular, cellular and organ based therapies toward regeneration of normal and functional tissue. This will

require a multidisciplinary approach that coordinates efforts between biology, engineering and clinical practice. The following enhancements represent the needed resources necessary to establish the regenerative medicine center as a premier facility of international reputation. It will be built upon an established group of investigators with extensive experience translating basic research into clinical practice.

## Enhancements Summary

Location	Faculty and Staff	Facilities and Equipment	Enabling Initiatives
<b>Hub at UA</b>	<ul style="list-style-type: none"> <li>• New Faculty members</li> <li>• Senior Research Specialists</li> <li>• Technical staff</li> </ul>	“Signature Facilities” <ul style="list-style-type: none"> <li>• Tissue Engineering</li> <li>• Pre-Clinical Instrument, Device and Drug Evaluation</li> </ul> Laboratory Suites (Laboratory for Biomaterials Design, Synthesis and Testing) (Laboratory for Biosensors and Actuators)	<ul style="list-style-type: none"> <li>• Collaboratory network</li> <li>• Bioengineering Genomics</li> <li>• Bioimaging Center</li> <li>• Animal test facilities</li> <li>• Application Center</li> <li>• Technology Transfer</li> </ul>
<b>Satellite at ASU</b>	Star Faculty to lead signature facilities Senior Research Specialists Junior Level Faculty Technical Staff	“Signature Facilities” <ul style="list-style-type: none"> <li>• Molecular, Cell &amp; Tissue</li> <li>• Engineered Diagnostic and Therapeutic BioDevices and BioSystems</li> <li>• Organ Engineering</li> <li>• Design and Manufacturing of BioProducts &amp; BioProcesses</li> <li>• Computational Bioengineering &amp; Quantitative Biosystems</li> </ul>	

### Rehabilitation Engineering Center

This center of excellence will bring together engineers and clinicians to a common research environment for conducting basic and applied research in diagnostics, therapeutics and rehabilitation. This center will enable multi-disciplinary research along two general themes:

- Enhancing Functional Abilities in Rehabilitation
- Engineering Human Health in Rehabilitation

Together, these themes constitute a comprehensive approach to improving quality of life by counteracting the effects of disability. The research facilities supporting these activities will allow development of diagnostic and therapeutic technology, assessment of the functional outcomes of this technology, assessment of the physiological effects of interventional therapy, and conduction of pre-clinical FDA trials. The application center will serve the dual purpose of translating engineering technology to the clinical environment as well as transfer of prototype technology to the medical industry.

## Summary of Enhancements

Location	Faculty and Staff	Facilities and Equipment	Enabling Initiatives
<b>Hub at ASU</b>	Stars to lead Signature Lab. Senior level faculty/researchers Junior level faculty Post docs PhD Grad students Physical Therapists Kinesiologists/Exercise Scientists Nurse Clinical Research Coordinator Engineers Res. Techs Administrative staff	General Labs <ul style="list-style-type: none"> <li>• NeuroMotor Systems lab</li> <li>• Metabolic,/Cardiorespiratory Systems Lab</li> <li>• Rehabilitation/neuroplasticity</li> <li>• Animal research laboratory</li> <li>• Small Animal Autonomic and Metabolic Monitoring Laboratory</li> <li>• Computaion and Visualization Laboratory</li> </ul> Signature Lab Advanced Rehabilitation Systems <ul style="list-style-type: none"> <li>• Facility for Measurement and Monitoring of Functional Performance</li> <li>• Facility for Quantitative Assessment of Health</li> <li>• Facility for Model Systems for Rehabilitation Research</li> <li>• Computation and Visualization Laboratory</li> </ul>	<ul style="list-style-type: none"> <li>• Collaboratory network</li> <li>• Bioengineering Genomics</li> <li>• Bioimaging Center</li> <li>• Animal test facilities</li> <li>• Application Center</li> <li>• Technology Transfer</li> </ul>

Location	Faculty and Staff	Facilities and Equipment	Enabling Initiatives
<b>Satellite at UA</b>	New faculty—computer engineering and a clinical scientist developing instrumentation for movement	General Labs <ul style="list-style-type: none"> <li>• A patient-behavioral facility that evaluates movement</li> <li>• Virtual reality laboratory and computer simulation equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Collaboratory network</li> <li>• Bioengineering Genomics</li> <li>• Bioimaging Center</li> <li>• Animal test facilities</li> </ul>
<b>Satellite at NAU</b>	New faculty members and graduate assistants	<ul style="list-style-type: none"> <li>• Facility for the design, fabrication and testing of devices/instruments for rehabilitation</li> <li>• Testing and Monitoring Instrumentation.</li> </ul>	<ul style="list-style-type: none"> <li>• Application Center</li> </ul> Technology Transfer

### Laboratories for Biomaterials

Biomaterials are a critical enabling technology for bioengineering and leading edge laboratories must be maintained at all locations.

### Summary of Enhancements

Location	Faculty and Staff	Facilities and Equipment	Enabling Initiatives
<b>UA</b>	Faculty Senior research specialists Technical staff	Laboratory for Biomaterials Design, Synthesis and Testing	<ul style="list-style-type: none"> <li>• Collaboratory network software</li> <li>• Bioengineering Genomics</li> <li>• Application Center</li> <li>• Technology Transfer</li> </ul>
<b>ASU</b>	Faculty Senior Research Specialists Junior Level Faculty Technical Staff	Laboratory for Biomaterials and Biomolecular Materials Design	
<b>NAU</b>	(see Biosensors)	Multi-user, multi-disciplinary Biomaterials facility—full chemical, biological, and materials synthesis equipment	

## Laboratories for Biosensors and Actuators

Biosensors and actuators are critical enabling technologies for bioengineering and leading edge laboratories and clean rooms must be maintained at all locations.

### Summary of Enhancements

Location	Faculty and Staff	Facilities and Equipment	Enabling Initiatives
<b>ASU</b>	Senior level faculty/researchers Junior level faculty, Post docs, PhD Grad students Res. Tech Engineers	Equipment and specialized facilities needed to fabricate prototype biosensors and actuators with and without biological components.	<ul style="list-style-type: none"> <li>• Collaboratory network software</li> <li>• Labs for Biomaterials</li> <li>• Application Center</li> <li>• Technology Transfer</li> </ul>
<b>UA</b>	Faculty Lab manager, Administrative support, Lab technicians Maintenance technicians	<ul style="list-style-type: none"> <li>• Laboratories for Micro electronic mechanical systems (BIO-MEMS) and/or microelectronic chemical systems (BIO-MECS)</li> <li>• BioSensor/BioActuator Testing Equipment</li> </ul>	
<b>NAU</b>	New faculty hires	Laboratory facility for biosensing and actuators, including: <ul style="list-style-type: none"> <li>• Class 100 Clean Room with Class 10 sub-enclosure</li> <li>• Exposure and Testing Facility/Instrumentation</li> </ul>	

## Bioengineering Genomics

Bioengineering Genomics will consist of three facilities. University of Arizona, Tucson will serve as the hub for expression profiling with TGen and ASU serving as a

Phoenix/Tempe satellites, and NAU will have a proteomics satellite.

The Tucson and Phoenix facilities will offer (1) experimental design consultation, (2) fee for service related work, and (3)

training for those laboratories interested in performing their own experiments. Both facilities will offer access to state-of-the-art analysis tools. The latter will most likely be jointly developed and take the form of internet-based, especially since expertise in this area (biological computational science) is in great demand and rare.

The two facilities will, and do, house different yet complementary expression profiling technologies each with unique strengths. The UA will offer access to specialized expression profiling arrays. For example, UA is already producing specialized arrays for human, mouse, rat, chicken, and zebrafish. TGen, on the other hand, will offer access to global and commercially available arrays. Such arrays will include but are not limited to Agilent Human Oligonucleotide Arrays (~36,000 genes) and Affymetrix's Human Arrays (~33,000 genes). These companies also offer arrays suitable for other organisms including mouse, rat, yeast, *C. elegans*, and *Drosophila*.

TGen will also serve as the incubator for tissue microarray and SNP genotyping development. Following expression profiling studies, both of these platforms will become an integral part of the Bioengineering Institute's Genomics Initiative especially as it pertains to Regenerative Medicine. Due to the fact that these technologies will be utilized following expression profiling, funds are not requested until years 2–5.

ASU has proposed genomics and proteomics labs as part of their regenerative medicine satellite operation. Two laboratories, for Proteomics & Proteomic technologies and Genomics & Genomic technologies, have been mapped out.

A Proteomics core would also be created at NAU, which could potentially search for upregulated cancer-associated

proteins in native populations, proteins expressed specifically during neuromuscular control and proteins expressed when host tissue contacts implanted medical devices as well as foreign objects such as bacteria. These efforts would be combined with a Genomics approach in collaboration with TGen.

In addition to the Proteomics equipment, gel imaging systems and 2-D software analysis are needed.

The personnel, capital investments, annual operating costs, and necessary square footage are in Appendix A.

### **Collaboratory for Real-Time Interaction between Hubs and Satellites**

The Collaboratory would integrate new communications technologies, including shared computer displays, electronic notebooks, and virtual reality collaboration spaces with videoconferencing and e-mail capabilities. These communication technologies could also be integrated with scientific and engineering resources, including instruments, data, analysis software, and the. The Collaboratory toolkit that could be used in Arizona should include:

- **CORE2000 or Real-Time Group Collaboration** – An open, cross-platform, collaboration system for multi-tool collaborative sessions. It includes a whiteboard, a chat room, desktop videoconferencing, and application sharing of computer screens.
- **Virtual Network Computing or VNC** – A secure collaborative (remote) instrument control application tool. VNC provides the authorization control and privacy essential for the safe control of expensive instruments or the sharing of sensitive data.

- **Electronic Laboratory Notebook** – A Web version of a traditional paper laboratory notebook that collaborators can share in real time.
- **Collabasuite** – A suite of Web-based tools that makes it easier for people from different organizations and in different locations to work together. The tools are used to manage resources, simplify coordination and development of information products, and facilitate

communication and collaboration. They allow dispersed groups to work on common projects in real-time.

Collaboratory sites should be established in Phoenix/Tempe, Tucson and Flagstaff at a minimum. For example, TGen has installed a videoconferencing system in Phoenix that can be replicated for the Institute. Also, NAU's strong presence in distance learning will be enhanced further by the integration of Interactive Instructional Television (IITV) facilities into the collaboratory.

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## COST ESTIMATES

### Specific Investment Requirements for Bioengineering Research Platform

Platforms: Neural Engineering, Regenerative Medicine, Rehabilitation Medicine, Biomaterials, Biosensors and Actuators, Bioimaging (Academic Component) and Genomics

#### Total Projected Faculty: 49 - 53

- Neural Engineering: 4– 6
- Regenerative Medicine: 9
- Rehabilitation Medicine: 5 – 7
- Biomaterials: 14

- Biosensors and Actuators: 9
- Bioimaging: 8

#### Associated Space Needs For Faculty Recruitment

- Professor – 2,000 to 15,000 nasf (includes office)
- Associate Professor – 1,500 to 4,000 nasf (includes office)
- Assistant Professor – 1,200 to 2,400 nasf (includes office)

#### Space

95,000 – 155,000 nasf general laboratory and office

## Projected Investments

Position	Five Year Total	Neural Engineering	Regenerative Medicine	Rehabilitation Medicine	Bio-Materials	Biosensors	Bio-Imaging	Genomics
<b>Central Administration</b>								
<b>Staff</b>	\$2.5M							
<b>Equipment</b>	\$0.1M							
<b>Consumable Supplies</b>	\$0.02M							
<b>Space Renovations</b>	\$0.4M							
<b>TOTAL</b>	\$3.1M							
<b>ASU</b>								
<b>Faculty</b>	\$18.4–\$32.2	\$1.8–\$5.6M	\$6.3–\$9.2M	\$2.1–\$4.6M	\$4.2–\$5.0M	\$2.0–\$4.7M	\$2.0–\$3.1M	
<b>Post-Doctoral Fellows</b>	\$1.8–\$4.1M	\$0.6–\$1.5M		\$0.4–\$0.8M		\$0.4–\$1.2M	\$0.4–\$0.6M	
<b>Graduate Students</b>	\$1.1–\$2.1	\$0.3–\$0.6M		\$0.3–\$0.7M		\$0.3–\$0.5 M	\$0.2–\$0.3M	
<b>Support Staff</b>	\$9.1–\$13.3M	\$0.4–\$2.0M	\$5.4–\$5.6M	\$1.3–\$2.4	\$1.6–\$2.2M	\$0.4–\$1.5M		
<b>Subtotal</b>	\$30.4–\$51.7M	\$3.1–\$9.7M	\$11.7–\$14.8M	\$4.1–\$8.5M	\$5.8–\$7.2 M	\$3.1–\$7.5	\$2.6–\$4.0M	
<b>Recruitment Packages</b>	\$14.5–\$28.9M	\$2.5–\$7.5M	\$3.3–\$5.5M	\$2.3–\$4.0M	\$3.6–\$4.2M	\$1.3–\$5.2M	\$1.5–\$2.5M	
<b>Pooled Equip &amp; Oper'ns</b>	\$23.2–\$41.9M	\$4.6M	Not estimated	\$11.0–\$29.5M		\$3.0M	\$4.6–\$4.8M	
<b>Clean Rooms</b>	\$3.6M					\$3.6M		
<b>Space Renovation</b>	\$10.9–\$20.6M	\$1.3–\$5.4M	\$2.9–\$4.4M	\$1.2–\$2.2M	\$2.4–\$2.7M	\$2.2–\$4.4M	\$0.9–\$1.5M	
<b>TOTAL</b>	\$82.6–\$146.7M	\$11.5–\$27.2M	\$17.9–\$24.7	\$18.6–\$44.2M	\$11.8–\$14.1M	\$13.2–\$23.7M	\$9.6–\$12.8M	

### Projected Investments (continued)

Position	Five Year Total	Neural Engineering	Regenerative Medicine	Rehabilitation Medicine	Bio-Materials	Biosensors	Bio-Imaging	Genomics
U of A								
Faculty	\$11.5–\$17.1	\$1.0–\$1.1M	\$5.0–\$7.1M	\$1.0M	\$2.3–\$3.6M	\$0.9–\$2.3M	\$1.3–\$2.0M	
Post-Doctoral Fellows	\$0.5–\$0.7M						\$0.5–\$0.7M	
Graduate Students	\$0.3–\$0.5M						\$0.3–\$0.5M	
<b>Support Staff</b>	\$6.2–\$7.8M		\$2.2–\$3.1M		\$1.7–\$2.4M	\$1.5M		\$0.8M
<b>Subtotal</b>	\$18.5–\$26.1M	\$1.0–\$1.1M	\$7.2–\$10.2M	\$1.0M	\$4.0–\$6.0M	\$2.4–\$3.8M	\$2.1–\$3.2M	\$0.8M
<b>Recruitment Packages</b>	\$8.3–\$12.9M	\$1.0–\$1.5M	\$2.5–\$4.0M	\$1.5–\$2.0M	\$1.8–\$2.4M	\$0.5–\$1.5M	\$1.0–\$1.5M	
<b>Pooled Equip &amp; Oper'ns</b>	\$31.7–\$36.7M		\$10.4–\$15.4M		\$7.5M	\$10.3M	\$1.5M	\$2.0M
<b>Clean room</b>	\$3.6M					\$3.6M		
<b>Space Renovation</b>	\$5.8–\$10.8M	\$0.6–\$0.9M	\$1.6–\$2.6M	\$0.6M	\$1.6–\$4.0M	\$0.6–\$1.6M	\$0.6–\$0.9M	\$0.2M
<b>TOTAL</b>	\$67.9–\$90.1M	\$2.6–\$3.5M	\$21.7–\$32.2M	\$3.1–\$3.6M	\$14.9–\$19.9M	\$17.4–\$20.8M	\$5.2–\$7.1M	\$3.0M

### Projected Investments (continued)

Position	Five Year Total	Neural Engineering	Regenerative Medicine	Rehabilitation Medicine	Bio-Materials	Biosensors	Bio-Imaging	Genomics
<b>NAU</b>								
<b>Faculty</b>	\$6.9–\$10.4M			\$1.0–\$1.3M	\$2.7–\$4.1M	\$2.2–\$3.3M	\$1.0–\$1.7M	
<b>Post-Doctoral Fellows</b>	\$0.4–\$0.5M						\$0.4–\$0.5MM	
<b>Graduate Students</b>	\$0.4–\$0.7M			\$0.2–\$0.4M			\$0.2–\$0.3M	
<b>Support Staff</b>	\$0.4–\$0.8M			\$0.1–\$0.2M	\$0.2–\$0.5M			\$0.1M
<b>Subtotal</b>	\$8.1–\$12.4M			\$1.3–\$1.9M	\$2.9–\$4.6M	\$2.2–\$3.3M	\$1.6–\$2.5M	\$0.1M
<b>Recruitment Packages</b>	\$6.4–\$10.3M			\$1.5M	\$2.4–\$4.8M	\$2.0–\$3.0M	\$0.5–\$1.0M	
<b>Pooled Equip &amp; Operations</b>	\$5.5–\$6.55			\$2.9–\$3.9M	\$1.95M	\$0.5M		\$0.2M
<b>Clean Room</b>	\$1.0M					\$1.0M		
<b>Space Renovation</b>	\$3.6–\$8.4M			\$1.0–\$1.1M	\$1.2–\$3.2M	\$1.1–\$3.6M	\$0.3–\$0.5M	
<b>TOTAL</b>	\$24.65–\$38.65M			\$5.7–\$8.4M	\$8.45–\$14.55M	\$6.8–\$11.4M	\$2.4–\$4.0MM	\$0.3M
<b>GRAND TOTAL – BIOENGINEERING</b>	<b>\$178.3–\$278.5M</b>	<b>\$14.1–\$30.7M</b>	<b>\$39.6–\$56.9M</b>	<b>\$28.4–\$56.2M</b>	<b>\$35.2–\$48.6M</b>	<b>\$37.4–\$55.9M</b>	<b>\$17.2–\$23.9M</b>	<b>\$3.3M</b>

## VI. Priorities

The Arizona Institute for Bioengineering will evolve concurrently at three major sites, according to the particular university's priority development program. However, for overall success of this initiative, the following general priorities should be adopted.

- *Primary:* Establish the hub-satellite infrastructure, organization and management for the three Centers of Excellence:
  - Neural Engineering Center: hub in Tempe; satellite in Tucson
  - Regenerative Medicine Center: hub in Tucson; satellite in Tempe (Center for Molecular, Cell & Tissue Engineered Diagnostic and Therapeutic BioDevices and BioSystems )
  - Rehabilitation Engineering Center: hub in Tempe; satellites in Tucson and Flagstaff

A key part of this phase is also to implement the “collaboratory” system so that bioengineering researchers

throughout Arizona become “connected” to each other and the resources that they need for their programs.

- *Secondary:* Upgrade laboratory suites for cross-cutting, enabling capabilities at all three sites:
  - Biomaterials
  - Computational Bioengineering & Quantitative Biosystems (at ASU)
  - Biosensors and Actuators
  - Bioimaging – Create state “User Facility”
  - Bioengineering Genomics

Potential funding sources will include a number of federal agencies such as NIH, NSF, DoD, DARPA, DOE, ONR, NIST, NASA, and AHA. In addition, opportunities with private Foundations, such as Whitehead, Flinn and Gates will be explored, and industry and VC will be engaged in financing the translation of discoveries into commercial products.

# ***Appendices for Arizona Bioengineering Research Strategic Plan***

*Updated September 2003*



## **Appendix A: Inventory for Bioengineering Platform**

### **I. Research Niche: Neural Engineering**

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#### **MAJOR PROGRAMS, PRIMARY FACULTY AND KEY FACILITIES BY APPLICATION AREAS**

Neural engineering is an interdisciplinary area with the common goal of analyzing the function of the nervous system, developing methods to restore damaged neurological function, and creating artificial neuronal systems by integrating physical, chemical, mathematical, and engineering tools.

Neural engineering is widely acknowledged to be one of the premier growth arenas of the 21<sup>st</sup> century, with major thrusts related to

- New technology and approaches to advanced basic research on the nervous system, including signal processing, modeling and simulation of neural systems and their functions
- Development and application of specialized technology for medical diagnosis, monitoring and treatment of nervous system disorders, especially prediction and intervention to avert catastrophic transitions, micro-structured and multifunctional neural prosthetic devices to replace the damaged or dysfunctional brain or spinal cord
- “Neurotechnology” applications, i.e., enhanced-performance systems designed on the basis of fundamental principles of nervous system structure and function.

The following are four related activity areas, which utilize the same capabilities.

#### ***Activity area 1: Neural Interfaces***

This application area encompasses development of advanced electrode systems for direct recording from the central and peripheral nervous systems as well as development of electrodes for stimulation of the central and peripheral nervous systems. Research in this area includes development of multielectrode arrays, microactuated electrodes, multifunctional sensors that combine recording of neural and chemical signals; development of bioactive coatings for implantable electrodes; and development of multipurpose stimulating electrodes that can provide both electrical and chemical stimulation.

#### ***Activity area 2: Advance Neural Signals and Systems Analysis and Control***

This application area targets the development of advanced approaches for analyzing spatiotemporally distributed stationary and non-stationary neural signals. Novel approaches for adaptive control of neural function are developed. This area also includes mathematical modeling of dynamic neural processes from the cellular to the network level. Applications range from analysis and control of neural activity in human subjects to electrophysiology in awake behaving primates, mammals and lower vertebrates as well as

*in vivo* and *in vitro* preparations. The application emphasis is on improving higher neural function as well as dysfunction in the neuromuscular system due to brain/spinal cord injury, stroke and progressive neurological diseases such as ALS, epilepsy and Parkinsonism. Major market opportunities exist in brain/spinal cord injury rehabilitation, epileptic seizure and stroke prevention and rehabilitation, biosensors design and fabrication, and biosensor applications in diagnostics, environmental monitoring and counter bioterrorism activities.

### ***Activity area 3: Advanced Neuroprostheses***

The application focus is to rehabilitate motor and neural function disorders through emerging neural interfaces and brain control technologies. This involves interfacing the central and peripheral nervous system with artificial devices

that replace either lost senses or missing or paralyzed limbs, as well as development of advanced neurostimulators (e.g. stimulators that serve as brain pacemakers for prevention of Parkinsonian tremors and epileptic seizures, stimulators for the auditory nerve, retinal and optical nerve stimulators, cortical and deep brain stimulators, and functional neuromuscular stimulators).

### ***Activity area 4: Neural Regeneration***

The application focus is to enhance the ability of the peripheral and in particular central neural tissue to regenerate. This could involve pharmacotherapeutic, genetic, and perhaps magnetic and electrical local field stimulation approaches.

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## **Research at ASU Includes:**

### ***Neural Interfaces:***

- Developing new biocompatible materials for neural interface by surface modification and improved biocompatibility
- Developing multi-functional biosensors for neuroprosthetic devices and machines
- Monitoring single neurons in transgenic mice
- Micropositioning systems for the brain

### ***Advanced Neural Signals and Systems Analysis and Control:***

- Brain-machine interface for motor and neural function recording, analysis and rehabilitation after stroke and spinal cord injury

- Integrative spinal cord stimulation and physical therapy to facilitate walking rehabilitation in spinal cord injured
- Neurodynamics and electrophysiological investigation to discover the neural structures and information flow responsible for higher brain functions (memory, cognition), movement control and regulation, spinal electrophysiology, sensory physiology, and brain-spinal cord interactions.
- Brain Dysfunction and Control–Development of signal processing algorithms for monitoring and long-term prediction of epileptic seizures and other dynamical brain disorders (Parkinson, strokes, sleep apneas, etc.)
- Brain Dysfunction and Control- Development of hardware (electrical, magnetic stimulators, drug release

devices) for timely intervention and control of epilepsy and other dynamical brain disorders

- Adaptive control systems for posture and movement after neurotrauma such as spinal cord injury.
- Automated customization of electrical stimulation
- Development of neuromorphic hardware for closed loop control of spinal circuitry

#### *Advanced Neuroprostheses:*

- Functional neuromuscular stimulation systems for posture control after spinal neurotrauma
- Functional neuromuscular stimulation systems for locomotion after spinal neurotrauma (human subjects and rodent models)
- Epidural spinal cord stimulation system for locomotion
- Cochlear stimulation systems for audition
- Corticothalamic stimulation systems to arrest epileptic seizures

#### *Neural Regeneration:*

- Pharmacotherapy to promote spinal regeneration after spinal cord injury (animal models)

#### *Promising science and technology includes:*

- Neurocomputation – Brain Information Flow, Nonlinear Dynamics, Modeling, Adaptation, Single cell to network models
- Neurosignal processing and Biosystem Analysis and Control—EEG, ENG, EMG, ECG, Respiratory signals

(spike trains, field potentials and intracellular recordings in humans, pigs, rats, lampreys)

- Localization of abnormal foci of activity inside the brain—epileptic foci (humans and rats)
- Biomaterial processing—new class of polymeric materials
- Surface modification techniques—application specific such as reduced immunoresponse of neural implants and improved biocompatibility
- Design and microfabrication of biosensors for neural interfaces—implantable neural probes
- Neurological basis of motor function control and learning—brain signal exploitation
- Pattern recognition and real-time adaptation algorithms for direct cortical control of neuroprostheses—computer model
- Direct spinal interfaces for motor control
- Adaptive functional neuromuscular stimulation systems
- Neuromotor function assessment and rehabilitation—biofeedback system
- Enhancing central nervous system neuroplasticity after spinal neurotrauma

#### **Major Assets**

#### *Key Faculty and Areas of Interest*

#### *Primary:*

- Jiping He – Software and hardware design of advanced neural implant devices for brain-machine interface for advancing neuroscience research and neural rehabilitation
- Leon Iasemidis – Software and hardware for neural signal processing, brain dynamics, neuroinformatics and genomic signal processing
- Steve Massia – Bioresponsive neural implants
- Jit Muthuswamy – Implantable microsensors and microactuators
- Ranu Jung – Computational neuroscience, neuromorphic hardware-spinal cord interfaces, neural signal processing and neurophysiology, animal models for development of advanced neuromotor prostheses, sensorimotor integration
- James Abbas – Adaptive control algorithms, neuromuscular stimulation; implantable systems for people with spinal cord injury; neuroprostheses for standing and locomotion
- Michael Dorman – Cochlear neuroprostheses
- Alyssa Panitch – Design and synthesis of hydrogels
- Bruce Towe – Biosensors and bioelectronics
- Amarjit Singh – Novel microsensors
- Michael Carhart – Musculoskeletal biomechanics
- Steve Helms Tillery – Neural control of arm movements; Neurophysiology
- James Sweeney – Applied neural control, implantable electrode design
- Gary Yamaguchi – Neuromuscular stimulation

- Steve Baer – Mathematical models of neurons
- Frank Hoppenstead – Mathematical modeling of neurons and networks

#### *Contributing*

- Jennie Si – Artificial neural learning systems
- Gregory Raupp – New biocompatible polymers
- Marco Santello – Motor control
- Yury Shimansky – Cortical and sensory feedback
- Kostas Tsakalis – Brain Control
- Andreas Spanias – EEG signal processing
- Don Sinnex – Auditory neurophysiology and signal analysis
- Stephen Phillips – Biomems
- Bruce Kim – Biomems

#### *Centers and Core Laboratories*

Center for Neural Interface and Brain Control Research

Center for Rehabilitation Neuroscience and Rehabilitation Engineering:

- Has complimentary facilities for design and development of neuroprostheses and neuromotor therapy in human and small animal models
- Has complimentary facilities for evaluation of neuromotor function in human and small animal models
- Has facilities for computational modeling of neural and musculoskeletal systems

Harrington Dept. of Bioengineering (Labs in three buildings, SCOB, Goldwater and Hayden Ferry Lakeside; shared use lab space is 2,649 sq. ft. in SCOB, 4,371 sq. ft. in Goldwater and 4,500sq.ft. in Hayden Ferry Lakeside. Total office space allocated to the dept. is ~6,630 sq. ft.; faculty each maintain 700–1000 sq. ft. research area; generally in good condition).

Featured labs are:

- Core Neural Engineering Instructional and Research Laboratory
- Neuromuscular Control Lab
- Neurobotics Lab
- Neural Microsystems Lab
- Brain Dynamics Lab
- Primate Research Facilities
- Chronic animal surgery

#### *Supporting Laboratories*

- Biomaterials Science and Engineering Lab

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#### **Research at UA Includes:**

- Motor Control Neurobiology – Spinal and cortical neurophysiology of motor control.
- Neuroprosthetics – Neural control of multijointed arm movements.
- The interface of biomechanics, robotics, and prosthetics with the neurophysiology of multijointed movements.
- Alterations in neural control and movement of patients with movement disorders; cervical spinal cord injury, stroke, Parkinson’s disease.

- Physiology lab (SCOB 366)
- Harrington Arthritis Research Center
- Center for Solid State Electronics Research
- Center for Low Power Electronics Research
- Materials Science Labs
- Systems Science and Engineering Research Center

#### *Key Collaborations*

- Good Samaritan Regional Medical Center – Richard Herman, James Abbas, Dan Lieberman
- Barrow Neurological Institute – Thomas Hamm, Neil Crawford, Eric Vu, Jie Wu, David Treiman
- Mayo Clinic-John Gaviness
- University of Florida – J. Chris Sackellares
- Stanford University – R. Fisher
- Johns Hopkins University – R. Lesser
- Case Western Reserve University – R. Triolo

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- The Electrophysiological Properties of Spinal Motoneurons and Interneurons.
  - Neural control of breathing—control of upper airway respiratory muscles.

#### **Major Assets**

#### *Key Faculty*

Gail Koshland, Andrew Fugelvand, Doug Stuart, Ralph Fregosi, Bruce McNaughton

### *Centers and Core Laboratories*

- Arizona Research Labs Division of Neurobiology
- Biomedical Engineering Labs are in College of Medicine and College of Engineering, Department of Aerospace and Mechanical Engineering.
- Two “core” facilities: The Bioimaging core involves predominantly space assigned in support of MRI activities. This equals ~ 800 NSF; and Animal Care and space assigned for Animal Husbandry, Surgery and Imaging. One dedicated fluoroscopy suite with a second being built. Two dedicated survival surgery operating rooms with associated prep and recovery areas. This

surgery facility (including prep and recovery) is ~ 1,100 NSF.

- A new transgenic mouse facility is planned as part of the IBSB/MRB building.
- Sensorimotor Neurophysiology Lab – Capabilities include electromyography, microneurography, microstimulation, computer modeling, electrical stimulation of nerves and muscle, biomechanics.
- Multijoint Lab
- Respiratory Neurophysiology Lab
- Spinal Cord Neurophysiology Lab

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### **Research at Barrow Neurological Institute Includes:**

- Fundamental research in motor systems concerning the organization of spinal networks involved in pattern generation and motor control; roles that spinal mechanisms play in motor dysfunction following spinal injury and neurological disease.
- Elucidating the roles of the different classes of neurons in the motor cortex in order to determine which neurons process the information related to locomotion and posture maintenance. The long-range goal is to develop a functional model of connectivity of the motor cortex that is grounded in both morphological and physiological realities and applies to the acting neocortex.
- How the nervous system controls limb movements.
- Development of therapies for treatment, such as the use of spinal cord stimulation following spinal injury.

- Novel percutaneously-inserted spinal fixation systems.
- Precise tissue cutting in neurosurgery—pulsed electron avalanche knife (PEAK).
- Hydrogel sealants for watertight dural repairs.
- Self-assembling scaffolds (biopolymers) for nerve regeneration.

### **Major Assets**

#### *Key faculty*

*Primary:* Thomas Hamm, Irina Beloozerova, Alan Gibson, George Teitelbaum, Volker Sonntag, Mark Gerber, Mark Preul

*Contributing:* Neil Crawford

Centers and Core Laboratories

- Neurosurgery/Neuroanatomy Labs
- Complex Movements Laboratory

Vivarium: The Animal Care Program (ACP) provides support services for all investigators at the Barrow Neurological Institute/St. Joseph's Hospital and Medical Center. It provides a complete program of veterinary care including: daily assessment of animal health; and prevention, control, diagnosis and treatment of animal disease and injury. The current staff consists of the Director/Veterinarian, two

full-time Laboratory Animal Technicians (LAT), and one part-time LAT. The vivarium consists of nineteen animal rooms (2,245 sq. ft.), office space (130 sq. ft.), and support rooms, including a cage-washing facility, surgical suites, an intensive care facility, work room, storage room and necropsy facility (1,125 sq. ft.). Total space is 3,500 square feet.

#### *Collaborators*

ASU, NAU, UA, Oxford U, and Karolinska Institute

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#### **Research at Banner Health (Good Samaritan Hospital) Includes:**

- Effect of epidural spinal cord stimulation on activity of brain areas for walking (with ASU).
- Implanted neuroprostheses for standing after SCI (with Case Western Reserve University and ASU).
- Effect of epidural spinal cord stimulation on activity of brain areas for walking (with ASU).
- Spasticity of the arm in patients with stroke (with ASU, Kinetic Muscles).
- Neural control of microcirculation.
- All major equipment for modern neuroscience research, including a new Zeiss electron microscope; Olympus confocal microscope; digital image microscopy system; maldi-TOP mass spectrophotometer; capillary electrophoresis; multiple HPLC/EC systems; multiple tissue culture facilities; multiple ultra-, super-, and table-top centrifuges; multiple scintillation counters; multiple fluorescence, inverting, and regular light microscopes.
- 29 Ph.D. or M.D. staff.
- Basic science, neuropathology, and clinical research divisions.
- Contracts, research agreements, and consultantships with multiple pharma and biotech firms (Pfizer, Pharmacia, Novartis, Lilly, Elan).
- National Institute of Health and other grants
- Best brain bank in the world.

#### **Major Assets**

##### *Key Faculty*

*Primary:* Richard Herman

##### *Sun Health*

- New (last 10 years) research building of approximately 50,000 square feet, including an approximately 5,000 square foot vivarium.

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## ***Activity 2: Neuromorphic Engineering***

Neuromorphic engineering takes inspiration from the signal processing structures found in the nervous system and physical attributes of animals to design new electronic circuits, computers and robots capable of the amazing sensorimotor feats seen in nature. From neurons to behavior, the low power, robust, real time and adaptive nature of

biological systems serves as a proof of concept of the unique implementation developed by evolution. These principles have been applied to software models of sensorimotor processing, VLSI, implementation of neural circuits and robot design.

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### **Research at ASU includes:**

Center for Low Power Electronics Research has a component focused on analogue VLSI chips for compact, low power vision sensors and robotic control systems. Examples include real-time VLSI systems for processing visual motion, disparity, and egomotion. Center for Rehabilitation Neuroscience and Rehabilitation Engineering has designed neuromorphic neural networks of spinal circuitry. Examples include interfacing analog VLSI neuromorphic circuitry of the spinal cord with the living nervous system in prototypical animal models and utilizing neuromorphic neural network algorithms to control movement of paralyzed limbs. Integrating such sensors with on-chip control systems will allow highly capable, inexpensive autonomous robotics, and adaptive flexible control of living systems in real-time.

- Chaitali Chakrabarti
- Ranu Jung
- Jennie Si

### ***Supporting Labs***

- Center for Solid State Electronics Research
- Systems Science and Engineering Research Center
- Center for Low Power Electronics
- Center for Rehabilitation Neuroscience and Rehabilitation Engineering
- Brain Dynamics Lab
- Neural Networks Lab

### ***Faculty***

- Leon Iasemidis James Abbas

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### **Research at UA Includes:**

VLSI sensory systems are ideal for small, inexpensive autonomous robots, whether for underwater, flight, or land-

based applications. Because a sensory system can be most efficiently utilized if tightly coupled to a motor system,

laboratory projects currently concentrate on building VLSI systems, which incorporate both sensory and motor control systems. Projects also involve integration of these systems with robotic platforms of various types, from Lego robots to custom biomorphic robots. Such VLSI systems can not only be efficient engineering solutions for sensory/motor applications, but also serve as real-time hardware models of complex nonlinear neurobiological systems.

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**Research at NAU includes:**

- Biomimetic Neural Network Models for Visual Target Recognition
- Neuromuscular Control of Ballistic Movements

**Major Assets**

*Key Faculty*

Elizabeth Brauer

**Major Assets**

*Key Faculty*

Charles M. Higgins

*Centers and Core Labs*

Higgins Lab

*Supporting Labs*

- Optical Sciences, Materials Sciences and Physics Department

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Kiisaa Nishikawa

*Supporting Labs*

Electrical Engineering, Biological Sciences

## II. *Research Niche: Biomechanics and Rehabilitation Engineering*

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### MAJOR PROGRAMS, PRIMARY FACULTY AND KEY FACILITIES BY ACTIVITY AREAS

This area is comprised of two related parts: biomechanics and rehabilitation engineering. Biomechanics applies both fluid mechanics and transport phenomena to biological and medical issues. Rehabilitation engineering uses concepts in

biomechanics and other areas to develop devices to enhance the capabilities and improve the quality of life for individuals with physical and cognitive impairments.

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#### *Activity 1: Biomechanics*

Biomechanics includes the study of motion, material deformation, flow within the body, as well as devices, and transport phenomena in the body, such as transport of

chemical constituents across biological and synthetic media and membranes.

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#### **Research at ASU Includes:**

- Dynamic Musculoskeletal Models (2D and 3D computer simulations).
- Spinal biomechanics (with BNI).
- Mechanical and metabolic response to lower extremity loading in walking and running.
- Non-operative approaches to treating carpal tunnel syndrome.
- Use of composite materials in orthopedic implants.

#### **Major Assets**

##### *Key Faculty*

*Primary:* Gary Yamaguchi, Richard Hinrichs,

*Contributing:* Jiping He, Neil Crawford, Karl Hamson, James Koeneman, Juixiang Hu, Anshuman Razdan, James Abbas, Ranu Jung

##### *Centers and Core Labs*

The ESRI Biomechanics Lab has an AMTI Force Platform, Peak Motus Motion Analysis System, Electromyography (EMG) system, Force Measuring Pedals, Constant Power Bicycle and Ergometer Isokinetic Dynamometer.

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**Research Areas at UA Include:**

- Development of analytical-numerical finite element models (FEMs) and experimental models for soft tissues in order to study both normal and pathological response—cardiovascular focus.
- Orthopedic implants—modeling, design and testing.
- Thermo-chemical treatments and devices for stabilizing joints such as shoulders.
- Mechanics of blood flow in capillaries—effects of vessel wall properties.
- Mass transport in artery walls.
- Bone estrogen studies for osteoporosis.
- Biomechanics of animal locomotion.

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**Research at Barrow Neurological Institute include:**

- Mechanical behavior of the spine in normal condition and after injury or disease.
- Computer modeling of the spine.
- Novel spinal fixation systems.

Major Assets

**Major Assets***Key Faculty*

Bruce Simon, John Szivak, James Benjamin, Timothy Secomb, Ann Baldwin, Randi Weinstein

*Centers and Core Labs (need details)*

- Arizona Research Labs—Biomedical Engineering, Microcirculation
- New Institute for Biomedical Science and Biotechnology (building planned)
- BEST—The Bone Estrogen Strength Training Lab
- Tucson Orthopedic Research Lab

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**Activity 2: Motor Control**

Research in motor control investigates how movement is regulated and controlled via the nervous system in normal and pathological populations. Motor development and

learning studies how human movement is generated and evolves through out the lifespan.

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### Research at ASU Includes:

- Kinematic and kinetics of movement and posture (humans and animal models)
- Motor function after neurotrauma such as spinal cord injury or stroke
- Control of manipulation in normal and pathological populations
- Cortical control of reaching
- Motor function in Parkinson's disease, neurodegenerative disease and aging
- Motor deficits attributed to basal ganglia dysfunction and upper extremity coordination, particularly finger and hand posture, in reaching and prehensile movements
- Learning and development of bimanual coordination—cerebral asymmetries, specificity of learning, individual differences, and dynamic patterns.
- Investigations of perceptual motor behavior in individuals with Down Syndrome

#### Major Assets

#### *Key Faculty*

George Stelmach, Marco Santello, Jiping He, Ranu Jung, James Abbas, Stephen Helms-Tillery, Gary Yamaguchi, Shannon Robertson

#### *Centers and Core Labs*

- The Motor Development and Learning Lab investigates the learning and development of bimanual coordination.

Timing and coordination in perceptual-motor skills are measured in normal developing children, individuals with Down syndrome, and adults to investigate cerebral asymmetries, specificity of learning, individual differences, and dynamic patterns.

- The Neurootor Control Lab investigates control of locomotion and posture in various populations such as people with spinal cord injury, cerebral palsy, and other pathological conditions. The laboratory includes facilities for kinematic, kinetic and motor analysis.
- The Center for Rehabilitation Neuroscience and Rehabilitation Engineering within AZBiodesign Institute and Harrington Department of Bioengineering—investigates motor control function in normal and pathological conditions with a special emphasis on control of posture and locomotion after neurotrauma. The Center includes facilities for kinematic, kinetic and sensorimotor analysis in both human and small animal (rodent) models.
- The Motor Control Lab investigates control of manipulation in normal and pathological conditions. The laboratory has facilities for measuring kinematics of the hand and arm as well as forces applied by each finger during grasp and manipulation tasks.

#### *Supporting Laboratories*

Other labs that are located in Harrington Department—Motor Control and Rehabilitation (ECB 144,148) and Physiology (SCOB 366)

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**Research at UA Includes:**

- The neurobiology of motor control.
- Segmental motor-control system and its components: motor units, muscle receptors, and spinal neurons and their synaptic connections. The relation between the organization of this neural system and the accomplishment of motor activities like locomotion.

**Major Assets***Key Faculty*

- Douglas Stuart, Thomas Hamm (BNI)
- Centers and Core Labs
- Motor Control Group

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**Research at Barrow Neurological Institute Includes:**

- Involvement of motor cortex (in brain stem and spinal cord) in locomotion and posture.
- Spinal motor function.

*Centers and Core Labs*

Motor Cortex Lab

**Major Assets***Key Faculty*

Irina Beloozerova, Thomas Hamm

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**Activity 3: Rehabilitation Engineering**

Rehabilitation engineering uses concepts in biomechanics and other areas to develop devices to enhance the capabilities and improve the quality of life for individuals with physical

and cognitive impairments. They are involved in prosthetics, the development of the home and/or workplace, and transportation modifications.

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**Research at ASU Includes:**

- Assistive devices to enhance functional capabilities
- Neural prostheses to restore posture control and locomotor function
- Therapy to improve neuromotor control
- Exercise technology for improved health and wellness
- Diagnostic systems for neuropathy

## Major Assets

### Key Faculty

*Primary:* James Abbas, Ranu Jung, Gary Yamaguchi, Richard Herman, Jiping He

*Contributing:* Polemnia Amazeen, Edward Castaneda, Michael Dorman, Sandeep Gupta, Kim Huey, Donald Herring, Leon Issamedis, Jitendran Muthuswamy, Alyssa Panitch, Stephen Phillips, Marco Santanello, Donald Sinex, Thomas Sugar, James Sweeney, Wayne Willis

### Centers and Core Labs

- **The Center for Rehabilitation Neuroscience and Rehabilitation Engineering** within AZBiodesign Institute and Harrington Department of Bioengineering – develops new technology (such as neural prostheses, novel neuromotor therapy and exercise technology) for applications in rehabilitation and investigates the effect of neurotrauma on neuromotor and cardiorespiratory function. The Center has complementary human and small animal facilities for neuromotor, cardiorespiratory and metabolic assessment. (R Jung has three labs, SCOB 290,294 and 306; and J. Abbas has 4400sq.ft lab space in Haydens Ferry Bdg.)
- **The Motor Control Laboratory** – develops rehabilitation technology (such as orthoses, prostheses,

assistive technology and electrical stimulation devices). The laboratory has facilities for kinematic, kinetic and motor assessment. ( ECB 144,148,Yamaguchi)

- **Program for Undergraduate Design Projects in Rehabilitation and Aids to the Disabled** – provides infrastructure and support of numerous design projects for undergraduate students in bioengineering. This program, which has been funded by NSF for more than 13 years, involves a number of ASU faculty and collaborations with clinicians from several Phoenix-area medical centers.

### Key Collaborations

- A number of researchers at Banner Good Samaritan Medical Center:
  - Dept. of Clinical Neurobiology and Bioengineering, which provides complementary neuromotor and neurobiological facilities in a hospital environment (Richard Herman, MD, James Abbas, PhD)
  - Department of Neurosurgery (Dan Lieberman, MD)
  - Movement Disorders Clinic (S. Mahant, MD)
  - PET Center (Eric Rieman, MD)
- Barrows Neurological Institute (Tom Hamm, PhD; Nancy Cutter, MD)

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### Research at Banner Health Includes:

- Control of standing posture with electrical stimulation.
- Exercise science and neurorehabilitation.
- Neuromotor assessment.
- Rehabilitation robotics—use of intelligent machines to assist in delivering rehabilitation therapy.

## Major Assets

### Key Faculty

James Abbas

### Partners

ASU, UA, NAU, Case Western Reserve, private industry

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## Activity 4: Kinesiology

This area investigates a wide range of topics concerning human movement, physical activity, and exercise. These include the study of different age cohorts, levels of health, levels of ability and fitness, levels and types of training, physical and emotional stresses, and genetic backgrounds.

Exercise physiology studies the physiologic systems (cardiovascular, respiratory, muscular, endocrine, metabolic) under conditions of stress, particularly exercise stress. Both acute exercise responses and chronic adaptations resulting from exercise training are considered in relation to health and performance.

Sport and Exercise Psychology examines the relationship between psychological constructs and physical activity, and the influence of participation in physical activity on psychological phenomenon.

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## Research at ASU Includes:

- How dietary nutrients influence resting and exercise metabolism, with a special emphasis on diabetes.
- Subcellular systems involved in the provision and regulation of energy transfer during exercise.
- Interrelationships of exercise and training with stress, hormones, neurotransmitters, and the immune system.
- Influence of physical activity, fitness, and particular sport practices on psychophysiological mechanisms and cognitive functioning.
- Effect of psychological skills for performance enhancement.
- Motivational aspects of physical activity across the lifespan and the effects of exercise on mental health.

## Major Assets

### Key Faculty

Wayne Willis, Kathleen Matt, Don Morgan, Kim Huey, Colleen Brophy, Jennifer Etnier, Daniel Landers, Darwyn Linder, Darren Treasure

### Centers and Core Labs

- **The Exercise Metabolism Lab** focuses on how dietary nutrients influence resting and exercise metabolism, with a special emphasis on diabetes; the Exercise Biochemistry Lab examines subcellular systems involved in the provision and regulation of energy transfer during exercise; and the Exercise Endocrinology Lab studies interrelationships of exercise and training with stress, hormones, neurotransmitters, and the immune system.

- **The Sport Psychology Laboratory** in the Exercise and Sport Research Institute consists of five spacious rooms containing behavioral assessment tools, questionnaire instruments, and psychophysiological equipment capable

of measuring the majority of behaviors that exist in sport and exercise settings.

*Key Collaborators*

Barrow Neurological Institute

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**Research at NAU includes:**

- Exercise for “exercise intolerant” individuals—cardiac and pulmonary diseases

*Centers and Core Labs*

Physiology Department—Physical therapy

**Major Assets**

*Key Faculty*

Stan Linstedt (Biological Sciences)

### **III. Research Niche: Regenerative Medicine**

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#### **MAJOR PROGRAMS, PRIMARY FACULTY AND KEY FACILITIES BY ACTIVITY AREAS**

Regenerative medicine is an emerging field that approaches the repair or replacement of tissues and organs impaired by disease, trauma or congenital abnormalities by incorporating the use of cells, genes or other biological building blocks

along with bioengineered materials and technologies. The scope of this field includes tissue engineering, cellular therapies, biosurgery and artificial and biohybrid organ devices.

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#### ***Activity 1: Tissue Engineering***

Tissue engineering can be described at its most basic level as combining cells with scaffolding materials to generate functional tissue constructs.

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#### **Research Areas at UA Include:**

- Tissue modeling (e.g., swelling of soft tissue).
- In vitro and in vivo models of tissue responses to biomaterials and devices.
- Tissue engineered glaucoma shunts.
- Soft tissue augmentation devices (ePTFE polymer).
- Specificity in endothelial cell calcium signaling.
- Strategies for manipulating the vasculature as a component in engineering of native and artificial tissues (see also cardiovascular engineering).
- Tissue engineered constructs for repair of Ischemic tissue.

- Wound healing.
- Tissue preservation technologies-freeze drying, vitrification, etc.

#### **Major Assets**

#### ***Key Faculty***

*Primary:* Stuart Williams, Bruce Simon, James Hoying, Robert Snyder, Scott Berman (Biomedical Engineering)

John Szivek (Orthopedic Surgery)

Mark Riley (Ag and Biosystems Engineering)

Dan Stamer (Ophthalmology)

Rob Noecker (Ophthalmology)

Doug Larson (Cardiothoracic Surgery)

Judy Ulreich (Surgery)

Scott Boitano (Respiratory Sciences)

Tim Secomb (Physiology)

### *Centers and Core Labs*

The formal space assignment to Biomedical Engineering (BME) is approximately 7,000 net square feet (nsf). This total will increase approximately 800 nsf with the completion of the animal imaging and animal instrumentation facilities in 2003. There are no finite commitments to BME for space in the planned Medical Research Building and the IBSB building space has already been committed to other programs.

Arizona Research Laboratories: Division of Biotechnology has four core facilities—Lab for Molecular and Systematic Evolution, Fluorescence Activated Cell Sorting Facility, Imaging and Histology Facility, and Biotechnology Computing Facility.

### *Biomedical Engineering Core Facilities and Labs:*

Two core facilities used across the three areas:

- Bioimaging involves predominantly space assigned in support of MRI activities. This equals ~ 800 nsf.
- Animal Care and space assigned for Animal Husbandry, Surgery and Imaging.

---

### **Research Areas at ASU Include:**

- Soft tissue repair and replacement
- Structural protein, collagen, as a multifunctional biomaterial

One dedicated fluoroscopy suite with a second being built. Two dedicated survival surgery operating rooms with associated prep and recovery areas. This surgery facility (including prep and recovery) is ~ 1,100 nsf.

Four core labs—tissue culture facility, a morphology/histology suite, an image analysis suite, and an image acquisition and output system. The tissue culture facility includes equipment for biomaterial scaffold synthesis, cell isolation from tissue samples, bioreactor design and construction, bioreactor facilities, cell analysis, media prep, cell freezing and storage. This facility serves as a primary resource for many faculty and equals ~ 500 nsf.

Williams' Research Labs—2,000 sq. ft.; resources for cellular, biochemical and physiological studies; includes an intra vital microscopy suite.

The Biomedical Engineering Program, in a collaboration with Pediatrics, established a genomics and proteomics facility to support array work related to regenerative medicine and biomaterials. There are now over 30 faculty using this facility. The space assigned totals ~ 400 nsf and is assigned to one investigator in Pediatrics who is a developmental biologist.

### *Supporting Labs*

- Aerospace and mechanical engineering lab has a 3,500 square foot space devoted to biomedical engineering activities.

- Control of the Cell / Material Interface—cell adhesion studies

- New methods for grafting biologically active molecules to biomaterials (polymer-based)
- Development of optimum scaffolding materials, cell lines, media and bioreactor design
- Signal transduction networks in osteoblasts

### Major Assets

#### Key Faculty

*Primary:* Eric Gilbeau, Stephen Massia, Vincent Pizziconi, Christine Pauken, Alyssa Panitch, Colleen Brophy, Lokesh Joshi

*Contributing:* James Ryaby, Brent Vernon

### Centers and Core Labs

Three core research labs support Molecular, Cell and Tissue Bioengineering—bioimaging, cell culture and bioanalytical (sixth floor of Goldwater Science and Engineering Building)

The Pizziconi labs, SCOB387,388,389, for tissue engineering/advanced biomaterials.

#### Supporting Labs

The Massia, Panitch and Vernon research labs for cell cultures, protein and tissue engineering are on the same floor in GWC. Total square feet is 4,874.

Surgical Suite, SCOB 392

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## Activity 2: Cardiovascular Devices

This application area refers to all materials and devices inserted in the body to replace systems used for carrying or containing blood.

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### Research Areas at UA Include:

- Artificial heart and valves.
- Vascular wall mechanics.
- Tissue engineered vascular implants.
- Vascular grafts—utilization of endothelial cells to line PTFE vascular grafts to reduce blood clotting complications in grafts.
- Scaffold-based three-dimensional human fibroblast cultures to provides a structural matrix that supports angiogenesis in infarcted heart tissue.

### Major Assets

#### Key Faculty

*Primary:* Stuart Williams, Francisco Arabia, Jack Copeland, Richard Donnerstein, Scott Klewer, James Hoying,

*Contributing:* Joseph Mills, David Arzouman, Scott Berman, Bruce Simon

### *Centers and Core Labs*

Arizona Research Laboratories: Division of Biotechnology has four core facilities—Lab for Molecular and Systematic Evolution, Fluorescence Activated Cell Sorting Facility, Imaging and Histology Facility, and Biotechnology Computing Facility.

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### **Research Areas at ASU Include:**

- Biosynthesis of self-assembling protein gels for arterial reconstruction
- Studies of blood vessel wall function to enhance function of endogenous vascular conduits and engineer biocompatible prosthetic graft materials
- Optimization of HSP20 analogues for use as adjuvants for vascular prostheses

### **Major Assets**

#### *Key Faculty*

*Primary:* Alyssa Panitch, Colleen Brophy

Biomedical Engineering Core Facilities: Four core labs—tissue culture facility, a morphology/histology suite, an image analysis suite, and an image acquisition and output system.

#### *Supporting Labs*

Sarver Heart Center (<http://www.heart.arizona.edu/>) a 30,000-square foot addition to the original College of Medicine building. Now equipped with new state-of-the-art research laboratories.

*Contributing:* Tedd Brandon, Lokesh Joshi

#### *Centers and Core Labs*

Harrington Department of Bioengineering  
(<http://www.eas.asu.edu/~bme/facility/facilityrest/facility02.htm>)

Includes Neuromuscular and Cardiovascular Control Lab, SCOB 291; Protein and Tissue Engineering Lab, GWC 643; MCTB Cell Core Facility, GWC 631, 627; Surgical Suite, SCOB 392.

## IV. Research Niche: Biomaterials

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### MAJOR PROGRAMS, PRIMARY FACULTY AND KEY FACILITIES BY ACTIVITY AREAS

Biomaterials are defined as all those materials used in medical devices in which contact with the tissues of the patient is an important and guiding feature of their use and performance. They include a range of metals and alloys, glasses and ceramics, natural synthetics, polymers, biomimetics, composites and natural or tissue-derived materials, including combinations of synthetic materials and

living tissue components. Research covers basic science and engineering aspects of biomaterials, including their mechanical, physical, chemical and biological properties, relevant design and production characteristics of devices constructed of these materials, and their clinical performance. Applications of biomaterials include implantable medical devices, tissue engineering and drug delivery systems.

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#### *Activity 1: Biopolymers*

This application area focuses on mimicking biological processes to develop classes of polymer-based materials for use in medical or other applications.

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#### **Research at ASU Includes:**

- Hydrogel development and synthesis (also included in surfaces).
- Temperature and pH responsive polymer development for drug delivery, tissue reconstruction and tissue engineering.
- Biomimetic drug delivery systems

#### **Major Assets**

#### *Key Faculty*

Steve Massia, Alyssa Panitch, Brent Vernon

#### *Centers and Core Labs*

**Harrington BME** – Core Research Labs ( GWC 681, 691) plus proposed Biomaterials lab for undergraduate training would include facilities for bulk material characterization, surface characterization, biocompatibility testing and materials synthesis and processing.

**Arizona Biodesign Institute** – Center for Bio-Optical Nanotechnology (Neil Woodbury); Center for Applied NanoBioscience (Frederic Zenhausen). Note: Current situation is that these groups are using existing labs in

Chemistry, Biochemistry, Materials Departments. A new building for the Institute is scheduled.

### *Supporting Labs*

Department of Chemistry and Biochemistry

Chemical and Materials Engineering Department

High Resolution Microstructure and Chemical Analysis: Materials Science Electron Microscopy Laboratory (MSEML) Facilities, Center for High Resolution Electron Microscopy (CHREM) Facilities, Scanning Probe Microscopy (SPM), and Optical Microscopy.

### *Computing, Consultation, and Analysis:*

High-speed computer graphics for physical modeling and visualization

### *Control Systems Engineering Lab:*

The Control Systems Engineering Laboratory (CSEL) at Arizona State University is committed to broadly-applicable research in the areas of system identification and advanced process control.

The laboratory facilities include a modern Honeywell Total Plant Solution (TPS) System, featuring six Universal

Stations, three Global User Stations, one Application Node, one Application Module, three Process Managers, one Network Interface Module, and one History Module.

### *Integrated Mechanical Testing Lab (IMT):*

The Integrated Mechanical Testing Lab provides closed loop uniaxial testing systems with various load testing capacities, testing equipment for fracture, creep, fatigue and cyclic loading, and a comprehensive characterization facility with light microscopy, X-ray diffraction, scanning and transmission electron microscopy.

### *Additional Facility Highlights:*

Transmission electron microscopes (high-resolution atomic imaging, diffraction patterns, magnetic domain and interface imaging) Ion Beam Tandem Accelerator (Rutherford backscattering for thin film depth profiling, chemical analysis, channeling analysis, and particle induced x-ray emission for elemental identification).

Electronic materials synthesis equipment (chemical vapor deposition with plasma and magnetic field enhancement, sol-gel spin-coating synthesis and processing facilities and molecular beam epitaxy tools for compound semiconductor and optoelectronics research).

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### **Research at UA Includes:**

- Formation of composites by the precipitation of reinforcing particles within the polymer structure.
- Diffusion and permeability in polymers.
- Embedding both piezoelectric and optical sensors, for stress and chemical changes, into polymer composites.
- Bio-mimetic reinforcement of hydrogels by mineralization and on gels with embedded electrodes as artificial muscles.
- Freeforming structures with controlled porosity for bone implants.

- Study, synthesis and modification of polymers, surfactants and surfaces for the development of metal-affinity separation techniques and development of selective adsorptive surfaces.

#### Major Assets

#### *Key Faculty*

*Primary:* Stuart Williams, Paul Calvert, Roberto Guzman

*Contributing:* Srinu Rhagavan (Material Sciences), Scott Savaadra (Chemistry)

#### *Centers and Core Labs*

Biomedical Engineering Core Facilities in College of Medicine and College of Engineering, Aerospace and Mechanical Engineering Department.

- Williams Lab Includes biomaterials evaluation laboratory that includes light microscopy and electron microscopy. Space is ~ 500 nsf and services >20 faculty.
- Arizona Research Laboratories—Division of Biotechnology
- The space formally assigned to support bioengineering on the engineering side of campus includes a laser laboratory (1,500 nsf) supervised by Jennifer Barton (BME) and space assigned to BME in the Aerospace and Mechanical Engineering (AME) building. This AME space is 2,000 nsf and is essentially a shell space that will undergo buildout to support two new BME faculty.

#### *Supporting Labs*

- Materials Science
- Chemistry
- Physics

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#### **Research at Barrow Neurological Institute includes:**

- Dural Substitutes.
- Fibrin gels for nerve regeneration.
- Testing and evaluation.

#### **Major Assets**

#### *Key Faculty*

#### *Centers and Core Labs*

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#### ***Activity 2: Biosurfaces and Surface Coatings***

This area of research is focused on the design and fabrication of degradable and non-degradable materials with novel surface characteristics, which make them compatible with the body.

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**Research at ASU Includes:**

- Hydrogels based on novel dextran chemistries for absorbable drug delivery vehicles or graft materials.
- Cell-membrane interactions with biomaterial implants.
- Biomimetic basement membrane-like coatings for implants.
- Sol-gel derived and ion-beam modified bioresponsive hydroxyapatite coatings for engineered tissue attachment.

**Major Assets***Key Faculty*

*Primary:* Steve Massia, Michael Caplan, Vincent Pizziconi

*Contributing:* Terry Alford, James Mayer (Chemical and Materials Engineering)

*Centers and Core Labs/Supporting Labs* (see page one for description)

Harrington BME

Arizona Biodesign Institute

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**Research at UA Includes:**

Design, modeling and fabrication of materials based on:

- Non-degradable expanded polytetrafluoroethylene
- Degradable hydrogels (with ASU)
- Dual-component materials using both degradable and non-degradable components.

**Major Assets***Key Faculty*

Stuart Williams

*Centers and Core Labs/Supporting Labs* (see page one and two for description)

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**Research at NAU Includes:**

- Biofilms for implanted medical devices.
- Surface Properties of extended Polytetrafluoroethylene (W.L. Gore Collaborations)

## Major Assets

### Key Faculty

Jeff Leid (Biology)

Cynthia Hartzell (Chemistry)

### Collaborators

J. W. Costerton, Mark Shitliff, Samuel Silverstein, Matt Parsek, Ruth Cutright, Ace Baty

### Centers and Core Labs

- Biology Department
- Chemistry Department (NMR)
- Partners
- Center for Biofilm Engineering
- Genome Therapeutics
- WL Gore and Associates

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## Activity 3: Biomolecular Arrays

This application area addresses the self-assembling properties of biomolecules, which can be used in tissue engineering, biosensors, etc.

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### Research at ASU Includes:

- Biosynthesis of self-assembling proteins with controlled mechanical and degradative properties.

## Major Assets

### Key Faculty

Alyssa Panitch

*Centers and Core Labs/Supporting Labs* (see page one for description)

- Harrington BME
- Arizona Biodesign Institute

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### Research at UA Includes:

- Bacterial macrofibers utilizing *Bacillus subtilis* as the experimental organism—understanding the origin of forces produced by cell growth, their magnitude and the role they play in driving the self-assembly of a mature macrofiber.

## Major Assets

### Key Faculty

Neil Mendelson

*Centers and Core Labs/Supporting Labs* (see page 3)

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**Research Areas at NAU include:**

- Structure/function/application studies of multifunctional self-assembling monolayers on nanoparticles and silicon substrates for surface functionalization of biosensors and in vitro diagnostic devices

TimVail (Chemistry)

Jani Ingram (Chemistry)

*Centers and Core Labs*

None

**Major Assets**

Key Faculty

## V. *Research Niche: Biosensors and Actuators*

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### MAJOR PROGRAMS, PRIMARY FACULTY AND KEY FACILITIES BY ACTIVITY AREAS

Biosensors make accurate measurements in the environment or in living systems, which are critical to diagnosing adverse

conditions, making health care decisions, or for controlling therapeutic devices.

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#### *Activity 1: Health Diagnostics*

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##### **Research at ASU Includes:**

- Diabetic monitoring by glucose sensors for potentially implantable applications (Guilbeau, Towe, Pizziconi)
- Intensive Care monitoring by blood intravascular pH, oxygen, and CO<sub>2</sub> sensors (Towe)
- Cardiac diagnostics by monitoring blood troponin (cardiac enzyme) biochemistry (Beaudoin, Booksh)
- Immunosensors of high sensitivity for health care diagnostics (Garcia, Towe, Matt, Booksh, Hayes)
- Molecular interactions that control the cost of clinical diagnostics (e.g., silver ion immobilization chemistry - Garcia)
- Microactuators and microsensors for Neurochemistry and drug delivery (Muthuswamy)
- Implantable device researches that concern sensor biocompatibility and tissue interface (Massia, Panitch, Kaplan)
- Cardiac bioelectricity monitoring with electrical defibrillation (Sweeney)
- Cardiac bioelectricity study using fluorescent optical methods to determine the pattern of bioelectric activity of the beating heart (Towe, Sweeney)
- Blood and tissue fluid single-molecule sensing (Pizziconi, Woodbury, Vermass, others)
- Blood diagnostics through the development of lab-chip microfluidics (Pizziconi, Hayes)
- Thermoelectric gas sensors for diagnostic breath analysis (Guilbeau, Towe, Pizziconi)
- Stress monitoring by immunosensors for cortisol, and stress hormones (Matt, Garcia, Hayes, Towe)
- Implantable sensors for chronic health monitoring
- Sensors for biotechnological applications that include the development of custom-made proteins (Sierks), and techniques for placing diagnostic sensors within the body by way of biocompatible coatings (Kaplan, Massia)
- Neural sensors and signal processing techniques for diagnosis of incipient epileptic seizure (Jassemidis)

### **Major Assets**

A large number of faculty members doing health diagnostic-related research with a long history of funding.

#### *Key Faculty*

##### *Key BME Faculty*

*Primary:* Towe, Garcia, Kaplan, Muthuswamy, He, Panitch, Massia, Pizziconi, Jassemidis, Guilbeau

##### *Interdepartmental Contributing faculty*

Booksh (Chemistry), Hayes (Chemistry), Lindsay (Physics), Gust (Chemistry), Woodbury (Chemistry), Sierks (CHE), Park (CHE), Kozicki (EE), Kiaei (EE)

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### **Research at NAU Includes:**

- Micropatterned Protein Biosensor Arrays

### **Major Assets**

#### *Key Faculty*

Timothy Vail, Edwin Lewis

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### **Research at TGen Includes:**

- Genetic basis of human disease for diseases including but not limited to cancer, diabetes, and neurodegenerative disorders
- Development of computational tools and algorithms for determination of disease specific gene expression “signatures”

### *Centers and Core Labs*

- Bioengineering Department Laboratories (e.g., SCOB 286, Bioinstrumentation, Towe)
- Bioengineering Cell Culture Laboratories ( e.g., GWC 627,631)
- ASU Animal Care and Research Facilities
- Center for Photosynthesis

### *Supporting Labs*

- Center for Solid State Electronics Research - photolithography and chip manufacture
- Center for Materials Science Research - composite material for implants
- Chemistry, Biochemistry Labs

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### *Centers and Core Labs*

Chemistry Department

## Major Assets

### Key Faculty

#### Primary:

- Michael Berens – Vice President Research; brain tumor research
- Michael Bittner – Program Director, Molecular Therapeutics and Target Validation
- John Carpten (summer 2003) – Program Director, Genetic Basis of Human Disease; Prostate Cancer Research Section
- Dietrich Stephan – Program Director, Neurogenomics
- Ed Suh – Chief Information Officer; High Throughput Computing
- Jeff Touchman – Director, DNA Sequencing; pathogen genomics research
- Jeffrey Trent – President, Chief Scientific Officer; melanoma research

- *Contributing:*
- David Duggan – Microarray Unit
- Galen Hotstetter – Tissue Microarray Unit
- Pam Pollock – Melanoma Research
- Johanna Wolford – Diabetes Research

### Centers and Core Laboratories

- DNA Sequencing
- DNA Microarrays
- Tissue Microarrays
- Small interfering RNAs

### Key Collaborations

ASU, Banner Health, International Genomics Consortium, Maricopa County Hospital, Mayo Hospital, NAU, St. Joseph's/Barrow Neurological Institute, Salt River Pima – Maricopa Indian Community, Sun Health, UA, commercial partners

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## Activity 2: Environmental Measurements

This application area addresses the use of biosensors to detect species in food, air, water or soil that might have health

consequences. Homeland security is one new emerging market need for these types of instruments.

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### Research at UA Includes:

- Molecular biosensors for environmental pollutants such as dioxin, based on green fluorescent protein (GFP) mutants.
- Cell-based approaches for detecting and characterizing toxic agents in the air and other media.

### Major Assets

#### Key Faculty

*Primary:* Indraneel Ghosh, Mark Riley, Joe Simmons

### *Centers and Core Labs*

- Department of Chemistry

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### **Research at ASU Includes:**

- Biodefense sensors for environmental monitoring, and homeland security (Towe, Booksh, Lindsay, Zenhausern, Hayes, Woodbury)
- Biosensors for viruses, bacteria, dispersed biologicals (Booksh, Park, Garcia)
- Heavy metal sensors, single molecule high-sensitivity sensors, nanoscale detection techniques (Pizziconi, Woodbury, Gust, other Chemistry faculty)
- Sensors for multiple analytes using a battery of environmental analyses employing a field portable, excitation-emission matrix (EEM) fluorometer.
- Environmental toxin, field analysis by compact highly sensitive fiber-optic surface plasmon resonance sensors (Booksh, Lee)
- Bioanalytical chemical probes, ultramicro sampling techniques, microseparations and novel sensitive detection (Garcia, Pizziconi, Towe, Booksh)
- Space Bioreporters for monitoring air-borne and water hazards on the International Space Station and potentially for extraterrestrial environments, biodefense, homeland security, and general environmental monitoring. (Towe, Stout)
- Environmental toxin monitoring technique development by sample analysis and testing (Abbazadegan)
- Environmental monitoring by “living cell” microfluidic “canaries” (Towe)

- Department of Materials Science
- Department of Agriculture and Biosystems Engineering

- Thermoelectric gas sensors for toxic chemical detection, environmental air-borne hazard monitoring, biodefense and homeland security (Guilbeau, Towe, Pizziconi)
- Lab-chip microfluidic autoanalysis systems for field monitoring (Zenhausern, Pizziconi, Hayes, Towe)
- Environmental DNA bacterial identifications using PCR technologies (Zenhausern)

### **Major Assets**

Active collaborations between departments including Microbiology, Civil Engineering, Chemistry and Biochemistry, Bioengineering

### *Key Faculty*

Towe, Garcia, Zenhausern, Lindsay, Booksh, Hayes, Guilbeau, Pizziconi

### *Centers and Core Labs*

- Center for Bio-Optical Nanotechnology (Woodbury)
- Center for Applied NanoBioscience ( Zenhausern)—collaboration with Motorola
- Bioengineering Dept. Labs
- ASU Animal Care and Research Facilities
- Center for Solid State Research - photolithography and chip manufacture

- Center for Materials Research - composite material for implants
- Center for Electron Microscopy
- Bioengineering Cell Culture Laboratories

- Analytical Chemistry Labs
- Center for Bio-Optical Nanotechnology (Woodbury)
- Center for Applied NanoBioscience ( Zenhausen)—collaboration with Motorola

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### Research at NAU Includes:

- Paramagnetic Nanoparticle Immunoassay for Food Pathogen Detection.
- Biodefense diagnostics (e.g., anthrax).
- Bioanalytical assay development for detection of endocrine-disrupting compounds in wastewater

- Electron Microprobe Lab  
<http://jan.ucc.nau.edu/~wittke/Microprobe/Probe.html>
- Electron Microscope  
[http://www4.nau.edu/bilby/electron\\_microscope.html](http://www4.nau.edu/bilby/electron_microscope.html)
- Merriam-Powell Center for Environmental Research:  
<http://www.mpcer.nau.edu>

### Major Assets

#### *Key Faculty*

Timothy Vail, Paul Flikkema, George Koch, Paul Keim, Cathy Propper, Amy Whipple, Paul Trotta

#### *Centers and Core Labs*

- Chemistry Department
- Biological Science Department
- Electrical Engineering Department

#### *Supporting Labs*

- Bilby Research Center  
<http://www4.nau.edu/bilby.html>
- Developmental Machine Shop  
<http://www4.nau.edu/bilby/instrumental.html>
- Analytical Chemistry Center  
[http://www4.nau.edu/bilby/chem\\_lab.html](http://www4.nau.edu/bilby/chem_lab.html)

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### ***Activity 3: Bio-MEMS***

This application area includes developments in both nanoscale and microscale systems and their convergence in devices that incorporate both nano-technology (novel materials, structures, and surfaces) and micro-technology

(microscopic flow channels for heat and mass transfer) in order to perform energy, chemical, and biological processes at dramatically reduced size, lower cost, higher efficiency, and with precision control.

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#### **Research at UA Includes:**

- Bio-based microelectromechanical systems (MEMs) and nanoelectromechanical systems (NEMs), focusing on biomolecule-surface interactions.
- Tactile Communication Micro Array with microscopic thermal actuators.
- Electroactive polymer actuators.
- Electrostatic MEMs for optical micro-assembly.
- Lab-on-a-chip MEMs-electrofluidics.

#### **Major Assets**

##### *Key Faculty*

*Primary:* Joel Cuello, Eniko T. Enikov

#### ***Centers and Core Labs***

- Advanced Microsystems Lab (Enikov)  
<http://www.ame.arizona.edu/memslab/>
- Biosystems Engineering Labs
- Arizona Research Labs  
<http://www.arl.arizona.edu/>

#### ***Supporting Labs***

- The Arizona Materials Labs  
<http://www.mse.arizona.edu/equip.html>
- Center for Electronic Packaging Research  
<http://www.ece.arizona.edu/~cepr/>
- Center for Low Power Electronics  
<http://clpe.ece.arizona.edu/>

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#### **Research at ASU Includes:**

- MEMs for single neuronal tracking, communication, neurochemistry and drug delivery (Muthuswamy)
- MEMS for neural prosthesis in brain and spine for prosthetics and man-machine interfaces (He)
- Micro-telemetry devices that transmit data from the brain. (He)
- Integrated “ionics” for next generation integrated circuits and systems

- Development of nanoscale transistors and integration with quantum devices
- Biophotonic molecular electronic devices
- Biological tools based on nano- and microscale technologies (Eg the development of micro and nanoscale lab-on-a-chip and electronic chip arrays for the detection and analysis of biological fluids)”
- Microminiature implanted piezoelectric nerve and neural stimulators (Towe)
- Microminiature nerve cuff electrode interfaces (Sweeney)
- Micro – thermopile detectors (Guilbeau, Towe, Pizziconi)

### Major Assets

#### Key Faculty

Primary: Muthuswamy, He, Ferry, Thorton, Michael Kozicki, Devens Gust, Neal Woodbury, Zenhausen, Chia-Fu Chou, Tom Picraux, Guilbeau, Pizziconi

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### Research at NAU Includes:

MEMS biosensors for environment

### Major Assets

#### Key Faculty

Tim Porter

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### Research at TGen Includes:

Lab-on-a-chip/diagnostic applications development (collaboration with Fred Zenhausen, ASU)

*Contributing:* Kiaie, Towe

#### Centers and Core Labs

- Chemistry and Biochemistry <http://chemistry.asu.edu/>
- Chemical and Material Engineering
- Arizona Biodesign Institute  
[http://www.asu.edu/asunews/research/AzBio-new\\_112202.html](http://www.asu.edu/asunews/research/AzBio-new_112202.html) includes:
  - Center for Bio-Optical Nanotechnology (Woodbury)
  - Center for Applied NanoBioscience (Zenhausen)—collaboration with Motorola

#### Supporting Labs

Center for Solid State Electronics Research—Nanostructures Group

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#### Centers and Core Labs

Physics Department

## Major Assets

### *Key Faculty*

Michael Bittner - Program Director, Molecular Therapeutics and Target Validation

### *Contributing Faculty*

- Michael Berens – Vice President Research; brain tumor research
- John Carpten – Program Director, Genetic Basis of Human Disease; Prostate Cancer Research Section
- David Duggan – Microarray Unit
- Galen Hotstetter – Tissue Microarray Unit
- Pam Pollock – Melanoma Research
- Dietrich Stephan – Program Director, Neurogenomics
- Ed Suh – Chief Information Officer; High Throughput Computing
- Jeff Touchman – Director, DNA Sequencing; pathogen genomics research

- Jeffrey Trent – President, Chief Scientific Officer; melanoma research
- Johanna Wolford – Diabetes Research

### *Centers and Core Laboratories*

- DNA Sequencing
- DNA Microarrays
- Tissue Microarrays
- Small interfering RNAs

### *Key Collaborations*

ASU, Banner Health, International Genomics Consortium, Maricopa County Hospital, Mayo Hospital, NAU, St. Joseph's/Barrow Neurological Institute, Salt River Pima – Maricopa Indian Community, Sun Health, UA, commercial partners

## VI. Research Niche: Bioimaging

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### MAJOR PROGRAMS, PRIMARY FACULTY AND KEY FACILITIES BY ACTIVITY AREAS

Bioimaging involves the application of image science to a broad range of biological problems, from single cells to the entire human body. Areas of emphasis include magnetic resonance imaging, magnetic resonance spectroscopy,

gamma-ray imaging, x-ray imaging, optical spectroscopy, optical imaging, image processing and image quality enhancement.

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#### *Activity 1: Magnetic Resonance Imaging and Spectroscopy*

Magnetic Resonance Imaging (MRI) is a process to identify tissue abnormalities (It is essentially the same thing as NMR). The basis of MRI is that hydrogens in water behave differently in different tissues. By placing the object to be

imaged between the poles of a large electromagnet, the variations of a proton's magnetic resonance behavior from normal patterns may be detected and used to make a diagnosis.

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#### **Research at UA Includes:**

- Imaging cells in bioreactor systems.
- Imaging tumors in small animal cancer models (transgenic mice).
- Contrast-enhanced MRI to image renal and tumor pH.
- MRI of brain function (fMRI) in human subjects.
- Diffusion-weighted MRI.
- MRI/MRS methods to non-invasively quantify the extent and location of Niemann-Pick Type C disease.
- Quantitative Assessment of Atherosclerosis via MRI.
- Cardiac MR of Right Ventricular Dysplasia.

- Mechanisms of Diffusion MRI with Chemotherapy.
- High Resolution MRI of the Arterial Wall.

#### **Major Assets**

#### *Key Faculty*

*Primary:* Arthur Gmitro, Maria Altbach, Jean-Philippe Galons, Robert Gillies, Natarajan Raghunand, Lee Ryan, Theodore Trouard, Robert Gatenby

*Contributing:* Elizabeth Kupinski, Dennis Patton, Evan Unger, James Woolfenden, Joachim Seeger, Hans Roehrig, Lee Ryan

### *Centers and Core Labs*

Research in biomedical imaging and spectroscopy is distributed across a number of departments and organizational units at UA.

- Department of Radiology has state of the art clinical imaging instrumentation  
<http://www.radiology.arizona.edu/>
- The Biological Magnetic Resonance (BMR) Facility provides advanced MRI equipment, expertise and resources—three major MR instruments  
<http://bmr.arl.arizona.edu/>

- Cognitive Neuroimaging Laboratory (CNL)  
<http://w3.arizona.edu/~cnl/>

### *Supporting Labs*

- The Southwest Animal Imaging Resource (SWAIR)  
<http://www.swair.arizona.edu/>
- The Arizona Cancer Center has an Imaging Core Shared Service
- University Medical Center has whole-body MRI equipment—GE 3T and two 1.5 T instruments

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### **Research at Barrow Neurological Institute Includes:**

- Development of motion insensitive MRI imaging.
- Functional and volumetric MRI brain mapping.
- Advancement of MRI as a tool for vascular diagnosis—phase-contrast MR angiography (PC-MRA).
- Proton magnetic resonance spectroscopic imaging (H-MRSI) for predicting length of survival of brain tumor patients.
- Development of turboprop, a variant of PROPELLER imaging (3T PROPELLER DWI) for high resolution brain images (GE systems).

### **Major Assets**

#### *Key Faculty*

Jim Pipe (Adjunct at ASU), Joe Heiserman, John Karis, Zografos Caramanos, Richard Leblanc, Leslie Baxter

#### *Centers and Core Labs*

MRI Lab

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### **Research at Mayo Clinic, Scottsdale Includes:**

In addition to general radiography, the Department of Diagnostic Radiology provides all new imaging techniques including ultrasonography, computed tomography, magnetic resonance imaging (MRI) and many interventional techniques.

#### *Key Faculty*

William Pavlicek (Adjunct at ASU)

There are over 20 doctors in this department. Not sure who does research.

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### Research at ASU includes:

- Volumetric analysis methods for confocal microscopy images to assess biocompatibility at the brain/implant interface
- Volumetric analysis methods for discrimination of calcified, fibrous, lipid-filled regions in soft tissue CT scan images
- Volumetric analysis of MRI scan images of the brain
- PET imaging for Alzheimer's
- MRI of muscles
- Diffusion anisotropy for assessing impairment of white matter tracts after Spinal Cord Injury (rodent model)

### Major Assets

#### Key Faculty

Steve Massia, Leon Iasemidis, Bruce Towe, Gene Alexander, Gary Yamaguchi, Jit Muthuswamy, Ranu Jung, Kathy Matt

#### Centers and Core Labs

Core Bioengineering Imaging Lab, Brain Dynamics Lab

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### Activity 2: Optical imaging

This area uses light sources across the entire spectrum (visible, UV, IR) to image biological systems, from cells to organs.

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### Research at UA Includes:

- Use of fluorescence confocal microendoscopy for in vivo imaging of tissues at the cellular level—multispectral imaging capability for brain, colon, esophagus, bronchus and prostate.
- 3D microscopic imaging and spectroscopy techniques for cellular, organ and systems level.
- Non- or minimally-invasive imaging of tissue using optical coherence tomography (OCT) applied to catheters.
- Multi-dimensional spectroscopic analysis of complex tissues—integrated Miniature Microscope.
- Development of fluorescent long wavelength absorbing dyes for biological imaging applications—multiphoton imaging and confocal microscopy.
- Development of optical techniques for early diagnosis of tissue pathologies and monitoring of drug activity (e.g., intraepithelial neoplasia of the ovary and endometrium).

### Major Assets

#### Key Faculty

Primary: Arthur Gmitro, Ronald Lynch, Jennifer Barton, Michael Descour, Seth Marder, Urs Utzinger

### *Centers and Core Labs*

- Laboratories for the Medical Applications of Optics  
[http://www.optics.arizona.edu/Research\\_Programs/Laboratories/laboratories\\_for\\_the\\_medical\\_app.htm](http://www.optics.arizona.edu/Research_Programs/Laboratories/laboratories_for_the_medical_app.htm)
- Bio-Imaging Lab (Descour)
- Medical Optics Laboratory (Gmitro)
- Electrical and Computer Engineering (Barton has 800 sq. ft.)

- Lynch Lab (in Cancer Center?)

### *Supporting Labs:*

- Ophthalmic Instrumentation and Analysis Laboratory
- All other Optical Sciences Center Labs  
<http://www.optics.arizona.edu>

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### ***Activity 3: Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT)***

Two radiotracer techniques, positron emission tomography (PET) and single-photon emission computed tomography (SPECT) are modern brain imaging methods affording unprecedented opportunities for the in vivo study of central nervous system (CNS) function. PET and SPECT provide

noninvasive measurements of local neuronal activity, neurochemistry, and pharmacology in the living human brain.

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### **Research at UA Includes:**

- Tumor imaging using SPECT and FASTSPECT (animal imaging)

### **Major Assets**

#### *Key Faculty*

Harrison Barrett

*Contributing Faculty:* Gail Stevenson

### *Centers and Core Labs*

Center for Gamma-Ray Imaging

<http://gamma.radiology.arizona.edu/research.html>

### *Supporting Laboratories*

The Southwest Animal Imaging Resource (SWAIR)

<http://www.swair.arizona.edu/>

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**Research Areas at ASU include:**

- PET imaging for Alzheimer's.

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***Activity 4: Image Quality and Enhancement***

The development of new algorithms and detector systems has greatly enhanced the quality and interpretation of images

from the foregoing imaging modalities.

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### Research at UA Includes:

- Theoretical image science applied to image quality.
- Use of computational methods to optimize hardware and software.
- Digital medical image processing (e.g., using Truncated Projection Computer Tomography for image reconstruction).
- Medical image perception—human factors issues in radiology and telemedicine.
- Optimization of display technologies (e.g., Totally Filmless Radiology Department (PACS)).

### Major Assets

#### *Key Faculty*

*Primary:* Eric Clarkson, Matthew Kupinski, William Dallas, Elizabeth Krupinski, Hans Roehrig

#### *Centers and Core Labs*

Research in biomedical imaging is distributed across a number of departments and organizational units at UA, including:

- Department of Radiology Labs—PACS (Roehrig)
- Kupinski Lab—has Linux cluster/new Beowolf cluster
- Optical Sciences Center—computers

#### *Supporting Laboratories*

- Sarver Heart Center
- Computer Science and Engineering computer network

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**Research at ASU Includes:**

- Volumetric analysis methods for confocal microscopy images to assess biocompatibility at the brain/implant interface.
- Volumetric analysis methods for discrimination of calcified, fibrous, lipid-filled regions in soft tissue CT scan images.
- Volumetric analysis of MRI scan images of the brain.

**Major Assets***Key Faculty*

Steve Massia, Bruce Towe, Gene Alexander, Gary Yamaguchi, Jit Muthuswamy, Ranu Jung, Kathy Matt, Leon Iasemidis

*Centers and Core Labs*

Bioengineering Labs—Bioimaging Core, Brain Dynamics Lab

## Appendix B: Best Practice Examples

To help create the Arizona Bioengineering Institute, there are several examples of best practices in bioengineering-related center development:

### Summary of Best Practices from Benchmarks

Best Practice	Benchmark
Design buildings to promote collaboration	Georgia Tech-Emory; California QB3
Adopt Hub-Node (Satellite) model for facility distribution in region	Michigan CTA
Install central management structure	California QB3; Michigan CTA
Operate unique labs as User Facilities	Michigan CTA, Cornell NBTC
Integrate product design & manufacturing with research	Cleveland FES Center
Develop balanced, sustainable funding profile-state/ federal, industry/foundation, institutional(1/3 each)	NJ Biomaterials Center
Establish fee paying Industry Affiliates program	Georgia Tech-Emory; NJ Biomaterials Center; Cornell NBTC
Include General Education and Outreach program	Cleveland FES Center; California QB3

More details on the selected benchmarks are provided below:

#### Georgia Tech-Emory Center for Engineering of Living Tissue

- Three interrelated activities in bioengineering at Georgia Tech and Emory, housed in same or adjoining buildings
  - A (Tech) Institute for Bioengineering and Biosciences, primarily a physical home for interdisciplinary research
  - The GTEC ERC, headquartered at Tech (2/3) but directly including many activities and facilities at Emory (1/3)

- A joint academic Department of Biomedical Engineering, divided roughly 2/3 at Tech, 1/3 at Emory.
- Design of building—e.g., atria, lounges, cafes, etc.—fosters interaction between faculty. Institute building used as recruiting tool for any underlying discipline
- Faculty grouped in research “neighborhoods” that cut across departmental lines.
- Three main program areas
  - Cardiovascular
  - Metabolic secretory organs
  - Orthopedic
- Institute is not usually a vehicle for funding. Funding proposals usually flow through the parent department of the investigator.
- Industrial participants pay \$15,000 in dues. Membership conveys no IP rights from either Tech or Emory, but rather a “right of first to know” and preferred access to research reviews, graduate students, etc. Generates \$500,000 annually.

### **California Institute for Quantitative Biomedical Research**

- The California Institute for Quantitative Biomedical Research (QB3) is “Multi-Campus Research Unit”—can take grants and recover indirect costs, but not decided yet.
- Research buildings being constructed at UC Berkeley, UC San Francisco and UC Santa Cruz.
- State funding, 2:1 match by non-state sources. Launched \$50–100M funding campaign.

- Buildings will house multi-department and multi-disciplinary laboratories, lecture halls, and shared scientific resources. Total ~250,000sq.ft.
- Four broad categories of research
  - Bioengineering and Biotechnology
  - Bioinformatics and Computational Biology
  - Structural and Chemical Biology
  - Experimental Genomics and Proteomics
- Executive Director and staff, plus campus directors. 110 faculty affiliated. 30–40 new hires planned.
- External Advisory Committee
- Educational and outreach programs, from K–12, and undergrad fellowships to entrepreneurs.
- Industry Alliance Program in place.
- Considering business incubator and satellite Tech Transfer Office.

### **Michigan Core Technology Alliance**

- Michigan Life Sciences Corridor Technology Alliance involves UM, MSU, WSU and Van Andel Institute.
- Governed by Executive committee comprised of reps. from four partners; four subcommittees assist in coordination and planning.
- A linked network of advanced labs; each lab managed by one of four institutions, remaining institutions serve as satellites (ie. Hub-Node Model).
- Five labs to date—Center for Genomic Technology; Proteomic Consortium; Center for Structural Biology;

#### Animal Model Consortium; Center for Biological Information

- Centers are “user facilities,” available to researchers in Michigan on fee for service basis
- \$50M annual budget, managed by MEDC, allocated to three categories—basic research (40%), collaborative applied research (50%) and commercialization (10%).
- \$1M initial capitalization for seed-stage VC fund, managed by Sloan Ventures

#### Cornell Nanobiotechnology Center

- The Cornell Nanobiotechnology Center (NBTC) is a shared, user-oriented research and education facility, designed to advance interdisciplinary programs in nanobiotechnology.
- Open to NBTC faculty, staff, students and affiliates, the Cornell community, and researchers from other academic institutions and industry.
- Growing list of industrial partners includes large and small firms; industrial access enhanced and promoted with funding from NYSTAR.
- Facility occupies 6,000 square feet of laboratory space, developed to offer full range of equipment and services for design, fabrication, and characterization of nanobiotechnology specimens.
- Three class-1000 clean rooms are available for photolithography, metal deposition, and assembly processes
- Full range of education offerings—K–12, undergraduate and graduate.

#### New Jersey Center for Biomaterials

- Center operates as a non-incorporated entity, defined by MOU among three universities: Rutgers, the State University of New Jersey, the University of Medicine and Dentistry of New Jersey (UMDNJ), and New Jersey Institute of Technology.
- Center Board of Managers is attended by presidents and vice presidents for research.
- Research focus is biomaterials that enable regenerative medicine and drug delivery. Provides platform technology by designing candidate materials, characterizing their behavior, and helping companies optimize them for particular uses.
- No lead university designated, but administrative headquarters are at the Piscataway joint campus of Rutgers and UMDNJ.
- \$3 million in state funding earmarked toward construction of a new, dedicated building. Satellite laboratory and office facilities in Newark. Co-Director is on the faculty of UMDNJ.
- Center itself is not a grantee. Participating institutions hold title to equipment purchased with Center funding.
- Center’s budget divides evenly in thirds: Federal and state funding for centerwide proposals that carry the direct costs of center administration; Industry and foundation funding for specific projects; and Institutional support.
- Industry participates through membership fee (which provides early access to results but no IP rights) and by supporting specific research projects.

- Center has excellent participation from clinical departments at UMDNJ and its Dental School

### **Cleveland FES Center**

- Cleveland FES Center (FESC) is a research consortium in Functional Electrical Stimulation including: Cleveland VA Medical Center, MetroHealth Medical Center, and Case Western Reserve University.
- Technical Development Laboratory on Case Western campus functions as a Resource Core for the FES community. Its primary functions include design, development, fabrication, and evaluation of both implantable and percutaneous electrical stimulation systems.
- Laboratory provides development capabilities in three major areas: implantable systems development, external hardware systems development, and software systems development.
- Resources include state of the art software and hardware design facilities for prototype development, and Class 1000 cleanroom to fabricate implantable medical devices such as electrical stimulators, electrodes and sensors.
- Technical staff expert in neurophysiological systems modeling, advanced control methods, sensor development, stimulator and electrode design, implantable device packaging and radio-frequency communication.
- Focus on FES systems to improve hand function, gait, standing, transfers, and bladder, bowel and respiratory function. Ability to design, develop, multi-center test and transfer to industry complete FES systems.
- Offer research fellowships and graduate degrees in biomedical engineering.
- Sponsors a monthly seminar series on neural prostheses and organizes educational programs on FES topics.