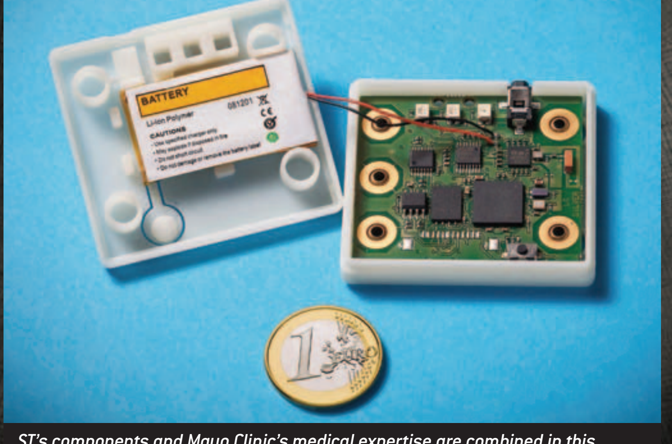
The heart of the matter

Technology development is an important part of the Mayo Clinic's health care provision. By **Graham Pitcher**.



ST's components and Mayo Clinic's medical expertise are combined in this remote heart monitoring platform

Ask someone what they associate the Mayo Clinic with and you'll probably get a response that includes the words 'celebrity' and 'therapy'. Over the years, the Clinic has certainly been the celebrity treatment location of choice, but that is a minor aspect of the clinic's work.

Alongside regular medical activities, the Mayo Clinic is also a pioneer in the development of diagnostic and treatment technologies.

Kevin Bennet (pictured right) is chairman of the division of engineering of the Mayo Clinic at Rochester, Minnesota. His division is responsible for the development and application of technology for research, infrastructure and clinical practice.

He said: "The Mayo Clinic is a large group practice of medicine. We have 50,000 employees and three main sites – in Minnesota, Florida and Arizona. There are some 3000 physicians working in hospitals and clinics."

The Mayo Clinic, which has been in existence since the end of the 19th Century, was one of the first not for profit organisations in the US. It treats some 500,000 patients a year, providing care, clinics and surgery. Bennet said patients are cared for in a collaborative manner, with all staff guided by the belief that the patient comes first.

So what does the Clinic's division of engineering do? Bennet said, enthusiastically: "We get to invent things." The division has a staff of around 60 people with a range of talents. "We have the ability to build anything," Bennet continued. "And, for the things for which we don't have expertise, we collaborate with other companies." The division not only collaborates externally, but internally. Bennet noted: "We have many different teams working on different projects and we undertake 50 or 60 projects a year."

The scope of these projects is wide. Bennet pointed to cardiac surgery equipment, automation, robotics and vision systems as some of the work his division has undertaken. "People come to us with problems and ideas, we work with them to build systems." One of these problems was solved with a specialised communications system which cost $7.5million, said Bennet.

Why does Mayo need to develop its own technology when there is a range of equipment available commercially? Bennet said: "By the time the concept for a solution to a problem enters the market, it could be five to 10 years old. Since the capability of electronics continues to increase dramatically and the understanding of human disease is also increasing dramatically, the original problem definition can be generations out of date by the time equipment makes it to the market.

"Since we are working on a current problem and our time to delivery is typically shorter compared to industry, we can assist our physicians and patients much faster. Current problems, or issues that are being identified by our researchers and epidemiologists are the drive for Mayo to develop current solutions."

Bennet is particularly proud of a recent innovation; a deep brain stimulation system for the treatment of Parkinson's disease.

In conventional DBS treatment of Parkinson's disease, an electrode is surgically implanted in an area of the brain called the STN. The DBS system consists of the electrode wire; a neurostimulator (electronics and battery), a bulky device implanted under the skin in the chest or the abdomen; and

Dr Richard Robb, pictured left with a 'phantom' model of a heart, is director of Mayo Clinic's Advanced Imaging Laboratory, which explores new ways to access, visualise and analyse the body.

an extension wire to connect the two. The electrode emits electrical pulses which, like a heart pacemaker, have an immediate effect.

However, it is difficult to place the electrode precisely. Before the procedure, surgeons use MRI to identify a trajectory for the electrode to access the STN. The patient is moved to the operating theatre, where neurosurgeons insert a recording electrode to identify the STN. That must be removed before sliding in the stimulating electrode. Following the procedure, multiple follow ups are needed to adjust the frequency and magnitude of stimulation.

The Mayo Clinic's ideal DBS system would include an electrode that not only stimulates the brain, but also measures several chemical concentrations at the same time. It would also know when the brain needs to be stimulated and when not. In addition, it would be wireless, with the battery and electronics small enough to be embedded directly in the bone of the skull.

> "I'm excited about how we can solve problems not yet solved. The more we discover, the more we know that there is to discover. I feel like a kid in a toy shop." Dr Richard Robb

"We are developing a single semiconductor to manage the wireless communication, as well as the medical functions," Bennet said. "The challenges include funding and settling on a design. So far, we have been working on this project for more than two years."

For the moment, a device called the Wireless Instantaneous Neurotransmitter Concentration System combines digital telemetry with fast scan cyclic voltammetry and fixed potential amperometry.

The Mayo based DBS Consortium is codirected by Dr Paul Garris, an electroanalytical chemist from Illinois State University, and Dr Pedram Mohseni, an electrical engineer from Case Western Reserve University. Other collaborators include Bennet, Dr Charles Blaha, a neuroscientist from the University of Memphis, and Dr Kendall Lee, director of the Mayo Clinic's Neural Engineering Laboratory.

One project which the group is pursuing is the development of a single wire that can be placed surgically in the STN. In addition to stimulating electrodes, the wire will include dopamine, glutamate and adenosine sensors at depths that correspond to areas of the brain where the corresponding neurochemical is released during DBS. The device will allow different pairs of contacts on the electrode to be stimulated, allowing researchers to learn more about the link between DBS stimulation and neurotransmission in specific areas of the brain.

"In fact," said Bennet during a telephone interview, "I'm assisting today in a procedure to implant a DBS system. My division has developed

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instrumentation for this neurosurgical procedure and this will be the first time this procedure has been performed on a human."

An example of how Mayo Clinic collaborates with external companies is a platform that allows patients with chronic cardiovascular disease to be monitored remotely.

The platform blends STMicroelectronics' sensor, microprocessor and communication products and Mayo Clinic's medical expertise. It combines sensors, ultra low power microcontroller and wireless modules, with interfaces to provide information about the patient's heart rate, breathing rate, physical activity and other measurements obtained wirelessly from external medical devices.

"Combining the clinical expertise of Mayo Clinic with our ability to provide highly integrated volume solutions at affordable costs, we are convinced we will open new frontiers to bring quality healthcare to everybody," said Alessandro Cremonesi, ST's vp of Advanced System Technology. "ST is using its expertise to develop advanced technologies and products satisfying the requirements of telemedicine platforms. This will allow medical device manufacturers and healthcare providers to develop new products and services to enhance the quality of medical support for their customers and patients."

Apart from benefiting the patient, the remote monitoring system is likely to reduce the cost of care, provide earlier diagnosis of health problems and allow comprehensive data collection.

Electronics plays a central role in many of the Mayo Clinic's activities. The Special Purpose Processor Development Group (SPPDG), part of the Clinic's Department of Physiology and Biomedical Engineering and based in Minnesota, is developing electronics technology for high speed signal processor applications. While the group has been set up to identify and exploit opportunities for technology transfer into Mayo clinical and research operations, its primary mission is the development of advanced technology for high clock rate digital signal processors and wide bandwidth, high centre frequency analogue systems.

SPPDG specialises in the design and development of a range of devices, including: SiGe, InP, GaN, antimonide compound semiconductors, cmos and silicon on insulator (SoI) cmos digital and analogue devices, and the packaging for these components.

Since the early 1980s, the Mayo team has designed around 300 chips using a range of III-V compound semiconductor technologies, as well as in cmos and SoI cmos.

From the 1940s to the 1960s, the Mayo Clinic researched a variety of diagnostic techniques for diseases of the heart and lungs using continuous motion biplane xray imagery, followed by analogue electronic processing.

In the early 1970s, this work led to the development of an experimental xray computed tomography (CT) imaging machine called the Dynamic Spatial Reconstructor (DSR). According to Mayo Clinic, the DSR was so far ahead of its time that only recently have helical scanning xray CT machines begun to approach the DSR's performance.

Mayo Clinic continues to develop imaging technology. Alongside systems that support virtual reality exploration of the patient's body, the Clinic is investing in systems that allow models to be produced of particular organs.

The work is being undertaken in the Advanced Imaging Laboratory, whose director is Dr Richard Robb. Some of the work has been the result of a conversation which Dr Robb had with a neurosurgeon many years ago. According to that neurosurgeon, 'if we can see it, we can fix it'. Dr Robb now explores ways to access, visualise and analyse the human body.

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'Phantoms' help surgeons to plan procedures

In some instances, surgeons can benefit from holding a model of the organ on which they are to operate; the Mayo Clinic calls these 'phantoms'. A phantom is an exact replica of the body part created using a 3d printing technique. Alongside use in heart surgery, phantoms have been used with great success in spinal surgery. The surgeon can plan in advance where screws might be inserted, rather than making the decisions during the procedure.

Dr Robb isn't happy with just three dimensions, however. He is already looking at four and five dimensions – time and function. On the larger scale, research includes smart rooms that can sense the positions of instruments and staff during a procedure. As to the future of medical imaging, Dr Robb said: "We're not even close to the limits."

Meanwhile, IBM and Mayo Clinic have developed a method for the early detection of brain aneurysms and are claiming a 95% accuracy rate.

Traditionally, a patient suspected of having a brain aneurysm would undergo an invasive test. However, using magnetic resonance angiography imaging technology, the partnership has created 'automatic reads' that run detection algorithms immediately.

Once images are acquired, they are routed to a server system in which algorithms align and analyse images to locate and mark potential aneurysms so radiologists can conduct a further analysis.

The project has examined more than 15m images since it began in July 2009. In the future, Mayo Clinic expects to use the same approach for other radiology detection tests, such as the diagnosis of cancer or vessel anomalies in other parts of the body.

But while the technology budget stretches to hundreds of millions of dollars a year, not everything that Mayo Clinic does is expensive. Bennet gave an example. "We needed a colour corrected camera to validate a problem in the opthalmics department. We solved that problem for $7; a cheap, but very important, solution," he concluded.