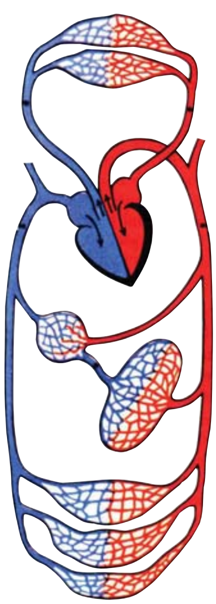
New Hope for Heart Patients

- Mini-turbine for cardiac assistance
- Automatic speed control with dSPACE Prototyper
- A possible alternative to a heart transplant

Donor hearts are scarce, and many cardiac patients never survive the long wait for a heart transplant. Even if a donor heart does become available on time, this does not automatically mean that the patient is saved. The patient's general health has often deteriorated so far that the new heart is unable to function properly. The solution could be artificial pumps that assist the patient's own heart. In a joint project with MicroMed Technology, Inc., the general hospital (AKH) in Vienna has developed a controller that continuously adjusts the output of a DeBakey VAD® blood pump to the patient's needs. dSPACE Prototyper was successfully used for laboratory testing and the first clinical study.



▲ *The left half of the heart (shown on the right in the illustration) supplies the body's entire blood circulation, while the right half serves only the smaller pulmonary circulation*

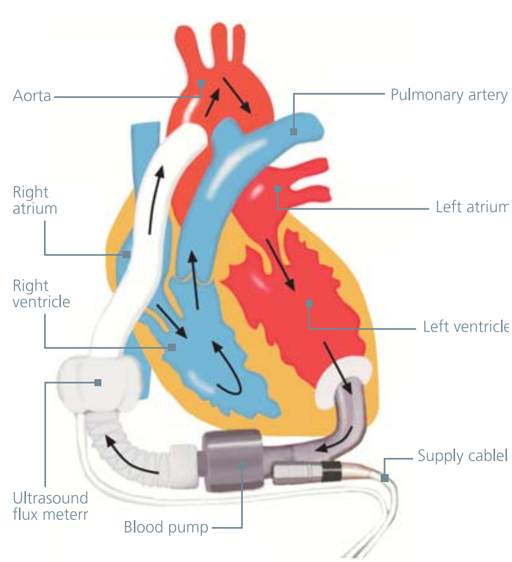
The idea for the miniature pump implant goes back to the end of the 1980s. Surgeon Michael DeBakey had operated on a cardiac patient who also happened to be a turbine machinery engineer at NASA, and together they came up with the idea of reducing the size of a Space Shuttle injection pump and adapting it to the human organism. This led to the founding of MicroMed Technology, Inc., in the mid-1990s, and it was this company that finally brought the pump, or, ventricle assist device (VAD), up to clinical application level. The pump has now been in clinical use for more than four years.

The Healthy Heart and the Sick Heart

In a healthy human heart, the right ventricle pumps blood that is low in oxygen to the lungs, where it is replenished with oxygen from inhaled air. The blood then flows back to the heart via the left atrium and into the left ventricle. This pumps the blood to the body to provide oxygen to all other organs. The depleted blood returns via the right atrium to the right ventricle, and the cycle starts from the beginning again. The right ventricle merely pumps the blood to the lungs, but the left ventricle has to provide the blood supply to the whole of the body. So it is the left ventricle that does the really heavy blood circulation work. It is this ventricle that needs the most help in the majority of patients with weak hearts. To assist an ailing heart, the pump inlet is joined to the lower left ventricle and its outlet is joined to the aorta by means of an artificial artery. This enables the pump to assist the left ventricle and generate blood pressure in the arteries.

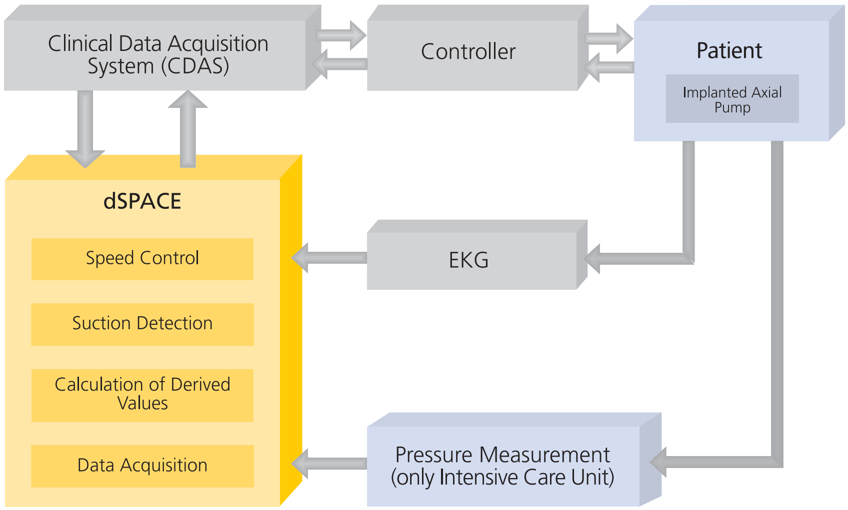
Tiny Life-Saver

The blood pump implant is actually a mini-turbine the size of a golf ball. Its special mechanical rotor bearing ensures quiet and non-wearing operation even at rotary speeds of 12,500 rpm. Now it has yet another special feature: the speed controller that adjusts its output to the patient's varying blood pressure requirement, whether he or she is sleeping or jogging. This was developed with the aid of



▲ *Cross-section through the heart with blood pump connected.*

dSPACE Prototyper. Up to now, rotary blood pumps have always had a constant speed, which can only be adjusted by the physician for specific cases. Automatic speed control can therefore increase the patient´s quality of life by adapting to his or her physiological requirements and avoiding overpumping in the case of reduced venous return.

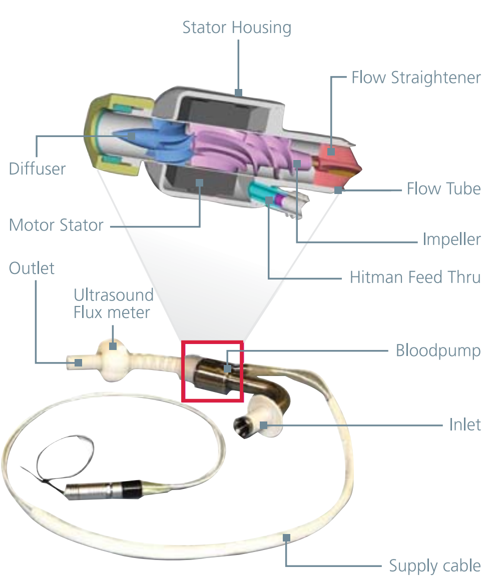


▲ *Schematic design of the speed control.*

Automatic Speed Control

There were several candidates for a development system for the speed control, and the choice fell on dSPACE Prototyper with the DS1103 PPC Controller Board.

- The hardware is easy to configure straight from MATLAB®/Simulink®, without having to bother with hardware details.
- The dSPACE hardware is especially reliable, because the independent CPU of the controller board runs even without a monitoring PC. It also has a high throughput as well as a large number of analog inputs and outputs.



▲ *The design of the blood pump in detail.*

The flow of blood through the pump, the pump current and the rotary speed are all recorded. For the clinical study, the heart's electrical activity was also captured using an electrocardiogram. To optimize the effectiveness and efficiency of the control, not only all the settings and reference values are registered, but various process reports are also continuously recorded and displayed. A total of 23 signals are recorded at a sampling rate of 100 Hz. The measurements are then used to compute the desired speed for the pump and send an analog signal to the MicroMed VAD pump controller, which adjusts the miniature pump's brushless DC motor accordingly.

The Alternative to a Heart Transplant

We expect we can considerably improve a patient's quality of life using the blood pump with automatic speed adjustment. Moreover, it should relieve the workload of the doctors and nursing staff that have to adjust the pump, and improve the blood supply in extreme situations. Optimization of implantable miniature pumps for everyday use could soon make them a genuine alternative to heart transplants.

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