### Center for Systems Imaging Core - MAJOR EQUIPMENT

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**Updated 1 July 2022**

**Major Equipment for the Center for Systems Imaging Core (CSIC) Users**

**CENTER FOR SYSTEMS IMAGING CORE (CSIC)**

**Magnetic Resonance Imaging (MRI)**

The Center for Systems Imaging Core (CSIC) operates three full-time research dedicated Siemens Magnetom Prisma 3T MR scanners, and a shared clinical/research 3T wide-bore Siemens Skyra scanner. With multiple human research 3T MRI scanners, MRI studies can be effectively distributed across the Emory community. Studies that require close proximity to Emory University Hospital (EUH) or studies performed on in-patients can be performed on the scanner located on the ground floor of the hospital (CSI-EUH). Outpatient studies, where convenience of parking and more flexible scheduling is required can be performed at scanner located at the Wesley Woods (WW) campus (CSI-WW). Both scanners have been recently upgraded to the PrismaFIT platform and VE11C software. Studies which require a wide-bore scanner or have a study population located at the Brain Health Institute (BHI) at Executive Park can use the Prisma scanner located there or the Skyra scanner next door for up to two hours per day (CSI-BHI).

**Research Dedicated 3T Prisma MRI Scanners (EUH and WW)**

MRI Scanners. Magnetom Prisma whole-body MR systems are equipped with a state-of-the art gradient system with a maximum (per axis) strength of 80 mT/m and slew rate of 200 T/m/sec, 64 independent RF receiver channels capable of 204 receiver connections, and a 2-channel RF transmitter. Multiple coils are available, including a 64-channel head/neck coil with 52 channels for imaging of the head region, a 32-channel head-only coil, a 20-channel head/neck coil, spine array coil, flexible chest coil, large and small flexible coil for extremity imaging, Tx/Rx CP Head Coil for large no-cap head space, and a 31P dual-tune flexible coil (only for Prisma@EUH) for phosphor spectroscopy. All scanners are running the VE11C version of the Siemens Syngo software. In addition, the scanners are equipped with DirectRF and DirectConnect technology, providing a significant increase in signal-to-noise ratio. The Prisma scanner platform allows efficient acquisition of high-resolution fMRI and DTI images with protocols compatible to those released by the Human Connectome Project. Furthermore, the Prisma scanner located at EUH is equipped with multinuclei spectroscopy and additional shimming power for improved magnetic resonance spectroscopy. A number of advanced research sequences are also available, including Vessel Size Imaging, quantitative Arterial Spin Labeling, Diffusion Spectrum Imaging (for High Angular Resolution Diffusion Imaging) and Simultaneous Multi-Slice EPI (allowing for sub-second high-resolution whole-brain fMRI data acquisition), 4D phase contrast MR for measuring time-resolved flow velocity, displacement encoding with stimulate echoes (DENSE), and multi-echo and ultra-short echo time sequences. With our master research agreement with the vendor, advanced work-in-progress MR sequences from the vendor, collaborators from other institutions, or developed sequences locally can be deployed.

Stimulus and response system for functional MRI. All scanners are equipped with peripheral systems for fMRI. Stimulus/response controls for behavioral tasks concurrent with fMRI are supported by an array of hardware specifically designed to allow investigator flexibility and precision. Visual presentation at EUH and WWHC sites are provided by a high resolution LCD projection system (1400x1050 SXGA, 4200 lumens, 1300:1 ratio) delivered from the back of the suite onto a custom fit screen mounted within the bore behind the participant’s head. The EP12 sites are equipped with Cambridge Research Systems BOLDScreen MRI compatible LED displays. Audio presentation is provided by an Avotec Silent Scan 3100 that has been calibrated to maintain sound pressure levels that are dependent directly on input (flat frequency response +/- 4dB, 200-4500Hz range). A fiber-optic ergonomic bilateral button response system from Psychology Software Tools exists, as well as a control unit to support custom response shapes (joysticks, steering wheels, wands) from Current Designs. Hardware are connected through a single switch that signals TTL trigger pulses and allows connectivity to an investigator’s laptop with non-proprietary connections (USB, 1/8” minijack audio, VGA & DVI). A dedicated stimulus and response monitoring computer running Eprime 2.0 and Presentation stimulus programming software also exists. An OptoAcoustics FOMRI MRI-compatible microphone featuring advanced active noise cancellation technology is available for speech fMRI paradigms. CSI-EUH MR scanner is also equipped with multi-nuclei option. Currently a 31P/1H dual tune flexible coil is equipped and is applicable to phosphor MRS and metabolism studies.

CSI-WW: Other Equipment. A Biopac MP150 (Goleta, CA) MRI-compatible physiological response measurement system is available for collecting peripheral physiological measures. The MP150 system provides high resolution (16 bit), variable sample rates for analog and calculation channels, 16 analog inputs and two analog outputs, digital I/O lines (automatically control other TTL level equipment), and 16 online calculation channels. The MP150 System provides high-speed acquisition (400 kHz aggregate) via an Ethernet connection to a host computer. AcqKnowledge, the Biopac control and analysis software package is used to control the acquisition and can be used for data analysis. Available physiological measures are cardiac pulse, heart rate, heart period, respiratory sinus arrhythmia, respiration and electrodermal activity. The physiological measurements recorded by Biopac can be viewed real-time on a dedicated laptop computer through the Biopac data acquisition software. All responses can be recorded in MatlabTM, text or proprietary Biopac software formats, for retrospective analysis. A MEDRAD (Warrendale, PA) Power Injector system for contrast administration is also available.

CSI-WW: Mock MRI Scanner. A mock MR scanner is set up in the Wesley woods facility. This mock scanner is similar in appearance to the Siemens MRI scanners. It provides stimulus presentation and scanner noise emulations and is used to familiarize pediatric subjects with MRI scanner operation and to acclimate them to the MR scanning environment.

CSI-EUH: Other Equipment. Peripheral equipment, including computers and software for paradigm generation, setup for stimulus presentation, devices for recording behavioral data and physiological parameters including heartbeat, respiration, blood pressure, eye movement, ECG, EEG, and EMG are also established for operation concurrent with MR acquisition. Stimulus generation and presentation setup allows us to present acoustic, electric, and vibrational stimuli and oral and venous administration of liquids. Setup for response via button box, keyboard, mouse, speech, eye movement, and grip force has also been established. We are also equipped with an electronic shop and a small machine shop, providing the capability to fabricate custom MRI coils, animal holders, and special purpose stimulation devices. Other equipment in the scanner rooms includes an Ohmeda Biox 3700 Pulse oximeter, a Sage 351 infusion/withdrawal syringe pump, and a Dinamap 1846 SX Critikon vital signs monitor.

**Shared Research/Clinical Skyra 3T MRI Scanner (BHI)**

The shared MRI unit is a Siemens Medical Solutions (Malvern, PA) 3.0 Tesla Skyra MRI scanner, a full body scanner (70 cm bore) with Sonata gradient set (gradient amplitude of 40mT/m, maximum slew rate of 200T/m/sec). The system is actively shielded and is equipped with 32 RF receiver channels and the total imaging matrix (TIM) suite. Multiple coils are available for the systems, including a, 20 channel head matrix coil, two body matrix 8 channel flex coils, 8 channel head coil, 4 channel carotid coil and a 24 channel spine coil.

This scanner runs Siemens Syngo VE11A software and has a number of advanced Siemens product sequences including parallel imaging, SWI, BLADE, Diffusion Tensor Imaging (DTI) & Tractography. Auto Align feature for reproducible slice positioning based on a 3D MR brain atlas, BOLD imaging and in-line analysis suite with 3D PACE realtime motion correction, advanced cardiac package, and single and multi-voxel spectroscopy. A number advanced research sequences including Vessel Size Imaging, quantitative Arterial Spin Labeling, Diffusion Spectrum Imaging (for High Angular Resolution Diffusion Imaging) and Simultaneous Multi-Slice EPI (allowing for sub-second high-resolution whole-brain fMRI data acquisition), 4D phase contrast MR for measuring flow velocity, displacement encoding (DENSE), multi-echo and ultra-short echo time sequences are also available.

**Computing Facilities**

The CSIC is equipped with a state-of-the art computing facility consisting of a twenty-four nodes linux mini cluster, disk RAIDs with 529 TiB total storage capacity, a full rack capable of supporting up to 16U calculation nodes, including three NVidia Tesla GPU enhanced nodes, and an automated off-site back-up server with 394TiB backup storage configure to bi-weekly rotation and one-year time machine backup scheme. For data processing and analysis, Matlab, IDL, LCmodel, SPSS, SPM, fsl, AFNI, freesurfer, ANTs, MrTrix, Slicer, tensorflow, and a variety of python based pipelines are installed and available on our cluster. VMware and Oracle VirtualBox are also available for special virtualization need. The computer cluster is also a dicom receiving server open to all collaborating PIs for data storage and analysis purpose.

**9.4T Bruker Animal MRI System**

A 9.4T/21-cm Bruker animal MR imaging/spectroscopy system is housed in the Whitehead Biomedical Research Building in approximately 400 square feet of space. The magnet is actively shielded to reduce the extent of the fringe field. The imaging console is interfaced with a Bruker AVANCE spectrometer driven by a LINUX workstation and Bruker ParaVision 5.1 imaging software. The system is equipped with actively decoupled RF coils (volume coil as a transmitter and the surface coil as a receiver) with 2-RF channels: one with 1000 Watt RF amplifier for 1H NMR studies and the other with 800 Watt broadband amplifier (frequency range from 6 to 365 MHz) for X-nucleus NMR studies. A quadrature volume coil optimized for imaging rat brains and a variety of surface coils are also available. The scanner is equipped with a state-of-the-art BFG 200/115-S-14 12-cm diameter gradient insert from RRI (maximum gradient strength 675 mT/m, 120 usec risetime), two actively shielded Bruker BGA gradient sets, BGA-12 (12 cm, maximum gradient strength of 400 mT/m, 88 usec risetime) and BG-6 gradient set (6 cm, maximum gradient strength of 1000 mT/m, 55 usec risetime), all driven by Copley 200A/300V Gradient Amplifiers. Peripheral equipment including a) physiological signals monitoring system (BioTrig), used for synchronizing MR acquisitions with ECG or respiration triggering signals; b) animal anesthesia and physiology maintenance system; c) a comprehensive set of RF coils, suitable for studying different sized animals, different tissues and locations, and different nuclei including proton, 17O, 13C, 19F, an 31P; d) acoustic, optic, and electrical stimulation accessories for functional study. This system is suitable for studying mice, rats, ferrets and other small animals.

**Cyclotron and Radiochemistry**

CSIC’s radiochemistry lab is directed by Dr. Mark Goodman, PhD and Ron Crowe (a licensed Radiopharmacist).  The lab houses a Siemens RDS 111 multiport, self-shielded, automated cyclotron producing a 11 MeV, 50 µA proton beam. The cyclotron is equipped with targets for the routine production of curie amounts of [18F]fluoride, [11C]carbon dioxide, and [15O]oxygen and millicurie amounts of [13N]ammonia. The radiochemistry area is a 2,100 square foot cyclotron vault and laboratory which includes four master slave manipulator arm-equipped hot cells, five mini-cells, one Siemens computer programmable two reaction vessel radiochemical processing unit, one GE TracerLab FXN unit, one GE Fastlab unit, one Siemens automated oxygen-15 water synthesis module, two GE PETtrace carbon-11 methyl iodide modules, one clean room , hot and cold waste systems and ventilation chemical and radiation monitoring systems. A pharmaceutical grade germanium-68/gallium-68 generator is located in the clean room for routine production of as [68Ga]GaCl for the preparation of as [68Ga]-radiopharmaceuticals for preclinical small animal and human clinical and research imaging studies. The radiochemistry laboratory is equipped with four pneumatic tube systems located in the four hot cells for rapid delivery of radiopharmaceuticals. The radiochemistry laboratory is fully equipped with a variety of modern analytical instruments which include one Carroll and Ramsey Associates eleven probe radiation detection system, one Waters Alliance radio-HPLC unit that is configured with UV/Vis and IN/US Radiometric detectors and one Waters Breeze radio-HPLC units that are configured with  UV/Vis, and Bioscan Radiometric detectors, one Lab Logic Scan-RAM radioactivity thin-layer chromatography system, two electrically activated rheodyne HPLC injectors, eight manual rheodyne HPLC injectors and 4 Waters' 515 HPLC pumps, one Bioscan hot cell radiometric detector, one Agilent 6890N radio-gas chromatograph equipped with a thermal conductivity and flame ionization  detectors, one Lab Logic Gamma-RAM Radio-GC detector, one Ortec sodium iodide detector and well counter/multichannel analyzer, two Capintec 712M dose calibrators with four remote ionization chambers and four remote readouts and four Mettler electronic balances. The radiopharmacy routinely prepares [68Ga]Netspot, [18F]FACBC aka Axumin, [15O]water, [11C]PIB and [18F]T807 for human imaging studies.

**Positron Emission Tomography (PET) High Resolution Scanner**

The PET HRRT scanner is the highest resolution human brain PET scanner available. It consists of concentric rings of LSO and LYSO detectors to provide depth of interaction information. Because of this, the resolution is 2mm and fairly isotropic throughout the field of view. Data is collected in list mode and reconstructed in 3D on a 16-node dual processor computer cluster. Attenuation scanning is performed very rapidly in singles mode with a 30 mCi 137Cs point source. This scanner provides state-of-the-art PET imaging for human or animal neuro studies or whole body imaging for animals or other objects less than 20 cm across.

The HRRT scanner room is a 400 sq. ft. room with 20 feet of bench space and a sink. The room is equipped with anesthesia gases and exhaust and a pneumatic tube system for delivery of doses from the cyclotron suite. The pneumatic tube system terminates in a lead cave that contains a Capintec CRC-712M dose calibrator. Stainless steel tubes from the cyclotron have been installed to deliver radiolabeled gases directly to the room from the cyclotron. The room also contains two 4 cu. ft. lead caves for storage of phantoms and calibration sources.

The PET/HRRT scanner control room (110 sq. ft.) contains two computer workstations, hardcopy output devices, the computers for controlling the scanner, and the video monitor command center, and a wide range of peripherals to read and write tapes and optical disks.

**MicroPET/CT Animal Scanner**

The Inveon microPET is a lutetium oxyorthosilicate (LSO)–based preclinical PET scanner used primarily for small rodent imaging. The system is comprised of 64 detector blocks arranged in 4 contiguous rings, with a crystal ring diameter of 16.1 cm and an axial extent of 12.7 cm. The energy resolution is 14.6 %, sensitivity of 6.7%, scatter fraction of 8-17 % and spatial resolution of 1.8 mm FWHM. Data acquisition options include static, dynamic, respiratory gating and cardiac gating. This represents the best available PET imaging for small objects. The microPET scanner can be docked to the microCT scanner to form a microPET/microCT system.

The Inveon microCT Module is a high resolution 3D anatomic computed tomography (CT) imaging system for laboratory animal studies. The x-ray source is for high speed whole mouse or rat preclinical x-ray CT studies and other applications requiring resolution down to 30 microns. The system is capable of respiratory and cardiac gating. The scanner can be docked to the microPET scanner to form a microPET/microCT system.This ultra-high speed implementation of a modified Feldkamp cone beam reconstruction algorithm exploits recent developments in microprocessor technology to provide reconstructed image volumes within seconds of scan completion. The base reconstruction system uses two Xeon processors to generate 512 x 512 x 768 voxel image volumes in real time during a scan. Larger volumes are quickly reconstructed in multiple passes.

**Peripheral quantitative computed tomography (pQCT)**

The XCT 2000 pQCT Bone Densitometer is a type of low-dose prescription x-ray device used to perform non-invasive measurements of bone mineral density (BMD) in a peripheral part of the body, such as the forearms or legs. The pQCT technique allows the calculation of bone strength with respect to bending, torsion, and compression from bone's cross sectional geometry. Additional morphometric parameter like endosteal and periosteal perimeter and bone cross sectional area are accessible in vivo. pQCT measurements at tibia or radius are widely performed in clinical routine.