WING- Wearable Interoperable Neuroprosthetic Gear

cosmiic.org

"WING" – Wearable Interoperable Neuroprosthetic Gear

Aims:

- Aim 1: Develop a wearable Wireless Link for PCs, mobile devices, and sensors.
  - This Wireless Link will facilitate wired or wireless communication between the COSMIIC implanted modules and PCs used to program the modules, external sensors (EKG, PPG, inertial, etc.), external stimulators (developed in Aim 2) or actuators (assistive devices, connected appliances, wheelchairs, etc.) using common wired (USB, I2C, SPI, CAN) and wireless (WiFi, ZigBee, ANT) protocols. This Wireless Link can also become wearable by configuring a battery to power sensors and facilitate closed-loop stimulation in response to physiological signals or smartphone app visualization. The Wireless Link allows an existing implanted COSMIIC System to be enhanced with external components for research exploration and evaluation.
- Aim 2) Develop an expandable wearable Surface Stimulation module.
  - This battery-powered, four-channel stimulator will receive stimulation commands wirelessly from other COSMIIC modules and apply electrical stimulation to the skin surface, which is a low-risk and convenient way to prototype new stimulation functions. Multiple Surface Stimulation modules can be linked together wirelessly to increase the number of channels.

“WING” – Wearable Interoperable Neuroprosthetic Gear

Aims:

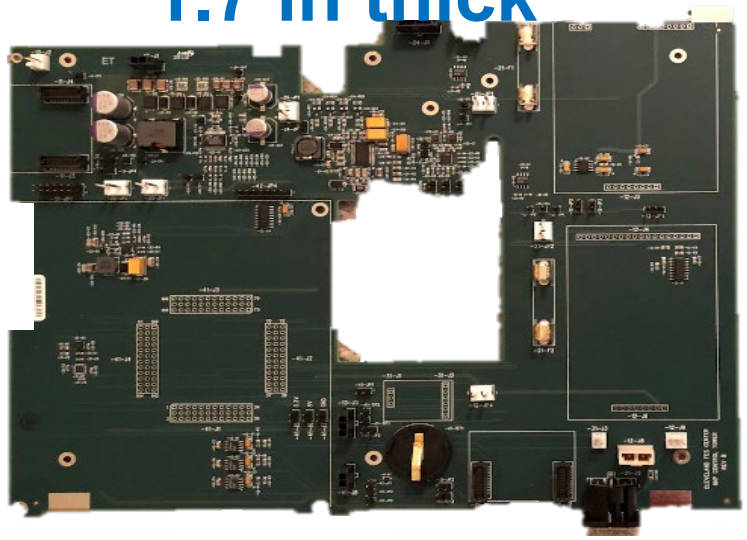
- Aim 3) Develop circuit board Evaluation Kit for COSMIIC modules.
  - These devices allow COSMIIC modules to function without implant-grade titanium enclosures or implant-grade connectivity to facilitate benchtop development. Electronic frames will be developed that house bare COSMIIC module circuit boards, supply network and power, and provide access to useful debugging connections.
- Aim 4) Develop a closed-loop rapid inductive battery charger.
  - The COSMIIC charger will be able to reduce charging time over the existing NNP charger by optimizing cooling and current flow based on battery status.

"WING" – Wearable Interoperable Neuroprosthetic Gear

Existing External Devices

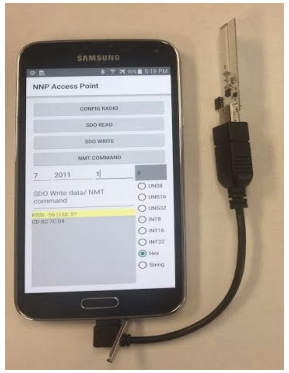
Control Tower (CT)

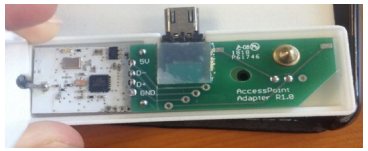
1.7 in thick



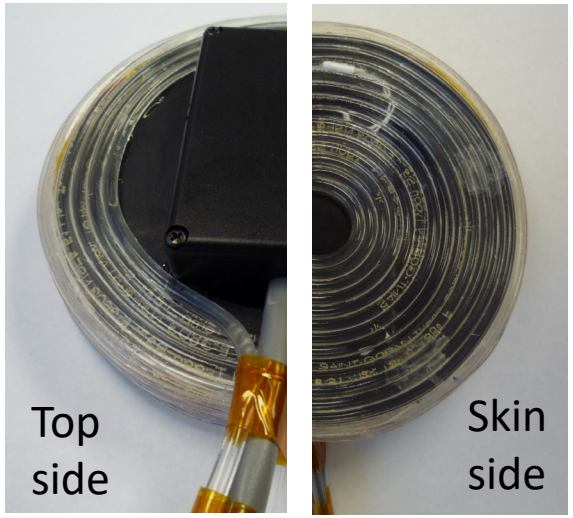
9 in

11 in





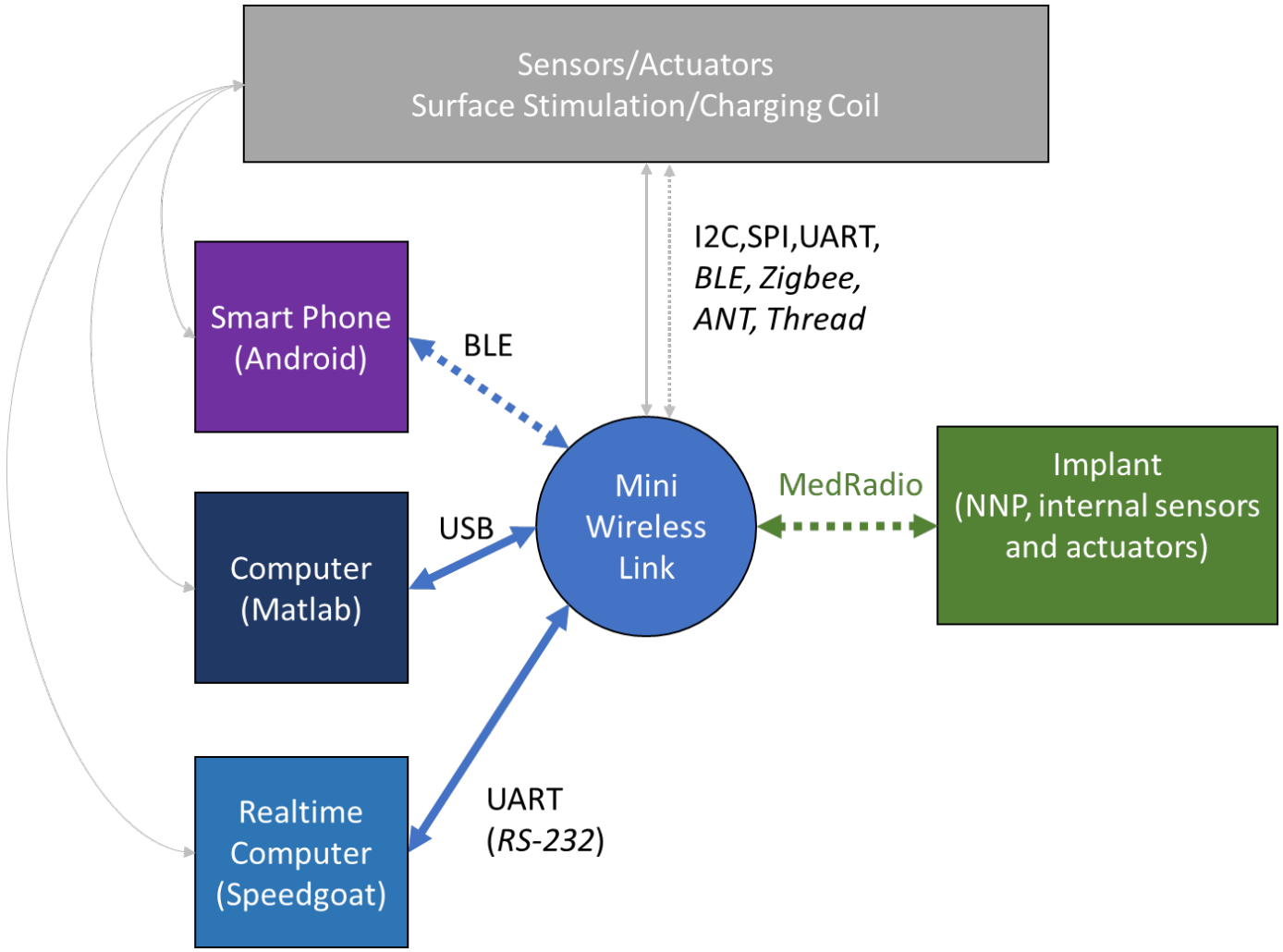
External Coil



"WING" – Wearable Interoperable Neuroprosthetic Gear

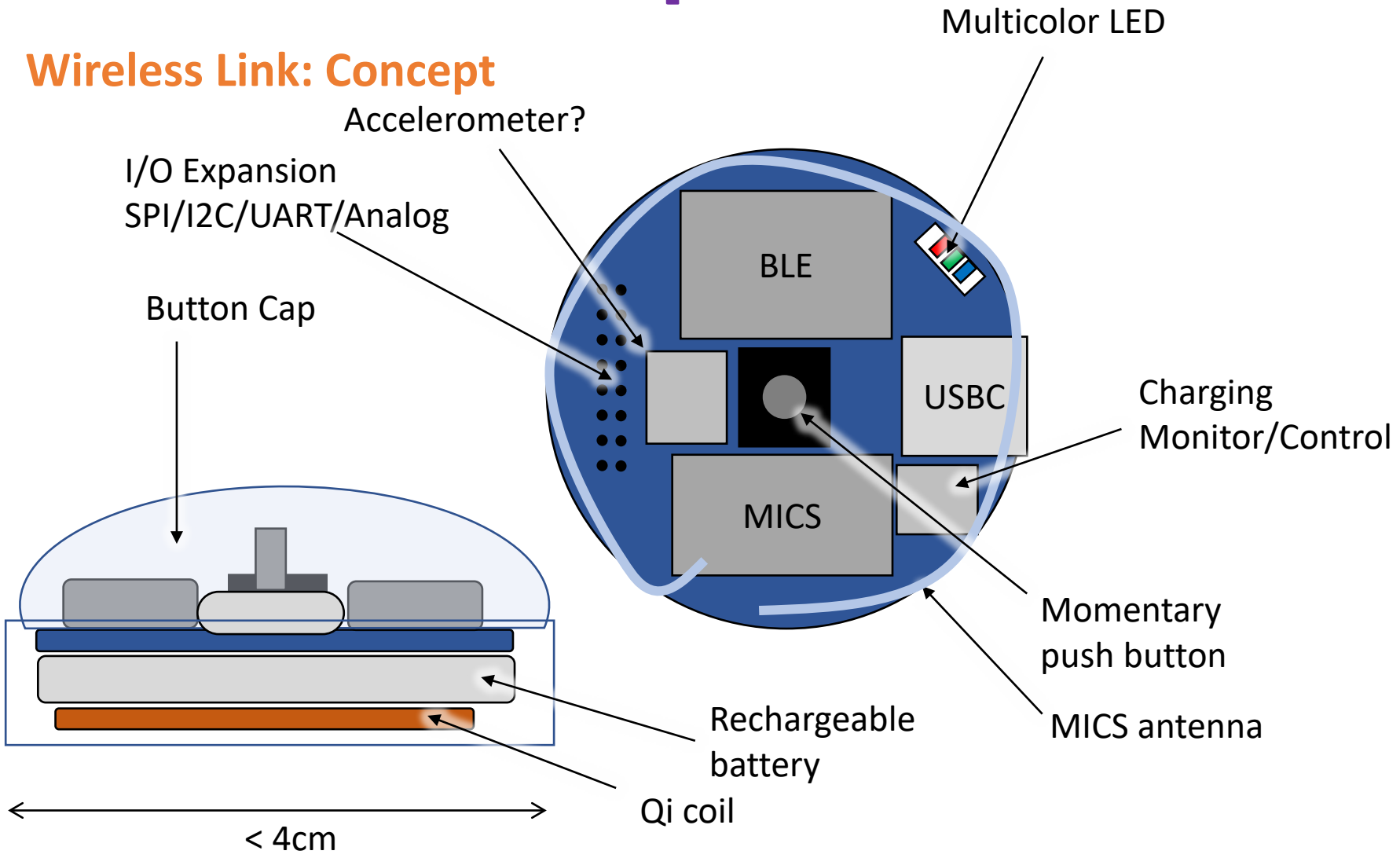
Wireless Link:

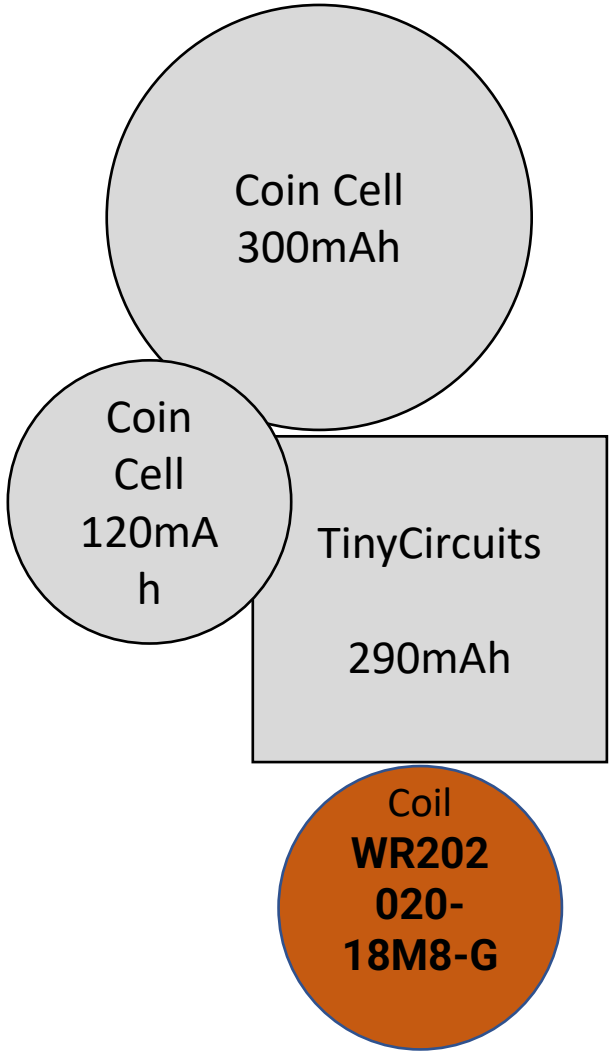
- Communicates between implanted modules and external components
- Wired or wireless communication to PCs, smartphones, sensors
- Enables module programing, visualization
- Battery power for mobile use
- Common wired (USB, I2C, SPI, CAN) and wireless (Bluetooth, MedRadio) protocols



"WING" – Wearable Interoperable Neuroprosthetic Gear

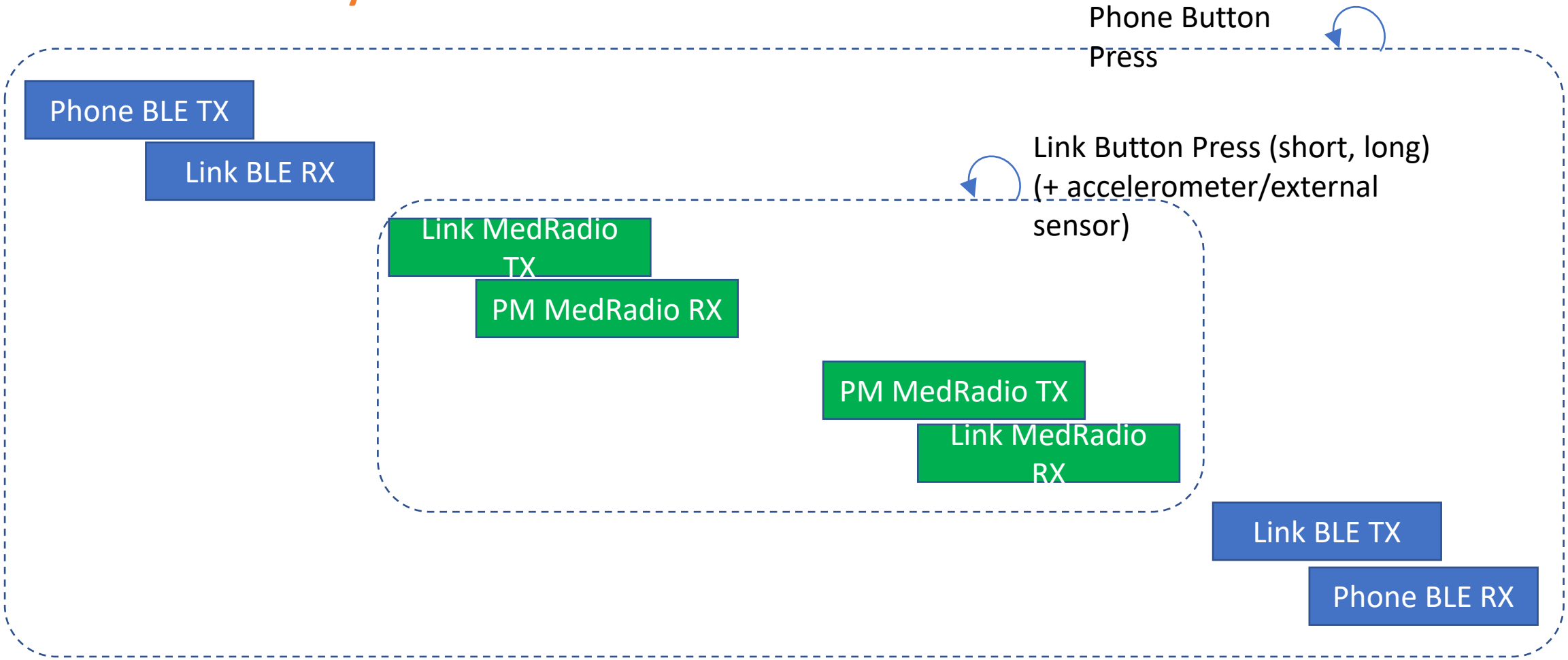
Wireless Link: Concept





"WING" – Wearable Interoperable Neuroprosthetic Gear

Wireless Link: Primary Function



“WING” – Wearable Interoperable Neuroprosthetic Gear

Wireless Link: Requirements

•Device Power Supply Requirements

- The device shall have the ability to be powered by an alternating current (AC) adapter.
- The device shall have the ability to be powered by a USB power supply.
- The device shall have the ability to be powered by a [rechargeable] battery.
- The device shall have the ability to recharge [its] battery.
- The device’s power supply interface should be accessible by people with disabilities by using inductive power delivery (Qi standard) or magnetic connectors for AC adapter or USB power.
- The device shall supply power to wired electronic components or sensors.

•Device Enclosure Requirements

- The device enclosure shall have at least one user interface switch.
- The device enclosure shall have at least one visual indicator.
- The device enclosure should have a wired sensor interface port.

“WING” – Wearable Interoperable Neuroprosthetic Gear

Wireless Link: Requirements

•Device System Board Requirements

- The device’s system board shall support wireless radio communications over Bluetooth (2.4 GHz) and implant-compatible communications over Medical Device Radiocommunications Service (MedRadio, 402-405 MHz).
- The device system board shall support wired communications over SPI, I2C, and UART protocols.
- The device system board shall support analog input from wired electronic components or sensors.
- The device system board shall have an expansion port to interface with wired electronic components or sensors.
- The device system board shall have a USB interface for firmware or software programming and computer control of device functions.

•Device Software Requirements

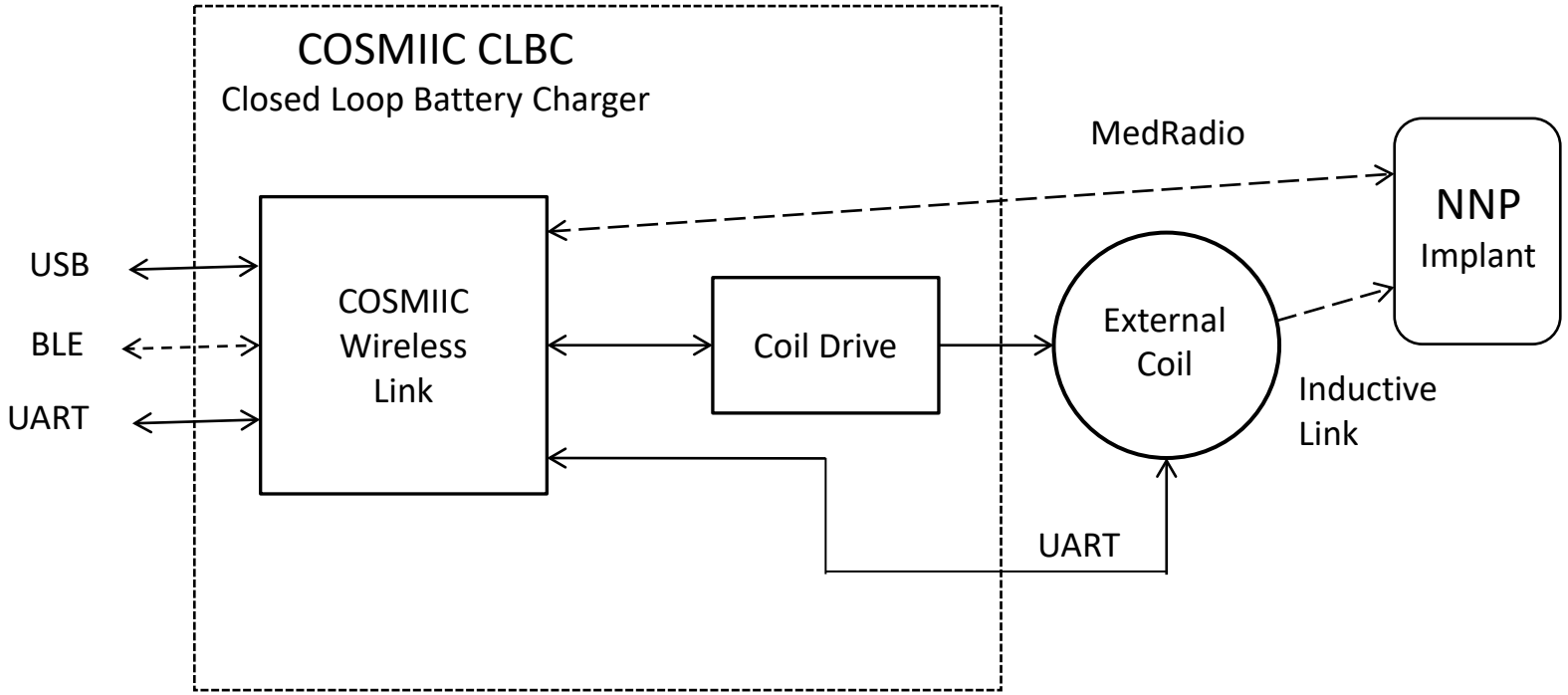
- The device shall have a software application programming interface (API)
- The software API shall define how to control the device and use it to issue commands to and acquire data from implanted devices, electronic components, and/or sensors that it communicates with.
- The device API shall be compatible with mobile computing devices for the purposes of data visualization or device control via wired or wireless communication.
- The device shall have firmware that is able to execute software programs in a stand-alone mode without being connected to a computer.

The device API shall have a method to restrict pairing to authorized devices.

"WING" – Wearable Interoperable Neuroprosthetic Gear

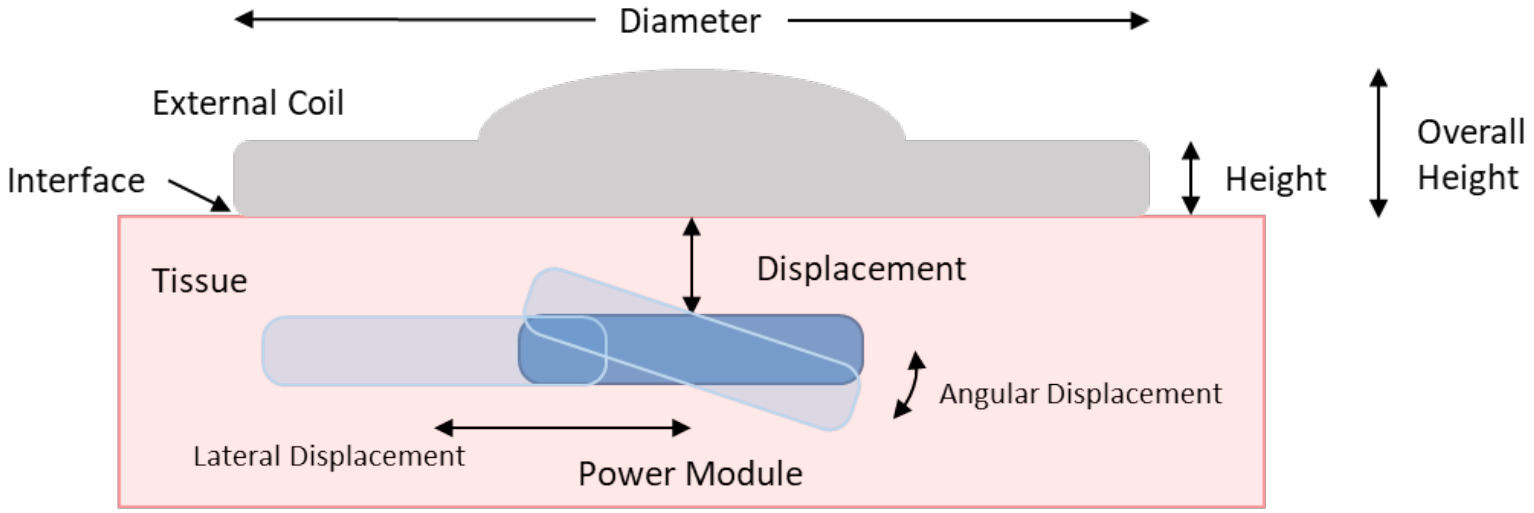
Closed Loop Battery Charger:

- Closed-loop charging based on real-time monitoring of battery capacity, temperatures, and current
- Active liquid cooling channels integrated with inductive charging coil

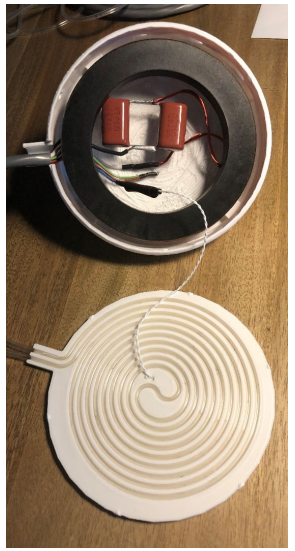


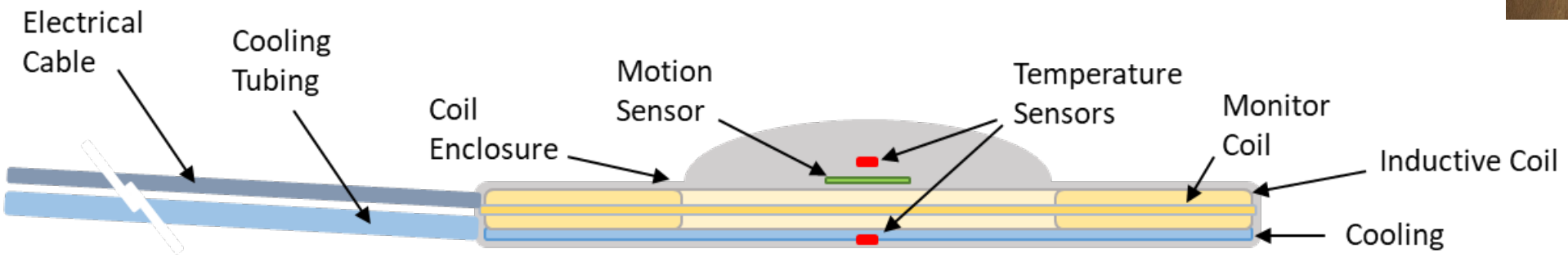
"WING" – Wearable Interoperable Neuroprosthetic Gear

Closed Loop Battery Charger:



Charger Coil Prototypes

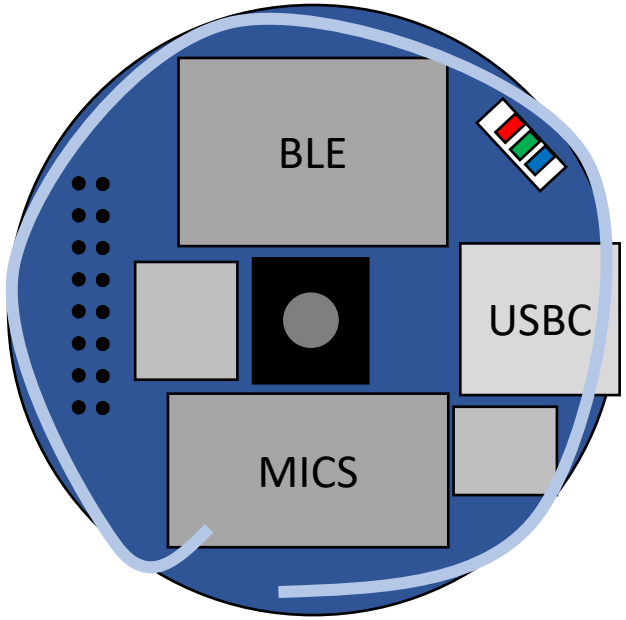


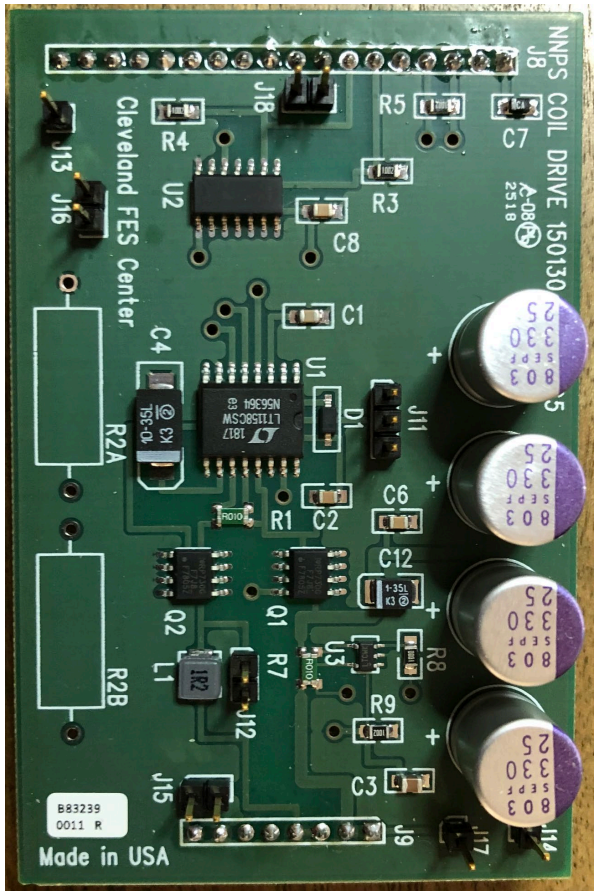


“WING” – Wearable Interoperable Neuroprosthetic Gear

Closed Loop Battery Charger: Concept

Wireless Link + Coil Drive Power System





"WING" – Wearable Interoperable Neuroprosthetic Gear

Closed Loop Battery Charger: Requirements

•Battery Charging Control Algorithm

- This device's control algorithm should adjust coil voltage based on transmitting coil enclosure motion, coil enclosure temperatures, transmitting coil current, battery voltage, battery temperature, implant temperature, and receiving coil voltage at the implant.
- This device's control algorithm shall maintain charging at up to 100 mA per battery cell.
- This device's control algorithm shall maintain skin and implant temperatures per FDA regulations.
- This device's control algorithm shall supply inductive power transfer up to a maximum of at least 1.7 W over a displacement of at least 1 inch.

•External Coil Enclosure

- This device's coil enclosure shall be skin contact safe at the interface between skin and the external coil.
- This device's external enclosure shall have integrated active cooling of the interface between skin and the external coil.
- This device's external enclosure shall sense temperatures at the interfaces between skin and the external coil enclosure.
- This device's external enclosure should have motion or orientation sensing of the external coil enclosure.

"WING" – Wearable Interoperable Neuroprosthetic Gear

Closed Loop Battery Charger: Requirements

•Coil Drive Power System

- The device's coil drive power system shall have an enclosure.
- The device's coil drive power system shall control voltage to the coil based on the Battery Charging Control Algorithm.
- The device's coil drive power system shall communicate with the implant using wireless communication.
- The device's coil drive power system shall have a real time clock and date.
- The device's coil drive power system shall log charging activity, time, and date.
- The device's coil drive power system shall have an audio transducer to indicate charging status.
- The device's coil drive power system shall provide visual indicator of charging status.
- The device's coil drive power system shall have at least one user input switch.
- The device's coil drive power system shall have a USB interface for firmware programing and control.
- The device's coil drive power system shall have the ability to be powered by [an] alternating current (AC) power adapter.
- The device's coil drive power system shall have the ability to be powered by a direct current (DC) supply.

•Electrical Cable and Cooling Tubing

- The device's electrical cable should have ergonomics, flexibility, and durability that is suitable for daily community use.
- The device's electrical cable and cooling tube [shall] use skin-safe material construction.

"WING" – Wearable Interoperable Neuroprosthetic Gear

Closed Loop Battery Charger: Requirements

•Cooling Device

- The device's active cooling shall supply chilled liquid to the external coil enclosure near the interface between skin per FDA specifications.
- The device's active cooling shall have the ability to be powered by AC power adapter.
- The device's active cooling shall have the ability to be powered by a DC supply.

•Battery Charger Software

- The device shall have a software application programming interface (API)
- The software API shall define how to control the device and use it to issue commands to and acquire data from implanted devices and/or sensors that it communicates with.
- The device API shall be compatible with mobile computing devices for the purposes of data visualization or device control via wired or wireless communication.
- The device shall have firmware that is able to execute software programs in a stand-alone mode without being connected to a computer.

[The device firmware shall be updated through a standard protocol]

“WING” – Wearable Interoperable Neuroprosthetic Gear

Proof of Concept

- Microcontroller functions inside charging coil
  - Microcontroller board needs to be oriented perpendicular to coil
    - Due to inductive link magnetic field
  - Enables sensors and buttons to be placed at coil enclosure
    - Temperature sensors
    - Magnetic field monitor
    - coil motion sensing (inertial measurements)
- Bluetooth Low Energy communicates in proximity with MedRadio
  - Enables both Bluetooth and MedRadio circuits to be placed within the same enclosure for Wireless Link and Battery Charger

"WING" – Wearable Interoperable Neuroprosthetic Gear

Feature Summary Table

Item	Feature	CT	CAP	LAP	LAB	LAB2	KickStart	MWL	CLBC
1	Coil Drive	X			X	X	X		X
2	Coil Frequency Control	X [1]			X	X	X		X
3	Coil Power Control	X			X [2]	X [2, 5]			X
4	Requires Bench Supply				X	X			
5	Coil Mag Field Monitor								X
6	Coil Temperature	X			X	X			X
7	Coil Cooling	X [3]							X [3]
8	Coil Motion Sensing								X
9	MedRadio	X	X	X	X	X		X	X
10	BLE					X		X	X
11	Requires USB [4]		X	X	X	X			
12	Battery	X					X	X	
13	AC Adapter	X							X
14	User Input	X					X	X	X
15	User Output Visual	X					X	X	X
16	Audio					X	X		X
17	Clock / Calendar	X				X			X
18	Enclosure Accelerometer	X				X			
19	Small Size		X					X	

CT - Control Tower

CAP - Chronos Access Point

LAP - LaunchPad Access Point

LAB - LaunchPad Adapter Board

LAB2 - LaunchPad Adapter Board 2

KickStart - LAB2 Based KickStart Coil

MWL - Mini Wireless Link

CLBC - Proposed Closed Loop Battery Charger

Notes:

1 - Manually adjustable

2 - Manually adjustable via bench supply

3 - Separate device

4 - All devices include USB

5 - Fixed 5V optional