The Ahmanson-Lovelace Brain Mapping Center

The faculty, staff and major physical resources to be used by this project are housed in the 13,000-ft² Ahmanson-Lovelace Brain Mapping Center. The primary lab spaces, described below, include the PET and cyclotron laboratories, the MRI lab, the transcranial magnetic stimulation (TMS) facility, the data viewing and computing labs. In addition to the laboratory space, there are offices for the PI's and several of the investigators, a 575-ft² conference/teaching and library space, a 140-ft² media laboratory for the production of computer and video graphics and a 410-ft² student center for trainees. The Ahmanson-Lovelace Brain Mapping Center is located adjacent to the Reed Neurological Research Center, the UCLA Center for Health Sciences and the Learning Resource Center.

The Cyclotron Laboratory: Residing in the Brain Mapping Center, we have acquired a cyclotron manufactured by Siemens-CTI. This device (RDS-111) is capable of producing a full spectrum of positron-emitting radioisotopes including: ^{15}O, ^{13}N, ^{18}F and ^{11}C. We currently produce sufficient quantities of oxygen-15 labeled water to perform cerebral PET activation studies. In addition, this includes an on-line continuous synthesis system capable of converting cyclotron-produced ^{15}O into ^{15}O- labeled water, carbon dioxide, carbon monoxide and oxygen gas for continuous or bolus inhalation or intravenous infusion (water) to the subjects. This system is fully automated and computer controlled thereby severely limiting or eliminating radiation exposure to personnel.

Brain Mapping PET Laboratory: This laboratory is in the Brain Mapping Center in a suite specially designed for its use. It occupies a space of approximately 700-ft² divided into a room for a cyclotron and its support equipment, a PET scanner, a control room, and a hot lab. Appropriate support rooms for patient waiting, reception and changing are available. The scanner is a Siemens-CTI HR+ EXACT device. It provides whole body high-resolution images for both dynamic and static imaging of the brain and body. Three-dimensional image acquisition and reconstruction are available with this device. These data can be collected as stationary scans or in dynamic mode. This system has a set of retractable septa as well as germanium-gallium-68 ring sources for attenuation measurement.

The detector system consists of specially designed BGO detectors that provide optical coupling to four photomultiplier tubes. The detector interactions are determined by analog logic similar to that of gamma cameras. The image resolution is nominally four millimeters in all planes. These measurements have been obtained as full-width half maximal estimates in the center of the field of view. In addition, the system has a separate and complete processing console and a 9-gigabyte storage capacity. Given this configuration, the available processors are able to reconstruct three-dimensionally acquired data sets from 36 separate water injections per day without backlog.

MRI Laboratory: The Magnetic Resonance Imaging (MRI) laboratory, occupies approximately 4,500-itu
ft² of the Ahmanson-Lovelace Brain Mapping Center. This facility houses a Siemens Trio 3.0 Tesla MRI Scanner, a Siemens Sonata 1.5 Tesla MRI Scanner and a Bruker 7.0 Tesla Small Bore MRI Scanner.

Siemens TRIO 3.0 Tesla MRI Scanner: This 3.0 Tesla device is configured with 32 receiver channels comprised of 102 integrated coil elements. The instrument has a

181 cm field of view. It is capable of integrated parallel acquisition techniques and provides high signal to noise in the parallel imaging mode. The system is capable of a variety of different forms of structural and angiographic imaging in addition to functional echo planar imaging, diffusion imaging, perfusion imaging, and proton MR spectroscopy. In addition to the 32 channel receive-only head coil, the instrument also has a transmit-receive head coil. Gradient performance for each axis include: maximum amplitude of 45 mT/m, minimum rise time 200 microseconds from 0 to 40 mT/m, and a maximum slew rate of 200 T/m/s. The vector gradient performance (vector summation of all three gradient axes) results in a maximum effective amplitude of 32 mT/m and a maximal effective slew rate of 346 T/m/s. The water cooled gradient amplifier has a maximum amplitude voltage of 2,000 volts and a maximum current output of 625 amps. The instrument has a minimum slice thickness (in two dimensions) of 0.1 mm and a minimum partition thickness (in three dimensions) of 0.05 mm. The instrument produces high sensitivity with 1.2 ppm homogeneity and impressive stability. Single shot EPI sequences for measuring diffusion-weighted data sets with up to 256 directions of diffusion weighting are also a part of this instrument's capability. It provides diffusion tensor imaging and parametric maps derived from fractional anisotropy calculated in real time, automatically. The high performance computer contains Pentium 4 CPU generation dual processors with a 3 GHz clock rate, 2 GB RAM, 136 GB systems hard disks, 136 GB hard disks for the database, 173 GB hard disks for storage of approximately 110,000 images (256^2 matrix, uncompressed), 1 CD-R drive for uncompressed image storage data in DICOM format.

Siemens Sonata 1.5 Tesla MRI Scanner: The Brain Mapping Siemens Sonata system is a FDA-cleared magnetic resonance imaging system that has been optimized for brain studies. The system is capable of a variety of different forms of structural and angiographic imaging in addition to functional echo planar imaging, diffusion imaging, perfusion imaging, and proton MR spectroscopy. It acquires fMRI using a gradient system that produces 40 mT/m per axis at a slew rate of 200 T/m/s per axis. Single shot echo planar imaging can be performed with T2- or T2*-weighting.

Bruker 7.0 Tesla MRI Device:
A Bruker Biospin 7.0 Tesla 30 cm clear bore MRI/MRS is operating in a 535-ft² space in the UCLA Ahmanson-Lovelace Brain Mapping Center. The instrument is capable of the full spectrum of modern neuroimaging including structural MRI, functional MRI, perfusion MRI, diffusion tensor MRI, and multinuclear MR spectroscopy.

Three gradient systems are available:
1) 200 mm inner diameter with a maximum gradient strength of 200 mT/m
2) 116 mm inner diameter with a maximum gradient strength of 400 mT/m
3) 60 mm inner diameter with a maximum gradient strength of 950 mT/m.

A variety of radiofrequency volume coils and surface coils are available for use with these gradient systems.
1) 1H 18mm inner diameter linear transceiver volume coil.
2) 1H 35mm inner diameter linear transceiver volume coil with 200W maximum transmit pulse.
3) 1H 72mm inner diameter linear transceiver volume coil with active decoupling and 750W maximum transmit pulse.

4) 1H 154mm inner diameter linear transceiver volume coil with 1000W maximum transmit pulse.
5) 1H receive-only surface coil with active decoupling.
6) 1HQuadrature array receive-only surface coil with active-decoupling.
7) 1H/13C Dual-tuned transceiver surface coil.
8) 1H/31P Dual-tuned transceiver surface coil.

Full physiological monitoring is available including core temperature control and monitoring of heart and ventilation rate, end-tidal PCO_2 and (non-invasive) blood pressure. A surgical suite which includes a surgical microscope and a downdraft air exhaust table is located in the adjoining room. The surgery and magnet rooms are equipped with isoflurane gas anesthesia equipment. A dedicated Linux workstation operating the Bruker Paravision software is available for offline image and spectroscopy processing. In addition the Brain Mapping Center operates a ring of high performance Macintosh workstations and a RAID data storage system, which are available to Center users. The 7.0 T 30 cm MRI Laboratory is available for use by UCLA-affiliated investigators who have research studies that require imaging of small animals, various phantoms and postmortem tissues. Operation and maintenance costs are recovered through user fees.

Transcranial Magnetic Stimulation (TMS): The TMS lab at the Ahmanson-Lovelace Brain Mapping Center is equipped with two Magstim 200-2 magnetic stimulators linkable by a Bistim-2 module for single and paired-pulse neurophysiology studies. The lab also has a Magstim Rapid-2 magnetic stimulator capable of repetitive and patterned stimulation trains such as theta-burst stimulation. Each stimulator can be used with a variety of different stimulation coils including circular, figure-8, angled figure-8 (for deeper stimulation), air cooled coils (for rapid repetitive stimulation). A sham-air-cooled coil is also available for blinded treatment trials.
The lab is also equipped with Brainsight software and hardware for frameless stereotaxy to allow registration and online monitoring of the subject's head position with his/her structural brain image and tracking the position of the magnetic stimulation coil with respect to the underlying brain structures. The tracking hardware uses a Polaris infrared stereoscopic camera to image the head and magnetic stimulation coils. Infrared reflective trackers are available to mount on the head and coils for tracking purposes.

The lab is also equipped with custom hardware, including a flexible coil holder and optional chin-rest and neck brace for holding the subject's head still during experiments.

Full neurophysiological tools are available including a 4-channel Delsys surface EMG amplifier, a pair of CED 1902 isolated preamplifiers, and general 6-channel Grass IP511 differential amplifiers. Experiments can be controlled either from a PC running Presentation (Neurobehavioral Systems) using an integrated parallel port breakout box or a PC running Signal (CED) using an linked CED 1402 micro2 analog/digital converter. The PC running Presentation is ideal for presentation and response recording with integrated TMS control during behavioral studies. The PC running Signal is optimal for detailed and complex neurophysiologic studies.

EEG: The Ahmanson-Lovelace Brain Mapping Center is equipped with a custom-built EEG laboratory housing a Geodesic 128-channel system for high-density EEG and ERPs recordings. The major system components are an EEG Acquisition System with NetAmps 200 in a rack-mount cart coupled with an articulated Net arm and NetStation

4.0 acquisition software, as well as a 1.25 GHz Macintosh G4 PowerPC as the CPU, and a 22-inch Apple Cinema Display LCD monitor for high-resolution online tracking of EEG data. The laboratory also features a Dell 866 MHz PC with a 17-inch monitor to be used in conjunction with the E-Prime 1.0 for NetStation as the experimental control workstation for millisecond-accurate stimulus presentation. The sound-shielded room in which data are collected is equipped with Audiometrics E-A-R Tone noise-reducing insert headphones that can be coupled to either the PC or Macintosh computers in the console room. A 17-inch Macintosh monitor mounted on the wall is also available to allow for presentation of visual stimuli. NetStation 4.0 Waveform Tools is available for EEG/ERP data analysis and visualization. This software is an integrated series of applications for digital filtering, artifact rejection, eyeblink correction, baseline correction, re-referencing, ERP averaging, waveform plotting, spherical-spline interpolation, and generation of 2D and 3D topographic potential maps and animations. This system is particularly well suited to study developmental populations thanks to use of Sensor Nets (available in sizes to fit infants to adults) which maximize ease of electrodes placement and minimize subject discomfort.

The Neuroscience Research Building Facility

The Neuroscience Research Building Facility: The NRB Facility resides within the Department of Neurology at the UCLA School of Medicine. The facility was designed and furnished for the acquisition, processing, and storage of brain image data from a variety of sources.

Physical Infrastructure: The facility is physically located in the Neuroscience Research Building (NRB), occupying approximately 8,425-ft² of the building's second floor. The space is comprised of a reception area, Director and faculty offices, a modern computer room, a user area, wet labs, a conference room, and the Data Immersive Visualization Environment (DIVE) discussed here within. The data center in this space includes a raised floor, a 130 KVa UPS/PDU capable of providing uninterruptible power to all equipment housed in the room, dual Leibert air conditioning units, humidity control, and a fire suppression mechanism. A sophisticated event notification system is integrated in this space to automatically notify personnel of any abnormal power, water, or HVAC issues that arise. Immediately adjacent to this machine room is a user space with eighteen individual stations separated by office partitions. Each station is equipped with a four copper Gigabit network ports and 802.11n wireless signals for networked image processing, visualization and statistical analysis. To provide telephony services, the facility relies on Voice over IP (VoIP) technology. VoIP units, including wireless handsets, are distributed throughout the laboratory. In addition, the conference room and the DIVE are equipped with supplementary H.232 videoconferencing systems.

Having reached the power, cooling, and physical capacity limits of the second floor data center, the facility was augmented with an additional 2,127-ft² space on the building's first floor containing a state-of-the-art data center and additional offices. The office space can support up to twenty researchers and is outfitted with the same technological specifications as the existing facility. The 580-ft² data center is outfitted with an "in-row" cooling solution that regulates temperatures strictly within the server racks—as opposed to the traditional raised floor, hot-cold aisle technique that uses more energy to cool the entire room. Multiple chilled water lines are fed from the building to a Rittal TS 8 rack system, which houses the servers and provides in-row cooling. The racks are fully enclosed and deliver chilled air to the front of the machines while recycling warm air exhausted at the rear. During normal operation, keeping the air within the system provides maximum efficiency, but should a component fail, once temperatures reach 80°F the magnetic locks on the rack doors are programmed to release, forcing the doors open to provide ambient air to the machines. A 550KVa Eaton UPS provides uninterruptable power to the facility's current equipment and is sized to accommodate future large hardware expansions. In order to support the additional personnel and computational resources, the data center is equipped with multiple 10 Gigabit connections in a fault-tolerant, load-balanced configuration that interconnect with the primary data center.

Finally, a tertiary 800-ft^2 data center, located in UCLA's Reed Building, is shared with the Department of Neurology. This physically separated building primarily houses tape-based backup systems, to provide a failsafe data backup in case of a catastrophic event at NRB. This third data center is connected to our primary by dual, redundant Gigabit fiber connections as well as dual single-mode fibrechannel connections to extend the facility's storage area network (SAN).

Compute Resources: Rapid advancements in imaging technology have provided researchers with the ability to produce very high-resolution, time-varying, multidimensional data sets of the human brain. The complexity of the new data, however, requires immense computing and storage capabilities. To meet the computational requirement, the NRB Facility houses the following high performance computing (HPC) clusters:

- a 306-node Oracle V20z cluster. Each compute node has dual 2.4GHz AMD Opteron processors with 8GB of memory. (612 cores total)
- an 80-node Oracle X2200 M2 cluster. Each compute node has dual 2.2GHz quad-core AMD Opteron processors and 16GB of memory. (640 cores total)
- a 416 node HP ProLiant SL2x170z G6 cluster. Each compute node contains dual quad-core 2.66GHz Xeon 5500 processors and 24 gigabytes of memory (3,328 cores total)

To augment the facility's cluster resources, a group of 8 HP DL580 G7 32-core 2.4GHz X7550 machines, each with 256GB RAM, provide the high-memory computing requirements needed for biomedical applications, particularly gene sequencing.

Storage Resources. The NRB facility is architected using a fault-tolerant, high-availability systems design to ensure 24/7 functionality. To complement its computational systems, the laboratory uses high performance network attached storage (NAS) and SAN technologies to accommodate current and projected storage requirements. The facility's current capacity is approximately 4 petabytes of online and offline storage.

To meet the extensive I/O demands of the laboratory's HPC clusters and address the bottlenecks inherent in traditional NAS technology, the facility has deployed three EMC-Isilon parallel storage clusters, with a combined capacity of 1.5 petabytes. These clusters accommodate a variety of network filesystem protocols including NFS, Samba and iSCSI. Each modular, self-contained Isilon storage node contains a standalone fileserver with both hard disk and solid state drives, processors, memory, and network interfaces. As additional nodes are added, all aspects of the cluster scale symmetrically, including capacity, throughput, memory, and fault tolerance. Each storage node is wired using dual 10 Gigabit Ethernet connections in order to provide maximum throughput to the computational resources.

The SAN hardware infrastructure is comprised of an SGI TP9400 & TP9500 storage arrays, Oracle 3510 & 7410 storage arrays, dual robotic tape silos, and a full complement of Brocade fibrechannel switches, providing 200 terabytes of fault-tolerant disk storage. Alternate paths exist throughout the fabric so that no single point of failure exists, guaranteeing access to critical data and processing power. The NRB facility utilizes two tape silos, a Storagetek SL8500 and a Quantum i6000 with a combined capacity of approximately 2.5 petabytes, to store mirrored copies of the facility's online, spinning-disk data. The i6000 tape silo is housed in the Reed data center, providing a secondary backup source and, owing to physical separation, comprising an element of a disaster recovery plan.

Additional Resources: The NRB Facility houses over 100 additional servers that provide the basis of its Enterprise-grade infrastructure. Basic services including DNS, DHCP, and SMTP relays are all deployed in redundant pairs. Authentication is handled using Active Directory, with performance, security, and failsafe best-practice considerations in mind. The facility also contains a ten-node VMWare vSphere cluster, allowing for rapid deployment of non-critical services as well as dedicated development and Q&A environments. The facility employs two Juniper hardware load balancers that split TCP/IP traffic between multiple, identical servers. Aside from load balancing generic network traffic, the units accelerate SSL communication, which is particularly important in transferring bulk amounts of sensitive research.

Postproduction Suite: The NRB Facility has a format and resolution-independent postproduction suite with A/V capture equipment and multiple video decks, including a Sony DSR 80 and a UVW 1800, capable of playing and recording in digital, component, Y/C and composite video. For audio, the suite has a Sony V77 sound processor, a 16-channel Mackie mixer, a 120-watt Crown amplifier and a JBL surround speaker package. In addition, the suite utilizes a 16-channel A/D Sierra router, a Miranda A/D converter and a DPS transcoder to facilitate video and audio signal routing. This equipment is connected to the Reality Monster described above for video and audio capture of real-time 3-D content processed by the supercomputer. Uncompressed content creation is done with AJA's HD-capable digital disk recorder. To complement this hardware, the laboratory utilizes a variety of professional 3D and motion graphics packages, including Maya, Lightwave, and the full Adobe suite. The NRB Facility is also capable of virtual reality content creation to complement the visualization and stereoscopic capabilities of the DIVE, discussed below.

Network Resources: The NRB Facility intranet consists of 100baseT, Gigabit and 10 Gigabit Ethernet as well as an IEEE 802.11n compliant wireless network. Two Cisco Catalyst 3560G units and three Enterprise-grade Cisco Catalyst 6500 Layer 3 switches provide redundant routing and non-blocking switching from the outside world to and from public-facing services, end-user workstations, and the network's core. A Juniper MX960, which is capable of handling 5.12 Terabytes/sec of traffic, connects the compute clusters to the Isilon storage, separating them as much as possible the rest of the network in order to reduce latency and increase throughput. The facility's routers and twenty Juniper switches use the Open Short Path First protocol to provide fast and fault-tolerant routing. System configurations for networking devices, as well as kernel-level parameters for Linux clients, are highly tuned to provide near line-level rates.

The facility is connected to the Cenic backbone of Internet2 via dual fiber Gigabit lines and utilizes a Cisco Firewall Services Module for edge network security. Both software-based PPTP and hardware-based SSL Virtual Private Network communications are provided for remote productivity and collaboration via encrypted communication.

Data Immersive Visualization Environment (DIVE): The DIVE features a 12’ 150-degree floor-to-ceiling curved screen, on which real-time computer graphics, high definition video, stereoscopic 3D visualizations, or even simple slideshows are projected. The space provides investigators with the unique ability to visually “step inside” their data and analyze it in new ways. The projection system of the DIVE is comprised of a spherical hard-shell screen and three ceiling-mounted 3-chip DLP active stereo capable projectors, each rated at 5000 ANSI Lumens with a native 1280X1024 SXGA resolution. The projectors support optical blending of 12.5%, digital image warping and CLO, or constant light option, to ensure that image quality is maintained throughout the array. Two visualization workstations, each with dual NVIDIA graphics cards, drive these projectors, producing a 3840X1024 immersive display. A sophisticated A/V matrix along with an AMX remote control system facilitate audio and video routing from the DIVE to the conference room or other displays throughout the facility.