4). The pump reservoir and housing are made from a polycarbonate-like 3D printable biomedical grade polymer. Parylene C microballoon are fabricated in small batches using a [redacted] technique[illegible]. The microelectrodes used for electrolysis are batch fabricated on glass wafers using standard microfabrication techniques[illegible]. We previously demonstrated wireless telemetry for inductive power transfer to biomedical implants, including Class D and E systems [redacted][illegible]. We achieved real-time control of drug delivery *in vitro*[illegible]. The same system triggered *in vivo* a microvalve developed for a subcutaneous microfluidic drug delivery pump used in freely-behaving mice[illegible]. Inductive power transfer (2 MHz) between an external primary coil and integrated secondary coil was achieved in both cases[illegible]. Our current wireless controller system builds off these previous results and consists of a primary and secondary circuit for inductive powering and control of the pump (Fig. 1). The base station primary circuit uses a class E amplifier to drive a 2 MHz inductive link[illegible] with a secondary circuit inside the pump housing. The primary and secondary circuit designs were optimized so that sufficient power transfer is obtained through inductive coupling at distances [redacted] cm within the mouse-accessible cage volume above the base station. There is no interference from adjacent base stations using such an approach (data not shown).

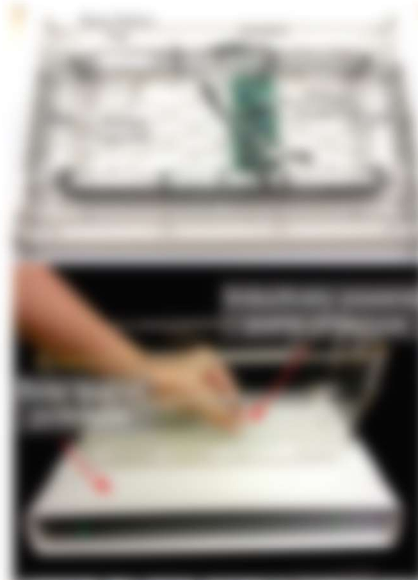

Figure 1. (Top) Base station container including transmitting coil and driving circuitry. (Bottom) Fully assembled base station with rodent cage atop.

The receiving power module within the pump is contained in a flexible printed circuit board and housed within the pump. The single coil wrapped around the pump reservoir collects power from the emitting base station; coupling is maximized when the pump lies in the horizontal plane (parallel to cage floor). The pump electronics rectify and limit the current that drives the electrolysis actuator ([redacted]). A single coil design provides excellent coupling with a pump frustration angle of about [redacted] from planar. In some cases, this angular frustration is insufficient to guarantee coupling between the base station and the pump (ie. if pump is implanted on its side, slides post-implantation, during animal movement or during rearing or climbing). It is estimated that rodents engage in exploratory activity (rearing, climbing standing, grooming) ~20% of the time on average. Therefore, there is a possibility that the pump may not receive sufficient power when desired. Given these observations, it is necessary to provide reliable inductive power transfer to the pump under all possible angular orientations.

Approach. To achieve orientation independence, we will investigate a three coil design on the receiving circuit. This implementation utilizes three orthogonal coils which can provide inductive coupling under all orientation angles. The proposed circuit topology (Fig 6.) parallelizes the output from three series-resonant coil systems which provides coupling with the primary under any orientation. This approach has been demonstrated in other implantable devices such as ingestible cameras and multi-modal sensors with similar angular orientation challenges[illegible], but is yet to be demonstrated as a viable powering scheme for implantable pumps. Integration of this three coil design within the pump housing and with the integrated electronics will be tested at the benchtop and evaluated for frustration performance and current output homogeneity. Wireless power transfer performance will first be validated using a pump-equivalent load in series with the tuned receiving coil network to obtain maximum power transfer capability including (1) link range (power transfer vs. distance of secondary coil) and (2) frustration power transfer vs. alignment angle of secondary coil. Current output homogeneity over the base station footprint will be assessed to ensure adequate power regulation in under and over coupling regimes. Power transfer will be measured for single and multiple pump conditions. In addition, multi-pump power transfer will be evaluated in lateral and vertical directions to assess possible mode of interference. Consistent with standards set by the International Commission on Non-Ionizing Radiation Protection, an operating frequency of 2 MHz is selected (absorption in tissue is minimal below 10 MHz[illegible]) and power exposure will be kept below the recommended maximum localized specific absorption rate (SAR) of 10 mW/g.

Expected outcomes, potential problems, and solutions. It is expected that increased frustration performance will come at a cost of suboptimal coupling. The ability to tune base station output power will be important in addressing this concern. Also, integration of additional coils is expected to incrementally increase the system weight (currently [redacted] g) but will still satisfy the size and weight acceptance criteria (Table 1).

Figure 6. Circuit topology for orthogonal 3-coil system. Each coil is series resonant.