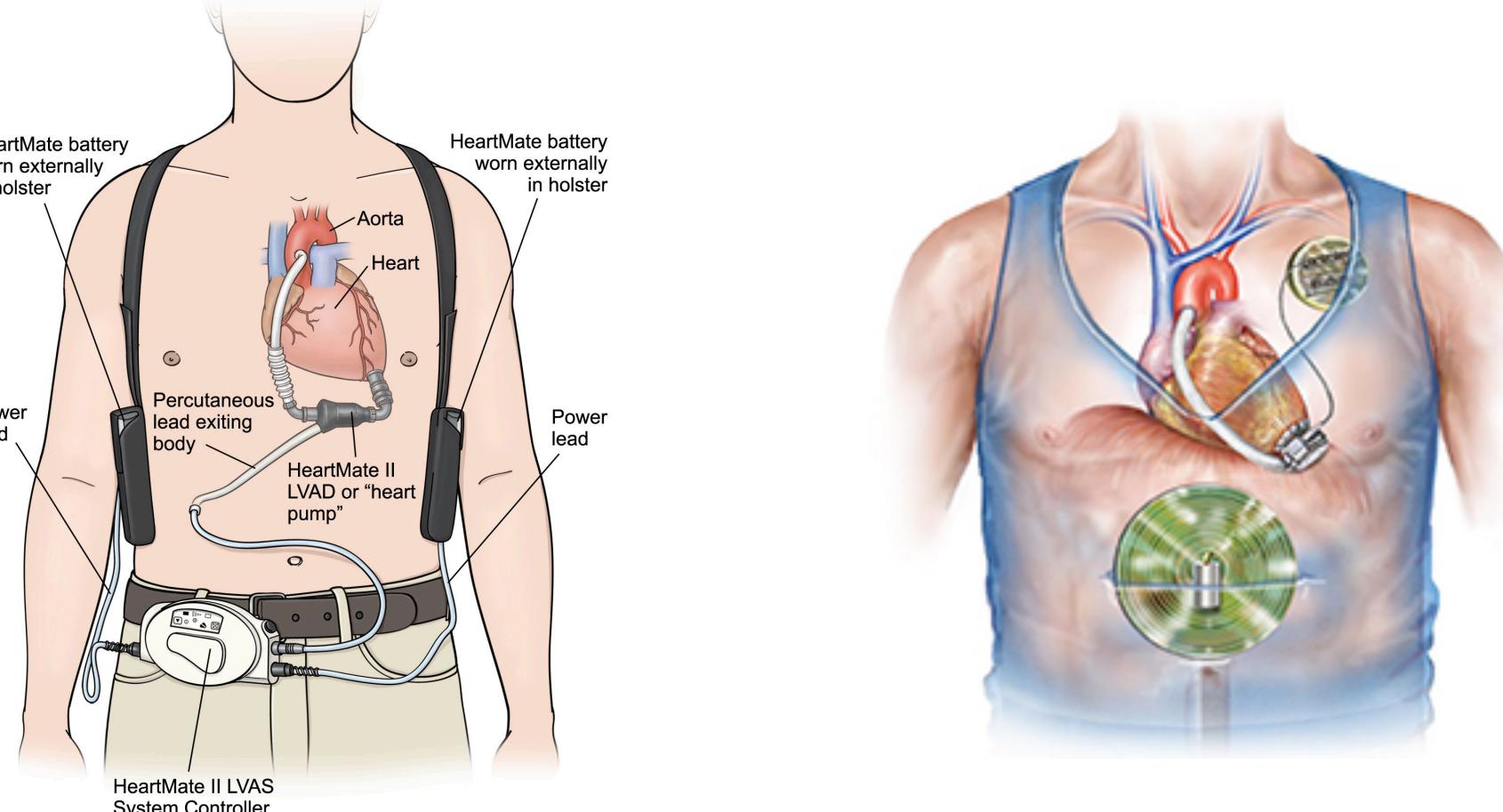




iOS Based App for Control and Communication of a Wireless LVAD

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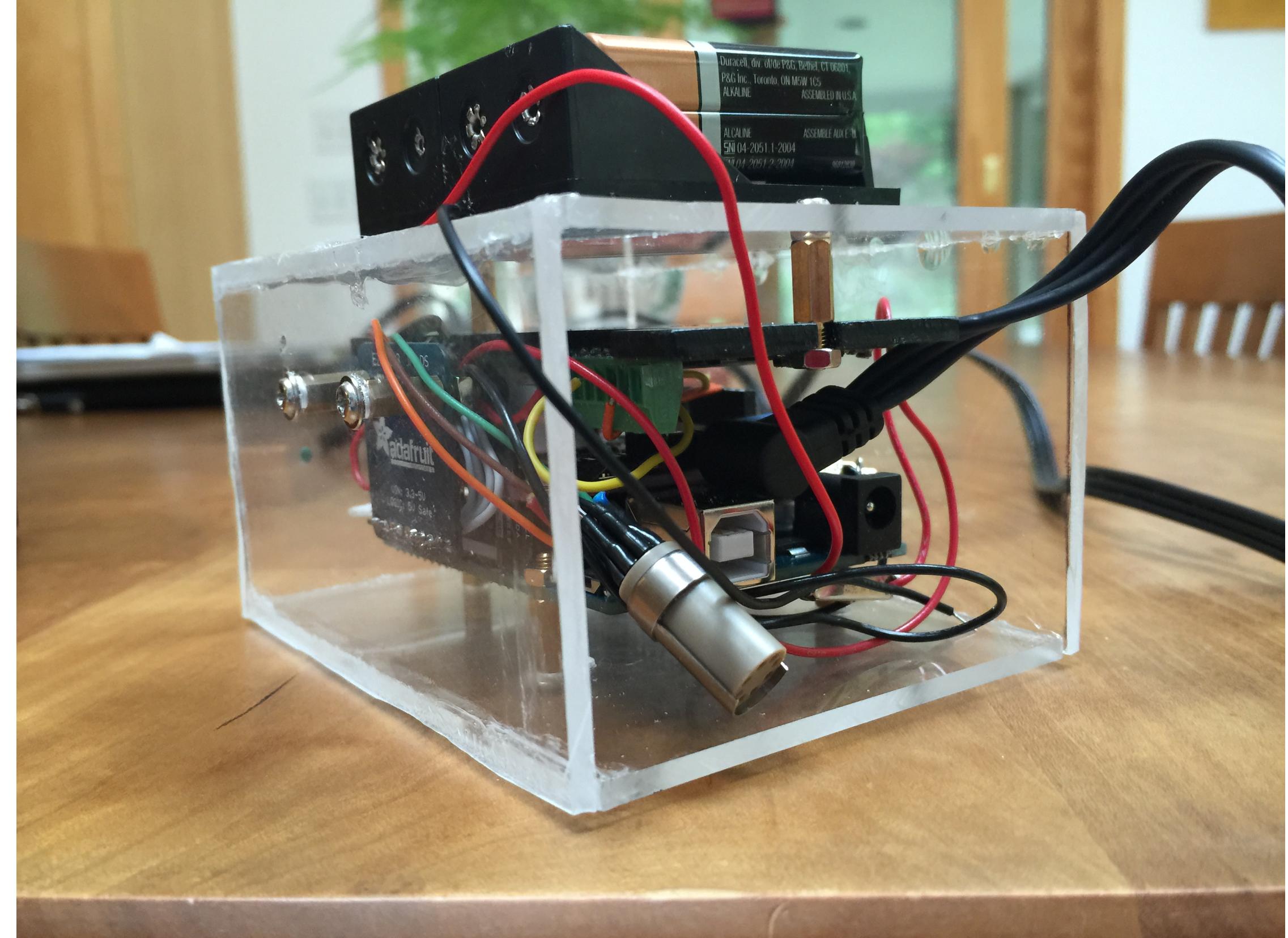
INTRODUCTION



Standard LVAD vs. Prototype of LVAD powered through wireless induction

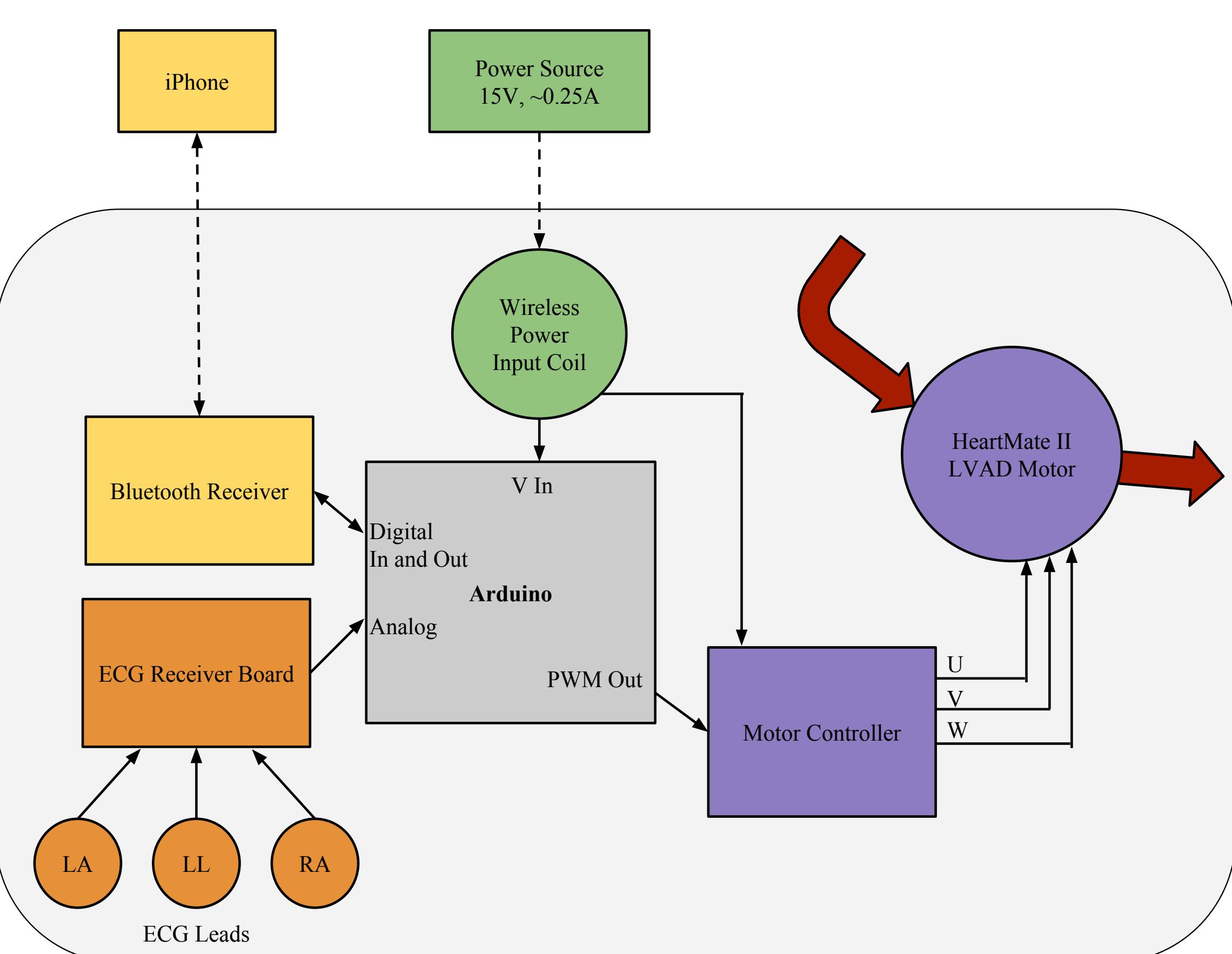
1. We have developed a wireless LVAD based on our FREE-D system for wireless powering over meter distances.
2. Such totally implanted system warrants to and from communication to the exterior.
3. We have developed an iOS based platform that allows us to communicate with an implanted LVAD and modulate speed based on physiological parameters (co/counter pulsation mode).
4. Such system can be easily adapted to current wired and future wireless LVAD systems to collate data, operate the pump and simultaneously measure physiological parameters and wirelessly communicate with any mobile platform.

Figure 2: Circuit Board Prototype



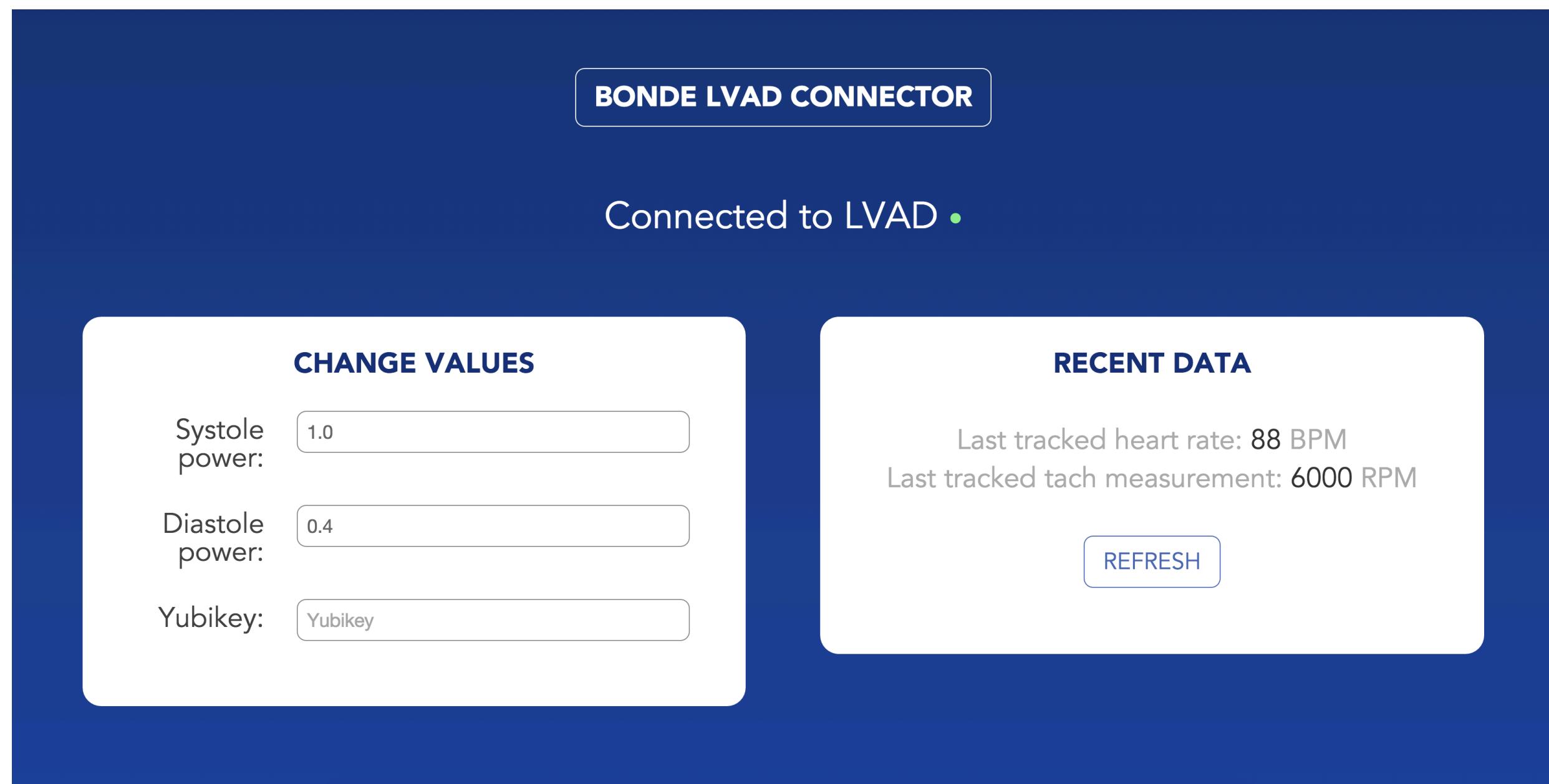
The circuit board prototype includes several separate, generic circuit boards that will be consolidated into a single printed circuit board eventually. Though the prototype is battery-powered, it can be powered with the wireless inductive coils.

Figure 4: Proposed LVAD System



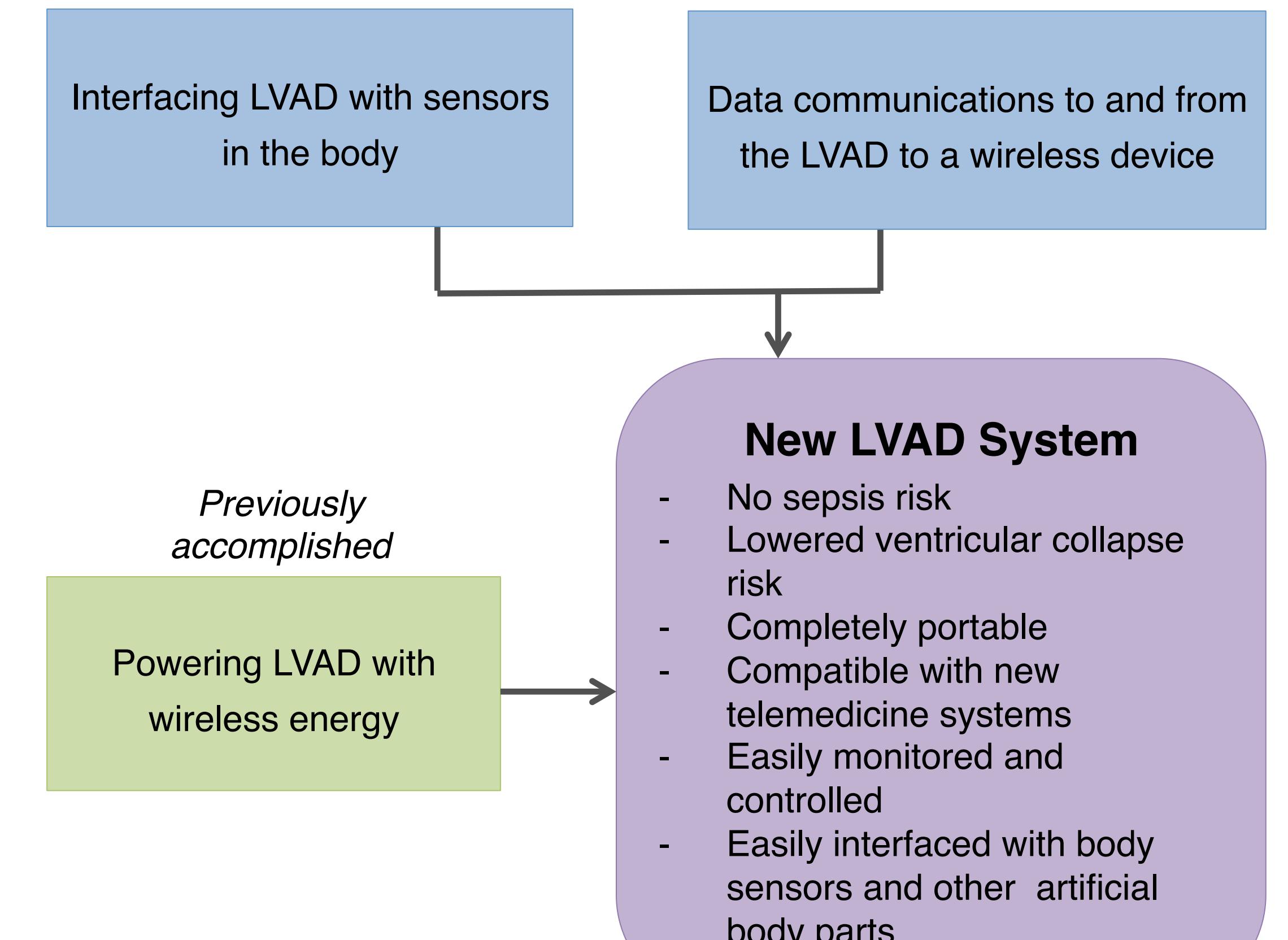
The system is centered around the Arduino, which runs regardless of whether or not a Bluetooth connection to the phone is established. If the ECG leads produce interference, the Arduino will automatically revert to a continuous flow mechanism.

Figure 3: Password-Protected Physician Website



Because the LVAD is now connected to a patient's iPhone through Bluetooth, the pump can be monitored and controlled through the internet. The above beta website shows recent data and allows for pump speed changes through encrypted connection.

CONCLUSIONS



The new LVAD system successfully integrates communication with iOS hardware to allow for easy and secure viewing and storage of data. Meanwhile, the Arduino utilizes ECG data for intelligent pump speed control during systolic and diastolic phases. The wireless, cloud-based storage system, protected by several layers of encryption, represents a step towards modern, "connected" implants.

An adaptor has been developed to allow patients already using heart pumps to take advantage of the Bluetooth and cloud-based technology while still using the external HeartMate II controller.

Figure 1: ECG-Controlled Pump Data

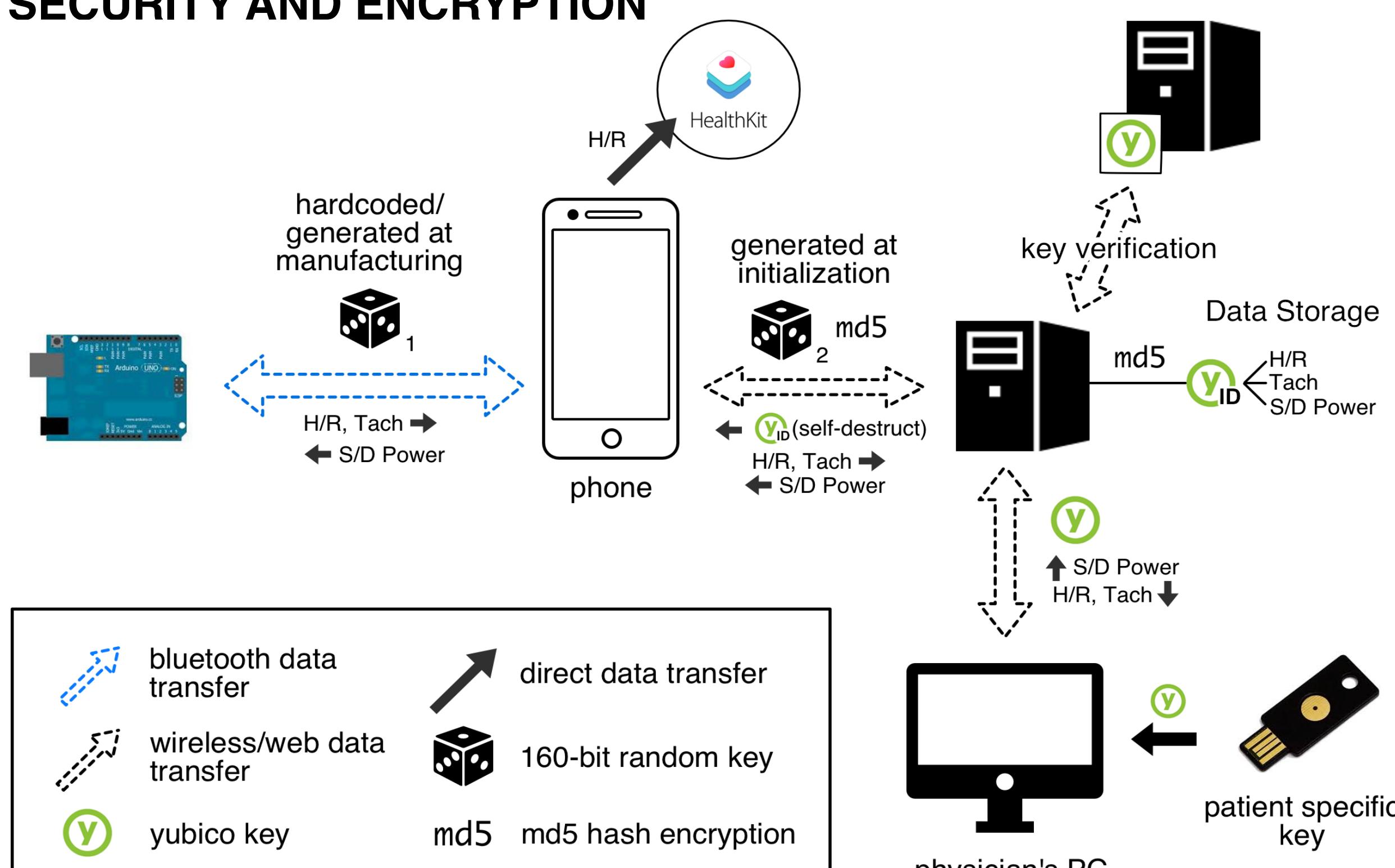


First Graph: Electrical Signal from the Arduino to the Motor Controller, changing after detecting the spike in the ECG signal.

Second Graph: ECG Signal being sent to the Arduino.

Third Graph: Flow rate of water after exiting the LVAD through the mock LVAD loop.

SECURITY AND ENCRYPTION



Patient data is sent via novel key-verified Bluetooth connection to the patient's mobile device. The device, at setup, is given the patient specific Yubico key-id in order to write data to the server. The server has encrypted values of the patient's 160-bit random key to verify the phone-server connection. The patient's data is stored in a 'secret' encrypted directory which can only be accessed through a verified patient-specific Yubico key connection, or the encrypted random key specific to the patient's phone. The only method of writing values to the device would be through a patient-specific Yubico key, the encrypted random key connection from server to phone, and another encrypted random key Bluetooth connection from phone to device.

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