From research to industry
English Portal

ISEULT PROJECT

11.7 teslas: The World-Record Magnetic Field Generated by a Human MRI Magnet

The Iseult project magnet being installed at Neurospin (CEA Paris-Saclay) reached a nominal magnetic field of 11.7 teslas (T) on July 18, 2019. This is a world record for a whole-body magnetic resonance imager (MRI) magnet, the culmination of years of R&D and at the forefront of innovation in the field of superconducting magnets. Over the coming months, the equipment required for neuroimaging will be installed around the magnet and in its central tube to create a human MRI scanner capable of examining the brain more accurately than ever before, in the interest of fundamental research, cognitive sciences and diagnosing neurodegenerative diseases.

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In the process of being installed at the CEA Paris-Saclay site since July 2017, the colossal magnet weighing 132 tons is now fully operational. To do this, the teams had to meet the many challenges involved in setting up such equipment:

- Connecting the magnet to auxiliary equipment already installed and tested (cryogenic plant, electrical power supplies, instrumentation and control system);
- Reaching a stable temperature of 1.8 K: the magnet must be cooled to 1.8 K (- 271°C), at which temperature helium, its "cooling liquid", is in a special physical state known as superfluid. At this temperature level, the conductor that forms the magnet (niobium-titanium alloy) has no resistance to the electric current passing through it, thereby preventing any power dissipation or temperature rise: it is in a superconducting state;
- Ramping-up to reach 11.7 T[1]: once the conductor has cooled to its nominal temperature, current was gradually injected into the magnet to reach the target magnetic field of 11.7 T. This "ramp-up" was performed in several stages, with numerous electrical and magnetic tests, as well as tests of emergency shutdown procedures. In total, 1,300 procedures intended to detect any potential defects were tested.

To reach its nominal magnetic field, the magnet is supplied with a current of 1,500 amperes and the conductor coils are cooled constantly by 7,000 liters of superfluid helium. With a magnetic field of 11.7 T, this is a world record in the field of MRI for a whole-body system and an all-time record with this type of superconducting material. Manufacturing this 132-tonne prototype – measuring 5 m in length with an outer diameter of 5 m and an inner diameter of 90 cm – will have taken six years of development in Alstom (now General Electric, GE) factories in Belfort and nearly two years of installation and testing before it is commissioned.

Over the following months, numerous items of equipment will be added to the magnet to transform it into an MRI machine capable of producing images of volunteers' brains: gradient coils, radiofrequency coils, patient table, outer casing, etc.

About the Iseult project

Neuroscientists wanted to acquire an 11.7-tesla MRI scanner in order to examine the human brain with an observation quality never before achieved, whether in terms of spatial or temporal resolution, or in terms of the accuracy of the images obtained. The Iseult project was started at the turn of the 21st century with the ambitious goal of developing a giant magnet (90-cm diameter opening) that could generate a magnetic field of 11.7 T. The project was jointly led by neuroscience researchers and CEA physicists specialized in magnets at the Institute of Research into the Fundamental Laws of the Universe (IRFU) and specialized in MRI at the Frédéric Joliot Institute for Life Sciences. The researchers and their partners, both academic and industrial, set out to design and manufacture the magnet, the core of the MRI scanner, which was delivered to Neurospin, on the CEA Paris-Saclay site, in May 2017.

The Iseult development is part of a larger Franco-German project initiated in 2006. It is the fruit of collaboration between:

- industrial partners (Siemens Healthineers, Bruker Biospin, Alstom – now part of General Electric – and Guerbet);
- academic partners (University of Freiburg, CEA's Fundamental Research Division);
- with partial financial support from public agencies (in France: Bpifrance; in Germany: the German Federal Ministry of Education and Research).

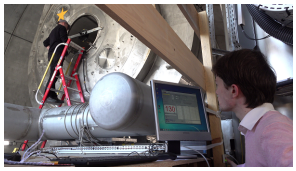
How did CEA become the spearhead of medical imaging?

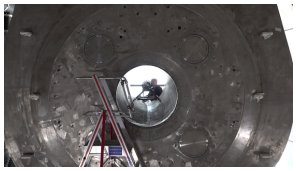
The interdisciplinary approach that characterizes CEA – from engineers, physicists and mathematicians to biologists, pharmacologists and doctors – constitutes one of the key strengths in its medical imaging research and particularly in running the Iseult project.

Life sciences are an integral part of the activities carried out at CEA since its creation in 1945. CEA scientists have contributed to the creation and development of medical imaging, the founding of the Frédéric Joliot Hospital Unit and the Iseult project, not forgetting the invention of the diffusion MRI technique. Today, medical imaging activities are mainly conducted at the Frédéric Joliot Institute for Life Sciences, based at Saclay, involving in particular the teams at Neurospin.

The large superconducting magnets are the linchpins of physics experiments conducted using particle accelerators. The Institute of Research into the Fundamental Laws of the Universe (IRFU) is behind several of the Large Hadron Collider (LHC) accelerator and detector magnets installed at CERN in Geneva. CEA-IRFU is leading a range of R&D programs in collaboration with industrial and institutional partners, both nationally and internationally, enabling it to figure among the best in the field and, consequently, participate in unique projects such as the Iseult or tokamak – nuclear fusion reactor – projects, including JT-60SA in Japan.

The front face of the magnet. In the left photo, the object on the left, known as "the satellite", is the component through which helium and current pass to reach the magnet. The photo on the right shows the magnet in its clinical setting being developed. © Francis Rhodes / CEA





The magnet is connected to the satellite from the rear face, via a component called the "heat pipe" (pipe-shaped connection in the foreground on the left). This 900-kilo complex mechanical structure is composed of almost 200 parts positioned with millimetric precision to provide for mechanical deformations caused by cooling. The heat pipe provides the connections for cryogenic circuits, electrical connections and internal instrumentation. Once installed, the team was able to begin cooling and then powering up the magnet. Photo on the right: measuring the magnetic field produced inside the magnet. © Francis Rhodes/CEA

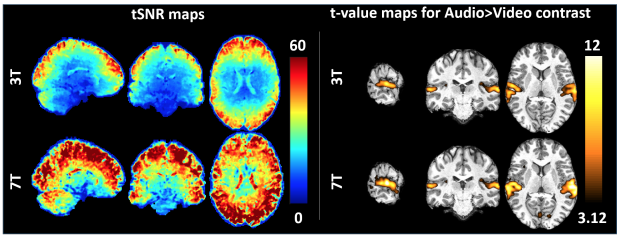


Illustration of the difference between a 3-tesla MRI and a 7-tesla MRI image with the same resolution. On the left: Temporal signal-to-noise ratio. On the right: activations for a paradigm developed in the laboratory. The color scale corresponds to the intensity of activations and the statistical power, that is, the level of confidence in the detection of activations. A similar improvement is expected between a 7-tesla MRI and an 11.7-tesla MRI. © Neurospin / CEA

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