Overview: We request funds to transform an existing 9.4T magnetic resonance (MR) scanner into a next-generation platform for engineering innovation and translational neuroscience studies. The proposed instrument will represent arguably the most powerful human-compatible ultra-high field (UHF) neuroimaging platform to date. This next-generation platform will serve as a flagship cross-institutional resource to scan humans, nonhuman primates (NHP), and rodents in the NYC tri-state area. Initially installed at the University of Minnesota's Center for Magnetic Resonance Research in 2004, the existing scanner illuminated the capabilities and challenges of UHF imaging, leading to a number of advances and lessons learned; only four such magnets currently exist in the world. Following its recent purchase in collaboration with Columbia University (CU), the Nathan Kline Institute (NKI) has taken ownership of the scanner and relocated it to a nearby facility as the foundation of the present proposal.

New technology in gradient systems will address the single most significant limitation of the first generation 9.4T scanners. Specifically, we will fit the scanner with the latest-generation head-only gradient system from GE Research (inner bore diameter = 42 cm). This prototype has dramatically increased contrast to noise ratios, while reducing image distortion and image acquisition times. The proposed gradient system can achieve a peak strength of 140 mT/m and slew rates up to 810 T/m/s, far beyond commercially available human 7T systems and non-commercial 9.4T MRI scanners. When the gradient system is inserted in the head-only 9.4T magnet (bore diameter = 65cm), we expect this scanner to generate anatomical images with a spatial resolution of 100μm isotropic and perform whole-brain functional imaging with a temporal resolution of 100ms and submillimeter voxel size. At 9.4T, this instrument will be a high-resolution NMR spectrometer comparable to those in organic chemistry labs, except with a bore size capable of observing human brain metabolism, in-vivo. The MR system also will be significantly upgraded with a state-of-the-art radiofrequency system and MR console developed by GE Healthcare as part of their 7T efforts. No other current MR system is capable of performing at these resolutions for in-vivo human and NHP neuroimaging.

Intellectual Merit: The proposed effort brings together the resources and expertise of four institutions in the New York (NY) area (NKI, CU, New York University Grossman School of Medicine [NYUGSOM], and GE Global Research Center). The leadership team will comprise the Directors of three NY-based imaging research centers (Milham, Vaughn, Sodickson) and a leader in the field of MR gradient design (Foo), each with complementary expertise. Technical expertise and support for the proposed resource will be provided by a cross-institutional team of researchers led by: PI Dr. J. Thomas Vaughan, a noted high-field MR expert, who is Director of MRI at the CU Zuckerman Mind Brain and Behavior Institute, and Director of the newly established UHF MR lab at NKI; co-PI Dr. Thomas Foo, Chief Scientist in the Biology and Applied Physics group at GE who currently leads externally-funded efforts developing novel high-performance, dedicated neuroimaging MRI systems, including highly efficient head gradient coils that exceed the performance of any existing clinical MRI scanner; and co-PI Dr. Daniel Sodickson, Director of the Bernard and Irene Schwartz Center for Biomedical Imaging at NYUGSOM and a recent President of the International Society for Magnetic Resonance in Medicine (ISMRM: 2017-2018).

Broader Impacts: Funds for the construction of the housing and magnetic shielding of the upgraded scanner (~$5 million) will be provided by the NY State Office of Mental Health (OMH, NKI's parent organization) to make the proposed instrument a statewide flagship resource for training and discovery in the fields of biomedical engineering, MR physics, and neuroscience. The 9.4T will provide the basis for an ongoing development and educational program that will serve as a training ground for STEM graduate students and postdocs in the NY tri-state area. This will be facilitated by an open-door policy for trainees, the creation of a 9.4T dedicated course at Columbia by PI Vaughn, weekly allocations of no cost imaging hours for students (awarded competitively), and a combination of quarterly webinars and annual onsite events that will document and disseminate the technical development process.

Due to the extraordinary imaging capabilities of this unique system, we anticipate extensive use by NSF- and NIH-supported researchers from NKI, Columbia, NYUGSOM, and the greater NY City neuroimaging research community (e.g., Mount Sinai, City University of NY, Cornell, Princeton, and Yale). Investigators from these institutions, with a total of 15 currently NSF-funded translational projects, have expressed their commitment and intent to use this newly configured system based on the expected substantial scientific benefits and the ethos of collaborative open science for which NKI is known. Our application identifies two domains of study that will be innovated by these investigators using the upgraded 9.4 T magnet, including A) Technical Development (e.g., RF coil development, Multi-coil B0 shimming, and Safety) and B) Scientific Applications in Spectroscopy, Structural Imaging, and fMRI (e.g., 3D amplified MRI, High-Resolution Ex Vivo Imaging, High resolution In-Vivo Brain Atlas Generation, layer fMRI, Multiscale Biophysical Modeling, and comparative studies of small animals).