Design Input Requirements	Specifications	Justification	Verification	Validation
1. Device must achieve arm movement in flexion and extension	**1.1** Elbow joint will be modelled as a hinge **1.2** Device will move at hinge up and down 75 degrees from extended	**1.1** Functioning elbow has 1-dimensional movement (up and down) **1.2** Device will achieve half of normal functional flexion extension range (150 degrees or 30-130 degrees)[3][7]	**1.1-2** Linear actuator will be tested using 12 V power supply to move arm for specified range of motion	**1.1-2** Linear actuator should move on command from subjects and microcontroller input
2. Device must have wrist joint that achieves radial and ulnar deviation movement	**2.1** Wrist joint will be modelled as a hinge **2.2** Device will rotate at the wrist ulnar (20 degrees) and radial (40 degrees)	**2.1 -2.2** Normal range of motion in radial is 20 degrees and in ulnar is 20 to 45 degrees[4][6]	**2.1-2** Linear actuator will be tested using 12 V power supply to move wrist for specified range of motion	**2.1-2** Linear actuator should move on command from subjects and microcontroller input

Design Input Requirements	Specifications	Justification	Verification	Validation
3. Hand must achieve grasping on command	**3.1** Hand will have one joint for each member for grasping **3.2** Hand will close at all joints simultaneously following user command **3.3** Hand will open following user command ***3.4*** *Grasping will cease based correct force to*	**3.1-3.3** Hand must hold an object without it slipping or falling until commanded release **3.4** Range of force is between 17.6 and 50.8 N for existing devices	**3.1** Linear Actuator will be tested using a 12 V power supply to simulate grasping motion **3.2-3** Linear actuator will be tested using 12 V power supply to test for binary action of opening and closing ***3.4*** Use as rig consisting of rubber balloon and force gage to test actuator of a range of force of 10-24 N	**3.1** Linear actuator should move on command from subjects and microcontroller input **3.2-3** Linear actuator should move on command from subjects and microcontroller input ***3.4*** *Force sensors should stop linear actuator to prevent crushing of items*

Design Input Requirements	Specifications	Justification	Verification	Validation
4. Arm device must be able lift specified weight	**4.1** The object lifted will be stationary **4.2** Elbow joint will provide 45N in tension to raise an object from 0 to 75 degrees **4.3** The object will be simply shaped (cubic, spherical, cylinder) and weigh no more than 1 lb or 0.453 kg	**4.1-4.2** Determined reaction force for given weight of object based on force equations **4.3** Weight of daily used simply shaped objects ranges from 0.129lbs or 0.0586 kg for a ball to 0.78lbs or 0.0354kg for a cup	**4.1-2** Linear actuator will be tested using a 12 V power supply and a range of loads	**4.1-2** Linear actuator should move on command from subjects and microcontroller input and lift the load

Design Input Requirements	Specifications	Justification	Verification	Validation
5. Device must obtain input signals for movement of the arm up and down and wrist left and right	**5.1** Identify EEG signals from headset electrodes placed on the motor cortex **5.2** Filter signals based on frequency range yet to be determined **5.3** Signals should be usable data that can be converted and sent to microcontroller then to relay for output	**5.1-5.3** Clear signals obtained from the EEG will be the primary source of data used for movement of the arm prosthesis	**5.1** Electrodes will be monitored through the OpenViBE software as movement is being performed by the subject to identify which respond to each range of motion. **5.2** Performing the Fourier transform, noise filtering, and amplification on the signals gathered will reveal the frequencies that distinguish motion. **5.3** Use oscilloscope or similar measurement tool to analyze output signal to ensure the signal is strong enough to use	**5.1-3** Desired motion of the arm/hand should occur when the subject performs the proper cue. **5.2** **5.3**
6. Device must obtain input signals for grasping motion of hand	**6.1** Motion would be initiated from the EMG signal **6.2** Filter signals based on frequency range yet to be determined **6.3** Signals should be usable data that can be converted and sent to microcontroller then to relay for output	**6.1** Clear signals are required that correspond to mechanical output for wrist that are different from output for arm	**6.1** Monitor the EMG waveforms for changes in the signal while the subject is at rest and when they perform the cue to initiate movement. **6.2** Performing the Fourier transform, noise filtering, and amplification on the signals gathered will reveal the	**6.1-3** Grasping should occur when the proper cue is performed by the subject. **6.2** **6.3**

			frequencies that distinguish motion. **6.3** Use oscilloscope or similar measurement tool to analyze output signal to ensure the signal is strong enough to use	

Design Input Requirements	Specifications	Justification	Verification	Validation
7. Device must differentiate between each type of signal for accurate movement of the arm/hand	**7.1** Convert the EEG/EMG signals from analog to digital ones (In Arduino or VRPN) **7.2** Each directional signal (left, right, etc.) must be converted to a unique digital command (hex or binary, etc.) that	**7.1-7.2** The Arduino needs to map each command to a specific actuator for proper directional movement of the arm/hand	**7.1** An oscilloscope or other measurement instrument can be used to measure the input and output signals to ensure proper A/D conversion is taking place **7.2** Send the specific commands to the Arduino	**7.1-7.2** The device will convert the analog EEG/EMG signals to digital signals which will correlate to a specific directional movement signal that will be sent to the proper actuators on the arm/hand

Design Input Requirements	Specifications	Justification	Verification	Validation
8. Device must attach noninvasively to remainder of limb	**8.1** At attachment site the arm must clamp above the elbow and remained fastened **8.2** Clamp must be adjustable 8.3 Should fit males and females of different arm sizes Mean mid-arm circumference for adults over 20 years of age:	**8.1** Attachment should be secure so shoulder use moves prostheses **8.2** Product manufacturing is less costly and product is more marketable with tailored fit	**8.1-8.2** Secure clamp to different size tubes and let it hang freely for 5 minutes monitoring sliding or loosening at the attachment site. If loosening occurs tighten **8.3** Have a stand with 5 mounting tubes of different circumferences (28, 30, 32, 34, 36 cm) representing	**8.1** The device must at least attach comfortably and securely around the upper arm of test subjects without use of device and with device laying stationary on table **8.2-8.3** The device must attach to male and female

	Females: 31.9 cm Males: 34.1 cm		average female and male arm	test subject upper arms when not in use
9. Device must weigh the same as average forearm and hand weight	**9.1** Arm component must weigh 1.72 lbs Male :1.87lbs Female: 1.57 **9.2** Hand component must weigh 0.575 lbs Male: 0.65lbs Female: 0.5lbs **9.3** Weight of electrical components < .4lbs **9.4** weight of battery must be 1lb or less	**9.1** Arm weight is equal to average (male and female) weight[5] **9.2** Hand weight is equal to average (male and female) weight[5]	**9.1** Determine weight of all material before construction. Weigh the constructed arm on a scale before adding electrical components with goal of 1.72lbs (0.25lb tolerance) **9.2** Weigh the constructed wrist on a scale before adding electrical components with goal of 0.575lbs (0.25lb tolerance) **9.3** Sum weights of each electrical component **9.1-9.4** If doesn't meet specified weights review design for each component separately. Minimize weight of electrical components first.	**9.1-9.4** When held by a user, the device should be lightweight. Loosely attach the clamp to the user and have device hang in 75 degrees flexion. Test for time to fatigue.

Design Input Requirements	**Specifications**	**Justification**	**Verification**	**Validation**
10.1 Device must be rechargeable	**10.1** Device should be used indoors for no more than 3 continuous hours at a time **10.2** Device will have 12V high torque motors/actuators and a 12V rechargeable battery **10.3** Device should power on and off with headset, if no signal is incoming for extended time period	**10.1** Fatigue can occur for extended use because of active thought required. Headset can be used for a maximum of 12 hours using wireless and 6 hours using bluetooth **10.2-10.3** Minimize energy usage	**10.1-10.2** Check response of battery, motors and each actuator during three continuous hours with movement of each hinge joint every 30 minutes **10.3** Have a light switch to determine if battery is on or off. LED light on headset is green when charged and red when drained and comes with charger	**10.1** Run device for 3 continuous hours with use every 30 minutes (of arm and hand) and determine battery life of headset and device. **10.2** Repeat after replacing/recharging batteries and recharging headset to make sure functions the same as the first time **10.3** Remove headset and turn off software, and check that device power turns off in response
11. Device must respond in real time with user friendly output	**11.1** Time to open and close hand must be within 2 s **11.2** Time to move arm up and down must be within 2 s **11.3** Time to move wrist left and right must be within 2 s	**11.1-11.3** At least a 300ms delay between signal presentation and EEG activity and average response time for muscle contraction is 1.8 s	**11.1** The linear acutuator will be tested using a 12 V and response to stimuli will be timed from thought to action. Check coding and ability of arduino and relay to convert electrical signal to mechanical signal <5s **11.2** Measure response time of device by timing when activity is recorded and when output response	**11.1** The device must present output that the user can navigate and understand easily. The output should provide battery life of headset, frequency range of signal to determine if electrode are getting a good read, ability to save data, etc. **11.2** The device should have a reset button that allows previous data to clear if response time is longer than

			occurs during 3 hour continuous run	5s. If the problem is mechanical then the function of each motor should be monitored and dysfunctional motors/actuators should be replaced