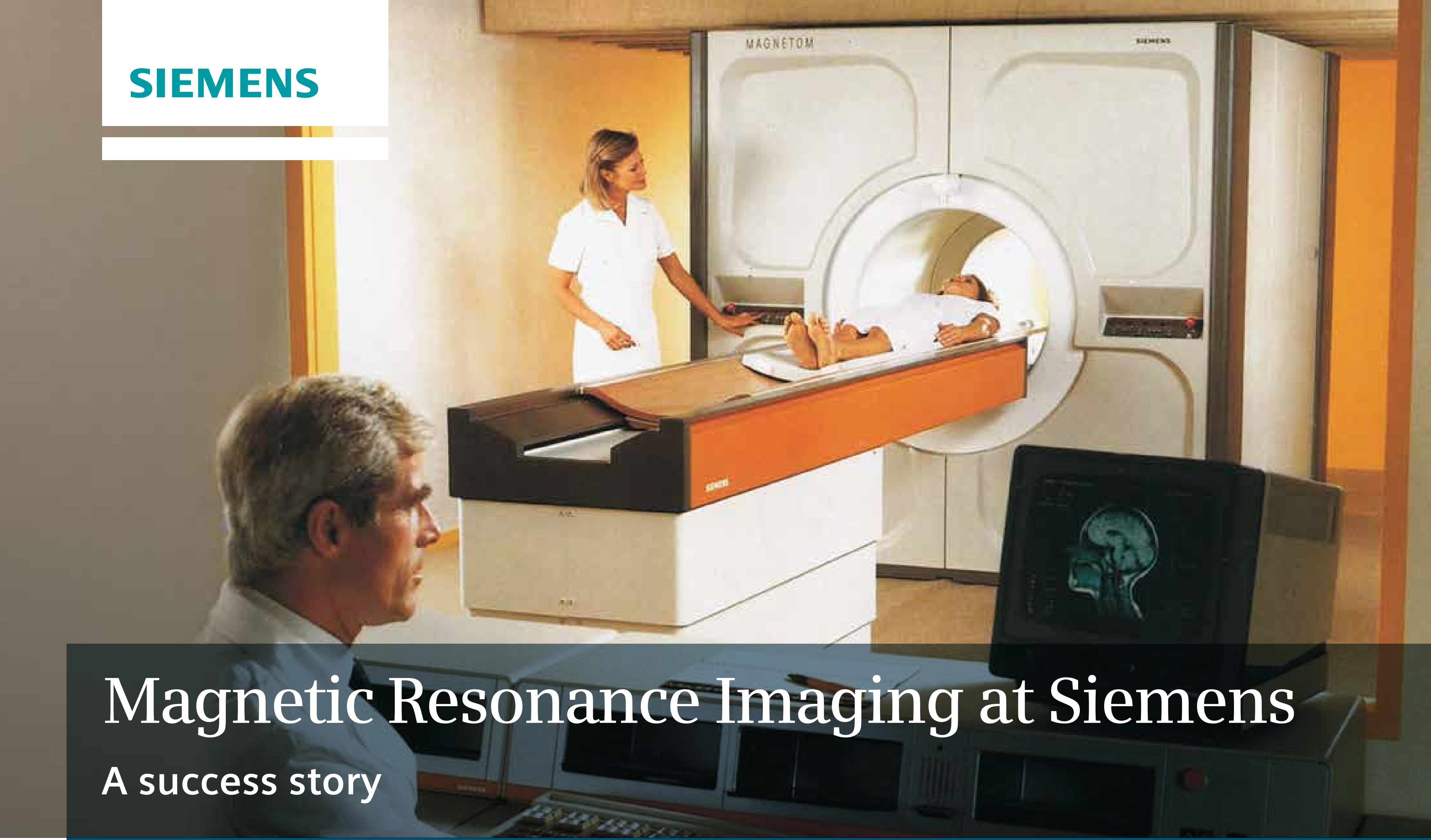
SIEMENS



Magnetic Resonance Imaging at Siemens

A success story

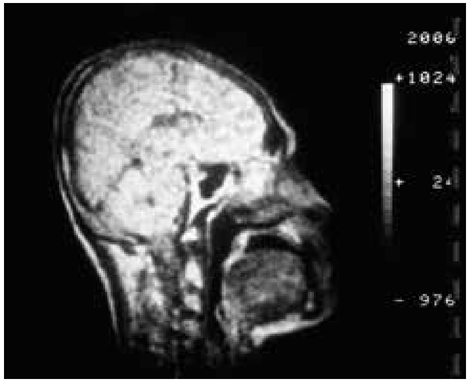
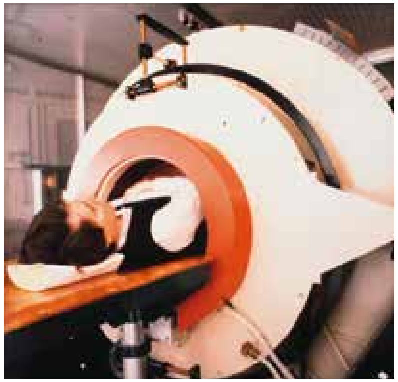
MedHistory Milestones

Answers for life.

Magnetic Resonance Imaging at Siemens

A success story




Foreword

Cover photo: Scanning a patient with the first MAGNETOM, 1983

Foreword

Bernd Ohnesorge

CEO der Business Unit Magnetic Resonance
Siemens Healthcare

The first Siemens MRI system bearing the MAGNETOM name was installed at a customer site in 1983. So should we say it has already been 30 years, or just 30 years, since then? At any rate, it's certainly a good time to take a look back.

This retrospective shows how impressively this technology has developed within the Siemens group of companies, from the early days to the first commercial steps and all the way to today's technology and market leadership.

Many innovations from Siemens have changed the world. With magnetic resonance imaging, we have been unlocking new possibilities for 30 years now – things that used to be mere dreams are reality today. Many people have helped to build this success, from the highly dedicated employees who have pitched in right from the start to our wonderful cooperation partners and my esteemed predecessors as heads of the Magnetic Resonance Business Unit (also see the overview on page 43).

> **The best way to predict the future is to invent it.**
>
> Theodore Edward Hook, 1825

Inventive spirit, belief in what we are doing, and sheer endurance have also definitely been important factors in getting us to where we are today. Employees who were there at the outset are still sharing their experiences with younger employees today, keeping the spirit of 1983 alive. One thing that I believe is crucial is that we have always stood – and continue to stand – together as a close-knit team. I'd like to thank each and every one of us for that.

All of the technological developments you will see in this book have helped make MAGNETOM what it is today. To assert our current position, we rely on four important pillars: Our integrated Tim coil technology, our unique Dot scanning software, our applications, which continue to set trends in imaging, and naturally also the design of our MRI systems, which makes scans increasingly efficient for our customers and increasingly pleasant for patients.

But don't let me keep you any longer – jump right in, and enjoy discovering the history of this fascinating technology.

Bernd Ohnesorge

Making the invisible visible

Taking a look inside the body – up until not too long ago, it was simply unimaginable. On November 8, 1895, one man revolutionized the field of medical diagnostics: Wilhelm Conrad Röntgen discovered X-rays. Doctors were then able to beam the rays through patients, making the skeleton visible for the first time. Over time, researchers developed other imaging methods to help doctors diagnose diseases: Computed tomography, ultrasound, and nuclear medicine all make use of different techniques, with each method supplying especially good images for specific scans. At the dawn of the 20th century, scientists also began researching the fundamentals of a technology that turned out to be outstanding for medical imaging purposes: Magnetic resonance imaging (MRI) technology generates slice images of the body, visualizing them onscreen in either two or three dimensions.

Magnetic resonance imaging does not use X-ray radiation. An MRI system consists of a huge magnet, an antenna that transmits and receives radio waves, and a computer that converts the signals into images and displays them on the monitor. In advanced MRI systems, the resolution of these images is so high that even metabolic processes in the brain and other organs can be examined with great precision.

The history of magnetism started with scientific curiosity and experiments. Ever since antiquity, people have been observing, experimenting, and thinking about magnetic phenomena. They marveled at the mysterious force exerted by certain stones, using them in magical rituals and in medicine. Some of the great Greek philosophers, such as Thales and Aristotle, attempted to explain magnetism. But they could not pinpoint the cause of these phenomena, and magnetism remained shrouded in mysticism and superstition long afterward. More than a thousand years passed before magnetic properties came to be studied with new scientific methods – and first put to practical use, with the invention of the compass.

In the late 19th century, two Dutch physicists laid the cornerstone of what would eventually become today's MRI technology. Pieter Zeeman discovered that optical spectral lines split within a magnetic field, and Hendrik Antoon Lorentz explained this effect. The two men shared the Nobel Prize in Physics in 1902 for this achievement. Further work followed soon afterward: In 1922, Otto Stern and Walter Gerlach discovered that atoms have parallel or antiparallel direction in a magnetic field. This phenomenon was explained by George Eugene Uhlenbeck and Samuel A. Goudsmit in 1925: The electrons in an atom have a kind of intrinsic momentum known as "spin". The magnetic properties of atoms were studied in greater detail at Columbia University, USA, starting in 1929, when Isidor Isaac Rabi and his team discovered that atoms in a magnetic field spin when they are exposed to high frequencies. Rabi developed a method for registering nuclear magnetic properties, an achievement for which he received the Nobel Prize in Physics in 1944. That same year, Yevgeny K. Zavoisky, a Russian physicist, was the first to successfully observe electron spin resonance.




In 1946, two physicists independently discovered the principle of magnetic resonance: Felix Bloch and Edward Mills Purcell showed that atomic nuclei in a magnetic field tilt when they are excited by a high-frequency electromagnetic field. If this high-frequency field is switched off, the atoms release the energy they have absorbed and return to their original state. By making this discovery, Block and Purcell laid the technical foundations for magnetic resonance imaging. It was an accomplishment for which they shared the Nobel Prize in Physics in 1952.

In 1950, Erwin Hahn proved that atomic nuclei generate an echo – a “spin echo” – when they are influenced with two high-frequency pulses. But magnetic resonance was still slow and imprecise as a method until 1968, when a group of researchers from Zurich made groundbreaking progress in enhancing its sensitivity. Richard Ernst, Weston Anderson, and Kurt Wüthrich improved the pulse excitation and used a new method to analyze the resonance signal. This made magnetic resonance technology about a thousand times faster and significantly more sensitive. Ernst went on to receive the Nobel Prize in Chemistry in 1991 for this achievement.

In the years that followed, magnetic resonance imaging became an important analytical method that was suitable for solids, liquids, and gases – and then, in 1971, an American doctor named Raymond Damadian showed that it could also be used to distinguish between tumors and healthy tissue. Modern MRI technology is considered to have been born in 1973, when chemist Paul C. Lauterbur and physicist Sir Peter Mansfield were the first to make it possible to visualize a fluid-filled object. The two men received the Nobel Prize in Medicine in 2003 for their groundbreaking work in developing MRI technology.

Siemens recognized the new technology’s great potential early on. Back in 1959, the company used magnetic resonance imaging to study plastics in a special research lab. Then, in 1965, the company’s Medical Technology Division, based in Erlangen, hired a physicist named Alexander Ganssen, who made significant progress in using magnetic resonance imaging in medical applications with his suggestions and developments. Ganssen also spurred the development of an MRI system in-house at Siemens. The fundamental research department was further expanded, greater effort and resources were devoted to component development, and the technical difficulties of the early stages were resolved. In August 1983, Siemens was the first company in the world to install a commercial magnetic resonance imaging system for clinical applications, when the MAGNETOM was commissioned at the Mallinckrodt Institute of Radiology, in St. Louis, Missouri, USA. But before things reached that point, a great deal had to happen. The history of the development of MRI technology at Siemens has been an eventful one – a story of research, a wooden shed, a green bell pepper, and a six-pack of beer.

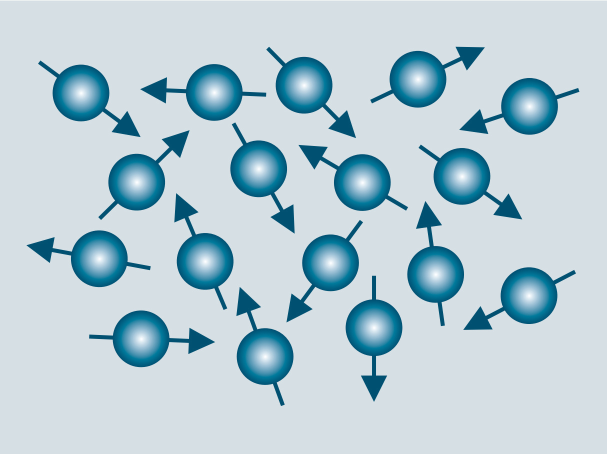
Using magnets to see inside the body

The human body's internal compass

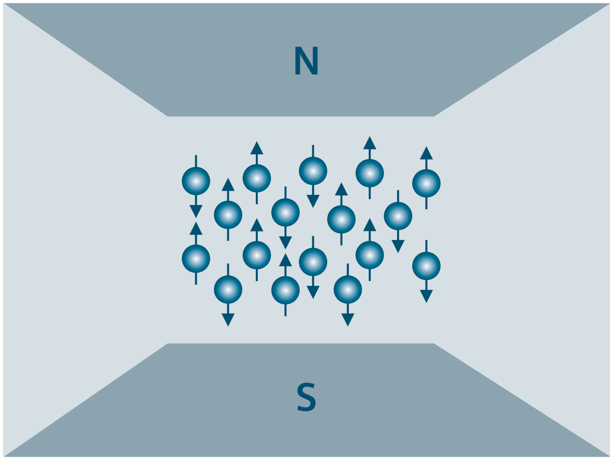
The human body consists largely of water, which in turn is composed of tiny particles – hydrogen and oxygen atoms. Magnetic resonance imaging relies on the fact that the nuclei of the hydrogen atoms possess magnetic properties: If they are exposed to a magnet, these nuclei align within the magnetic field, like the needle of a compass within the earth's magnetic field. An MRI system generates a high-frequency electromagnetic field by transmitting radio waves.

These waves meet the nuclei of the hydrogen atoms, which are pointing in a certain direction, and set them in motion. If the waves are turned off, the atoms return to their initial position within the magnetic field. As they do so, they release some of the energy that they have absorbed from exposure to the high-frequency waves. This released energy is measured by highly sensitive receiver coils, and suitable techniques can be used to pinpoint its origin.

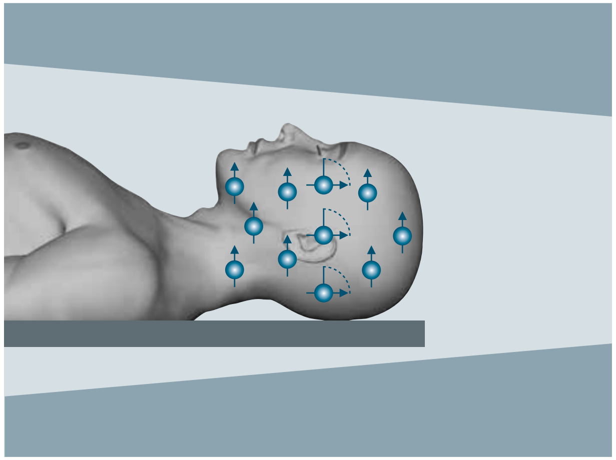
A computer converts the data and uses them to generate tomograms, or slice images. The doctor can view these images onscreen in two or three dimensions. MRI technology is especially well suited to scanning soft tissue, such as the brain, internal organs, and joints. The patient doesn't feel a thing while all this is going on – an MRI scan is completely painless.



Hydrogen atoms are located in the body.



These atoms possess magnetic properties.



Atoms align within the MRI's magnetic field.

What happens during scanning?

Once the patient has taken his or her place on the MRI table, technicians place coils on the part of the body that is to be scanned. In some types of scans, the patient is first given a dose of a contrast agent that makes specific structures within the body – such as blood vessels or tumor tissue – visible with even greater clarity. Then, the automatic table slides into the bore with the patient on it. Patients have to lie still during the scan so no artifacts appear on the image. The gradient system makes tapping or knocking noises, which can vary in volume depending on the measurement program. Patients can elect to use earplugs or listen to music via headphones to counter the noise. Magnetic resonance imaging uses magnetic fields that are usually over 20,000 times stronger than the earth's magnetic field. This means that anything magnetic, such as jewelry, piercings, wristwatches, and eyeglasses, has to be taken off and set aside beforehand.

The components of an MRI system

Magnet

The magnet is the centerpiece of an MRI system. It generates a magnetic field at a certain strength – in today's clinical MRI systems, generally 1.5 or 3 Tesla. In comparison, a standard commercially available horseshoe magnet has about 0.1 Tesla. Strictly speaking, the "Tesla" unit is used to denote magnetic flux density, which has become commonly known as "magnetic field strength", although this term is not correct from a physics perspective.
The stronger the magnetic field, the more clearly the signal stands out from the background noise. This means the field strength affects the possible image resolution, the amount of time needed to produce a scan, and image contrast (the difference between dark and light points in the image). Alongside the desired field strength, the magnet also generates an undesired "scatter field," meaning that a magnetic field that is not needed to generate the image is also generated in the room containing the MRI system. This scatter field affects magnetic objects in and around the MRI room, so the room has to be shielded. Older forms of shielding consisted of iron, raising the weight of the magnet to as much as 32 tons. Today's MRI systems are shielded with advanced coils, so they are significantly lighter. The operating temperature of the magnet is minus 269 degrees Celsius (4 Kelvin, or slightly above absolute zero). To reach this temperature, the magnet is cooled with liquid helium. In older systems, the helium had to be replenished after about six weeks. Advanced Siemens MAGNETOM systems rely on "Zero Helium boil-off" technology, which allows MRI systems to keep running in normal operation without using up any helium, so regular refills are not necessary.

Gradients

The body's signals within the magnetic field have to be traced precisely to where they originate – a process that uses the "gradient system", among other things. Gradients are also magnetic coils. They generate additional magnetic fields within three dimensions. These three fields are superimposed over the main magnetic field, supplying the spatially encoded data that the computer uses to calculate the slice image.

Coils

To boost reception of the magnetic resonance signal, high-frequency coils are placed on the part of the body that is to be scanned. Some of these coils transmit MRI signals, and all of them receive these signals. This improves the signal-to-noise radio. A stronger signal makes the image clearer, since the image "noise" is reduced. This noise consists of undesired pixels with a brightness that deviates from the actual content of the image.

High-frequency system

The high-frequency system generates high-frequency signals in pulse form. Transmitter coils transmit these high-frequency waves into the body, thereby exciting the hydrogen atom nuclei. The nuclei "respond" through nuclear resonance, which is detected via a receiver coil's antenna. The received signal is amplified and converted for further processing.

The computer system

Advanced magnetic resonance imaging systems generally include three computers, which perform different tasks. One is used to operate the system, one controls the overall measurement system and the coils, and one calculates the image and runs the numerous programs needed to analyze and interpret the scan.

Thorax coil, 2012

Foot coil, 2012

Early history at Siemens

Alexander Ganssen, 1954

The wooden building used as the first MRI research lab, Erlangen, 1979

0.1 Tesla magnet with Faraday cage, 1979

The first work on magnetic resonance was theoretical in nature. Scientists studied how atomic nuclei interacted with their molecular surroundings, discovered spin, and experimented with hydrogen nuclei in magnetic fields.

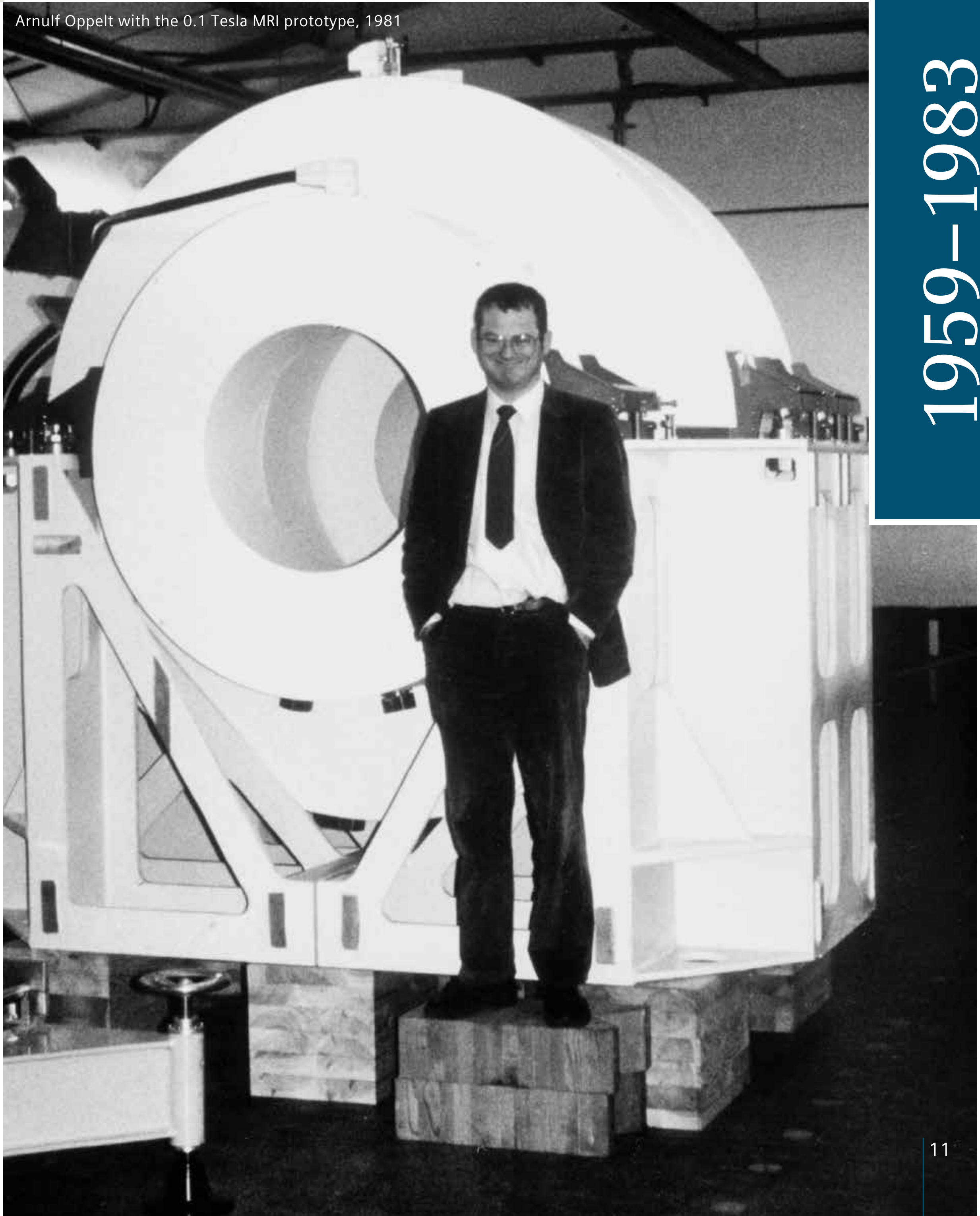
As research advanced, the first applications soon became possible. Starting in 1951, chemists used magnetic resonance to study molecular structures and bonds, including a groundbreaking discovery in biology: the form and structure of genes. Siemens recognized the new method's potential and displayed great interest in research and development involving this technology. Engineers at the Siemens research lab used magnetic resonance to study the qualities of plastics back in 1959. In 1965, the company hired a man who would play a significant role in shaping the development of magnetic resonance imaging in the years to come: the physicist Alexander Ganssen.

Ganssen's interest in magnetic nuclear resonance was awakened while still a student, and he remained true to his passion for the rest of his life. His 1953 dissertation in physics elaborated on findings by Nobel laureates Felix Bloch and Edwin Purcell, who had discovered the principle of magnetic resonance in 1946. At Siemens, Ganssen's research focused on magnetic resonance techniques for medical diagnostics. He developed a system that was built in 1966 and patented a year later: the world's first unit that used magnetic resonance to measure a patient's blood flow at the carotid artery or arm. Further patents and inventions followed. Among other things, Ganssen built a compact tabletop MRI system that could be used to diagnose certain vascular diseases.

The Siemens Medical Technology Division launched the company's first planning activities regarding construction of an MRI system in 1977. Peter Mansfield, who would later be awarded a Nobel Prize, was involved in the plans as an advisor. Magnetic resonance imaging had already made great strides by this time. For example, Paul C. Lauterbur, also a later Nobel laureate, was able to show slice images of living mice in January 1977, when he visited the medical technology team at Siemens in Erlangen. That same year, Raymond Damadian, an American doctor, scanned his chest using magnetic resonance technology – but at four and a half hours, the imaging process still took a very long time.

The medical technology management at Siemens approved the development of an MRI system. The head of fundamental development, Rudolf Schittenhelm, and his lab manager, Alexander Ganssen, hired physicist Arnulf Oppelt to manage the project starting on February 1, 1978. Working with a small team, Oppelt built the first MRI prototype: a 0.1 Tesla system with a magnet that could already accommodate for a person's whole body. This magnet was ordered from Oxford Instruments Ltd., a company in England, while the Siemens research lab designed and constructed the gradient system, and the controls and software were developed by the Medical Technology Division. The first experimental system was completed in late 1978, on the grounds of the Siemens research lab in Erlangen – in a wooden building, not much more than a large shed, that had been built specifically for the purpose.

To avoid disrupting the magnetic field, the building was constructed without any magnetic parts at all – not even a single steel nail. And yet, the researchers still struggled with issues: The power supply to the magnet fluctuated, and since the frequency of the nuclear resonance was in the same range as that of radio waves, the physicists received shortwave broadcasts instead of MRI signals in the evening. To solve this problem, they built a Faraday cage around the magnet to shield it. This kind of cage is an enclosure made of electrically conductive material that forms an electric shield around the interior.



Arnulf Oppelt with the 0.1 Tesla MRI prototype, 1981

In 1979, Oppelt's team dealt with the machine's "teething troubles" and made improvements in the software. The researchers were supposed to present results – finally, after a long process – at the end of the year. Time was pressing, and the pressure was mounting, so the team had to accept long scanning time for the time being to compensate for remaining disruptions. The researchers looked around for a suitable test object, ultimately deciding on a fairly unusual one: a green bell pepper. After all, "It would definitely hold still, it was big enough to stand in for a human organ, and you could also cut it open to ascertain the similarity between the potential image and its anatomy," according to Oppelt.

To while away the time waiting for the final test measurement, the physicists bought themselves a six-pack of beer, "which significantly lifted the mood." But preparing the image of the pepper took until well into the evening, so the team had to wait until the next day to present the results to their supervisors. The image was a smash hit! The researchers were thrilled, but noticed a minor error in the image reconstruction a few weeks later. This is why the image is dated February 14, 1980, the day the error was resolved. In fact, however, the image was taken back in November 1979. The bell pepper image convinced management of the great potential of magnetic resonance imaging, and so Ganssen, Oppelt and the entire MRI team received approval to continue their activities.

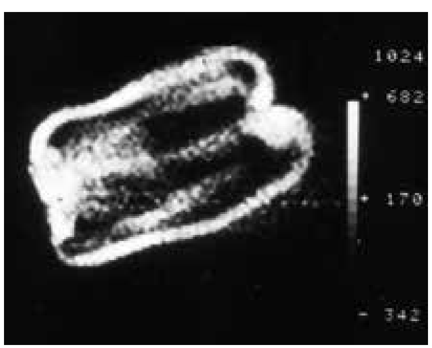
The team's research soon brought further successes. The first image of a human skull followed just a few months later, in March 1980. Ganssen himself volunteered for the scan, which took only eight minutes – already significantly shorter than the amount of time needed to scan the bell pepper just a few months before. The result provided a rough idea of MRI technology's potential, especially in terms of imaging of soft parts of the body.

The next step came a few months after that, in September 1980, when the first few patients were scanned using an MRI system. Movements were still blurry in the images produced by the pilot system, so the researchers initially limited themselves to the head, arms, and legs. The early scanning process was not very comfortable for the test subjects, who had to crawl into the magnet – which was a very tight fit – on a wooden board. Convenience was limited for the scanning technicians, too, who had to use two long poles to adjust the coils in the magnetic field.

Oppelt presented magnetic resonance imaging at the annual meeting of the German Society of Neuroradiology in 1980, but it didn't initially resonate with the medical community. Over the course of the year 1981, the engineers significantly enhanced the MRI system's image quality. A second pilot unit was built, this time with a field strength of 0.2 Tesla. Ernst Zeitler, a radiologist in Nuremberg, used the new system to scan his patients. By then, the images were so good that tumors in the head or abdomen and changes in the brains of patients with multiple sclerosis could be localized.

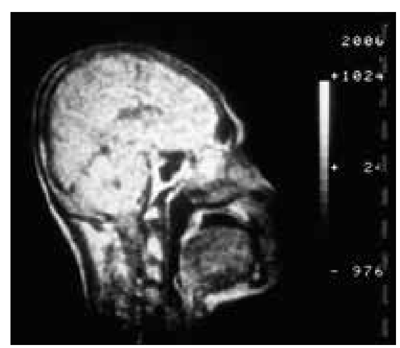
"The potential that MRI technology had for diagnostic purposes was clear in 1981, when we saw the first tumor in a head scan," Oppelt says. That year, the Siemens research center began developing a new magnet with support from the German Federal Ministry of Research and Technology. The new magnet also generated a magnetic field 0.2 Tesla strong, but it consisted of four oil-cooled coils, making the system significantly more efficient to operate.

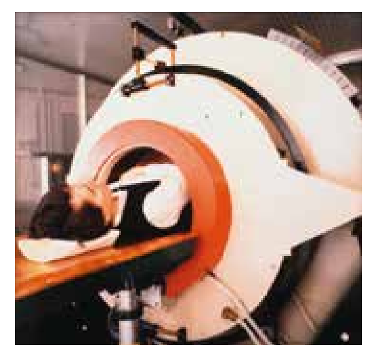
The magnet technology that had been used to date had a number of drawbacks. For one thing, it took about half an hour for the magnetic field to stabilize once the system was turned on. More critically, the engineers faced great difficulty when they tried to raise the field strength above 0.2 Tesla, thereby further improving image quality; Power consumption spiked, and the coils emitted substantially more heat.



MRI image of a bell pepper, 1980


Arnulf Oppelt's head in the pilot system, 1980

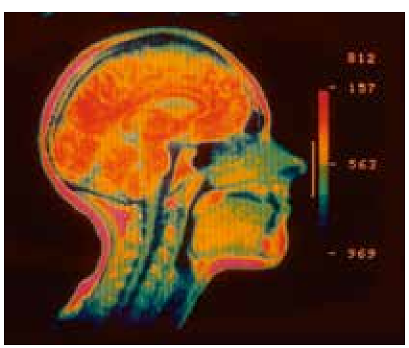

Alexander Ganssen's head, 1980


A whole-body scan using the pilot system, 1980


Pilot system with head coil, 1982

In response, Siemens developed a superconducting magnet for its third experimental system. "Superconducting" in this case means that the wires of the magnetic coils have exactly zero electrical resistance at a temperature of -269°C. To bring the wires down to this low temperature, they are cooled with liquid helium. In addition, liquid nitrogen shields the helium so that it is not heated up by heat radiation, slowing the rate of evaporation.

It wasn't long before the superconducting magnets made it possible to achieve higher field strengths, and the third pilot system reached 0.5 Tesla. A short while later, Siemens was already developing 1.5 Tesla magnets. Higher field strength means a better signal-to-noise ratio, and that in turn means better image quality. Alongside the magnets, the engineers also improved the programs used to analyze the magnetic resonance signal and display it onscreen. Later that same year, Siemens developed the technology at such an advanced stage that preliminary product development could get started. Two years later, in the summer of 1983, the company installed its first commercial MRI system, which featured a superconducting 0.35 Tesla magnet, at the Mallinckrodt Institute of Radiology in St. Louis, LA, USA. The first MAGNETOM was born.



MAGNETOM head scan, 1982

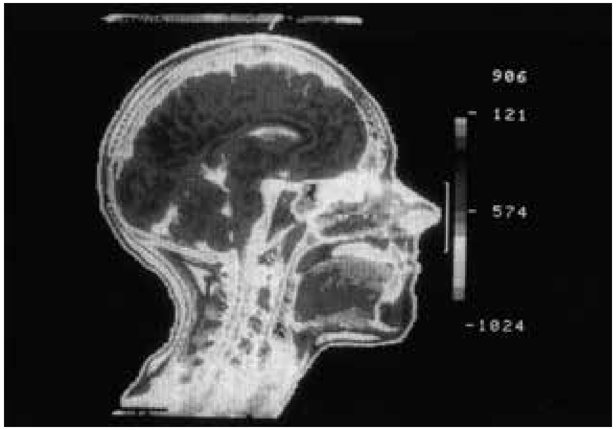
The first MAGNETOM, St. Louis, 1983

Commercial MAGNETOM prototype, 1982

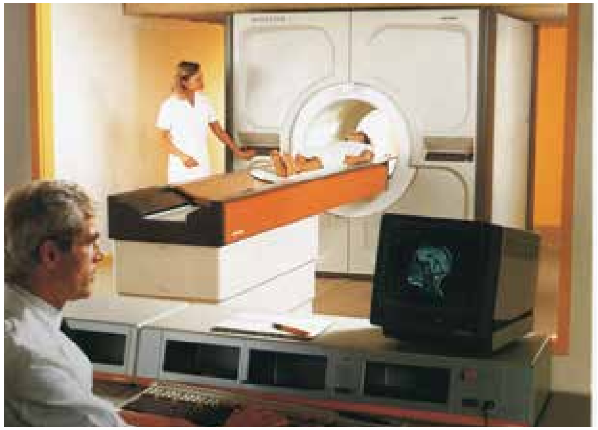

MAGNETOM
SIEMENS

1983: The MAGNETOM

Head coil with various pillows, 1983



Head scan, 1983



Scanning a patient with the first MAGNETOM, 1983

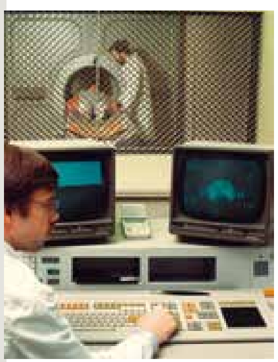
By the summer of 1983, the time had come: After years of research and development, Siemens presented its first commercial MRI system – the MAGNETOM. This model already incorporated a superconducting magnet, which the company could supply with different field strengths: an approximately 5.3-ton configuration rated at 0.35 Tesla, followed shortly thereafter by a similarly heavy one with 0.5 Tesla, and a 1.5 Tesla system, weighting 7.3 tons. Once the MAGNETOM had been set up in the shielded MRI room, the magnet was cooled to -269°C using liquid nitrogen and liquid helium, and then charged with electricity. After that, no further electrical power to the magnet was needed, and the power supply was permanently cut off. The helium and nitrogen, however, slowly evaporated, so regular replenishments were necessary – the first MAGNETOM used about two liters of nitrogen and half a liter of helium per hour.

In front of the room containing the MRI system was the operating and analysis console, and an adjacent computer room housed equipment including the electronic controls and image computer, while an engineering room held the cooling unit and power supply. The 0.35 Tesla MAGNETOM took up about 95 square meters of space in all total in 1983, and the 1.5 Tesla system needed even more, at about 140 square meters. Another factor that had to be kept in mind in choosing where to install the system was the fact that steel located anywhere near the MRI system affects the magnetic field, so certain minimum distances from the center point of the magnet needed to be observed. For example, users were cautioned not to install the system within 15 meters of any street used by cars and trucks, and elevators with steel cages also had to be located farther away.

The system's diagnostic performance was already impressive at the time: During whole-body scanning, the MAGNETOM was able to visualize structures smaller than 2 millimeters in an image section with a diameter of 50 centimeters. In a head scan, doctors could even see structures smaller than one millimeter in an image 25 centimeters in diameter. The image consisted of pixels with 256 different shades of gray to depict the various types of tissue within the body. This showed significant contrast between different tissue types, allowing doctors to recognize pathological changes in the body. The analysis and interpretation software offered a wealth of options; plus it could be expanded at any time.

MRI technology grows out of its infancy

Preparing for a scan, 1984



Klinikum Charlottenburg, 1983

Magnet shield, 1984

Fundamental research and preliminary development had proven their value: As early as 1982, researchers at Siemens were able to generate meaningful images using MRI prototypes.

The systems had previously been tested under laboratory conditions. For routine operation in clinical settings and private medical practices, however, the engineers needed to develop easy-to-use control elements. Their goal was to make it easy to operate the system, but without restricting the many options available during scanning. The researchers also overhauled the electronics used in the system with the aim to speed up the time needed to calculate the images and visualize them on the monitor. Documentation options were tailored to existing practices in the medical sector, and the necessary work steps were integrated into everyday clinical procedures based on existing practices. Engineers also worked on comfort and convenience: With the prototypes, patients had to climb into the magnet over a wooden board, but now a motorized patient table was used to position the patient correctly for the scan.

Finally, in early 1983, the time had come: At Hannover Medical School, Siemens installed the first MRI system that would be tested in a clinical setting to ensure that it was suitable for day-to-day use. The system's centerpiece was an oil-cooled, normally conductive magnet with a field strength of 0.2 Tesla, which Siemens had developed with support from the German Federal Ministry of Research and Technology. Doctors at the medical school examined more than 800 patients with the system. The testing went so well that Siemens ramped up product development efforts, establishing the new Magnetic Resonance Business Unit within the Medical Technology Division.

"Magnetic resonance imaging is growing out of its infancy," was the message a few months later, in a Siemens press release publicly unveiling the company's first MRI system that was ready for mass production: the MAGNETOM.

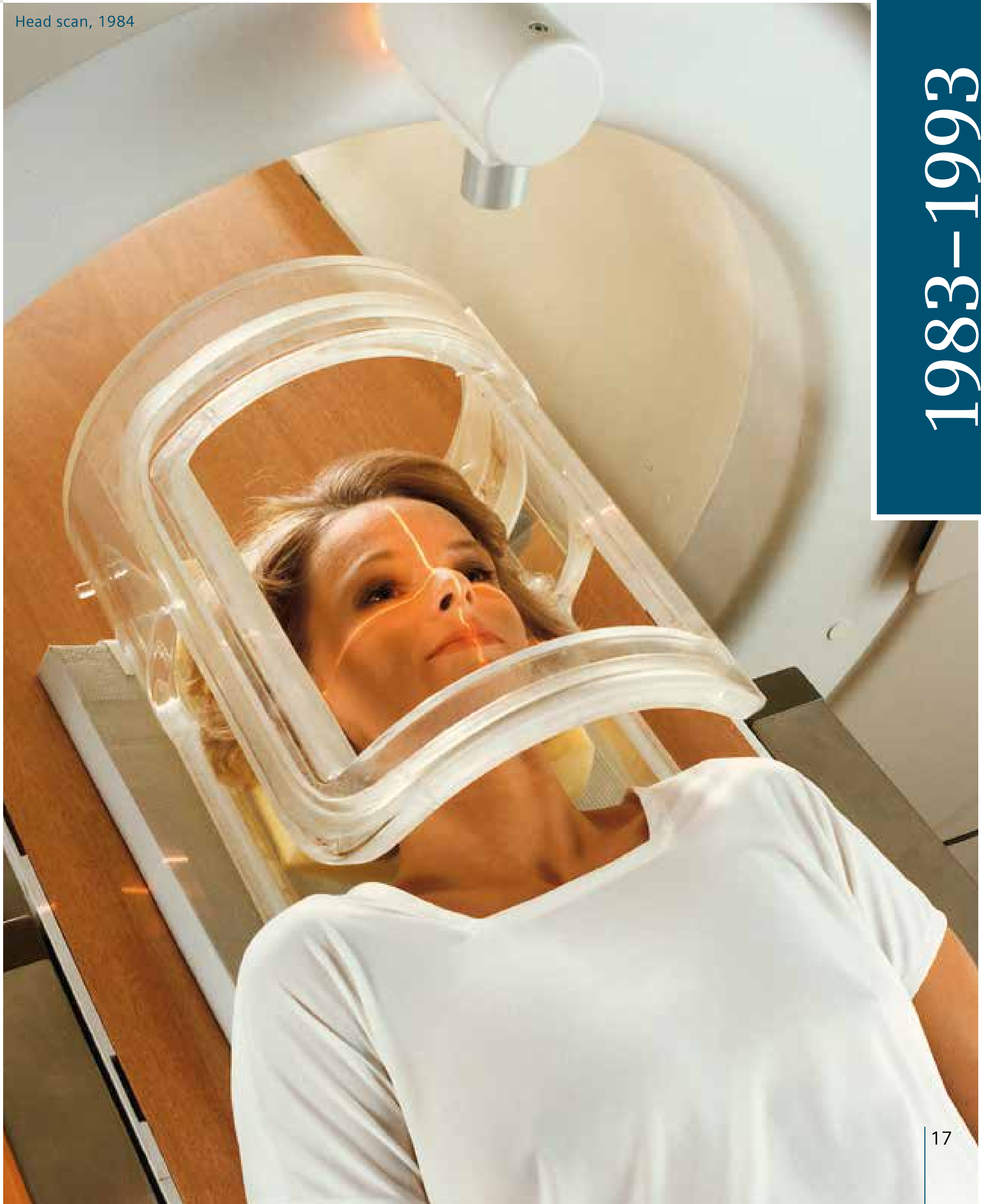
Not long after that, in August, the first patients underwent scanning in a MAGNETOM system with a field strength of 0.35 Tesla. Siemens installed the first system at the Mallinckrodt Institute of Radiology, in St. Louis. This made the company one of the first providers worldwide to offer magnetic resonance imaging for clinical applications.

The first MAGNETOM in Germany went to a radiologist named Armin Kühnert, who used a system with field strength of 0.35 Tesla at his practice in the town of Dietzenbach, near Frankfurt. At almost the same time, Hansjörg Heller, a radiologist based in Munich, received a 0.5 Tesla system. Heller commissioned significant renovations to get his practice ready to accommodate the MAGNETOM. Since the system was not yet actively screened at the time, disruptive influences from the surrounding area had to be eliminated. But Heller accepted the expense and inconvenience of the renovation as a trade-off for the system, saying, "Well, I couldn't very well move to the outskirts of town. No one would have come in if I had."

In December 1983, Klinikum Charlottenburg, a hospital operated by Freie Universität Berlin, became the first university medical center in Germany to receive an MRI system with superconducting magnets from Siemens. From then until June 1984, the company shipped 14 MAGNETOM systems to destinations all over the world. That same month, the U.S. Food and Drug Administration (FDA) granted the MAGNETOM its final approval for the U.S. market. In 1986, Siemens became the first manufacturer of MRI systems to win approval for 1.5 Tesla systems in Japan, where 0.35- and 0.5 Tesla systems were already approved.

The magnets used in the first MRI systems could only be installed in rooms measuring at least 40 square meters in size. The reason for this was the strong scatter field generated by conventional magnets. These kinds of magnets do not have any shielding for the magnetic field, which affects technical equipment and devices, cardiac pacemakers and prostheses. With this in mind, Siemens developed a superconducting magnet with a scatter field about five times smaller. This design, found nowhere else in the world, shielded the magnetic field through "magnetic return", meaning that a cage-shaped shield conducted the scatter field back to the magnet. This meant the magnet only needed about half as much space, or about 20 square meters. Many of the changes that rooms had previously needed in order to accommodate an MRI system were no longer necessary, cutting the cost of installation.

Head scan, 1984



The superconducting magnets also enabled higher field strengths. In magnetic resonance imaging, the principle is that the stronger the magnetic field, the higher the image quality. Through improvements to magnetic coils and shielding, Siemens made rapid advances in boosting field strength, and a MAGNETOM with a 1.5 Tesla field strength was launched early on, in 1984. For medical research, Siemens engineers developed the first MRI system with a 4 Tesla whole-body magnet in 1986.

Even as these gains were being made in terms of performance, Siemens also introduced a number of technological innovations that unlocked new diagnostic possibilities, shortened scanning times, and reduced power consumption. As early as 1985, the company was able to cut scanning time nearly in half by using a "half-Fourier matrix". In this measurement technique, the MAGNETOM determined about half the data through direct measurements, while the other half was reconstructed mathematically. To further reduce scan times, Siemens relied on "gradient echo" techniques, which allowed engineers to make use of imaging methods that were previously impossible.

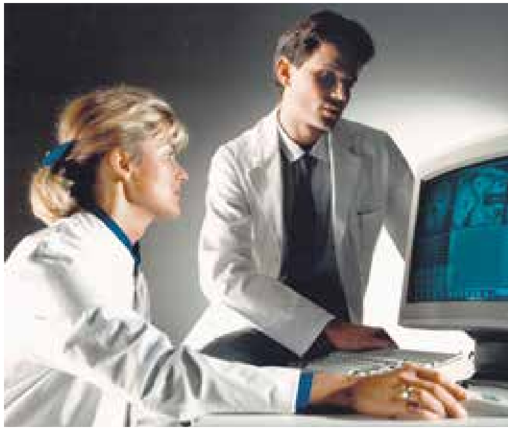
In medicine, the use of imaging systems to visualize blood vessels is known as angiography. This makes it possible to detect things like deposits in blood vessels, or to diagnose vascular diseases such as thrombosis. Siemens introduced angiography functions in its MRI systems early on – in 1989 – when the MAGNETOM began using a method known as 3D volume MR angiography to calculate the vessels from different directions and visualize them in three dimensions.

Magnetic resonance made it possible to generate detailed slice images of the beating heart back in the mid-1980s. These images were of particular interest to doctors, since at the time there was no other method that could visualize the inside of the heart with such good quality. Siemens was one of the first manufacturers to supply special programs that visualized cardiac anatomy and functioning and measured important values such as volume and

Advertising brochure, 1984

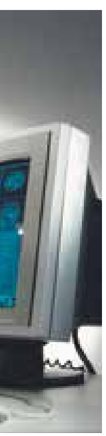
Early angiography image, 1987

Knee image, 1987


Interpreting a scan, 1988

muscle thickness. Even back then, it was possible to generate meaningful films of the beating heart.

In 1989, Siemens launched a 1.0 Tesla system with an actively shielded magnet, the MAGNETOM 42 SPE. Active shielding means that in addition to the coils that generate the magnetic field, there are also coils installed on the magnet itself, which weaken the magnetic field toward the outside – where no magnetic field is needed for imaging purposes. It was followed in 1991 by an MRI system with an actively shielded 1.0 Tesla whole-body magnet that was operated via an intuitive user interface similar to that of a PC: the MAGNETOM Impact.



Preparing for a scan, 1990

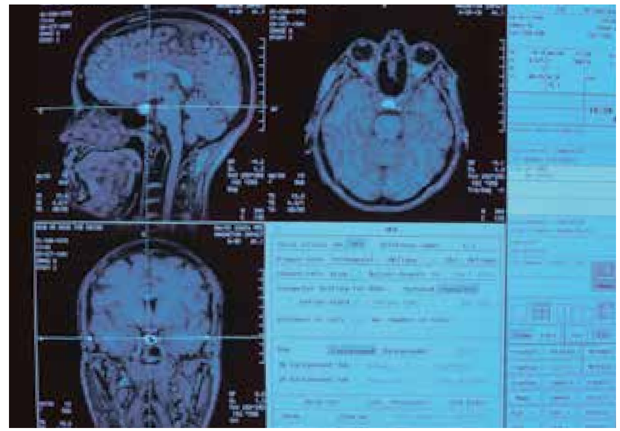
Head scan, 1991

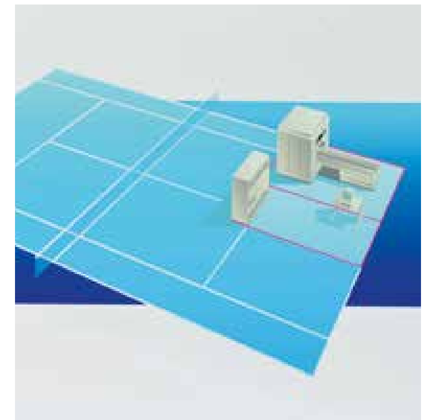
The Erlangen research lab, 1987


SIEMENS
MAGNETOM
IMPACT

New developments in tight quarters


MAGNETOM Impact patient table, 1991


Results of a head scan, 1991


Size of the MAGNETOM Impact vs. a tennis court, 1991


Head scan, 1993

The MRI systems of the 1980s presented practical difficulties for a number of medical centers and private practices that would otherwise be interested in using the technology. They needed a lot of space – often 100 square meters or more – and renovating rooms to accommodate them was costly and labor-intensive. The costs of operating an MRI system were also high, and maintenance was time-consuming, since the systems had to be refilled with nitrogen and helium after a few weeks. In 1991, Siemens launched an MRI system that was also suitable for use in limited space, with significantly lower operating and maintenance costs: The MAGNETOM Impact, which featured an actively shielded 1 Tesla whole-body magnet, fit in spaces measuring just 40 square meters, and it needed only two helium fillings per year.

The compact size was due primarily to improvements in active shielding of the superconducting magnet. This magnet technology helped break the link between the size of the magnet system and its field strength. The 1 Tesla MAGNETOM Impact even needed less space than most of the 0.5 Tesla systems in use at the time. The magnet came standard with a helium cooling system and needed only two to three helium fillings per year. Plus, even with these other advances, the magnet was one of the lightest on the market in 1991.

Alongside the improvements in the magnet itself, MAGNETOM Impact also featured new image processing technologies, and it was the first system to visualize scan results on a user interface similar to that of a PC. A computer mouse was used to navigate through the scanning programs, which had been grouped together intuitively, and all of the important information was available at a glance on the high-resolution monitor. In addition to greater convenience for the user, the design of MAGNETOM Impact also benefited patients, since all of the important connections for the high-frequency coils and other accessories were built right into the patient table. This reduced prep time and made the scanning process both faster and more comfortable.

Open and standardized

By the early 1990s, magnetic resonance imaging had become an integral part of everyday clinical practice, supplying the fastest and most accurate responses to many questions. New functions and programs unlocked additional diagnostic options, and faster computers shortened scanning times. In 1992, the standard was 20 patients in eight hours. But MRI technology was still not suitable for everyone: Some patients felt uncomfortable when they were moved into the MRI system's narrow magnet tunnel. Children[1] and elderly patients, in particular, were difficult or impossible to scan. One of the biggest challenges facing engineers was how to make MRI technology accessible to everyone – without restricting the scanning possibilities. In 1993, Siemens succeeded in doing this, introducing the first truly open MRI system, MAGNETOM Open.

MAGNETOM Open, which was equipped with a 0.2 Tesla magnet, was open on three sides. This design even made it possible for doctors to use the system to monitor patients during surgery. The patient lay on an MRI operating table designed specifically for this purpose, and was quickly positioned under the MAGNETOM Open as needed. This allowed neurosurgeons, for example, to see where the margin of a tumor was located and whether it had already been fully removed. The operation itself took place outside the MRI system's scatter field, so normal surgical instruments could be used.

From elbow pain to a sprained ankle or head injury, the body part to be scanned was simply centered under the MAGNETOM Open's magnet. For hand scans, the patient could even sit next to the system, simply placing his or her hand under the magnet. Another advantage of the open design was that a joint could be scanned, for example, while the patient moved the part that was causing pain. The doctor could see the moving joint onscreen and diagnose the tissue injury. Even with its open design, the MAGNETOM Open still had all of the functions and programs needed for clinical use. Even MR angiography was possible with the system.

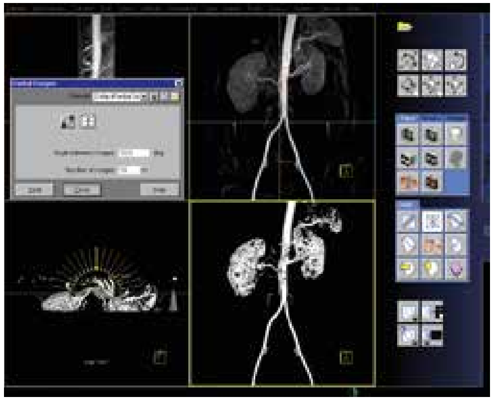
The software used for the Siemens MRI systems in the 1990s was structured similarly to PC software, so it was already much more intuitive to use than the software for the first MRI systems. However, MRI and computed tomography (CT) or other imaging systems from the same manufacturer had always used different software interfaces – which operators had to learn individually. Around the turn of the 21st century, Siemens became the first medical technology manufacturer to craft a standardized user interface for all of its systems: *syngo* software.

From then on, all imaging systems from Siemens featured standardized operation.

When a hospital or medical practice purchases a new system from Siemens, the learning curve for staff is much shorter. The graphical user


An MRI scan in Singapore, 1993

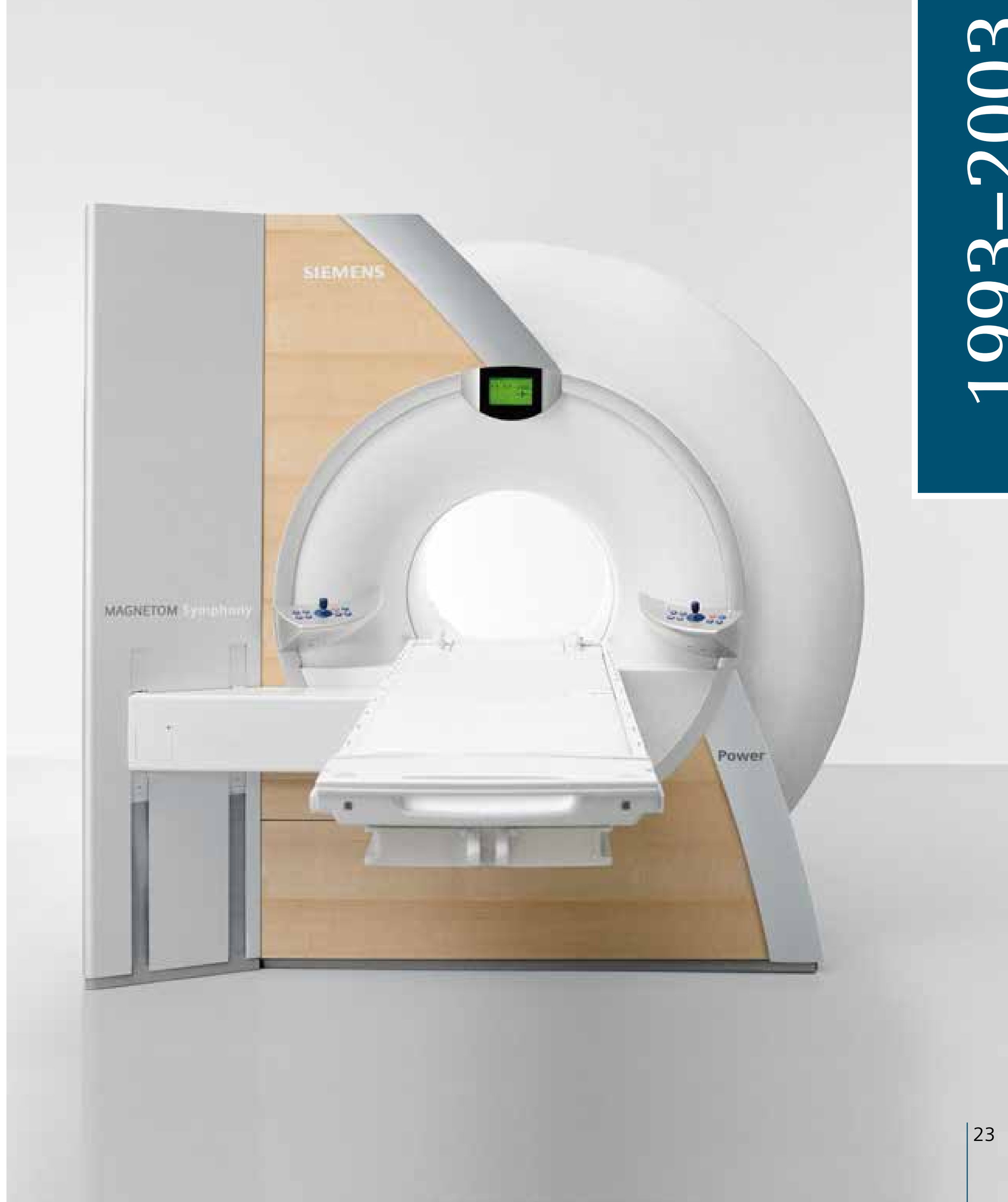

Open on three sides: the MAGNETOM Open, 1994


Angiography with *syngo*, 2001

interface consists entirely of simple, self-explanatory symbols. Behind the *syngo* interface are numerous functions that have been optimized for workflows in clinical settings and medical practices. For example, all of the data on a patient can be compiled in the electronic patient file, so the physician can always keep track of past scans and tests, including MRI findings, lab results, and operative reports. Cross-department networking speeds workflows, allowing doctors to focus more on patients. Siemens, too, benefits directly from *syngo*, which makes it easier to integrate new developments into the existing system.

One of these developments is the MAGNETOM Symphony. Originally introduced in 1997, the system has undergone continuous improvement and the addition of new functions. Its modular structure makes the MAGNETOM future-proof. The user puts the system together according to his or her needs and could then upgrade or retrofit conveniently after a few years. The user's needs play an important role at every stage of the process, including during development: Siemens surveyed radiologists, radiology assistants, and patients, asking about their clinical and personal requirements for an MRI system. Alongside performance capacity and flexibility, user convenience and patient comfort were paramount.

MAGNETOM Symphony, 1997

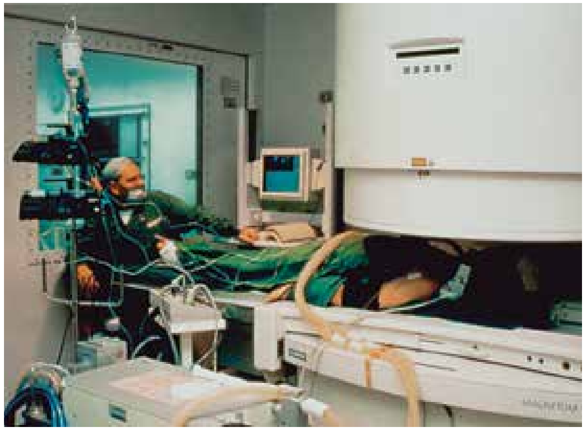


To give doctors and patients unrestricted access to the patient, Siemens has developed technology such as the self-supporting patient table. The MAGNETOM Symphony table, for example, supported a weight of up to 200 kilograms and could be lowered to 45 centimeters above floor level. When the patient is slid into the bore, the bright, open appearance helps counteract any fears he or she may have. The magnet tunnel was only 120 centimeters long, which helped enhance patient comfort, as did the system's individual lighting settings and good ventilation. Design was an important factor in all aspects of the MAGNETOM Symphony. In fact, the casing and doughnut-shaped opening were available in various warm colors that created a pleasant, calm atmosphere.

If the scan involves visualizing especially fine structures in the brain or rapid metabolic processes, MRI systems with stronger magnets enable even higher image resolution. As a result, the early 2000s saw an increase in the use of 3 Tesla systems for clinical diagnosis. These high-performance systems expanded the options available in fields such as neurological diagnostics and oncology. They also shortened scanning time, which can bring real relief during scanning of larger regions of the body.
Many patients, especially children[1], have a hard time holding still in the tube for a long time. In 2001, Siemens introduced the MAGNETOM Trio, a 3 Tesla MRI system that can scan the entire body in a single examination, equipped with the industry's most powerful gradient coils and new high-performance imaging technologies.

That same year, the company also launched MAGNETOM World – not a new MRI system, but a forum where users can share their experiences with their MAGNETOM systems with each other and with Siemens. MAGNETOM World offers user tips, training programs, case studies, and working groups on certain disciplines, such as neurology and orthopedics. The MAGNETOM World Summit, initially held annually and later held every two years, offers an opportunity for personal dialogue with other users and researchers. Dialogue, cooperation, working groups – all of these are things Siemens has always viewed as important opportunities to develop and establish innovations. Over the years, the Magnetic Resonance Business Unit has established numerous partnerships with other companies, medical centers, and research institutions.

The quality of MRI head images, 1983 to 2002


Using the MAGNETOM Open to monitor an operation, 1994

Sketch of an examination room with MAGNETOM Symphony, 2001

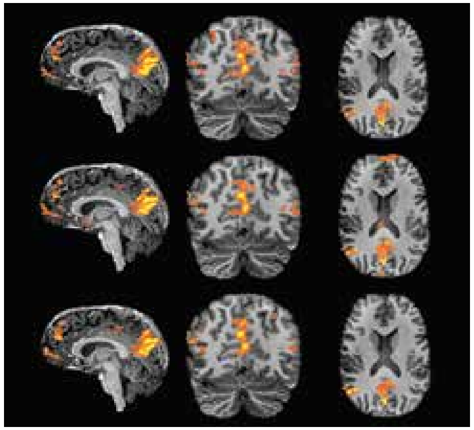
Chest image, 1996

MAGNETOM WORLD clinical portal, 2014


MAGNETOM
7T MRI

At the limits of technological feasibility

Sketch of a MAGNETOM 7T examination room, 2010



Functional MRI with MAGNETOM 7T, 2012

MAGNETOM 7T ultra-high field system, 2010

In medicine, diagnosis and planning for the best possible treatment are not the only important factors; doctors also have to understand the root causes and effects of diseases at a fundamental level. Scientists all over the world use magnetic resonance imaging in their research. MRI systems developed specifically for research allow them to visualize previously unknown processes taking place in the human body. The researchers observe extremely fine structures in the brain and the changes that occur in patients with diseases such as multiple sclerosis, brain tumors, or Alzheimer's disease. These studies rely on systems with very high field strengths, known as "ultra-high field" MRI systems.

As far back as 1986, when MRI technology was still relatively new, Siemens built a MAGNETOM with a 4 Tesla whole-body magnet for use in research. Then, in the first decade of the new millennium, research institutions were able to use MRI systems with much greater field strength, at 7 Tesla – about 140,000 times the strength of the earth's magnetic field. Field strengths of 1.5 to 3 Tesla remain the most suitable for diagnosing disease in everyday clinical practice, while ultra-high field systems are advantageous for research on the causes of disease and various other studies. The stronger magnetic field enhances contrast and image resolution, providing distinct images of even structures just 0.2 millimeters in size. This resolution and new technologies allow researchers to recognize even the tiniest connections in the brain. In terms of metabolic activity in tissue, they can distinguish between different chemical molecules and see things like how medications work within the body.

To adapt the ultra-high field systems for specialized use in research, Siemens works hand in hand with scientists at universities and research institutions worldwide. For example, the company worked with the first cooperation partner for the MAGNETOM 7T[2], Boston's Massachusetts General Hospital, to develop an entire range of specialized coils and application-oriented techniques. This cooperation with academic partners and the new techniques tested in the process have prompted great strides in clinical MRI system technology, with many of the insights arising from research-focused development activities also going toward systems with lower field strengths. The research community is a large one, as Siemens is also the world market leader in ultra-high field MRI, supplying more than half of the MRI systems used for research.

MAGNETOM
Espree, 2006

Whole-body scan, 2003

Tim changes MRI forever

In late 2003, Tim revolutionized magnetic resonance imaging. “Tim” is not the name of the newest developer working on MRI research at Siemens, though – it is actually an acronym for “Total imaging matrix”. To explain what makes Tim so revolutionary, we have to delve into the technology a bit. In imaging, the term “matrix” denotes a pattern of points, composed of individual pixels, that generates an image. The centerpiece of Tim technology is the completely innovative High-frequency (HF) coils that collect data based on this kind of matrix concept. Tim localizes points in the patient’s body and converts them into a data matrix. Tim technology then uses this vast trove of data to calculate the slice images of the body.

Whole-body scans used to require various coils, which were changed to produce images of certain areas of the body. In addition, the patient was asked to stand up at various times during many scans. Now, for the first time, Tim made it possible to produce images of the entire body from head to toe in a single pass, since the matrix coils cover all areas of the body at the same high level of detail. Labor-intensive, time-consuming partial scans are automatically measured at the same time. This enables many scans, such as scanning of the vascular or nervous system, and the diagnostic images are easier to evaluate. Scanning the entire body is now possible in about twelve minutes for patients as tall as 2.05 meters. Tim represented tremendous technological progress in image quality, significantly lower patient prep time, and shorter scanning times, but it also had additional advantages for operators and patients. Tim supported staff with a wealth of automated programs designed for specific applications, such as cardiac or bone scans or scanning children[1]. Patient comfort was enhanced because the coils weighed less: At just 950 grams, the “body matrix” coil was lighter than some winter bed comforters.

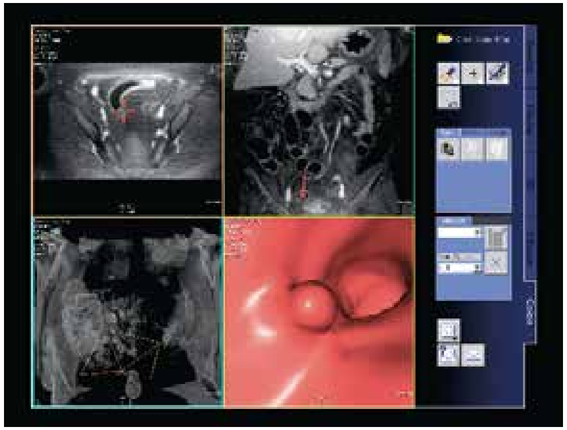
Tim technology also made it possible for patients to be positioned feet first for almost all scans – a big relief for many patients, since it means the head can stay outside the “bore”. Siemens combined all of these features in the MAGNETOM Avanto, which was commissioned for clinical operation at University Hospital Tübingen on November 25, 2003.

A few months later, Tim technology, working in tandem with optimization of components such as the magnet, gradient system, and receiver electronics, enabled another milestone in magnetic resonance imaging: The MAGNETOM Espree was the world’s first 1.5-tesla system with a 70-centimeter opening. This gave obese patients unrestricted access to high-field MRI for the first time. In addition to sufficient space, the MAGNETOM Espree also offered a signal-to-noise ratio that was as much as four times higher than that of commonly used open MRI systems with lower field strength. This meant that it was possible to visualize deep layers of tissue in high-field quality, even in overweight and obese patients.

From then on, Siemens engineers have been working on technologies and software that further improve and support Tim technology. The *syngo* software has received numerous new MRI applications that further enhance comfort and convenience, expand the range of scanning options, and make images even clearer. New developments in MRI technology from Siemens included the 2005 introduction of BLADE, a feature that supplies even sharper images, even if the patient moves. That same year, SPACE enabled high-resolution 3D visualization of areas such as the brain and joints.

Healthcare providers face mounting pressure. Doctors and assistants have to work on a cost-optimized basis while also offering the very best in diagnosis and treatment. As a result, technological innovations and enhanced productivity play a large role. In 2009, Siemens launched its MAGNETOM Aera and MAGNETOM Skyra systems. The 1.5 Tesla MAGNETOM Aera system and the 3 Tesla MAGNETOM Skyra were the first two MRI systems to feature the fourth generation of Tim technology (Tim 4G) as well as Dot ("Day optimizing throughput") technology, an optimized examination software for faster scans. Dot simplifies hospital workflows, thereby boosting productivity by as much as 30 percent. It uses images and text to guide operators step by step through the scanning process, even during complex scans.

A surface coil suitable for pediatric use[1], 2011



Virtual colonoscopy, ca. 2006

MAGNETOM Skyra 3 Tesla system, 2009

A knee scan with the MAGNETOM Aera, 2009

In the process, all settings can be adjusted to the specific patient with just a few mouse clicks. This kind of adjustment is needed for various reasons, for instance because the length of time patients can hold their breath varies by individual.

Tim 4G represented another significant increase in image quality. The matrix coils contain even more coil elements and receiver channels, which make higher resolution possible and further enhance the signal-to-noise ratio. Some of the coils are now wireless, so they are lighter and easier to handle. The new dockable MRI patient table allows patients with restricted physical mobility, including bedridden and obese patients, to be prepped outside the MRI room and then moved into the room on the table for the scan. Even when being pushed, the table can support as much as 250 kilograms. Patients benefit from the 70-centimeter opening featured in the MAGNETOM Aera and MAGNETOM Skyra – which has already become a standard element of many MRI systems from Siemens.

Another technological breakthrough from Siemens unlocked completely new views of the inside of the human body in 2010: The Biograph mMR system combines magnetic resonance imaging and positron emission tomography (PET). These two methods have different strengths, and they supply the physician with important, complementary information on diseases. While MRI provides detailed images of organs and soft tissue inside the body down to the millimeter, molecular imaging makes it possible to visualize metabolic activity in the cells on a detailed basis for specific organs. For example, if MRI and PET are to be used to assess the success of chemotherapy, the doctor can see with just a single scan whether a tumor has shrunk and its metabolic rate has slowed. This used to require two separate scans, with the images being superimposed over each other afterward.

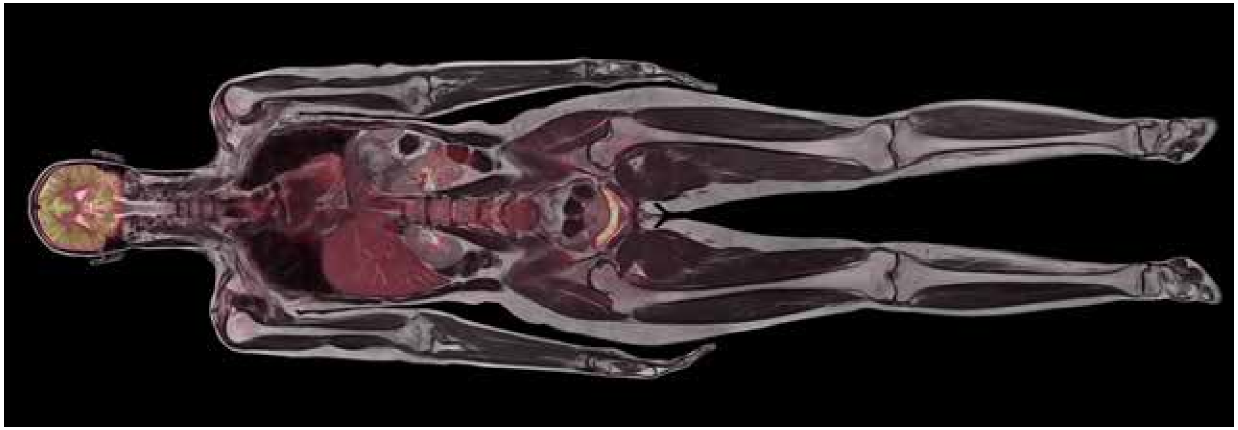
These kinds of revolutionary developments from Siemens have also opened new doors for researchers. At Forschungszentrum Jülich, a German research center, scientists worked on new possibilities for diagnosis and treatment of brain diseases such as Alzheimer's and Parkinson's disease. In the process, they relied on a unique large-scale device that Siemens had developed in cooperation with the team of researchers in Jülich: a MRI system with a whopping 9.4 Tesla field strength – almost 200,000 times stronger than the earth's magnetic field – which was also combined with a PET system. This ultra-high-performance system allowed the researchers to identify even the tiniest structural changes in the brain in precision detail while also observing metabolic processes. In numerous other projects all over the world, Siemens has worked closely together with scientists to make further advances in the development of high-performance magnets (currently up to 11.7 Tesla) for use in research. These activities have also benefited the Siemens engineers in the development of clinical MRI systems with lower field strengths, since they have been able to apply what they have learned from working at the limits of technological feasibility there as well.

Along its path from fundamental research in the wooden "shed" to world market leadership in MRI technology, Siemens has garnered multiple awards and distinctions for groundbreaking advances and innovations. They include awards such as the Frost & Sullivan Product Innovation Award for 2003, being named Best Innovator in 2004 in the Organization and Culture category by corporate consulting firm A.T. Kearney and business magazine Wirtschaftswoche, and the prestigious Innovations-preis der deutschen Wirtschaft (Innovation Award of German Industry) for the development of Tim technology.

Advanced scanning environment, MAGNETOM Prisma, 2013

Clinical image generated
with the Biograph mMR
(TU Munich), 2011

Two in one: the Biograph mMR



Morphological and functional insight into the human body: a whole-body scan taken with the Biograph mMR, 2010

Scan preparation, Biograph mMR, 2011

In November 2010, Siemens unveiled the first-ever system of its kind, combining two of the most advanced technologies available in clinical imaging. Biograph mMR was the first system to bring together all the benefits of MRI and positron emission tomography (PET) technology in one. This innovation unlocked new possibilities in medicine and research. For the first time, doctors were able to see the position of organs within the body, their functioning, and metabolic processes in a single image. This made diagnosis even more accurate and allowed for very early detection of many diseases, which are frequently accompanied by changes in cellular metabolism. Structural changes in the tissue follow these metabolic changes, sometimes with a significant delay.

Like magnetic resonance imaging, positron emission tomography had long been an established procedure in day-to-day medical practice, but for certain diagnoses, the patient had to undergo scanning with both methods separately. Afterward, the images were superimposed one over the other, combining the results of scanning. Biograph mMR unites both methods in just a single scan process. Alongside the advantages this brings for the physician during the diagnosis process, this also benefits the patient: Instead of two scans, which together used to take more than one hour, the patient's entire body can now be scanned in about 30 minutes. The patient no longer needs to be prepped for multiple scans in various rooms. In addition, the increased accuracy of diagnosis makes it possible to craft a more individualized treatment plan and facilitates follow-up care. Combining MRI and PET yields especially meaningful results in diagnosing cancer and for examinations of the nervous system and the heart.

To visualize metabolic processes taking place in the cells of the tissue using PET technology, substances called tracers are injected into the patient's bloodstream. The tracer is usually a form of glucose that is slightly radioactive. The tracer spreads through the cells and is involved in metabolic activity. After a short time, the tracer undergoes positron emission decay, emitting positrons, a kind of subatomic particle. Biograph mMR measures the exact position of these positrons, generating a visual representation of the cells' use of energy. This makes it possible for doctors to do things like track down tumor cells, which use more of the radioactive glucose than healthy cells do.

Production in Erlangen, 2013

Joinville, Brasilien, 2013

Everything from a single source

Erlangen, Oxford, Shenzhen – with these three sites around the globe, Siemens has all the technology and capabilities needed to build state-of-the-art MRI systems entirely from a single source. The sites interact seamlessly and work closely together on research and development. Ongoing investments give rise to numerous innovations that add to the product family and are adjusted to meet the needs of the various markets Siemens serves. At all of the locations, the superior standard of quality that applies to development and production activities is supplemented by consulting and other services for customers from all over the world. In August 2012, another production site was added to support worldwide sales and distribution of the MAGNETOM family. In the southern Brazilian city of Joinville, Siemens Healthcare operates a 6,000-square-meter factory that builds systems for medical imaging, including about 300 MRI systems per year.

Erlangen, ca. 2013

Oxford, 2012

Shenzhen, 2012

Erlangen, Germany

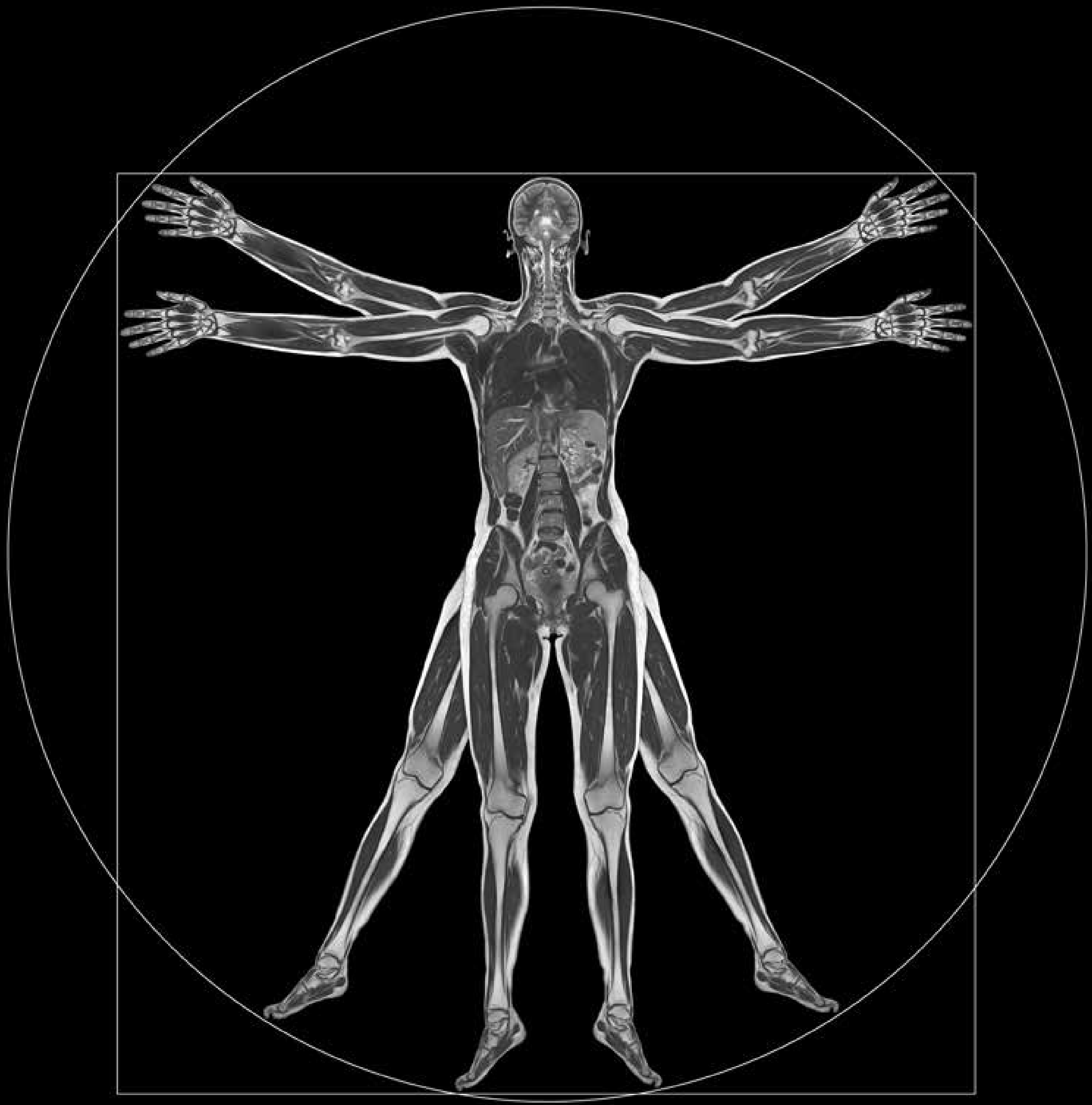
The birthplace of magnetic resonance imaging at Siemens. The Erlangen headquarters of Siemens Healthcare was the site of the wooden "shed" where Siemens engineers researched the fundamentals of magnetic resonance imaging – and today, the location is home to the world's most advanced production site for MRI systems. The facility was built in 1999 and has been expanded on a regular basis since then. It combines production, research, development, marketing, and logistics in a single campus. Thousands of MRI systems have been constructed here and sent to locations all over the world. The Siemens research lab operates almost 30 fully functional MRI systems. Over 10,000 visitors and customers visit the site annually to learn about MRI technology at Siemens, tour the production facilities, and attend presentations on magnetic resonance imaging.

Oxford, UK

The centerpiece of the MRI systems from Siemens – the magnet – comes from Oxford. The company's very first prototypes worked with magnets from a company named Oxford Instruments. The two companies soon developed a close relationship, and the Oxford plant grew, producing just under 50 magnets per year in 1982 and then 300 just two years later. In 1989, Siemens acquired the majority of Oxford Magnet Technology, which completely became part of Siemens in 2003. Today, Siemens Magnet Technology (SMT) builds about 1,500 magnets for MRI systems in Oxford each year. More than one-third of the magnetic resonance tomography systems installed at hospitals worldwide work based on magnets from SMT. The company has a long history of innovation, including the world's first superconducting whole-body magnet, launched in 1980, the first actively shielded magnet, introduced in 1986, and the shortest 1.5 Tesla magnet, which was introduced in 2000.

Shenzhen, China

A group of Chinese scientists began working on MRI systems in Shenzhen in 1998. They developed an entry-level model and then began working with Siemens in order to design systems for higher market segments as well. Over the years, this partnership developed into a new high-tech site, Siemens Shenzhen Magnetic Resonance Ltd. (SSMR). Part of the global Siemens research network, the Shenzhen facility builds various things, including MRI systems geared particularly to those starting out with MRI technology. The team in Shenzhen worked with Erlangen and Oxford to develop the MAGNETOM ESSENZA in 2008. This system offers a low-priced alternative to other 1.5 Tesla systems without compromising on quality. The researchers in Shenzhen focus especially on providing access to state-of-the-art MRI technology to an even broader clientele.



The most important MRI systems in Siemens history

MAGNETOM, 1983

MAGNETOM Impact, 1991

MAGNETOM P8, 1991

MAGNETOM Open, 1993

(1983) MAGNETOM

The first commercial magnetic resonance imaging system from Siemens. In the early days, the systems installed had a superconducting 0.35 Tesla whole-body magnet. Not long afterward, they were followed by the 0.5 Tesla MAGNETOM M and MAGNETOM H, with field strength of 1.5 Tesla.

(1986) 4 Tesla MAGNETOM

Siemens installed the first MRI system with a 4 Tesla whole-body magnet. It was used predominantly for research on new possibilities in diagnostics and imaging.

(1989) MAGNETOM 63 SP

The first MRI system in which all 3D imaging and postprocessing technologies were fully integrated. A similar configuration with an actively shielded 1.0 Tesla magnet appeared under the MAGNETOM 42 SP name.

(1991) MAGNETOM Impact

The first MAGNETOM with a user interface like that of a personal computer. A new form of active shielding for the magnet meant that the 1.0 Tesla system only needed about 40 square meters of space. Helium consumption was reduced to a maximum of two refills per year.

(1991) MAGNETOM P8

The first MRI system with a 0.2 Tesla whole-body permanent magnet. It needed just 25 square meters of installation space, and could be used for angiography.

(1993) MAGNETOM Open

The first MRI system on the market to be open on three sides. The 0.2 Tesla system made it possible to scan even very fearful or claustrophobic patients.


MAGNETOM Vision, 1993


MAGNETOM Symphony, 1997


MAGNETOM Harmony, 1997


MAGNETOM Allegra, 1999


MAGNETOM Sonata, 2000

(1993) MAGNETOM Vision

The new coil technology in this 1.5 Tesla system accelerated calculation of the scan image. A new imaging method offered greater detail and accuracy when investigating brain activity and was especially suitable for diagnosing strokes.

(1996) MAGNETOM Open Viva

The new design of the MAGNETOM Open continued to work with a 0.2 Tesla magnet, but new technology significantly shortened scanning times.

(1997) MAGNETOM Symphony

New coil technology made further significant advances in the quality of images produced by this 1.5 Tesla system. At the same time, Siemens made the scanning experience more pleasant for both patients and operators. A 1 Tesla version was introduced under the MAGNETOM Harmony name.

(1999) MAGNETOM Allegra

The first MRI system with a 3 Tesla field strength developed specifically for head scans. It was used to diagnose brain diseases such as epilepsy, among other uses.

(2000) MAGNETOM Sonata

This 1.5 Tesla system featured especially high-performance gradients. It was used mainly to scan the heart and nervous system.

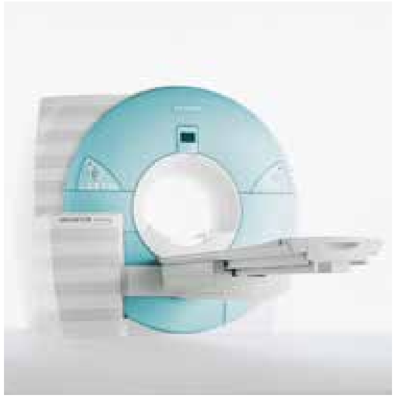
(2000) MAGNETOM Rhapsody

The world’s first open MRI system with field strength of 1 Tesla. Many aspects of the system represent a combination of the technology used for the MAGNETOM Harmony and MAGNETOM Open viva.

MAGNETOM Rhapsody, 2000

MAGNETOM Concerto, 2000

MAGNETOM Trio, 2001



MAGNETOM Avanto, 2003

MAGNETOM C!, 2004

(2000) MAGNETOM Concerto

The next step in the evolution of the MAGNETOM Open viva. The 0.2 Tesla system featured the most powerful gradient coils of all low-field strength MRI systems available at the time.

(2001) MAGNETOM Trio

The first clinical 3 Tesla whole-body system worked with *syngo* software, which had been optimized for workflows in clinical settings and private practices.

(2003) MAGNETOM Avanto

The first system with Tim technology. In addition to the new coil concept, this 1.5 Tesla system was equipped with technologies that reduced operating noise by as much as 97 percent.

(2004) MAGNETOM C!

The compact, C-shaped permanent magnet of this 0.35 Tesla system did not require any liquid helium. Low operating costs made the MAGNETOM C! an especially good choice for rural hospitals.


MAGNETOM Espree, 2004


MAGNETOM 7T, 2005 (Bild von 2010)


MAGNETOM Verio, 2008

(2004) MAGNETOM Espree

The world's first MRI system with a 70-centimeter opening. This meant that the 1.5 Tesla system offered added comfort for obese patients and those with claustrophobia.

(2005) MAGNETOM 7T[2]

The high-performance system for scientific use and research. The three-meter-long magnet weighed 32 tons and was cooled with 1,750 liters of liquid helium, but still needed just 40 square meters of installation space.

(2007) MAGNETOM ESSENZA

Siemens developed this 1.5 Tesla system specifically as an entry-level MRI system for hospitals and medical practices with high patient numbers and lower budgets. Alongside low purchase costs, the costs of installing this lightweight, short system were as much as 25 percent lower than for other systems.

(2007) MAGNETOM Verio

The first MRI system in the world to combine a field strength of 3 Tesla with a 70-centimeter opening. The new MAGNETOM Verio was 4.7 tons lighter than the previous 3 Tesla system. Liquid helium refills are typically required only once every ten years.

(2009) MAGNETOM Aera

The world's first 1.5 Tesla system to feature the fourth generation of Tim technology, a 70-centimeter opening, and optimized Dot scanning technology. Tim 4G eliminated the need for a separate computer room.

(2009) MAGNETOM Skyra

The first 3 Tesla system to feature the fourth generation of Tim technology, a 70-centimeter opening, and Dot technology. The shortest 3 Tesla system on the market at the time, it needed no more space than most conventional 1.5 Tesla systems.

MAGNETOM Aera, 2009

MAGNETOM Skyra, 2009

Biograph mMR, 2010

MAGNETOM Prisma, 2012

(2010) Biograph mMR

A revolution in diagnostic imaging, Biograph mMR was the first system to combine magnetic resonance imaging (MRI) and positron emission tomography (PET) entirely in a single system.

(2012) MAGNETOM Prisma

This 3-tesla system based on MAGNETOM Skyra technology features the most high-performance gradients of any commercial system in the world. The MAGNETOM Trio can also be upgraded with MAGNETOM Prisma technology.

CEOs of Magnetic Resonance

1982–1985	Edgar Tschunt (MR Development)
1986–1989	Erich Reinhardt
1990–1992	Lothar Koob
1992–1994	Tom Miller
1994–2000	Hermann Requardt
2001–2006	Heinrich Kolem
2006–2011	Walter Märzendorfer
Seit 2011	Bernd Ohnesorge

Publishing details

Publisher
Siemens AG
Healthcare
Henkestr. 127
91052 Erlangen
Germany

Author
Ingo Zenger

Editorial cooperation
Siemens MedArchiv Erlangen, Germany
Siemens Healthcare –
Magnetic Resonance Business Unit

Layout
Andrea tom Felde, Siemens AG,
Henkestr. 127, 91052 Erlangen, Germany

Production
Norbert Moser, Siemens AG,
Henkestr. 127, 91052 Erlangen, Germany

Print run
800

Sources
This publication is based primarily on sources held in the collections of the Siemens MedArchiv (SMA) and contemporary reports.

Images
© All images:
Siemens MedArchiv, Erlangen, Germany
Siemens Healthcare –
Magnetic Resonance Business Unit

[1] The safety of imaging infants under two years of age has not been established. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.

[2] The product is still under development and not commercially available yet. Its future availability cannot be ensured. This research system is not cleared, approved or licensed in any jurisdiction for patient examinations. This research system is not labelled according to applicable medical device law and therefore may only be used for volunteer or patient examinations in the context of clinical studies according to applicable law.

Global Siemens Headquarters
Siemens AG
Wittelsbacherplatz 2
80333 Muenchen
Germany

Global Siemens Healthcare Headquarters
Siemens AG
Healthcare
Henkestraße 127
91052 Erlangen
Germany
Phone: +49 9131 84-0
www.siemens.com/healthcare

Order No. A91MR-100-66-7600 | Printed in Germany | CC MR 2073 11140.8 | © 11.2014, Siemens AG

siemens.com/medhistory