VT-WFU SBES Biomedical Imaging Division

Virginia Tech (VT) – Wake Forest University (WFU) School of Biomedical Engineering & Sciences (http://www.sbes.vt.edu) (SBES) was established in 2003 as a joint venture between VT and WFU to develop novel solutions to challenging biomedical problems through interdisciplinary teamwork across engineering, science and medicine. SBES is also a major component of the Institute for Critical Technologies and Applied Sciences (ICTAS; http://www.ictas.vt.edu), Virginia Tech. The strategic emphases of SBES are biomedical imaging, biomechanics, tissue engineering, and other emerging technologies.

Biomedical Imaging Division (http://www.imaging.sbes.vt.edu) directed by Dr. Ge Wang consists of four parts: Computed Tomography (CT) Labs, Optical Molecular Tomography (OMT) Lab, Grating-based X-ray Imaging (GXI) Lab, and High-Performance Computing (HPC). This team consists of over 20 members and collaborators. This division is operated on both VT and WFU campuses, which are linked by video software and gigabit network. This Division is also considered as an ICTAS Center for Biomedical Imaging.

In VT, there is office and laboratory space of >2000sf in the ICTAS Building I (Figure R1) on the main campus. Additional ~1000sf for CT Lab and GXI Lab are in the ICTAS-CRC Building A, which is designed to shield sensitive instruments from environmental factors such as building vibration, stray electromagnetic field, and temperature fluctuation. The Nano-scale Characterization & Fabrication Laboratory (NCFL; http://www.ICTAS.vt.edu/NCFL) is also in the ICTAS-CRC Building A, with >$10M of modern instrumentation for nano-scale imaging and manipulation. The NCFL consolidates most of the advanced equipment on the Virginia Tech campus under one roof. In WFU, there is ~300sf workplace in the MRI building for CT Lab (directed by Dr. Hengyong Yu, adjacent to modern CT scanners). All the offices are equipped with high performance workstations.

Figure R1. Biomedical Imaging Division research space within the new SBES space in ICTAS Building I.

VT CT Lab (Director: Ge Wang): For clinical imaging, an x-ray tomosynthesis system Selenia (Figure R2) was acquired under a collaborative agreement with Hologic (http://www.hologic.com) and installed in summer 2010. Selenia uses selenium-based direct capture to eliminate light diffusion, a 24x29cm detector to cover the whole breast in a single view, and a HTC grid technology to reduce radiation scatter. For preclinical imaging, a true-color micro-CT scanner MARS (Figure R3) was acquired under a research agreement with MARS Bioimaging Ltd (MBI; http://marsbioimaging.com). Also, there are an x-ray imaging platform, a Scanco micro-CT scanner, an Xradia micro-CT scanner and an Xradia nano-CT scanner in our Division, which cover six orders of magnitude in terms of image resolution and sample size (Figure R4). The Scanco system has a field of view (FOV) of 20-38mm with a best resolution of 16µm at 10% MTF. The Xradia micro-CT system, purchased using an NIH SIG grant in 2008, is the highest resolution micro-CT system on the market, which can achieve 0.5µm
resolution at 10% MTF, and handle samples of up to 100mm in diameter. Under a developmental NSF-MRI grant support and in collaboration with Xradia (http://xradia.com), we acquired a 50nm resolution nano-CT system in 2009 and are developing ROI-focusing and interior reconstruction capabilities for this system. This next-generation nano-CT system will allow us to accommodate specimens much larger than that the current nano-CT protocols permit. Because of the high-resolution performance of the micro-/nano-CT systems, the nature of the housing is vital to ensuring their technical development and biomedical applications. Our Lab has one dedicated space for these systems in the ICTAS-CRC Building A, adjacent to the Nanoscale Characterization and Fabrication Lab (NCFL).

Figure R2. Hologic x-ray tomosynthesis system Selenia. Figure R3. True-color micro-CT system MARS.

Figure R4. SBES Advanced Multi-scale CT (SAM-CT) Facility, comprising Xradia nano-/micro-CT systems and a Scanco micro-CT scanner (http://www.imaging.sbes.vt.edu/research/sam-ct).

WFU CT Lab (Director: Hengyong Yu): See below in the WFUHS Resources.

X-ray Systems Lab in VT (Director: Guohua Cao): The X-ray Systems Lab is directed by Dr. Guohua Cao, who joined SEBS at Virginia Tech as an Assistant Professor in August 2011. His X-ray Systems Lab focuses on novel x-ray sources, detectors, and system engineering. His expertise is highly complementary to the existing strength of our Biomedical Imaging Division, especially in the instrumentation aspect (Figure R5). His recent x-ray imaging prototypes include a carbon nanotube (CNT) micro-CT system and a stationary digital breast imaging system.
tomosynthesis (s-DBT) system. The micro-CT scanner is one of the best in 4D CT imaging of small-animal models with high spatial and temporal resolution and minimum radiation dose. Dr. Cao built three such state-of-art scanners: one at the UNC Department of Physics & Astronomy for research and instrumentation development, one installed at the UNC Biomedical Research Imaging Center as a user facility, and one at the Department of Radiology, the University of Iowa College of Medicine. The s-DBT system is a clinical-trial ready 3D mammography scanner for early detection of breast tumors. It is made possible with the novel CNT x-ray source technology, which Dr. Cao made major contributions in translating the technology from a laboratory curiosity to a powerful building block for next-generation imaging systems.

OMT Lab in VT (Director: Ge Wang): In 2002, we pioneered bioluminescence tomography (BLT) in this lab. The first BLT prototype has been in operation since then. The second BLT prototype was developed in this Lab with major functional enhancements, including components for diffuse optical tomography (DOT), mirror and filter based multi-view multi-spectral data acquisition, and so on (Figure R6). A fluorescence molecular tomography (FMT) system has been recently developed for studies on bioengineered vessels (Figure R7). The LN-cooling 16bit digital CCD (Princeton Instruments VersArray 2048B and VersArray 1300B) and TE-cooling 16bit EMCCD cameras (Princeton Instruments. PhotonMAX 512B) are used for optical imaging experiments. A PXI machine (National Instruments) is for integration of all the instruments. A low light level integrating sphere LR-8²-LC (Sphere Optics Inc. NH) is for calibration of CCD cameras. There are also a highly sensitive spectrometer (USB-2000 FLG, Ocean Optics), a single photon counter (SPCM-AQR-16FC, PerkinElmer), a calibrated tungsten light source (LS-1-Cal, Ocean Optics), filter sets, lenses, fibers, automatic rotation and translation stages, as well as other optical and mechanical components. Furthermore, there are a set of spherical focused US transducers (Boston Piezo-Optics Inc, Bellingham, MA), a US function generator and a power amplifier (AG 1020 Series Amplifier, T &C Power Conversion Inc.), an optical fiber temperature measurement system (Luxtron m3300 thermometers, probes, and software, Luxtron Corp.), and an ultrasound controller (T&C Power Conversion Inc.) for ultrasound heating required by temperature-modulated bioluminescence tomography (TBT) we developed in 2006. Furthermore, we are actively developing a platform for x-ray fluorescence and luminescence CT targeting preclinical applications.

The commercial software packages include the COMSOL Multiphysics (http://www.comsol.com), TracePro Optomechanical Modeling Software (Lambda Research), Amira (Visage Imaging), Intel C/Fortran compiler, Intel Math Library, IMSL C/Fortran Numerical Library (Visual Numerics), Microsoft Visual Studio, MATLAB (MathWorks), Mathematica (Wolfram Research), AutoCAD (Autodesk), Solidworks (Dassault Systèmes
SolidWorks), and LabView (National Instruments). In addition to the above commercial products, the in-house programs include a Molecular Optical Simulation Environment (MOSE) version 2.0, a Finite-Element Based BLT Solver, a 3D Geometric Modeler (3DGM) for finite-element meshing, and a TIM-OS Simulator for Monte Carlo optical simulation in inhomogeneous complex geometry (http://www.imaging.sbes.vt.edu/software), which was highlighted twice by a top professional journal Physics in Medicine and Biology.

**GXI (Grating-based X-ray Imaging) Lab in VT (Director: Ge Wang):** The phase-contrast and scattering mechanisms allow unique distinction of soft tissue features at a reduced dose level. Recognizing the potential of the grating-based x-ray imaging technology, in 2007 we set up this lab in conjunction with our CT Lab. We are developing grating-based x-ray phase-contrast and dark-field imaging/tomography theory and technology for biomedical applications. Our lab has one grating-based x-ray imaging platform (Figure R8, in a dedicated room in the ICTAS-CRC Building A).

![Figure R8. Grating-based x-ray-imaging platform for phase-contrast and dark-field tomography.](image)

**HPC Lab in VT (Director: Haiou Shen):** A Micro-way PC cluster of 16 AMD Dual Opteron nodes runs up to 150GFlops. This cluster supports an IMSL C/Fortran Library, MPICH, Intel Math Lib, Intel C/Fortran compiler, and MATLAB. The lab can freely use the VT System X (http://www.tcf.vt.edu), which is a top high-performance computing system in the world. System X contains 1100 Dual 2.3GHz Apple Xserver and supports IBM XL Fortran, IBM XLC and GCC compiler. After the relocation of a major part of this lab from the Univ. of Iowa to VT in 2006, the remaining part of the lab in Iowa became a new lab directed by the former co-director Dr. Ni (http://www.uiowa.edu/%7Emihpclab/facility.html), in collaboration with the HPC Lab in VT.

**IT Infrastructure (Master: James Bennett):** Since 2010, significant resources and efforts have been committed by the VT-WFU Biomedical Imaging Division for upgrades to internal and external Information Technology (IT) infrastructure. The goals for internal upgrades are to provide indexed repository for all experimental results / documentation, standardize lab hardware and procedures for data storage / backup, and improve communication within lab members. The goals for external upgrades are to consolidate all web contents to a single location, create user friendly interface for data, results and software sharing, improve communication with external collaborators, and promote interdisciplinary, crossdisciplinary and transdisciplinary teamwork.

The solution for meeting our internal goals is to implement **Alfresco** (http://www.alfresco.com), an open-source Enterprise Content Management System (CMS). We have a dedicated server with on/off-site backup and power redundancy. We utilize the Share functionality, quoting from Alfresco:

*Alfresco Share users can now browse and access any content managed by Alfresco irrespective of type, format or location. Alfresco Share 3.3 provides one interface to access all of the core components – Document Management, Collaboration, Email Archive and Records Management.*

Our external requirements are met by several tools centered around our **WordPress** (http://wordpress.org) implementation. WordPress is an open source web publishing platform, quoting from their site:

*WordPress is a powerful publishing platform, and it comes with a great set of features designed to make your experience as a publisher on the Internet as easy, pleasant and appealing as possible. We are*
proud to offer you a freely distributed, standards-compliant, fast, light and free personal publishing platform, with sensible default settings and features, and an extremely customizable core. This site drives our publication library, wiki, web development, training and more. It also hosts a commercial virtual video conference system ooVoo (http://oovoo.en.softonic.com), which further improves our external communication. This feature is especially useful for interaction with our out-of-state and international collaborators. As an example of our frequent multi-site video conferences, Figure R9 presents a snapshot from a BRP proposal preparation meeting.

![Figure R9. Video conference among Virginia Tech, Mayo Clinic, Central Florida Univ. and Wake Forest Univ.](image-url)