The HeartQuest LVAD employs a hybrid magnetic suspension system to levitate the pump impeller. The suspension system consists of an actively controlled voice-coil thrust bearing together with passive permanent-magnet suspension for radial, pitch, and yaw motions. The thrust control system is interesting and complex for several reasons: a) impeller axial position is sensed via a non-contact eddy-current sensor which must "see through" conductive housing materials, b) fast and unstable axial dynamics due to negative magnetic stiffness, c) requirements for low power consumption, and d) dynamics of mechanical lift-off during levitation start-up.

The eddy-current probe impedance varies with the impeller position in a complex manner due to the material properties of the housings. Models for this impedance involving the skin-depth and the shell and target materials are presented. Further, the sensor signal processing is described at a block-diagram level. According to Earnshaw's theorem, the axial stiffness of the permanent-magnet suspension is the negative of twice the radial stiffness. The negative stiffness is both an asset and a liability. It forces the use of active thrust control, but enables the use of virtual-zero power control method to attain stable suspension and minimal suspension power. Power consumption is further minimized through actuator optimization.