B. TECHNICAL EXPERTISE

As an institutional research core facility, the Martinos Center is fortunate to have extensive technical expertise available to support the proposed instrumentation upgrade. Members of the Martinos Center Technology Core collectively have many years of experience in the development of advanced MR instrumentation, pulse sequences, and image reconstruction and their application to functional, structural and anatomical brain imaging. The broad range of expertise among the Martinos faculty includes the development, translation and dissemination of techniques for high-field imaging; high-gradient imaging; high-speed imaging; pulse sequence design and programming; electromagnetic simulation; and data processing and modeling. In addition to these technical domains, Martinos investigators and their collaborators from other MGH and BWH departments and other local, national and international institutions lead major basic science and translational research programs that apply the Center's cutting-edge imaging techniques to investigate neurological and psychiatric disorders; basic and cognitive neuroscience; cardiovascular disease; and cancer. More broadly, the Martinos Center supports hundreds of clinical/translational and basic scientists who are users of the Center's imaging resources. The P41 dissemination efforts have also helped make the developed tools available to labs around the world.

Over the past 23 years, researchers at the Martinos Center have contributed substantial new technologies to the imaging community that have helped drive the transformation to make 3T MRI commonplace. In addition, MGH has for years pioneered the development and application of parallel imaging techniques and hardware at 1.5T, 3T, and 7T and provides a unique environment to put the new product 3T system to immediate and successful use. MGH has been at the forefront of developing and applying large-scale parallel imaging and high-performance gradient systems through a longstanding partnership with the engineering teams and gradient laboratory at Siemens, offering a core team of technical experts and staff who are highly qualified to consult and aid in optimal experimental design, acquisition, preprocessing and analysis of data obtained on such systems.

MGH has an international reputation for its unique combination of technical, neuroscience, and cardiovascular/body imaging expertise and a successful track record in developing and integrating large-scale parallel imaging systems and state-of-the-art gradient technology in cooperation with Siemens, which are now standard commercially available features on the proposed instrument. In 2005, a Siemens Avanto 1.5T MRI system was upgraded to 96 receiver channels, and a 90-ch head-receive array-coil was designed and constructed at the Martinos Center, demonstrating the benefits of high-density arrays. In 2007, a Tim Trio 3T system was upgraded to 128 receiver channels, and three generations of 96-ch head array coils and a 128-ch thorax/cardiac coil, among the first of their kind, were designed and built at the Martinos Center. In 2010, the dedicated whole-body high-gradient (AS302) Siemens Connectom 3T MRI system was installed at MGH, equipped with a maximum gradient strength of 300 mT/m and slew rate of 200 T/m/s. This system was the first of its kind and was expressly built to support the strongest gradients on a human scanner to date as part of the Human Connectome Project (HCP). Taken together, the HCP helped to establish the routine use of high-density arrays and higher gradient strengths by hospitals and research centers alike. Similarly, with the increases in channel count come increases in computational demands for image reconstruction. In close collaboration with engineers from Siemens, Martinos Center personnel developed and assembled custom computation servers to process the large amount of data acquired with these highly parallel systems. The wealth of experience and knowledge gained in these successfully executed projects uniquely qualifies MGH to integrate and operate the new instrument to the maximum benefit of its users. The proposed instrument uses many of the same technologies and algorithms that were developed at the Martinos Center, making our expertise critically relevant in the optimal use of the new system.

Similarly, MGH has a unique and internationally unparalleled track record in the development of receive array coils. MGH demonstrated the first 24-, 32-, and 90-channel head array coils at 1.5T and the first 32-channel head array coil at 3T using a soccer-ball geometry. The 32-channel coil design was eventually commercialized by Siemens and is now used by many Siemens customers (research and clinical) worldwide in 1.5T and 3T MRI systems. Siemens serves as an industry leader, delivering the 32-channel coil with nearly all 3T Siemens product systems, including the proposed instrument. MGH has refined this technology over several design generations and produced over twenty 32-channel coil arrays for collaborators working on several continents. In addition, MGH developed a pipeline for fusing electromagnetic computer simulations with practical experimental knowledge to incorporate computer-aided design into the array coil development stage. The evolution of three generations of coils provides MGH researchers with unique expertise on many-channel receive arrays, including the strategies of developing the optimal coil geometry, choice of conductor materials, and electronic circuits.

To our knowledge, no other facility in the world, academic or industrial, possesses this level of experience in high-performance gradient technology, parallel imaging acquisition or in large receive coil arrays. MGH is thus uniquely qualified and well positioned to turn the proposed upgrade into a success. In the following paragraphs, we describe the roles of the technical personnel who will directly support the new scanner, filling critical roles for the initial set up, operation, maintenance, quality control, and training for this advanced 3T MRI system.

Shared Instrument Director. The Principal Investigator, Susie Huang, M.D., Ph.D., is an Associate Professor of Radiology at Harvard Medical School and has worked in the field of NMR spectroscopy and MRI

physics for more than 20 years. She is also a board-certified neuroradiologist and serves as the Director of Translational MR Imaging at the Martinos Center and within the Department of Radiology at MGH. In this role, Dr. Huang oversees the development, validation and translation of cutting-edge, clinically useful MRI techniques across the eight human MRI systems at the Martinos Center. In her 15+ years at the Martinos Center, Dr. Huang has specialized in the robust augmentation and translation of MRI technology used by the large and diverse group of researchers utilizing the MR imaging services at the Martinos Center, with a range of expertise in highly accelerated imaging methods for anatomical, diffusion, perfusion and functional MRI. In addition, Dr. Huang has an international reputation for the development, validation and translation of cutting-edge diffusion microstructural imaging methods leveraging the high gradient strengths on the original MGH Connectome 3T scanner. She is now leading efforts to develop the next-generation Connectome MRI scanner (Connectome 2.0) for multiscale imaging of the human brain. Dr. Huang serves as a key member of the MR Steering Committee of the Martinos Center. She possesses all the necessary technical expertise to oversee the installation, administration and appropriate use of the proposed next-generation Vida 3T MRI system.

While the Advisory Committee will provide guidance on the utilization and operations of this new research system (see **Sec. E.1 Organizational/Management Plan**, below), as PI of this proposal, Dr. Huang will be responsible for the implementation of these policy directives within the Martinos Center. As Instrument Director, Dr. Huang will be responsible for all related quality assurance activities and evaluation of the scanner's use for technical development and clinical translation. She will also ensure that utilization of the instrument is in strict accordance with all MGH and federal policies and will be responsible for all NIH reporting on the activities associated with this grant. Dr. Huang serves as a key liaison with Siemens through her work on clinical translational research and collaborates closely with the company's on-site engineers and managers. Dr. Huang provides key expertise in high-performance gradient technology and MRI acquisition and will work closely with other Advisory Committee members and core staff to ensure the proper integration of technical advances developed on-site into the next-generation Vida. Specifically, she will consult regularly with Lawrence Wald, Ph.D., Director of the Martinos Center Imaging Core, on RF coil development and siting of the instrument. Dr. Wald heads the RF coil laboratory that has developed all of the RF coils mentioned above. Also, it was also under Dr. Wald's supervision that the previous two receiver upgrades and installation of the Connectom 3T MRI scanner at MGH were performed. He is internationally renowned for his pioneering work in high-gradient MRI, 7T MRI, parallel imaging methodology, and receive array coil hardware, and as Chair of the Advisory Committee, gladly lends his support and partnership to Dr. Huang in advancing the next phase of the Martinos Center's 3T program.

Technical Director. John Kirsch, Ph.D., is the Director of the Human MR Imaging Core, encompassing all human MRI instrumentation at the Center. Dr. Kirsch will be responsible for the technical oversight and daily management of the proposed shared instrument and will supervise the staff of physicists and programmers, technicians and operations staff required to assure the smooth and safe day-to-day operation and quality assurance (QA) of the MRI system. Dr. Kirsch will ensure that proper logs of instrument use, performance, and maintenance are kept and that the instrument is maintained in proper working condition and utilized according to all federal codes, with safety being of paramount importance. He will ensure that users are properly training and that progress reports are prepared promptly in close consultation with Dr. Huang, the Instrument Director.

Dr. Kirsch has extensive experience with similarly new and advanced MRI systems through his decades of experience as an applications and senior staff scientist at Siemens—including his integral role in supporting the installation, maintenance, and use of the Connectom 3T MRI scanner, and his involvement with previous major upgrade projects at 1.5T and 3T. In particular, he has detailed knowledge and understanding of image acquisition techniques across a wide range of body parts and has supported tailored protocols for neuro, body, cardiovascular, pediatric and musculoskeletal imaging in his positions at Siemens and Chief MR physicist for the clinical MRI service at MGH. He is eminently qualified to design and tailor protocols for the wide range of neuroimaging, body and cardiovascular imaging applications, thereby ensuring that current and new users will be well-supported in their proposed use of the new instrumentation, including adapting the novel aspects of the next-generation Vida to advance their research. In summary, Dr. Kirsch will take an active role in the installation of the new scanner, its maintenance and safe operation, and dedicated user training in its advanced imaging capabilities.

MR Physicists and Programmers. MR physicists and programmers are required for the optimal use of the MR system. This group of approximately one dozen faculty-level MR physicists and programmers together ensures that experiments are properly designed to extract the best possible performance from the system, respond to special needs of the users, and troubleshoot instrumentation problems. The Martinos Center also employs a full-time staff programmer/software engineer, Daniel Park, Ph.D. Dr. Park's function at the Martinos Center is to develop, test and maintain a portfolio of standard in-house pulse sequences available to all users, and in many cases also to the community via the C2P program. These sequences include modified structural and functional MRI sequences, QA sequences and improved field mapping sequences. In-house sequences are developed and maintained to provide our user community with the most state-of-the-art technologies.

Siemens Local Support Team. As part of the close collaboration between Siemens and MGH, Siemens has co-located a significant R&D team onsite at the Martinos Center. This team, led by the on-site collaborations

manager, Shivraman Giri, Ph.D., consists of a software developer, a hardware/systems expert, and an applications engineer to support collaborative projects such as this. The on-site Siemens team assists with all questions regarding the internals of the system and facilitates a direct line of communication to the product innovation team in Germany and the Siemens MR factory. For new scanner installations, such as the one proposed here, this team will assist with all issues as they arise and during testing of the new system, including training users on new software interfaces and applications. The presence of this team is a critical resource in this project and allows MGH to bring the expertise of Siemens to bear whenever it is needed. Dr. Giri has enthusiastically committed the support of his team to assist with the installation of the proposed new 3T system.

MR Technicians and Operations Staff. The Martinos Center employs a staff of four certified MR technologists who carry out the day-to-day operation of the human MR scanners and assist researchers with research setup, subject preparation, and scanning. They perform daily quality control checks of MRI system stability, including execution of an RF system performance check and EPI stability analyses developed by in-house software engineers. The MR technicians are also responsible for maintaining stimulus and response monitoring equipment, ordering supplies, and safety and operations training of new and existing users. They ensure and document IRB and HIPAA compliance of all researchers who use the MR systems prior to and during scan sessions. Grae Arabasz, Technical Research Manager, and Jacob Calkins, RT, MRI Research Specialist, jointly supervise this team. They also run the Center's bi-weekly MR System Operation and Safety Training.

Research Protocol Nurse. Amy Kendall, N.P., is a dedicated Research Protocol Nurse. She is trained in MR safety and provides all nursing care for clinical imaging studies. This includes taking medical histories, performing physical screening examinations, collecting specimens, placing ECG leads, starting IVs, administering study drugs, collecting physiological measures during studies, and monitoring subjects.

Siemens Service. In addition to a comprehensive service contract with the manufacturer, Siemens service engineers are stationed at the Martinos Center full time. They are responsible for preventative maintenance duties and perform regular quality assurance routines, which total approximately 5–10 hours per week. This new 3T system, despite its recent introduction to the Siemens product line, is and will remain under a standard commercial Siemens service contract, and all Siemens components are serviced by the Siemens service organization.

Administrative Assistant. Karen Dervin is the Technology Core Administrator. She is responsible for scanner scheduling and billing, and user account registration, all under the direction of Scientific Advisory Committee, with daily supervision from the Martinos Center Imaging Core Director, Dr. Wald.

Training. New users will receive assistance from Technology Core staff for all administrative and scientific issues relating to the shared instrument under the management of the Shared Instrument Director and with direct supervision from the Technical Director. New users of the shared instrument will complete an orientation to the instrument and its enhanced capabilities, which will be led by Dr. Kirsch and an MR technologist with advanced applications training. New users will be ushered through the process of setting up new user computer and imager accounts for appropriate data collection, storage and management. *In addition, a dedicated safety training module will be established by Dr. Kirsch with guidance from Drs. Wald and Guerin to instruct all users in the safety considerations surrounding the use of very strong MRI gradients such as peripheral nerve stimulation. Finally, technical development users will receive training from Dr. Kirsch and an MR technologist in the use of the new Open Recon interface as well as best practices for handling source code and data on the scanner.*

Data collection, management and analysis. Dr. Kirsch will ensure that the experimental design for each study is tailored for the users' technical and scientific needs, drawing upon the expertise of the Shared Instrumentation Director, Dr. Huang, as well as the acquisition and applications expertise of Operations Committee members Drs. Andre van der Kouwe and Bilgic and other members of the Martinos Center user community as needed. Users will be trained in the use of data analysis tools available on the Martinos Center compute cluster. Depending on the data acquired, users will be directed to the appropriate in-house scripts and training courses for data preprocessing and appropriate use of anatomical segmentation and parcellation tools that have been installed on the Martinos Center computing system, including tools such as FreeSurfer, FSL, SPM, DSI Studio, and Matlab-based tools developed by individual labs and customizable for different data types.