

# USC's Plan for Science & Technology Facilities

## *Creating the Foundation for Transformative Research*

Prepared by the Provost's Office of Research in cooperation with the:

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- Dornsife College of Letters, Arts and Sciences
- Keck School of Medicine
- Ostrow School of Dentistry
- School of Pharmacy
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## USC's Plan for Science and Technology Facilities

Scientific and technological discovery promises to help people live longer and healthier lives, to improve the sustainability of the environment and the earth's resources, to provide resilience to natural disasters, and to improve the quality of life for people around the globe.

The University of Southern California is positioned to lead this effort. To do so, USC needs to create and expand its centers of excellence for fundamental scientific and technological research, providing the precision instruments that our faculty and students need to: design drugs and other compounds at the molecular scale with nanoscale delivery mechanisms; study the mechanisms that underlie the behavior of cells and organisms; realize the goal of materials by design; and analyze how massively complex systems interact and change over time.

USC's Plan for Science and Technology (S&T) Facilities provides the foundation by which the university can dramatically change the trajectory of its scientific and technological research. As emphasized in USC's Strategic Vision, "We need to imagine and build new types of research facilities that foster collaboration and informed risk-taking," and in USC's Strategic Plan, we need to incentivize "convergence across the sciences, technology and health."

The Plan for S&T Facilities defines the resources to make this happen – positioning USC to be a leader in research that addresses societal needs through fundamental research on living systems, the environment and engineered products.

The plan describes an integrated set of facilities that span the University Park and Health Science campuses, ensuring that faculty, students and staff have access to facilities on either campus, no matter where their labs are located. Each of the Centers of Excellence listed in this document is committed to providing tools and services to support sharing of facilities and expertise across the entire university.

## The Foundation for Science and Technology

USC's leadership in science and technology must be built on a foundation of outstanding facilities that enable our students and faculty to perform cutting-edge research and that attract a new and diverse faculty to the university. These facilities must provide capabilities that:

- Create data, images, models and simulations that reveal how cells, organisms and materials behave, with linkages from the scale of individual atoms and molecules through the nano- and micro-scales to real world systems;
- Decipher the mechanisms of living systems, their evolution and aging, as well as disease models, through examination of DNA, epigenetics, proteins, lipid membranes, biological markers, organ systems and fully integrated organisms;
- Precision engineer and fabricate new substances, nanostructures and devices within highly controlled environments;
- Build scientific libraries that facilitate collaborative science;
- Provide the computational backbone for scientific analyses;
- Manage big data and make data sources available to the biomedical research community.

## Revealing the Behavior of Molecules, Organisms and the Composition of Matter

Dynamic imaging and microscopy are revolutionizing all aspects of science and technology, providing the ability to create detailed pictures of how tissues (e.g. brain) function, how cells behave and respond to stimuli, and how materials are structured down to the level of molecules and atoms. They also enable understanding at the small scale of the transport processes of momentum, mass and heat. Through spectroscopy, we are able to generate data that explain physical, chemical, and structural properties of atoms, molecules and nanostructures. These insights are helping USC researchers understand how materials and complex physiological systems function, so that we can engineer new materials, devices and medical therapies.

### Centers of Excellence

- Microscopy & Analysis
- Cell & Tissue Imaging
- Brain Imaging
- Molecular Imaging
- Molecular Characterization
- Single Cell Technology

## Deciphering the Codes of Life

Systems biology and “omic” technology (genomics, epigenomics, proteomics, metabolomics) illuminate the interactions between the components of biological systems, and how these interactions give rise to the function and behavior of living systems. DNA sequencing, including the ability to sequence the whole genome, is enabling scientists to discover the pathways of evolution, how human development depends on interactions with the environment, and how drugs and other therapies can be personalized for each individual. Proteomics helps USC investigators assess markers for the presence and interactions of proteins, how diseases are expressed in individual patients and how selected proteins can be targeted to treat and diagnose disease. Chemical biology harnesses the intrinsic biosynthetic power of diverse living organisms for clean synthesis of novel therapeutic agents and diagnostic tools. These and other platform technologies will help USC scientists conduct research that reveals the underlying structures and processes of life.

### Centers of Excellence

- Therapeutic Discovery & Development
- Translational Pharmacogenomics
- In Vivo Translational Research
- Genomics & Precision Medicine
- Proteomics and Biomarkers
- Nanobiophysics
- Metabolic Assessment
- Circulating Tumor Cells (CTCs)
- Flow Cytometry

## **Precision Engineering of New Substances and Devices**

Research on the next generation of engineered products – digital devices, nano-fabricated compounds and cells, and innovative materials – requires highly controlled environments, often in clean rooms. This demands precision tools and equipment, highly trained staff, and facilities that fully satisfy requirements for good manufacturing practice (GMP). Through technological advances, manufacturing is being revolutionized. USC can use these new facilities to design and build new integrated circuits for faster and more compact computers, devices that efficiently convert sunlight into electricity or fuel, compounds that are precisely targeted to treat disease and materials that can be used to create precision medical devices.

### **Centers of Excellence**

- **Nanofabrication**
- **Stem Cell Engineering**
- **Peptide & Protein Engineering**
- **Cellular Therapies**
- **Advanced Manufacturing**

## **Science Library of the Future**

The science library of the future will not be limited to the written word. Instead, it will bring together research products of all sorts, including moving images, data sets, software and tools, clinical samples, and de-identified health records on millions of individuals, in addition to books and articles. USC is creating libraries that permit our faculty and students to share research products of all forms, so that our scientific research can progress more rapidly and with greater impact. USC is also positioned to become a leader in the creation of digital representations of physical collections, including tissues and artifacts that can be studied by scholars everywhere.

### **Centers of Excellence**

- **Digital Repository (USCDR)**
- **Big Data for Health Outcomes & Microsimulation**

## **Computing of the Future**

Research at USC has had a tremendous impact on computers, software and communication, for instance creating the domain name system that defines all world-wide-web addresses. All of these computational tools are changing how science is conducted, enabling massive data sets to be analyzed and enabling scientists to work within networks of collaborators, as well as to connect physical entities and devices. To stay at the forefront of this effort, USC needs to continually grow its high performance computing capabilities, as well as develop new technologies that answer the biggest questions facing the scientific community. In addition, the approaching end of Moore's law requires research into extending the power of computing and communications by changing the paradigms for computing, allowing us to answer new and more complex questions.

### **Centers of Excellence**

- **High Performance Computing & Communications**
- **Quantum Information Science & Technology**

## What USC's Centers Need

Each of USC's Centers of Excellence for science requires resources for:

- Acquisition of the most modern equipment that will keep USC at the leading edge of research;
- Staffing each center with expert researchers, able to extract the best performance from the equipment and to train newcomers in best practices;
- Endowment that supports costs of operation (including staffing, maintenance, and equipment upgrades) as well as pilot research studies to initiate new investigations;
- Renovation or construction of new scientific buildings and facilities.

These efforts must be complemented by the recruitment of transformative faculty who will ensure that we will utilize facilities toward completing research that advances the state-of-the-art in instrumentation and the scientific discovery that results from advanced instrumentation. This will include faculty who can lead in the creation of new instruments and methods in all areas of this plan.

Additional information is available from the Office of Research ([research.usc.edu](http://research.usc.edu)) or from these USC schools:

- **Davis School of Gerontology**
- **Dornsife College of Letters, Arts and Sciences**
- **Keck School of Medicine**
- **Ostrow School of Dentistry**
- **School of Pharmacy**
- **Sol Price School of Public Policy**
- **Viterbi School of Engineering**

Information on existing core labs and services can be found at <http://research.usc.edu/laboratoriesandservices/>

Centers of Excellence for Revealing the Behavior of Molecules, Organisms and the  
Composition of Matter

## Center of Excellence for Microscopy & Analysis

**Research:** As scientists continue to work with structures at near-atomic and even atomic scales, tools to visualize and analyze these nano-structures have become essential to new discoveries. Recent technological advances in electron and light microscopy, such as noble gas-focused ion beams with nanometer spatial resolution, aberration correction/super resolution, and high speed electron energy loss spectroscopy (EELS) have opened up new research paths, providing insights into physical, chemical, and biological phenomena in diverse domains of science.

**Impact:** State-of-the-art instruments foster cross-disciplinary research at USC, leading to a convergence of man-made nanostructures (e.g., sensors and particles designed at the atomic scale) with biological molecules (e.g., lipid, proteins and blood components). The Center of Excellence for Microscopy and Analysis (CEMMA), supports these diverse research areas.

**Existing Facilities:** A TEM (transmission electron microscope) with cutting-edge electron energy-loss spectroscopy, a high resolution SEMs, a combination SEM/FIB (focused ion beam) for progressive sectioning and a site-specific TEM sample prep, a super-resolution light microscope, a wavelength dispersive x-ray fluorescence spectrometer (WDXRF) for ppm elemental detection, and an XPS (x-ray photoelectron spectrometer) for surface analysis, as well as technical staff support. The instruments provide complementary spectroscopies — of surface topography (SEM) and angstrom resolution of internal structure of materials (TEM) — that enable both compositional and chemical analysis of a wide range of specimens.

**Future Growth:** CEMMA will move to a purpose-built space in Michelson Hall, at the USC Michelson Center for Convergent Bioscience. To serve its growing user base, CEMMA is targeting the addition of new instruments in three categories: ion beam microscopy, bio-TEM, and high-resolution TEM, in addition to needed core instrument upgrades.

- *Focused Ion Beam Microscope (FIB).* A new FIB represents the highest priority for the inorganic materials characterization labs at USC. The proposed device should incorporate and be used for a) milling and deposition, b) TEM sample preparation, and c) analytical capabilities to determine atomic composition of surfaces. The FIB would be equipped with analytical channels to perform electron backscattered diffraction (EBSD) and energy dispersive X-ray spectroscopy (EDS). This tool is a necessary primary sample preparation tool to leverage the use of Aberration corrected TEM proposed below. The nanoscale milling capabilities will enable 3D imaging (tomography) for both topographical and analytical studies
- *Advanced high resolution TEM.* The combination of dramatic improvements in electron optics, instrument stability, and camera performance has resulted in a new generation of TEMs. These instruments require great attention to siting, including vibration and thermal control; the Michelson Hall was designed to meet these demands, and a suite of two rooms are available for a pair of “next-gen” TEMs. These include an Aberration-Corrected TEM and a Cryo TEM.
- *Surface analysis tools.* A suite of surface analysis tools will enable cutting edge imaging and analytical characterization of nanoscale devices and materials produced by several groups at USC. (1) Upgrading the current aging XPS to new state-of-the-art multi-technique surface analysis suite with capabilities such as fast scanning XPS and Auger electron spectroscopy (AES) chemical analysis, Ultraviolet photoelectron spectroscopy (work function) and ion scattering spectroscopy (depth profiling) will enable *in situ* chemical and electronic characterization with sub-micron to nanoscale spatial resolution in all the three directions. (2) High scan rate atomic force microscopy with nanoscale mechanical, electrical, chemical, and magnetic characterization capabilities.



## Center of Excellence in Cell & Tissue Imaging

**Research:** The Center of Excellence in Cell and Tissue Imaging provides instrumentation for biomedical and engineering research aimed at improving human health. The Center offers state-of-the-art technologies supporting research ranging from the biological to materials science and chemical engineering. In particular, the Center supports direct observation of cells and tissues – either as they function in the living organism, or within preserved specimens and also underpins critical translational research such as the “California Project to Cure Blindness.” The Center comprises three independent facilities: the **Broad CIRM Center (BCC) Microscopy Core** Facility, the **Norris Cancer Center Cell and Tissue Imaging Core (NCCC-CTI)** and the **ZNI Multiphoton Core Facility (ZNI)**.

**Impact:** Research supported by the Center is leading to a better understanding of the complexity and connectivity of the human brain, the normal functioning of the body’s organs, and the nature of health and disease. Other topics of research impact include a greater understanding of normal and aberrant development and its application to regenerative medicine; discovery of disease mechanisms and biomarkers; characterization of dangerous emerging pathogens and how they infect the body and cause disease, and how this may be prevented; novel pharmaceuticals and biomedical devices; and applications of stem cells and regenerative medicine to cure degenerative disorders.

**Existing Facilities:** The **NCCC-CTI** is sponsored by the National Institutes of Health core grant to the USC Norris Comprehensive Cancer Center. Major instrumentation includes: (1) single molecule super-resolution fluorescence microscope (Nikon N-Storm); (2) spinning disk confocal microscope with live cell imaging (PerkinElmer Ultraviewer spinning disk confocal); (3) transmission electron microscopes (200 kV JEOL JEM 2100 LaB6; JEOL 1011 ); (4) scanning electron microscope (JEOL JSM/6390LV); and (5) whole slide scanner with quantitation of cell parameters and immunocytochemistry (Aperio digital ScanScope), as well as access to a two-photon SPIM light sheet imager and hyperspectral phasor imaging (HPI).

Additional resources for intravital imaging of living intact organs in mice and rats including a sterile surgery room, anesthesia, iv fluid and body temperature control, and animal monitoring accessories are available in the specialized **Multi-Photon Microscopy (MPM) Core** facility located in the ZNI. In addition to a Leica SP5 multiphoton system, the MPM Core is in the process of upgrading to a Leica SP8 multiphoton confocal microscope with extended IR spectrum (<1300 nm) discovery laser (Coherent), high speed resonant scanning (8-12 kHz), motorized stage, and ultra-high sensitivity 4 external and 3 internal HyD detectors for multicolor deep in vivo imaging.

The BCC offers four confocal and several wide-field light microscopes. Confocal microscopes, including a Zeiss LSM 780 and an LSM 800, two Leica SP-8X confocal with resonance scanner, and white light and argon lasers. One of the SP-8X’s is equipped with Digital Light-Sheet while the other offers multiphoton capabilities and can be used for intravital and deep tissue imaging. Widefield microscopes include three inverted Zeiss fluorescent microscopes, and two Zeiss upright systems with monochrome and color cameras and ApoTome module, Zeiss AxioScan .Z1 slide scanning system and an AxioZoom fluorescent microscope with ApoTome. Other equipment includes an Optical Projection Tomography (OPT) microscope, Harvard Apparatus perfusion chamber and incubation for the confocal microscopes. Several imaging processing and analysis software packages (Amira, Imars and Huygens) are also available. We have recently purchased a super-resolution confocal microscope, two multi-laser scanning confocal microscopes (one with light sheet capability) and a multiphoton confocal microscope.

**Future Growth:** Highest priority will be placed on establishment of cryo-electron microscopy, which provides state-of the art imaging for structural biology and crystallography. Also needed are an upgraded laser capture microdissection microscope, to enhance patient biopsy tissue-profiling capabilities, and a dedicated light sheet microscope.

## Center of Excellence in Brain Imaging

**Research:** Despite remarkable progress in the neurosciences, the workings of the human brain remain a considerable mystery. The knowledge that we lack is important for understanding what makes us human (the goal of cognitive neuroscience) and for the management of brain diseases (the goal of neurology, psychiatry, and allied medical specialties). Impairments of language or movement, emotions, memory, and decision-making lead to loss of independence and delay recovery from brain damage, resulting in cost and suffering, a problem that only gets worse as our population ages. The Center of Excellence in Brain Imaging marshals the strengths of USC's neuroscience community in an attack on the challenges posed by fundamental cognitive neuroscience and brain disease.

**Impact:** Biomedical imaging technologies are essential to elucidate the structure and operations of the human brain, and how it is disrupted by disease. Neuroimaging technologies make it possible to:

- Identify brain circuitries that are associated with specific cognitive and motor functions;
- Identify brain characteristics that allow clinicians to differentiate brain diseases with overlapping symptoms;
- Identify biomarkers of conditions such as Alzheimer's and Parkinson's disease, so that preventive and therapeutic measures can be instituted;
- Test, in experimental systems, the impact of new drugs for the treatment of diseases such as multiple sclerosis, and select the brain circuits most suitable as targets of treatment in schizophrenia, depression, autism and epilepsy;
- Document brain changes related to recovery and response to drug and behavioral treatments;
- Relate imaging findings with other measures from genetics to behavior.

The National Institutes of Health has emphasized the incorporation of brain imaging into research endeavors, and is directing increasing resources to large-scale national imaging consortia. Strengthening neuroimaging will support USC's leadership in these areas. In addition, a revolutionary grid system developed at USC's Information Sciences Institute called Globus MEDICUS has enabled physicians and scientists to exchange high-resolution medical images online. This is now being adapted for use in sharing of neuroimaging data, and will serve as a resource to the Center.

**Existing Facilities:** Key instrumentation already exists on the Health Sciences Campus within Keck Medicine and the **Mark and Mary Stevens Neuroimaging and Informatics Institute** INI (GE 3-Tesla brain scanner and other high-resolution research tools located within Keck Hospital clinics and the 3-Tesla Siemens TIM Prisma MRI (magnetic resonance imaging), 128 RF (radio frequency) Channels and 7-Tesla Siemens TIM Terra actively shielded MRI, 32 RF Channels) and at the University Park Campus (a Siemens 3-Tesla brain scanner and an adjoining EEG (electroencephalogram) laboratory at the **Dana & David Dornsife Cognitive Neuroscience Imaging Center**). Extensive informatics and image analytic resources and experience are available at the INI.

**Future Growth:** Additional instrumentation needed to keep USC at the cutting edge includes: an MR-PET (simultaneous magnetic resonance-positive emission tomography) Siemens mMR scanner; a High density MEG (magnetoencephalography); and a High-Performance Low-Field MRI that will employ a low polarizing field (~0.5 Tesla), high performance gradients, and modern programmable console and be equipped with physiological monitors, custom RF receiver coils, real-time console, real-time GPU reconstruction, and simultaneous EEG.

## Center of Excellence in Molecular Imaging

**Research:** With the development of new techniques to acquire information, it has become possible to “see” the internal structures of the human body at work without invasive surgery. The Center of Excellence in Molecular Imaging supports state-of-the-art instrumentation, technical services, and collaborative expertise in molecular imaging technologies for use by USC biomedical scientists, engineers, psychologists, and physicians. This Center synergizes with, and provides essential resources to the Center of Excellence in Brain Imaging.

**Impact:** Molecular imaging uses biological probes to image the living subject via means of sound (ultrasound), magnetism (MRI or magnetic resonance imaging), radioactivity (PET or positron emission tomography), or light (optical techniques of bioluminescence and fluorescence), as well as other emerging techniques. Research projects include:

- Quantitative measurements of brain physiology and biochemistry in diseases and disorders such as Alzheimer’s and Parkinson’s disease and vascular dementia, stroke and epilepsy;
- Novel imaging probes for diagnosis and early assessment of response to therapy in cancer and in infection;
- Imaging probes to enhance delivering of therapeutic substances, leveraging advances in biotechnology, nanotechnology, and engineering;
- Imaging to facilitate drug discovery and development by exploring the pharmacology, metabolism, and efficacy of parent drugs using labeled analogues.

**Existing Facilities:** The Center is comprised of three core facilities on the Health Sciences Campus (HSC). The Small Animal Imaging Laboratory instrumentation at the USC Molecular Imaging Center (MIC) includes a microCT, a nanoCT, photoacoustics, a microPET, a high-resolution ultrasound, and optical imaging. The cGMP Cyclotron and Radiochemistry Laboratories at MIC support radiopharmaceutical development and production for molecular imaging studies. The Center houses a state of the art GE PET trace 860 Cyclotron and ancillary equipment. The Clinical PET Imaging Center houses a state-of-the-art a Siemens PET-CT Biograph True Point scanner for whole body and brain tomography. The CT scanner is a 64 slice, offering diagnostic quality spiral CT imaging for image co-registration and attenuation correction and/or diagnostic evaluation.

**Future Growth:** Instrumentation needs include:

- New animal imaging instrumentation, a high field preclinical MRI scanner (7-11T); a preclinical PET/MR scanner; a mobile high resolution ultrasound and photoacoustic unit, an optical/CT scanner; cryogen free preclinical MRI; a preclinical nanoSPECT/CT, large animal autoradiography cryostat and imager, a helical nanoCT scanner, and a translational human PET/CT;
- Surgical support suite for animal prep for imaging procedures and large animal imaging;
- Support suite for GLP (Good Laboratory Practice) imaging;
- High precision hot cell manipulators;
- Radiochemistry support synthesis modules for preparation of research radiotracers containing isotopes such as F-18, C-11, I-124, Cu-64 and Zr-89.

In addition, upgrades are needed in ancillary laboratory equipment (HPLC, MS, GC, etc.), as well as for the high precision hot cell manipulator, IT hardware and software, high end imaging software and the pneumatic tube transport system.

## Center of Excellence for Molecular Characterization

**Research:** The Center of Excellence for Molecular Characterization provides instrumentation for nuclear magnetic resonance (NMR), mass spectrometry (MS), optical spectroscopy (IR, UV-vis, CD, Raman, polarimetry), elemental composition (EA, ICP-OES), X-ray diffraction (single crystal and powder), electron paramagnetic resonance (EPR), and materials characterization (PPMS) for interdisciplinary research spanning chemistry, engineering, and the biosciences. Essential for fundamental research on the structure and interactions of molecules in solution, our spectroscopic modalities complement our X-ray diffractometers and growing materials characterization platforms and enable important synergies with our neighbors in CEMMA, the USC Center for Electron Microscopy and Microanalysis.

**Impact:** Spectroscopy is the looking glass of molecular structure and dynamics and is our central service, providing a dynamic view of small molecules and proteins, useful for examining unfolded proteins and fundamental molecular events in complex reactive systems. We have expanded into the molecular-materials interface with tools to study nanoscale and solid state materials, e.g. PPMS, powder diffraction, Raman microscopy. Our goal is to maintain and augment existing capabilities at USC with state-of-the-art equipment and facilities to create a center that is the best anywhere, enabling advances in key research areas at the interfaces of chemistry with medicine, biology, energy science, materials engineering, and nanotechnology.

**Existing Facilities:** Thanks to significant investments by the NSF, NIH, the Anton Burg Foundation, and the USC Office of the Provost, our NMR instrumentation includes a 600 MHz, two 500 MHz and three 400 MHz NMR spectrometers (2008-2009). Our EPR instrumentation is anchored on a pulsed EPR spectrometer (2010), operated at X-band, and capable of multiple-resonance measurements. We have upgraded our X-ray lab (2011), completely rebuilt our MS facility (2017) to include high resolution and proteomics capability, and we have opened centers for elemental composition analysis (2014) and materials PPMS (2015). Further, we have secured our cryogen sustainability with a helium liquefier and recovery system (2012) to protect our cryomagnets.

**Future Growth:** Our vision incorporates solution to the following critical needs of the center:

- Modernized physical infrastructure for existing instruments, strengthened staff support, and enhanced student user training for broadened access to diverse users, site renovation/maintenance, and continued, consistent upgrades to electrical power stability and cyberinfrastructure;
- High-throughput screening capability and specialty materials infrastructure (F2, toxic gas, high pressure) that will accelerate the pace of structure and reactivity discovery in molecular sciences;
- Continued growth in mass spectrometry with an emphasis on biomolecular structure determination;
- Strengthened capabilities in optical spectroscopies, anchored by a new ultrafast transient absorption kinetics facility and including enabling upgrades to our existing platforms (particularly intermediate magnification in Raman microscopy, infrared absorption by ATR);
- Strengthening magnetic resonance instrumentation by enhancing sensitivities with a cryoprobe-equipped NMR, updated controller hardware in EPR, and capability in solid state NMR.

## Center of Excellence in Single Cell Technology

**Research:** Individual cells can differ by size, protein levels, genome and mRNA transcripts expression, providing a portrait of biological context and function in both disease and normal states. Single-cell genomics and proteomics is one of the frontiers in molecular biology, offering unprecedented access to study how genetic variability and gene expression impacts cell function, progression of disease and indeed, outcomes for patients. Novel technologies and methods allow us to isolate and analyze limited biological material, revealing a genome and proteome view at the single-cell level. This field of research is opening up developmental and disease biology. For example, this approach can identify distinct sub-populations of cells within liquid biopsies from the blood and the bone marrow of cancer patients to provide mechanistic insights to disease development and become the driver in precision medicine by matching treatments with disease characteristics.

**Impact:** The impact on biomedicine of new single cell technologies is revolutionary. Previous proteomic and gene expression studies related to disease have been based on bulk tissue samples containing large numbers of heterogeneous cells, and thus reflect an average of cell properties. Single cell technologies both establish rare cell sensitivities, needed for advance methods in liquid biopsies, and simultaneously achieve very high specificity through deep molecular content data. Liquid biopsies in prostate cancer assess and model the physical attributes of tumor cells over the course of the disease across various body compartments. Integration of liquid and solid biopsies with single cell technologies can establish a complete spatiotemporal trajectory of the disease within individual patients. This Center of Excellence integrates experimental with quantitative physical science techniques to analyze patient samples in terms of cell size, mechanical properties and ultrastructural complexity. This unprecedented approach delivers a rich database for further longitudinal statistical and mathematical analysis and yields much needed insight into the behavior, survival and destination of circulating tumor cells, which propagate metastatic cancers, and will drive therapeutic decisions in the future.

**Existing Facilities:** USC is a leader in high-definition single cell analysis (HD-SCA) workflow, conducting single cell proteogenomics in translational clinical trials in oncology, with state-of-the-art rare cell identification, single cell genomics and single cell proteomics platforms. Leadership is provided in the Bridge Institute ([CSI-Cancer](#)) and the Norris Comprehensive Cancer Center. In unique external partnerships with technology providers and internal partnerships for future developments, USC's HD-SCA is now being replicated by the National Cancer Institute.

**Future Growth:** The Center of Excellence will require high-end infrastructure, expert staff and faculty leadership in rare cell identification, single cell genomics and single proteomics. Specific needs are to:

- Scale-up current infrastructure to serve the needs of multiple disease areas, with focus on cancer but expansion to other systemic diseases;
- Suite of genomic and cell culture platforms from Fluidigm and Illumina;
- Integrate mathematical oncology and quantitative biology faculty and infrastructure;
- Develop the ability to “fingerprint” single cells, in terms of the complement of genes expressed over time, and monitor evolution in vivo and in vitro through advanced imaging technology.

These capabilities should be completed by a partnership with clinical and biorepository infrastructure to leverage the diversity of patient populations along the translational continuum (bench to bedside and back) as well as the translation of single cell research to clinical decision-making through distinct setup of CLIA-certified research facilities for laboratory-developed tests.

## Centers of Excellence for Deciphering the Codes of Life

## Center of Excellence in Therapeutic Discovery & Development

**Research:** As early-stage drug development increasingly transitions from industry to academia, USC is focusing on the development of unique technologies to create novel biological and chemical therapeutics. Drug effectiveness will be optimized based on discoveries of molecular mechanisms and biological pathways of diseases and sophisticated targeting and encapsulation strategies. Such efforts are a key part of USC's biomedical research portfolio and a critical driver of translational research.

**Impact:** Development of more effective therapies for society's most pressing and unmet health challenges including obesity, infection, cancer, neurodegenerative and inflammatory diseases, by providing targeted approaches to therapeutic discovery and development.

**Existing Facilities:** The Center houses two core facilities: the Translational Research Laboratory at the School of Pharmacy features a range of medium and high-throughput instruments covering molecular biology, cell and immunobiology, protein and nanoparticle and analytical applications, as well as computer modeling capabilities, mass spectrometers, Nuclear Magnetic Resonance equipment, and a Histology Laboratory (providing tissue processing, sectioning and staining). High-throughput DNA, protein, and metabolite analysis instruments support the rapid investigation of candidate drugs on animal and human subjects while high-end computer modeling facilitates rapid design and development of drug candidates at the molecular level.

The Choi Family Therapeutic Screening Facility in the Department of Stem Cell and Regenerative Medicine supports early stages of drug discovery as well as high throughput screening. It features a compound library of more than 3,000 FDA approved therapeutic compounds, a Nikon Biostation CT for automated microscopic imaging within an automated incubator to maintain living cells during the phenotypic screening process, an ImageXpress Micro XLS automated high content imaging system for phenotypical screening for cellular changes in both living as fixed/stained cells, and a i3x multimode plate reader for traditional high throughput screening. Robotics enable screening with chemical compounds using in house libraries but can also be adapted for molecular screens (viral, shRNA etc.) to analyze biological targets in either high content screening or high throughput screening.

**Future Growth:** Investment in key facilities is needed to excel in drug discovery and development:

- A Good Laboratory Practice (GLP) facility for the production and purification of large quantities of candidate drugs while retaining quality for the translation of drug discovery into clinical trials;
- Advanced flow cytometric capacity for novel immunobiological therapeutics development;
- Expansion of the quantitative metabolomics and lipidomic instrumentation and software capabilities to identify novel targets for disease dissection, target identification, and drug development and for pharmacokinetics, pharmacodynamics, and pharmacometric analysis;
- Expansion of the Chemical Library and Antisense Oligonucleotide (ASO) and Small Interfering RNA (siRNA) Libraries and addition of CAS9-directed libraries;
- Antisense Oligonucleotide (ASO) and Small Interfering RNA (siRNA) Libraries: many of the biological targets or phenotypes observed at the CFTSF have no known mechanism or pathway. ASOs and siRNAs, along with the chemical compound that "hit" in the screen, can be used to validate a target or pathway. Future CAS9 directed libraries are likely to be useful;
- Automated liquid handlers that can dispense sub microliter volumes and mix several reagents for screening of small molecule mixtures in which multiple signaling pathways are perturbed simultaneously.

## Center of Excellence in Translational Pharmacogenomics

**Research:** Precision medicine demands that clinicians apply pharmacogenomics (PGx) to ensure that patients are prescribed the right drug at the right dose based on their individual genetic variations to maximize efficacy and minimize toxicities. Advances in sequencing technologies and the lower cost of genetic testing have accelerated the identification/validation of genetic variants responsible for drug efficacy/toxicity. Thus far, drugs affected by an actionable pharmacogene represent 18% of outpatient prescriptions in the U.S. The Center will centralize the physical and intellectual resources necessary to achieve three core missions to: 1) advance the discovery of novel genetic variants in predicting drug responses and evaluate outcomes of genotype-guided prescribing; 2) establish the infrastructure for clinical implementation of genotype-guided prescribing by assisting providers in translating genetic test results into specific prescribing actions for drugs; and 3) train future translational scientists and health care professionals in discovery and implementation science to promote widespread adoption of PGx in clinical practice.

**Impact:** Genotype-guided prescribing eliminates the one-size-fits-all use of medications, trial and error of new prescriptions, costly ineffective drug therapies and preventable adverse events. Facilitation of research efforts via sequencing, biostatistical, and regulatory resources will further enhance the field of PGx. The Center will work closely with the international Clinical Pharmacogenetics Implementation Consortium (CPIC) to establish pharmacogenetically-based prescribing guidelines and implement existing ones. These endeavors will have an immediate and direct impact across diverse health conditions and disease states such as cancer, HIV/AIDS, mental illness, diabetes, and cardiovascular and autoimmune diseases. With a strong track record of pharmaceutical sciences and clinical research as well as an eminent team of clinical pharmacist faculty who are recognized medication experts in a variety of medical specialties, the School of Pharmacy stands poised to lead USC in delivering pharmacogenomics-based care in the era of precision medicine.

**Existing Facilities:** Our Translational Research Laboratory offers users training and access to a wide variety of investigative tools available to bench and clinic-based researchers. Specific to pharmacogenomics efforts, the core supports investigators in DNA and RNA extraction, library preparation and genotyping. Current instrumentation include ABI 7900HT Fast Real-Time PCR System, ABI OpenArray Real-Time PCR System, and the Bio-Rad Experion Automated Electrophoresis System. Importantly, the Center will leverage our faculty expertise in Regulatory Sciences and Pharmaceutical and Health Economics to evaluate the regulatory and payer viewpoints on the clinical utility of Pgx.

**Future Growth:** Immediate implementation efforts will focus on the establishment of infrastructure for (1) genotyping (sample preparation services, experimental design expertise, and data analysis); (2) clinical implementation (establishment of Pgx pharmacist consult service) and training program to educate providers and future scientists and clinicians; (3) informatics necessary for the integration of genetic information into electronic health records, facilitating clinician access and use of these data. Ultimately, the goal is to implement PGx-based care across all components of the health system at USC and affiliated sites to deliver precision medicine to all of our patients.

The Center will need:

- Biobanking robotics to enable large scale archiving of clinical samples from multiple investigators for pharmacogenomics discovery research.
- Bioinformatics enhancement necessary for the integration of genetic information into electronic health records, facilitating clinician access and use of these data as well as supporting the large data sets that accompany each study.



## Center of Excellence for In Vivo Translational Research

**Research:** To meet the unmet needs of patients suffering from diseases for which there is no known cure, USC is enabling multi-disciplinary collaborations among medicine, science and engineering, bridging the gap between fundamental research and clinical testing in humans. The COE supports these collaborations through the In Vivo Translational Research Core, which is designed to carry out live-animal research (in vivo), offering imaging technology and advanced surgical equipment. To test novel medical devices and therapies, surgeons can perform a broad range of surgeries, which include ophthalmic, neurosurgery, orthopedic and head and neck on all animal types.

**Impact:** The core supports multidisciplinary initiatives, creating novel medical devices and therapies in areas such as neurodegenerative medicine. Preclinical studies conducted in the facility have helped facilitating getting FDA approval of an ophthalmic medical device and the submission of an Investigational New Drug application that has led to the approval of a phase I/IIa clinical trial. The core enables investigators to perform critical translational research that may produce a direct path to the development and commercialization of novel treatments to meet the unmet medical needs of our patients.

**Existing Facilities:** The In Vivo Translational Research Core is an accredited space containing equipment specialized for both small and large animal research. The core has more than 12,000 sq. ft. and includes a dedicated small animal electrophysiology room. Two full-time animal technicians assist researchers with surgical procedures and equipment operation. A third technician processes animal tissue for histological analysis postmortem. The state-of-the-art instrumentation and services include: 1) Surgical equipment- Bausch & Lomb Stellaris PC Surgical Machine, Iris Oculight Red and Green lasers, multiple ophthalmic surgical instrument sets; Zeiss operating microscope, OTI scan 10000 Ophthalmic Ultrasound System, OR table, anesthesia machines for large and small animals; 2) Imaging- Heidelberg Spectral OCT (posterior segment, retina), Heidelberg HRT3 OCT (anterior segment, cornea), Zeiss digital fundus camera, Zeiss photographic slit lamp, Kowa fundus camera (fundus and fluorescein angiography photography), indirect ophthalmoscopes and 3)-Histology services-, Leica Paraffin Tissue Processor TP 1020, Leica Paraffin Embedding Station EG 1150H, Leica Ultracut R Microtome, Leica Microtome 2125RT, Leica Dissecting Microscope MZ16 with Leica DC Camera and Computer Imaging System for tissue processing, sectioning and staining.

**Future growth:** To continue to advance translational research efforts, the core plans to purchase a Micron IV Retinal Imaging System. The customizable system can image rodent (mouse and rat) animals and some larger animals (rabbit) using various ophthalmic imaging modalities that assess both the structure of neurosensory tissue as well as its function. These imaging modalities include optical coherence tomography (OCT), focal and global electroretinography (ERG), fluorescein angiography (FA), and color imaging. The device is further customizable for short or long-wavelength imaging using custom filters. Additional upgrades to current equipment and servicing are also necessary to maintain the level of expertise provided by the core.

## Center of Excellence in Genomics & Precision Medicine

**Research:** The development of next-generation sequencing (NGS) technologies has significantly improved DNA sequencing throughput, reduced costs, and advanced research in virtually all areas of biological and biomedical research, from evolutionary biology to precision medicine (PMED), where treatments can be tailored to an individual's own genetic signature. This includes complex molecular profiling, along with aspects of environment, exposures, and lifestyle, to help understand individual molecular risk assessment and to identify more tailored approaches to health management and disease intervention.

Researchers at USC are using these revolutionary technologies to sequence the genome of organisms in agriculture, ecosystem sustainability and human health. Others are developing personalized cancer treatments based on gene expression profiling of matching tumor and circulating tumor cells from the same patient. The most significant traction in PMED growth has been in the area of cancer, where individualized molecular profiling has led to greater precision for diagnosis and has also provided a new paradigm for individually tailored treatment regimens.

**Impact:** The shared use of NGS core resources has facilitated use of these technologies, establishing a committed user base. The Center assists in inter-disciplinary collaborations, boosting genomics research at USC, expanding and fostering the use of novel therapeutic treatments.

**Existing Facilities:** There are two genome core facilities at USC, one on each campus (UPC and HSC):

- The UPC Genome Core, located in the CEM building, is supported by the Dornsife College. It is equipped with two NGS sequencers: an Illumina HiSeq 2500, upgraded to the latest software and hardware versions, and capable of running Rapid and High-output flowcells; and an Ion Torrent PGM. Other ancillary pieces of equipment include an Agilent Bioanalyzer 2100, a SOP qPCR machine, and a Covaris S2;
- The Molecular Genomics Core is part of the Norris Comprehensive Cancer Center and is located at HSC in the Norris Research Tower. Supported by the Keck School of Medicine, the lab is equipped with four Illumina sequencers: two NextSeq 500 systems, and two MiSeq systems. The MGC also has an Illumina Beadlab production level SNP methylation-profiling platform.

**Future Growth:** The core facilities provide sequencing capability to cover small and mid-size research projects. However, neither core has the hardware to retain large-scale projects and the necessary regulatory framework to perform clinical sequencing. Investment areas to advance genomics research capabilities and personalized medicine clinical sequencing capabilities include:

- Large-scale production sequencers, such as the new Illumina NovaSeq system;
- Clinical sequencing capabilities at USC similar to those at Children's Hospital Los Angeles Center for Personalized Medicine;
- Robust BioMedical Informatics (emphasis on medical) program for the development of methods and approaches for integrating critical measurements for each patient including clinical, molecular, physical (i.e. imaging), epidemiological, and environmental data;
- An Office of Precision Medicine (OPM), possibly under the Keck School of Medicine Vice Dean of Research and/or within the Clinical Translational Sciences Institute.

## Center of Excellence in Proteomics & Biomarkers

**Research:** DNA sequence information in the genome (or genes) is copied into RNA transcripts, which are then translated into proteins within the cell. Proteins are the building blocks of living organisms, as well as molecular machines that operate cellular functions. The Center of Excellence in Proteomics and Biomarkers provides high-sensitivity and high-resolution mass spectrometry for protein analysis. Separately, levels of peptides, hormones, metabolites, and small molecules circulating in the blood stream and present in cells and tissues vary with age and are hallmarks of physiologic state. The ability to precisely measure these molecules is paramount to their diagnostic use as biomarkers of healthy aging and disease prognosis.

**Future Growth:** The Center will continue to identify and develop novel target platforms as well as provide increased availability of commercially available kits for screening. Efforts will also target integration with bioinformatics platforms for analysis of large data sets.

**Impact:** In medicine, a biomarker correlates with the risk or progression of disease, or with the susceptibility of the disease to a given treatment. Protein biomarkers are used in clinical trials, where they are derived from bodily fluids that are easily accessible for analysis. Analogous to the genome, the proteome is the entire complement of proteins, including the modifications made to a particular set of proteins, produced by an organism or system. This will vary with time and distinct requirements or stresses that a cell or organism undergoes. A biomarker, such as proteins or other molecules, is an indicator or proxy of a biological state.

**Existing Facilities:** The Proteomics Core Facility, located on the Health Science Campus and the Aging Biomarker & Service Core include:

- Q Exactive™ Hybrid Quadrupole-Orbitrap Mass Spectrometer coupled with EASY-nLC 1000 Liquid Chromatography, one of the most advanced LC-MS/MS system for proteomics profiling and biomarker discovery and quantitation;
- Eksigent NanoLC-2D, a fully automated 2-dimensional chromatography system ideal for whole proteome profiling, low abundance protein identification, and post translational modification;
- ThermoElectron Finnigan LTQ, a linear ion trap mass spectrometer equipped with an electrospray ionization source;
- Thermo Scientific LTQ Orbitrap XL ETD, an instrument for proteomics analyses that combines three different and complementary fragmentation techniques with the benefits of Orbitrap™ technology.
  - QuickPlex SQ 120 (Meso Scale Discovery, MSD) and SpectraMax M3 multi-mode microplate readers (Molecular Device);
- Measurement of cytokines, Alzheimer's-related markers (Amyloid beta, phospho-tau), hormones (GH, human and mouse IGF-I& IGFFBPs, among others), metabolic biomarkers such as insulin, leptin and adiponectin and mitochondrial derived peptides (MDPs) including humanin and the other novel MDPs;

**Future Growth:** Equipment upgrades and purchases, as well as the core services, are envisioned to include:

- Upgrading the current Eksigent NanoLC-2D, LTQ Orbitrap XL ETD, and LTQ;
- Acquiring automated sample preparation and handling instruments;
- Creating a bioinformatics infrastructure and novel platforms;
- Providing the ability to assess protein posttranslational modifications as well as lipidomics, glycomics, and small molecule assessment through the Orbitrap Fusion Mass Spectrometer.

## Center of Excellence in Nanobiophysics

**Research:** The Center of Excellence in Nanobiophysics supports the study of molecular nano-assembly, structures and functions. Housed in the Dornsife College, the Center is used by research programs in structural biology, nanotechnology, nanomedicine, molecular biology, biochemistry, and material sciences. While the scope of research supported by the Center is wide and diverse, the majority of the activity focuses on fundamental problems of nanobiology, structural biology, biomedical engineering and molecular medicine. For example, the core has supported studies that examine biomolecule and drug interactions, by determining X-ray atomic complex structures, characterizing the thermodynamics and kinetics of ligand/drug binding, and elucidating nanoscale molecular assembly and disassembly mechanisms.

**Impact:** The Center strives to contribute not only to the discovery of new drugs that treat cancer and other diseases, but also provide and understanding of the basic molecular mechanisms and fundamental principles governing cellular signaling pathways. It provides powerful state-of-the-art technology for basic and medical sciences and offers ample collaborative opportunities between scientists and clinicians. Its work appears in *Nature*, *Cell*, the *Proceedings of the National Academy of Sciences* and other journals, which has helped USC researchers obtain major extramural funding and increased academic prestige and visibility.

**Existing Facilities:** The Center features two core facilities on the University Park Campus. The **Nanobiophysics Core** is housed in SHS160 and has a range of instruments including a Biacore T100, a DLS System (Wyatt Technologies), a Multitask Spectrofluorometer, two Atomic Force Microscopes, a CD Spectrometer, a microplate reader, and a micro-Isothermal Titration Calorimetry (ITC). The **X-Ray Crystallographic Core**, located in RRI-103, has an X-ray generator (007), two X-ray diffraction detectors, a multi-task screening robot, and high-power computer system for simulation and modeling. Recently funded acquisitions include a Microplate Reader Synergy H4, a Microcalorimeter to measure thermodynamic parameters of biomolecular interactions/reactions and an X-Ray Crystallization robot for high-throughput screening of crystallization conditions, and a typhoon multi-channel laser scanner for versatile and flexible imaging for precise quantitation and documentation of biomolecules and their reactions.

**Future Growth:** The current equipment only provides a part of what is needed for the structural and biophysics characterization of biomolecules and nanomaterials. USC has the potential to significantly expand its research through additional instruments and technology. High-priority instruments needed in the next three years include:

- Zetasizer to measure nanoparticle and biomolecular size;
- High-end atomic force microscopy system (coordinated with CEMMA);
- Advanced multi-angle light scattering system coupled with an HPLC chromatography system;
- Graphic computer work station for imaging and simulation;
- Analytical ultracentrifuge to study molecular properties of proteins, nucleic acids and protein complex interactions.

## Center of Excellence for Metabolic Assessment

**Research:** Metabolism plays a central role in cellular and physiological processes and is linked to the etiology of several diseases where metabolic dysfunction and/or reprogramming occurs. Expertise, state-of-the-art technical resources and instrumentation necessary for phenotypic characterization of metabolic and behavioral parameters throughout the lifespan are provided through the **School of Gerontology Aging Mouse Phenotyping Core**, the **School of Pharmacy Translational Research Laboratory**, and the **Diabetes and Obesity Research Institute / CHLA Saban Rodent Metabolic Core**.

**Impact:** Core facilities support investigation of the impact of diet and metabolism in healthy aging across the lifespan and to promote translational therapeutic discovery. In particular, Seahorse XF Analyzers facilitate the real time acquisition of data with the ability to measure both mitochondrial respiration and glycolysis in live cells, in real time.

**Existing Facilities:** Core facilities provide access to the following equipment and services:

- **Seahorse analyzers:** Located at the School of Gerontology (**Seahorse Core Facility**) and School of Pharmacy **Translational Research Lab** (XF96 and XF24, respectively), analyzers offer measurement of oxygen consumption, extracellular acidification rates and kinetic responses, automatically adding up to four test compounds (drugs or substrates) to each well. The XF96 model does not require radiolabeled substrates, and it is possible to make high throughput measurements on 96 samples simultaneously in a microplate format. Additionally, no cleaning is required as all parts that contact cells, media or drugs are disposable. Cell types assayed include cell lines, primary cells, isolated mitochondria, and worms;
- **Hematology Profile** using the HEMAVET® 950FS Multi-species Hematology System, blood pressure is measured with the CODA® (Kent Scientific) system, which utilizes volume pressure recording (VPR) sensor technology;
- **Metabolic Profile** using the TSE PhenoMaster System for fully automated assessment of home cage metabolic monitoring of food and water intake, energy expenditure, and voluntary locomotor activity. A fully computerized treadmill system for monitoring exercise motor coordination and performance is also available;
- **Body Composition** using the Bruker LF90II NMR minispec for non-invasive measurement of body fat, lean mass, body fluids and total body water;
- **The Behavioral Unit** is a dedicated room that minimizes disturbances. Equipment/behavior measurement include: (i) Spontaneous Alternation Behavior; (ii) Novel Object Recognition and Placement; (iii) Barnes maze; (iv) Fear Conditioning; (v) Tail suspension, and (vi) Elevated Plus Maze and Forced Swim. Data are collected, analyzed and archived using the Noldus EthoVision XT Tracking System with computer-directed video camera capture and image analysis software.

Additional services: monitor (i) glucose and insulin levels; (ii) GTT; (iii) food and water intake, energy expenditure (by indirect calorimetry), voluntary or forced locomotor activity using the TSE PhenoMaster system (TSE Systems, USA); (iv) body composition analysis using the LF90 time domain nuclear magnetic resonance (TD-NMR; Bruker, USA).

**Future Growth:** Cores will continue to identify and develop new platforms and procedures for tissue measurements and small invertebrate studies as well as expand the capacity to allow more animals in each cohort. Additional efforts will focus on enhancement of bioinformatics support.

## Center of Excellence in Circulating Tumor Cells (CTCs)

**Research:** Precision medicine – tailoring therapy to individual patient tumors – is the key to successful cancer treatment. In order to track a patient’s cancer and adjust therapy over time, tumor cells must be sampled repeatedly, but traditional tumor biopsies involve high patient risk, discomfort, and cost. A novel alternative has emerged in the last decade: Circulating tumor cells (CTCs) shed by tumors and metastases into the blood stream can now be captured from a standard blood sample using new technologies capable of enriching and separating these rare cells from the vast number of background red and white blood cells. By analyzing CTCs, clinicians and investigators can identify cancer-specific protein markers, gene mutations, or expression profiles that drive disease progression. Importantly, a patient’s CTCs can be re-sampled simply and non-invasively during treatment and at disease progression to identify mechanisms of therapy resistance and to guide treatment.

**Impact:** Elevated CTC counts have been shown to predict poor therapy response and short survival in breast, colon, lung, and prostate cancer, as well as many other malignancies. Beyond enumeration, CTCs can be stained to assess the presence of therapeutic targets like estrogen receptor, androgen receptor, or epidermal growth factor receptor, and DNA and RNA from CTCs can be amplified and sequenced to identify cancer-driving mutations and gene expression signatures. Recent CTC studies at USC have involved faculty in six departments at two schools, as well as investigators around the country participating in large multi-centered trials coordinated by the NCI Southwest Oncology Cooperative Group. These have led to high impact publications and large federally-funded research projects that are helping to elucidate therapy response and disease progression in cancers of the prostate, breast, bladder and melanoma among others.

**Existing Facilities:** USC’s Norris Comprehensive Cancer Center has the first and only NCI-designated **CTC Research Core** in the United States, which was singled out for its novelty and received a merit score of “outstanding” at the recent 2015 NCI site visit. The Core’s mission is to deliver the full potential of CTC profiling to a broad spectrum of clinical and translational cancer investigators who would otherwise not have access to these technologies. To achieve this goal, we procured multiple cutting-edge CTC platforms through collaborative loaner instrument agreements with manufacturers, such as CellSearch (Menarini Silicon Biosystems, formerly developed by Janssen Diagnostics), LiquidBiopsy (Cynvenio Biosystems), Parsortix (Angle), ClearCellFX (Clearbridge Biomedics), and DEPArray (Menarini Silicon Biosystems).

**Future Growth:** While we have been productive with existing loaner instruments, additional resources are needed in order to procure more effective technologies, support technical expertise, and expand service capacity, enabling USC investigators to discover and compete at the highest level. Some key future components needed to sustain a state-of-the-art, effective USC CTC Core include:

- **Equipment:** RareCyte platform for high content CTC imaging, analysis, and recovery; Silicon Biosystems Nxt platform for pure CTC fluorescence analysis and dielectric manipulation; Leica Bond RxM platform for CTC staining; LabCyte (or similar) platform for microvolume manipulation for DNA/RNA amplification and library construction; BioRad Q200 (or similar) digital droplet PCR platform; service contract support for new equipment.
- **Personnel:** Research Assistant Professor or Senior Research Associate (Ph.D. level) for protocol development, project oversight, and bioinformatic data analysis; Research Associate for facility management, instrument acquisition and maintenance, and user and vendor interface; Research technician for specimen/sample handling, instrument operation, and molecular assays.
- **General:** Basic laboratory equipment for sample handling, including fluorescence microscope, centrifuge, cell culture incubator, sample freezer, and computer/data storage.

## Center of Excellence in Flow Cytometry

**Research:** Flow cytometry cores are critical to providing the USC research community with state-of-the-art technology to selectively phenotype and isolate specific populations of cells. Using fluorescent probes and transgenic proteins, researchers monitor several aspects of their cell populations, including phenotype, cell viability, proliferation, cell cycle and cell activation. Additionally, cell purification by electrostatic cell sorting enables cutting-edge research on low frequency cells.

**Impact:** The sorting amongst different cell types in a population supports regenerative medicine, cancer, stem cell biology, and the molecular and cellular analysis of a broad array of diseases. With the increasing number of assays being developed that utilize flow cytometry, this resource supports a diverse group of investigators.

**Existing Facilities:** Equipment available at the [Eli and Edythe Broad Center Flow Cytometry Core](#) includes an LSR2- Cell analysis instrument capable of detecting ten colors and a High Throughput Sampler capable of running 96-well plates; an ARIA IIu-Cell sorter capable of detecting fifteen colors and performing sterile sorting into various collection devices; a MoFlo Astrios EQ- Cell sorter capable of detecting twenty-one colors and performing sterile sorting into various collection devices. Other core facilities offering flow cytometry services to USC researchers include the [UPC Genome & Cytometry Core](#), equipped with a high-throughput Beckman Coulter Biomek® 3000 Automated Workstation, and Cell Sorter; the [CHLA Fluorescence Activated Cell Sorting \(FACS\) Core](#), providing absolute counts, apoptosis, calcium flux, co-localization, cytometric bead assay (CBA) for up to 30 soluble cytokines or proteins per sample, DNA cell cycle analysis, flow-FISH for telomere length, immunophenotyping for surface, intracellular and nuclear proteins, live cell sorting, PhosFlow, Luminex multiplex assays, rare event detection/sorting, reporter molecules, side population, single-cell cloning, single color, apoptosis, sizing, spot counting for viral load, subcellular compartmentalization, synapse activity, translocation, and viability; the [School of Pharmacy Translational Research Laboratory](#) houses a BD LSR II Flow Cytometer with 3 lasers and 6 color capabilities. The Translational lab also provides the researchers access to FlowJo analysis software for their needs. Additionally, the [Immune Monitoring Core](#), equipped with a Beckman Coulter FC500 flow cytometer with a 488 nm blue laser and a 633 nm red laser, capable of 5-color detection. Flow cytometry services are paired with immune monitoring services to offer full-service support for investigators.

**Future Growth:** Core facilities aim to maintain state-of-the-art equipment and expand their current capability and services to the broader USC community, with consideration of future replacement options to ensure there is no loss in sorting capability. Due to the difficulty in transporting samples, facilities will continue to be needed in multiple locations, which will coordinate their services and acquisition of new instruments.

## Centers of Excellence for Precision Engineering of New Substances and Devices



## Center of Excellence in Nanofabrication

**Research:** Nanofabrication forms the foundation of all transformative scientific discovery and innovative technological advances. Though invisible to the naked eye, nanotechnology has a global societal impact. Innovations that rely on nanofabrication methods have advanced therapeutic delivery for cancer and Alzheimer’s disease, increased cybersecurity, and improved alternative energy technologies. At USC, researchers from Viterbi, Dornsife, and Keck use the nanofabrication facility to push the boundaries of discovery in research efforts that span all disciplines. This research relies on access to a broad spectrum of instrumentation, including equipment not found in a conventional nanofabrication facility.

**Impact:** The nanofabrication facility supports all USC researchers in their efforts to solve the grand challenges facing the global society. By providing access to state of the art instrumentation, as well as opportunities for intellectual collaborations, the facility strives to accelerate scientific discovery and technology translation in all fields of science and engineering. In this vein, the facility supports a very diverse range of research that spans from fundamental science, including understanding qbit generation in quantum computers, to applied technology, including prosthetics for vision. Access to nanofabrication facilities on-campus has helped USC researchers obtain funding from a wide range of external agencies including Centers.

**Existing Facility:** USC’s nanofabrication research is centered in the 5,000 sq. ft. W. M. Keck Foundation Photonics Cleanroom located in Vivian Hall, providing class 100 clean-room operation with a class 10 photolithography area. The facility is equipped with research tools for device fabrication (patterning, etching, and deposition) and device characterization (imaging and metrology).

**Future Growth:** The John D. O’Brien Nanofabrication Laboratory, located in Michelson Hall, will greatly increase the functionality and user capacity of the cleanroom. The new 10,000 sq. ft. Center of Excellence in Nanofabrication facility is under construction. Design, fabrication, synthesis and characterization tools will be provided in class 1,000 and class 100 clean-rooms. The tool set will need to be significantly expanded to improve our ability to leverage a range of next generation materials as well as support the growing user base at USC.

Future components needed to sustain a state of the art nanofabrication facility include:

**Instrumentation:** As the only nanofabrication research facility on the USC campus, researchers rely on it to support nano-related efforts that range from the nano-structure and device level (component) to the systems level. These can be separated into two categories:

*Component:* To fabricate nanostructures and devices, fabrication and characterization instrumentation is needed. Fabrication includes patterning (e.g. photo, laser, e-beam), etching, and deposition systems. Characterization includes optical, mechanical, and electrical properties, as well as metrology (e.g. imaging, surface profile). For all systems, the associated support infrastructure, such as chemical handling, is also needed.

*Packaging:* To create a packaged device, instrumentation such as die and wire bonders and vacuum coaters are needed.

**Personnel:** Personnel can be roughly categorized as facility support staff and research support staff.

*Facility support staff:* This staff will support the equipment and the operation of the facility, overseeing equipment repairs and maintenance as well as user training and facility operation.

*Research support staff:* This staff will fabricate devices and structures for researchers who have well-defined protocols or non-experts who are looking to expand their research programs. They will also help troubleshoot protocols for cleanroom researchers.

## Center of Excellence in Stem Cell Engineering

**Research:** Stem cells are truly remarkable. They have the potential to become any cell type and thus may be a uniquely powerful tool to treat a wide range of degenerative diseases. The Chang Stem Cell Engineering Facility provides expertise in the generation, culture and genetic modification of human pluripotent stem cells to facilitate basic science investigations and in clinical applications.

**Impact:** USC has built an exceptional group of stem cell researchers centered at the Eli and Edythe Broad Center for Regenerative Medicine and Stem Cell Research within the Keck School of Medicine on the HSC campus. Through the USC Stem Cell Initiative, the Broad Center serves as the hub to connect over 100 PI-level researchers and clinicians across USC schools, and our colleagues at CHLA, working in the stem cell area.

Ongoing clinical trials emerging from USC stem cell leadership include:

- New stem cell therapeutics to treat macular degeneration;
- Method to genetically alter blood stem cells for the treatment of HIV/AIDS;
- Treatment of paralysis from spinal cord injury.

A number of research areas (notably skeletal research, ALS) are at preclinical stages of development and are likely to enter a clinical phase in the next few years while the majority of research on a multitude of body systems is at an earlier stage of discovery research and clinical model development.

**Existing Facilities:** In the past two years, with generous gifts from two philanthropies, the Broad Center founded two core facilities, the Choi Family Therapeutic Screening Facility and the Chang Stem Cell Engineering Facility. The focus of the Chang Stem Cell Engineering Facility has shifted from training stem cell researchers to providing comprehensive support service for the generation (including patient iPSC-derivation) and genetic modification of pluripotent stem cells. The genetically modified hESCs/iPSCs provide important tools for investigators at USC/CHLA and beyond to study basic biological processes, understand mechanisms underlying various diseases, and model disease in a dish. This facility serves the pipeline for drug discovery, generating modified cells and disease models that enter the Choi Family Therapeutic Screening Facility.

**Future Growth:** Most critical is the need to maintain existing facilities beyond the termination of the current philanthropic support in the next two years. For the next phase of development of the Chang Stem Cell Engineering Facility we anticipate developing additional capabilities in conjunction with new faculty hires:

- Stem cell directed multicellular tissue engineering for research and treatment;
- 3D organoids generated from hESCs/iPSCs to create reflective models of disease processes.

New equipment and services will be available for multicellular tissue engineering and organoid development. In addition, we will likely require additional staff to support both genetic (1-2) and tissue (1-2) engineering components.

## Center of Excellence for Peptide & Protein Engineering (CPPE)

**Research:** The ability to manufacture and engineer peptides and proteins—creating designer molecules—is essential to enable the convergence of biological science, engineering, and medicine. The **USC Center of Excellence in Peptide & Protein Engineering (CPPE)** will provide this feature to the USC community, fueling new collaborative research by establishing a powerful and unique resource.

The CPPE is being established within the Michelson Center for Convergent Biosciences and will serve as a nexus for providing new molecular tools, new approaches to characterization, and fundamental expertise on peptides and proteins to the USC community.

The Center will consist of two parts: 1) A *core laboratory* (fee for service) that contains the equipment and technical expertise to design and produce peptides and proteins, and 2) A *center* that combines mRNA display with new automation technologies to enable engineering cost-effective, stable, specific peptides and proteins directed against virtually any target protein, nucleic acid, or other biomolecule.

**Impact:** Peptides and proteins are the cornerstones of biological recognition and are essential reagents for imaging, diagnostics, and human therapies. Engineered peptides and proteins enable new control and understanding of biological systems. The Center currently supports projects with collaborators in the Viterbi School of Engineering, the Dornsife College of Letters Arts and Sciences, the Keck School of Medicine and the Ellison Center for Transformative Medicine.

USC's CPPE supports the creation of engineered peptide and protein ligands for uses in basic biology, imaging, diagnostics, and therapy. These reagents provide a unique opportunity for the USC community and collaborators to generate reagents that enable their research and grants. Current projects include creating new peptide and protein ligands for (1) G protein coupled receptors (GPCRs); (2) Cell-surface tumor markers; and (3) intracellular/extracellular markers relevant for neurobiology and cancer.

**Existing Facilities:** The USC CPPE is being housed on the 2<sup>nd</sup> floor of the Michelson Center for Convergent Biosciences, with a target date of July 2018 for commencing operations. The newly established partnership between Agilent and USC has provided the Center with several key instruments, including preparative and analytical HPLC/MS capabilities, robotics and automation for ELISA and protein based assays, fluorescence and UV/Visible optical spectroscopy, PCR, and high-vacuum pumps.

**Future Growth:** Over the next year, our goal is to acquire the equipment needed for specific functions: (1) *High-throughput, Protein Characterization* (96-tip high-throughput protein binding characterization, Octet Red96); Scintillation Counter); (2) *Automated DNA Plasmid Construction for Protein Expression* (Robotic DNA plasmid construction; High Throughput DNA sequencing, Mini Seq); (3) *Mammalian Cell Culture for Protein Expression and Cellular Characterization* (Tissue culture tools for growth/handling - TC hoods; mammalian cell incubators; cryo-storage; microscope; centrifuge; equipment; Cell Counting and Cell Sorting Capabilities, FACS); (4) *Equipment suite for Protein Purification from Cells* (Fast Protein Liquid Chromatography, FPLC; Cell Lysis, Emulsiflex; Incubators for bacterial cell growth; Preparative Centrifuge; Protein Gel Electrophoresis; Gel Imager); (5) *Peptide Synthesis* (Multipartite synthesizer; Flash Purification; HPLC Columns for Purification)

## Center of Excellence in Cellular Therapies

**Research:** The term “cellular therapy” encompasses all treatment modalities in which cells are used to treat a disease. The form of cellular therapy that is being used most commonly currently is Bone Marrow (or Stem Cell) Transplant. However, with the recent progress made in the fields of cellular immunotherapy, gene therapy, genome engineering, induced pluripotent stem cells (iPSC) and stem cell reprogramming, novel approaches to cellular therapies are poised to revolutionize the treatment of a number of human disease conditions. Recognizing the importance of these advancements, our vision is to create a world-class Center of Excellence in Cellular Therapies at the Keck School of Medicine. The center will a) promote basic and translational research in novel cellular therapies; b) facilitate clinical development of novel cellular therapies; c) enable cGMP production of cell and gene-therapy products for Phase I and II clinical studies, employing current Good Manufacturing Practices (cGMP), as required by federal regulations; d) serve as a resource to all USC investigators interested in basic, translational and clinical research in cellular therapies

**Impact:** The Center will bring together basic, translational and clinical investigators working on developing novel cell based therapies for the treatment of hard-to-treat diseases, such as cancer, diabetes, infections, immunodeficiency disorders, cardiovascular conditions, neurodegenerative disorders, osteoarthritis, eye diseases, autoimmune disorders, genetic diseases and in-born errors of metabolism. The Center will actively collaborate with investigators working in cell-based therapies at the Eli and Edythe Broad Institute for Regenerative Medicine and Stem Cell Research, the Zilkha Neurogenetic Institute, the USC Roski Eye Institute, the Norris Comprehensive Cancer Center and the Saban Research Institute of CHLA. The Center will also result in increased funding from federal (e.g., NIH and DoD), non-federal (e.g., CIRM), foundation and philanthropic sources, and stimulate creation of biotechnology start-up companies.

**Existing Facilities:** USC has a rapidly growing Blood and Marrow Transplant program that has received accreditation by the Foundation for the Accreditation of Cellular Therapies (FACT) and is approved by the FDA for processing of cellular products. According to a recent report by the Center for International Blood and Marrow Transplant Research, the program has the best 1-year survival among adult allogeneic transplant programs in the country. The program, however, lacks capabilities for cGMP manufacturing of cellular products. Although there is a small cGMP facility at the CHLA campus, it cannot handle the current and future needs of the USC investigators due to limited capacity. Fortunately, as described below, new modular cGMP facilities have come on the market that cost a fraction of the traditional clean rooms. Therefore, there is a strong justification for building a cGMP facility at the KSOM from both the need and the cost perspectives.

**Future Growth:** The anticipated equipment and personnel needs for the Center of Excellence in Cellular Therapies include:

- cGMP cell processing facility: an XVIVO Cell Production Unit. This is a self-contained, cGMP compliant, modular cell processing and production facility. Importantly, the unit can be relocated, reconfigured, & repurposed in days, allowing use for multiple different cell therapy applications.
- CliniMACS Prodigy System. This is designed to automate and standardize complete cellular product manufacturing processes. It combines CliniMACS Separation Technology with wide range of sensor-controlled, cell processing capabilities.

## Center of Excellence in Advanced Manufacturing

**Research:** The Center for Advanced Manufacturing (CAM), at the USC Viterbi School of Engineering, supports the research of faculty and students in coming from diverse backgrounds in design, materials systems and computer science. CAM's current focus includes:

- *Additive Manufacturing:* Uses digital models to automatically build components by depositing material(s) in layers without any part specific tooling. Researchers are developing new additive manufacturing processes for realizing multi-material objects, multiscale structures, composite structures, and metal parts, facilitating innovation in aerospace, defense, and biomedical devices.
- *Robotics and Automation:* Develops rapidly reconfigurable robotics and automation technologies for low production volume applications. Examples include robotic assembly of compliant parts, automation for meso and micro assemblies, automated finishing, robot-assisted additive manufacturing, and automation of composites fabrication.
- *Smart Manufacturing:* Integrates sensors, networking, and analytics technologies to improve manufacturing operations by improving resource utilization and enabling fast recovery from errors. Examples include improved process modeling and control, efficient resource utilization and optimization using big data concepts, energy efficient manufacturing, and personalized manufacturing.
- *Digital Manufacturing:* Develops simulation, visualization, analytics, planning, optimization, and collaboration tools to reduce product development time, enabling innovation, and reducing waste. Examples include high fidelity simulations of manufacturing processes, augmented and virtual reality for training human operators, manufacturing system design and optimization, and automated planning.

**Impact:** CAM conducts basic and applied research in manufacturing to enable innovation. CAM shares manufacturing expertise and research results with companies in the Southern California region to transition research results into practice and organizes events to identify new opportunities in manufacturing. CAM supports interdisciplinary manufacturing education programs and outreach support to the K-12 education community. CAM also provides the Southern California community access to advanced manufacturing capabilities to prototype their concepts.

**Existing Facilities:** CAM's 6000 sq. ft. facility has the following capabilities: (1) computer controlled vertical machining center and laser cutter for machining, (2) mesoscale injection molding, liquid silicone molding, and vacuum casting for polymer processing, (3) robotic manipulators and mobile base for automated material handling and processing, (4) 3D printers for printing polymer and metal parts, and (5) surface roughness measurement and laser scanning for metrology.

**Future Growth:** The ability to rapidly fabricate heterogeneous soft and/or hard objects will enable innovation in areas such as prosthetics, orthotics, soft sensors, actuators, and biologically-inspired robots. CAM requires a 3D printer that can print heterogeneous objects made from user-defined materials, which would enable new research projects in computational design, simulation, visualization, advanced manufacturing, robotics, and biomedical devices. Metal-based additive manufacturing technology is expected to revolutionize the aerospace industry. Currently good process models do not exist for metal-based additive manufacturing technology. Acquisition of a high-resolution Computed Tomography (CT) scanning system will enable researchers to initiate new research in process modeling, process control, and metrology for metal-based additive manufacturing. This will also create new opportunities for partnering with aerospace and defense companies.

## Centers of Excellence for the Science Libraries of the Future

## Center of Excellence for the Digital Repository (USCDR)

**Research:** The USC Digital Repository (USCDR) offers state-of-the-art resources for the digitization, cataloging, and preservation of scientific and scholarly collections, as well as the means to manage and host such collections online. USC's long-term vision is for the Digital Repository to be an internationally recognized digital library for the sciences, accessed through a cloud-based archival system. Currently, the USCDR manages 50 petabytes of online data tape and eight petabytes of online disk storage, with preservation systems located in multiple locations in the United States. The USCDR builds on USC's strengths in technology and librarianship to capture and preserve collections of significant research, educational, and cultural value. The Digital Repository will be a scientific library within the USCDR, dedicated to preserving and making available a range of scientific materials, including large data sets, video simulations, clinical samples, books, and articles. The USCDR's commitment to long-term preservation will ensure that the digital materials stored in the USCDR will be accessible to researchers for years to come, making the USCDR a valuable scientific resource for researchers around the world.

**Impact:** Digitizing, hosting, and preserving scientific materials are time-intensive, highly specialized activities that can unnecessarily detract from time that scientists would otherwise devote to research. Moreover, professional services for large-scale collections can require costly equipment and facilities. The USCDR would provide a cost-effective, time-efficient way for USC researchers to share scientific data sets and other research materials, enabling them to fulfill the data management plans required by the NSF, NIH, and other grants regardless of the size of the collection. The USCDR services would make the research findings of USC scientists accessible to departments and researchers within USC, as well as to researchers and organizations around the world.

**Existing Facilities:** The USCDR will help researchers create, manage, and preserve important scientific materials by uniting the expertise and resources of the USCDR's three founding partners: the USC Libraries, the USC Shoah Foundation Institute (SFI), and USC's Information Technology Services (ITS). The USC Libraries bring expertise in imaging services, physical preservation, metadata, and online access to digital collections. USC's SFI offers the technological infrastructure for mass-conversion media preservation and cataloging systems, as well as facilitates library and classroom delivery of collection-based content for primary, secondary, and higher education environments. USC's ITS will contribute to the infrastructure for digital preservation through the processing power of one of the nation's most powerful academic supercomputers.

**Future Growth:** Through the USCDR, the networking and storage needs for the USCDR will grow dramatically. To achieve the university's vision and ensure that the materials stored in the USCDR are preserved for future generations, resources will be needed to:

- Upgrade the technology of its digital preservation systems at regular intervals;
- Dedicate staff to help meet the specialized cataloging and access needs of scientific researchers;
- Upgrade servers to maintain high-speed access to the collection for large-scale processing;
- Dedicate high-capacity equipment to guarantee continual access to the preserved materials.

## Center of Excellence for Big Data on Health Outcomes & Microsimulation

**Research:** The Center of Excellence for Big Data on Health Outcomes and Microsimulation is led by faculty in the Pharmaceutical and Health Economics Department in the School of Pharmacy and in the Sol Price School of Public Policy. The Center of Excellence is housed at the USC Leonard D. Schaeffer Center for Health Policy and Economics, recognized as a national leader in health policy research and analysis. The USC Schaeffer Center conducts interdisciplinary research to increase value in health care markets and delivery; improve health and reduce disparities; and foster better pharmaceutical policy and regulation. The Center excels in data analysis, attracts highly skilled scholars, maintains an effective communications team, and supports a collaborative research infrastructure.

**Impact:** Econometric analysis and microsimulation provides policymakers and stakeholders evidence-based analysis on the trends in population health including effects of changes in aging, chronic conditions, and health disparities and the relationship between these trends and policy changes. With its computing environment, staff, and data holdings, the Schaeffer Center Data Core has rich resources for analyzing questions related to health, and strives to make them available to researchers throughout USC, through training and knowledge sharing about data sources.

**Existing Facilities:** The Schaeffer Center Data Core maintains several analytic computing server clusters and a non-networked computer to accommodate a wide range of data security and data analysis requirements. Our 60+ data holdings cover a range of data sources including survey data, public and private insurance claims, and electronic health record network data feeds. Our two analytic computing clusters consist of secure multi-processor Linux servers configured with software, memory, and disk storage to accommodate complex analyses of large data sets in a HIPAA-compliant environment that includes technical controls combined with operations that provide around the clock security event monitoring. The Center's computing staff includes a full-time system administrator, eight full-time research programmers and a data resources administrator. They provide expertise, training, and support for the application of diverse data resources to dozens of research projects.

**Future Growth:** The Center has access to the High Performance Computing Center (HPC), Census Research Data Center (RDC), and Amazon Web Services (AWS). We have used HPC's current environment and are exploring the use of HPC's recently developed HIPAA-compliant environment for analysis of big health data. The Data Core and the Health and Retirement Survey (HRS) are working to establish a secure enclave for use of their restricted data by USC researchers and their collaborators.



## Centers of Excellence for Computing of the Future

## Center of Excellence for High-Performance Computing & Communications (HPCC)

**Research:** USC's Center for High-Performance Computing and Communications (HPCC) provides a foundation and model for research in computational sciences and engineering by bridging USC's unique strengths in scientific computing, computer science, medical research, and communications. HPCC supports approximately 125 research groups, representing more than 1,200 researchers in a variety of disciplines, including computational biology, bio-nano interface and biophotonics, cosmology, geophysics, linguistics, medicine, materials science, nanosciences and engineering, and pharmacology.

**Impact:** The computing power of HPCC enables USC researchers to tackle grand-challenge class problems in a broad range of disciplines. With its advanced computing and communications resources, HPCC allows researchers to develop the models, simulations, and visualizations that will lead to ground-breaking advances in medicine, new materials for clean energy technologies, earth sciences, defense, and oceanography. HPCC resources have helped researchers at the Southern California Earthquake Center (SCEC) conduct seismic hazard research and researchers at USC's Collaboratory for Advanced Computing and Simulations develop stress corrosion cracking simulations that deepen our understanding of chemically influenced corrosion.

**Existing Facilities:** Housed in USC's state-of-the-art data center, HPCC has two Linux clusters. The primary cluster is a 56-GB low-latency bandwidth cluster. This cluster was ranked as the 9<sup>th</sup>-fastest academic computer in the U.S. and the 127<sup>th</sup> fastest computer in the world.

HPCC includes the USC Center for Data Visualization and Collaboration, whose resources allow researchers to study high-resolution simulations and computer-generated models. The tile wall enables researchers to project these images onto a 14-foot-wide by 8-foot-high, all-glass screen for multi-perspective analysis.

**Future Growth:** HPCC requires continual upgrading of its hardware and software to return to the ranks of the world's top 100 supercomputers and to offer USC's faculty and graduate students the necessary infrastructure for scientific discovery. Investment is needed in the following areas:

- Hardware and software upgrades, including graphics processing units, or GPUs, which accelerate computationally intensive processing;
- Upgraded technology for interactive and immersive 3-D visualization, which would include 14 stereo projectors for the tile wall, along with infrared technology for wireless synchronization, computing and visualization nodes, and software;
- Additional staff to support researchers and HPCC's infrastructure.

## Center of Excellence in Quantum Information Science & Technology

**Research:** Quantum information science and technology is concerned with the study of the new possibilities quantum mechanics offers for the acquisition, transmission, and processing of information. Quantum computers are predicted to solve classically intractable tasks such as breaking cryptographic codes, efficiently searching large databases, and efficiently simulating quantum dynamics. Quantum cryptography offers unconditional security. Quantum information theory has also revolutionized our understanding of the capacity of communication channels. Theoretical and experimental quantum information processing and quantum control research at USC spans electrical engineering, physics, chemistry, and computer science.

**Impact:** Quantum computing research at USC has catapulted to a world leadership position with the establishment of the Center for Quantum Information Science & Technology (CQIST), and especially the USC/ISI-Lockheed Martin Quantum Computing Center (QCC). CQIST and QCC researchers have already been awarded numerous NSF grants, a \$7M grant from IARPA, a \$6.5M MURI grant, and most recently a five-year \$45M contract from IARPA. We have attracted stellar young faculty and organized several major conferences on quantum computing, attracting hundreds of researchers from around the world. Multiple Nature and Science papers have been co-authored by QCC and CQIST members, and our members have given numerous media interviews resulting in significant exposure and enhancement of the USC brand. Our research has led to significant advances in the practical realization of quantum computing using solid state devices, which are expected to ultimately lead to large scale quantum information processing, capable of outperforming the most powerful classical computers. Interest in quantum computing has skyrocketed in the last few years, with large and small private companies (IBM, Google, Intel, Microsoft, Alibaba, etc.) investing in the fabrication of new quantum processors.

**Existing Facilities:** QCC is the first and only university-based entity worldwide to have its own D-Wave processor, the world's only dedicated quantum optimizer. Since 2011, QCC has housed three generations of such devices, and is currently home to a 1098-qubit D-Wave Two X processor. A focus of the Center is theoretical and experimental quantum adiabatic optimization, including both algorithm development and fundamental physics research. Adiabatic quantum optimization has the potential to dramatically speed up the solution of problems in, for example, machine learning, image recognition, software debugging, database searching, portfolio optimization, and combinatorial drug design. USC is a world-leader in quantum computing thanks to the presence of the D-Wave processor.

**Future Growth:** QCC facilities are presently located at and supported solely by internal funds from ISI. The currently installed quantum processor has been surpassed by a newer version, the 2048-qubit DW2000Q, which has been acquired by Google/NASA, Los Alamos National Lab, and Temporal Defense Systems. Thus, our leadership position has slipped. However, USC has a unique opportunity to be once again at the absolute leading edge of quantum information processing: being the first to upgrade to the next generation D-Wave "X16" system. This new device is expected to boast a complete architectural redesign, new and more quantum-coherent fabrication materials, and expanded user control. It will be by far the world's most advanced quantum computer. We anticipate being able to, possibly for the first time, demonstrate an unequivocal quantum speedup over classical computing. We also expect this device to potentially be the first to be capable of quantum-accelerating the solution of a problem of real-world relevance. The expanded user control will permit more detailed investigations into the physics underlying the processor and how processor performance and scaling depend on the quantum resources present. The estimated cost of the upgrade is approximately \$3M.

## APPENDIX I: CORE FACILITIES BY CENTER OF EXCELLENCE & SCHOOL

<b>BEHAVIOR OF MOLECULES, ORGANISMS AND THE COMPOSITION OF MATTER</b>		
Microscopy & Analysis	Center for Electron Microscopy and Microanalysis	Dornsife; Viterbi
Cell & Tissue Imaging	Broad CIRM Center Microscopy Core Facility	Keck
	Norris Cancer Center Cell and Tissue Imaging Core	Keck
	ZNI Multiphoton Microscopy Core Facility	Keck
Brain Imaging	Dornsife Cognitive Neuroscience Imaging Center	Dornsife
	Stevens Neuroimaging and Informatics Institute	Keck
Molecular Imaging	cGMP Cyclotron and Radiochemistry Laboratories, Molecular Imaging Center	Keck
	Clinical PET Imaging Center, Molecular Imaging Center	Keck
	Small Animal Imaging Laboratory, Molecular Imaging Center	Keck
Molecular Characterization	Center of Excellence for Molecular Characterization	Dornsife
Single Cell Technology	CSI-Cancer	Dornsife
<b>DECIPHERING THE CODES OF LIFE</b>		
Therapeutic Discovery & Development	Translational Research Laboratory	Pharmacy
	Choi Family Therapeutic Screening Facility	Keck
	Histology Laboratory	Pharmacy
Translational Pharmacogenomics	Translational Research Laboratory	Pharmacy
In Vivo Translational Research	In Vivo Translational Research Core	Keck
	Genomics & Precision Medicine	Molecular Genomics Core - NCCC
	UPC Genome Core	Dornsife
Proteomics & Biomarkers	Proteomics Core Facility	Keck
	Aging Biomarker and Service Core	Gerontology
Nanobiophysics	Nanobiophysics Core	Dornsife
	X-Ray Crystallography Core	Dornsife
Metabolic Assessment	Seahorse Core Facility	Gerontology
	Aging Mouse Phenotyping Core	Gerontology
	Diabetes and Obesity Research Institute	Keck; CHLA
	CHLA Saban Rodent Metabolic Core	Keck; CHLA
	Translational Research Laboratory	Pharmacy
Circulating Tumor Cells (CTCs)	Circulating Tumor Cells (CTCs) Core - NCCC	Keck
Flow Cytometry	Eli and Edythe Broad Center Flow Cytometry Core	Keck
	UPC Genome & Cytometry Core	Dornsife
	CHLA Fluorescence Activated Cell Sorting (FACS) Core	CHLA
	Translational Research Laboratory	Pharmacy
	Immune Monitoring Core	Keck
<b>PRECISION ENGINEERING OF NEW SUBSTANCES AND DEVICES</b>		
Nanofabrication	Keck Photonics Cleanroom	Viterbi
Stem Cell Engineering	Chang Stem Cell Engineering Facility	Keck
	Choi Family Therapeutic Screening Facility	Keck
Peptide & Protein Engineering	Center for Peptide and Protein Engineering*	Viterbi
Cellular Therapies	Center of Excellence in Cellular Therapies *	Keck
Advanced Manufacturing	Center for Advanced Manufacturing	Viterbi
<b>SCIENCE LIBRARIES OF THE FUTURE</b>		
Digital Repository (USCDR)	Digital Repository (USCDR)	USC Libraries; USC ITS
	Shoah Foundation Institute	Dornsife
Big Data on Health Outcomes & Microsimulation	Schaeffer Center Data Core	Pharmacy; Price
<b>COMPUTING OF THE FUTURE</b>		
High-Performance Computing & Communications	Center for High-Performance Computing & Communications	USC ITS
	Center for Data Visualization and Collaboration	USC ITS
Quantum Information Science & Technology	Center for Quantum Information Science & Technology	Dornsife; Viterbi
	USC/ISI-Lockheed Martin Quantum Computing Center	Dornsife; Viterbi
<i>* Core under development</i>		