Factors to Consider when Selecting a Powered Elbow Prosthesis

• **Weight Lifting Ability** - the Boston Digital™ Arm is an extremely strong prosthesis. It delivers more than 10 ft-lbs of torque, three times that of its competitor. This results in a maximum lift for a typical prosthesis (with a forearm length of 14", elbow centerline to TD grasp point) of about 9 pounds. Since elbows are generally equipped with electric hands or grippers weighing as much as 1.2 pounds, the active lift is reduced to about 8 pounds.

• **Reverse Locking Clutch** - the Boston Arm has a reverse locking mechanism so that it can lift greater weight passively once the elbow's motor is locked. Depending on the socket and harnessing, it can lift 40-50 pounds passively. The Boston Arm's reverse locking clutch can be unlocked under load, enabling it to gracefully lower a heavy weight.

• **Speed** - the Boston Arm is fast, completing a full excursion in about one second. Its superior torque shows up in the measure of speed when a terminal device is added (1.2 pound Greifer). The elbow is essentially unaffected by this weight.

	no load	**with 1.2 lb load**
flexion (against gravity):	1.1 sec	1.2 sec
extension (with gravity):	1.0 sec	1.0 sec

• **Weight of the Elbow** - the Boston Arm assembly weighs about 2 lb. The heavier components are mounted proximally in the forearm. The electronic circuits are located in the forearm and the battery is mounted near the elbow joint. The center of mass of the prosthesis is 3.5" from the rearmost point on the elbow.

• **Terminal Device Compatibility** - the Boston Arm can be used with many terminal devices: Steeper Select hand, Otto Bock hand or Greifer, Sensor-Speed hand, Motion Control hands, bebionic, iLimb Ultra and iLimb Revolution hands. The forearm can mate with wrists from many of the major suppliers of friction wrists, quick disconnect wrists or even wrist rotators. The forearm inside diameter is 50 mm.

• **Control Options** - the Boston Arm has many control options to suit the patient's unique needs based on anatomical, muscular and other physical or neurological constraints. The prosthesis can be controlled with myoelectrodes, Touch Pads (FSR - force sensing resistors), switches or a servo transducer. This wide variety of choices allow the prosthetist to fit each patient with the optimal control strategy. The Boston Arm is a myoelectric system that can be configured to one of the following controls:

  • **Myoelectrodes** - the electrode preamplifiers are significantly smaller than competitors, about half the size. Prosthetists want to create a socket that does not have unsightly bumps where the electrodes sit, so these electrodes are beneficial. The Boston Arm's electrodes measure; 1" long x 11/16" wide x 3/16" thick. Myoelectrodes provide proportional control of the prosthesis.

  • **Touch Pads**™ - the system can be configured to use Touch Pads in lieu of myoelectrodes. These are wafer-thin disks that adhere to the inside of the socket or the frame where the amputee can conveniently press them. They are an excellent alternative to myoelectrodes for amputees who have weak muscle signals or a shoulder disarticulation. Touch Pads also provide proportional control of the prosthesis.

  • **Servo** - the arm can be operated with a positional-servo transducer. This is a small cable-operated device that mounts to the harness. It provides both speed and position control of the prosthesis.

  • **Switches** - the arm can also be configured to operate with switches. These are available in a wide variety of pull and push choices. Switches do not provide proportional control of the prosthesis.

  • **Multiple or Sequential** - the Boston Arm can be configured to allow multiple control of two or even three devices at the same time if the amputee has sufficient control sites. Other amputees may prefer sequential operation of their prosthesis, where Myoelectrodes or Touch Pads control several devices, one after the other.

• **Independent Control** - the Boston Arm has the ability to control multiple devices independently and simultaneously if adequate input signal are provided. This is the reason the Boston Arm is ideally suited for Targeted Muscle Reinnervation (TMR) patients. In fact, there is a special version of the Boston Arm – TMR (BE300-TMR) specifically for these users.

• **Mode Selection** - the Boston Arm offers several function switching options for sequential operation of the elbow, TD and wrist (if used). Co-contraction of input signals (myoelectrodes or Touch Pads) is the most popular, but various switches (i.e. nudge, chin, harness, bump, etc.) can also be used to select mode. Additionally, for the convenience of the user, the Arm has the ability to automatically "revert" or switch back to a previous device after a predetermined period of time.

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• **Proportional TD Controller** - the Boston Arm has proportional control capability for the elbow and terminal device(s). The proportional controller allows the patient to regulate the speed of the device (elbow, wrist, hand) for better control.

• **Batteries** - the Boston Arm is supplied with two high-capacity (2000 mAHr) 11 volt (nominal) lithium-polymer removable batteries. One battery generally provides sufficient energy to power the prosthesis for an entire day. The second battery is a spare.

• **Battery Installation** - the Boston Arm's removable battery is inserted through an access cover on the top of the forearm.

• **Battery Charging** - the Boston Arm has a built-in recharge connector that allows the patient to charge the battery in the prosthesis rather than removing it. The battery can also be charged out of the prosthesis which is convenient for keeping the spare battery charged.

• **Chargers** - the Boston Arm comes with a fast charger for the patient's convenience. The charger can recharge an elbow battery in about one hour.

• **Humeral Rotation Friction Adjustment** - the Boston Arm has an adjustable humeral friction that allows the patient to secure the elbow in any position or to rotate with controlled friction. An optional Locking Humeral Rotation lamination collar is also available.

• **Elbow Disarticulation Patients** - the Boston Arm can accommodate most long residual limb and some elbow disarticulation patients. The lamination collar allows the patient's residual limb to come to within 2.8 inches of the bottom of the flexed elbow (within 1.75" of the elbow centerline), shorter than most competitive systems.

• **Forearms** - the Boston Arm is offered with a molded high-strength urethane forearm in tan or black. The wrist diameter (ID) is 50 mm. The range of lengths of the elbow (from rearmost point of flexed elbow to wrist) is 8.5 to 14.5 inches and the maximum circumference is 9.5 inches.

• **Free Swing** - the Boston Arm has a mechanical free-swing feature providing 45 degrees of free swing to facilitate a normal gait while walking. This feature uses no battery power!

• **Modular Construction** - the Boston Arm uses modular construction to facilitate assembly and servicing. Circuit boards are constructed with state-of-the-art Surface Mount Technology (SMT) for maximum reliability and durability. These are mounted on a back plane (mother board) and can be swapped-out rapidly for trouble-shooting and repairs.

• **Drive Train** - the Boston Arm uses modern direct drive gearing technology and a "wave generator" to achieve the necessary gear reduction resulting in superior torque and speed.

• **Noise Level** - the Boston Arm generally would be difficult to hear above the background noise level in most active environments (i.e. busy office or restaurant, mall, city street, industrial setting, etc.). Clothing over the prosthetic arm helps to reduce the noise emitted and generally, the noise level is lower for slower speeds and lighter loads. More power often results in greater noise, and the patient must consider this trade-off.

• **Cost** - because of configuration differences, options, discounts, etc, it is difficult to make direct comparisons of price. However, generally a Boston Arm system is 15-20% less expensive than competitive electric arm prostheses.

• **Warranty** – the Boston Arm comes with a two year limited warranty against defective materials or workmanship.

• **Reimbursement** - In January 1997, the Health Care Financing Administration (HCFA) revised their L-codes and qualified the Boston Arm for reimbursement under code **L7180** which was subsequently revised (2004) to be used for **Sequential Control**. In 2004 another code was added, **L7181 – Simultaneous Control.** This is used in cases where the elbow and terminal device or wrist rotator can be operated simultaneously. Boston Arm Systems that provide proportional control such; myoelectrodes, Touch Pads (FSR), and Servo-control also qualify for L-code **L7274** - "Proportional Control". Boston Arm Systems using switch control will use code **L7180-52**. The "-52" modifier is a less costly version of the Boston Arm System. In January 2002 HCFA issued a new L-code (**L6882)** for Microprocessor-based control of the terminal device. The Boston Digital Arm should also qualify for this code.

• **Targeted Muscle Reinnervation (TMR) and Pattern Recognition** - the Boston Digital Arm-TMR is designed specifically to accommodate patients who have undergone TMR surgery and therefore have additional myo-sites. This enables the user to independently control multiple prosthetic devices simultaneously. The Boston Arm can operate 4 devices in addition to the elbow joint, making it the most versatile powered elbow on the market today. Researchers have also been using the Boston Arm with new pattern recognition algorithms. This new technology expands the capabilities of the system and enables the user to operate their prosthesis more effectively. This emerging technology is expected to reach the commercial stage toward the end of 2013.

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