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Big Magnets

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Big Magnets

Tallahassee, the capital of Florida, is located in the center of that panhandle of the state, just south of its border with Georgia. In a town of about 200,000 inhabitants, between its regional airport and downtown, one finds the National High Magnet Field Laboratory (or, for short: Mag Lab). This facility comprises a group of angular, clean, white buildings, which, from an aerial photograph, are somewhat reminiscent of a modern dairy farm. It is the largest (over 370,000 sq ft) facility of its kind in the world and attracts about 1000 visiting scientists every year. Before Mag Lab, the largest and most prestigious laboratory of this sort was at the Massachusetts Institute of Technology (MIT). The Francis Bitter Laboratory at MIT was funded in the mid-1960s, and in the 1970s, it began its MR operations. Today, it houses several 17.6T magnets and a 21T unit, all dedicated to research.[1] During the 1980s, 3 institutions—Florida State University, Los Alamos National Laboratory (the Pulsed Field Facility), and the University of Florida—proposed the creation of Mag Lab to the National Science Foundation. To the surprise of the folks at MIT, the state of Florida was awarded the right to build what is today the most complete research ultra-high-field MR facility in the world. Its first magnet took nearly 10 years to design and build. Completed on time, the center was inaugurated by former Vice President Al Gore in June 1994. Mag Lab research includes physics, biology, bioengineering, chemistry, geochemistry, biochemistry, materials science, and engineering. It also houses the Center for Research and Learning, which serves as its education arm.

When Mag Lab opened, it housed a 27T magnet, at that time the strongest in the world. One year later, a 30T magnet rivaling one found at MIT was in operation, and high-homogeneity, high-field-strength magnets—matching those only found at the Laboratoire National des Champs Magnétiques Intenses in Grenoble, France—were also ramped up. In France, powerful research magnets producing continuous fields are housed in Grenoble, whereas those producing pulsed and even higher strengths are housed in the Toulouse facility (see below).[2] The Mag Lab facility houses both types of magnets. By 1996, Mag Lab had been awarded nearly US $100 million for research, including the creation of a resistive magnet to be deployed to the International Space Station, in addition to outside contracts such as building a 30T unit in Tsukuba, Japan, the only one of its kind in Asia for many years.

In 1999, Mag Lab made it into the *Guinness Book of World Records* when it built a continuous field 45T hybrid MR system. Pictures of this apparatus show it to resemble some infernal machine from Nikola Tesla's imagination (such as the ones built during his Colorado years) or, perhaps, the core of a nuclear reactor. Several stories high, this vertical magnet has a bore opening about the size of a golf ball (1.6 in or 4.2 cm). Tiny samples of the materials to be interrogated descend into the bore via a probe. To reach such enormous magnetic strength, the magnet is of hybrid design—that is, resistive and superconductive at the same time. So in reality, it is 2 magnets in 1. The inner magnet is a resistive one surrounded by a superconductive one. Pulsed field magnets are housed in a 75,000-sq ft building. One unit is capable of reaching 100T, but for now, it gets up to 85T and only for very short periods of time (59-μs pulses); its bore is 10 mm in diameter. This unit is considered a multishot one because it can be used repetitively up to once per hour.

One can request magnet time by sending in a short 3-page description of a project, and a committee will decide which magnet and which facility is most appropriate for each individual experiment. Generally, researchers are granted 1-week-long periods, so they work around the clock to complete their projects during those short 7 days. Magnet time there is expensive: about US $4000–5000 per hour. Additional support such as computers, cryogenics, an electrical shop, and so forth is also available. For reasons not explained on their Web site, open footwear such as sandals, which are commonly used by research faculty in many universities, are not allowed in Mag Lab. A list of visiting scientists (including names, parent institutions, and title of project) is available on-line.[3] When I consulted it, no experiment directly related to medicine or the neurosciences was taking place. Most research was being done by personnel from chemistry, physics, astronomy, or engineering departments.

An interesting series of lectures is held at Mag Lab throughout the year, and the program and a short explanation of it are also found on their Web site. Among the different topics, one can find a vodcast by Sir Harry Kroto, a Nobel Prize winner for chemistry, chatting about great minds of the 16th and 17th centuries. Most interesting, he states that we are not in the midst of a scientific revolution but rather of a technical one. Mag Lab has received many accolades and does not rest on its laurels; this year they completed construction of the highest field strength (36.2T) resistive magnet in the world.

The Magnet Lab at Los Alamos National Laboratory also houses impressive equipment. Pulsed magnets there are capable of generating fields of up to 100T for very short periods of time. A single turn magnet can generate up to 300T for a 6-μs burst but is destroyed by explosives in the process of doing this. For years, magnet engineers have thought of 100T as the Holy Grail. Materials used at these field strengths have enormous tensile strength. These magnets force electrons to a direction perpendicular to the flow of current, resulting in forces equivalent to packing 200 dynamite sticks into a volume of space the size of a marble.[4] Eight other magnets, the weakest being 17T, are currently functioning at Los Alamos. The facility looks exactly like what one expects to find in Los Alamos: boxy, brown, secretive-looking, nondescript buildings. Finding exactly where these laboratories are located on the campus map is not as easy as expected because despite it being open to the public, an air of secrecy continues to surround these installations. Los Alamos National Laboratory is located in New Mexico, and the largest nearby town is White Rock; the better known Santa Fe is about 35 miles away. The entire Los Alamos site is a group of about 1800 buildings spanning 35 square miles.

The third and complementary site of this effort resides at the University of Florida in Gainesville, a town of about 130,000 inhabitants located in northern Florida about 100 miles from Disney World. The University is simply enormous with over 51,000 students and nearly 5000 faculty members.

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There the Mag Lab facility is located in the McKnight Brain Institute and emphasizes MR spectroscopy, hence its name: the Advanced MRI and Spectroscopy Program. The Institute is one of the world's biggest neuroscience research operations with a faculty of over 300. There one finds 7 magnets, including an 11T unit with a 40-cm bore and a whole-body 3T unit, dedicated to high-resolution spectroscopy. Unfortunately, their Web site seems a bit anachronistic and simple and does not offer a great deal of information.

The Laboratoire National des Champs Magnétiques Intenses in Grenoble is one of the main institutions belonging to the Centre National de la Recherche Scientifique in France and is open to researchers from the 27 states of the European Union and adjacent countries such as Turkey, Israel, and others. Grenoble is located in southeast France, close to the Italian border and at the foot of the Alps, a location that has earned its nickname: the Capital of the Alps. Housed in this laboratory is a 35T magnet with a 34-mm-wide bore that operates at room temperature (in many of these ultra-high-field magnets the temperature inside the bore is very low). The Laboratoire National des Champs Magnétiques Intenses in Toulouse is found in southwest France. Because Toulouse is also known as La Ville Rose, it is not unexpected that its building has pinkish tones. There one finds magnets capable of 45T or 60T during pulses as long as 1 second in duration and of 150T–260T for only milliseconds. Both of these facilities form part of the larger EuroMagnet Net II (Research Infrastructures for High Magnetic Field in Europe).[5]

Other facilities that are part of EuroMagnet Net II include the High Field Magnet Laboratory in Nijmegen, the Netherlands.[6] This laboratory is housed in a beautiful modernist building that has a curvy, sensuous façade and contains 33T, 38T, and 45T magnets. A large part of their research centers on levitation such as is used in magnetic levitation trains and levitation displays (used in those globes that seem to float on air). A provocative idea is that humans, if placed in a strong enough magnetic field, can also levitate. Another EuroMagnet Net II facility is the Dresden High Magnetic Field Laboratory located in Germany.[7] This facility is located in the countryside outside the city of Dresden. It is a part of a large physics campus called the Helmholtz-Zentrum Dresden-Rossendorf. Magnets ranging from 70T to 1 MG are housed in a no-nonsense, industrial-looking modern building. Laser beams allow spectroscopy at very high field strengths.

The largest similar installation in Asia is the Tsukuba Magnet Laboratories in Japan.[8] This facility became fully operational in the mid-1970s, and today it houses 17 high-field-strength magnets. Their emphasis is on hybrid magnets and water-cooled magnets capable of generating fields of up to 25T. As of this writing, the laboratory was closed due to the 2011 earthquake, though its Web site indicates that their equipment suffered no physical damage. The facility was not open to external researchers until 1998. It is under the direction of the National Institute of Materials Science, which has established a collaborative research effort with the University of Washington in Seattle.

I hope that this short editorial complements my previous one about the industry of CT scanning. It is important for us, clinical neuroradiologists, to realize that our techniques are used by other researchers whose areas of interest are very different from ours. I wish to thank Dr Robert Quencer, who gave me the idea for this *Perspectives*.

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