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February 17th, 2003

Lakshman One
Simon Fraser University
Burnaby, British Columbia
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RE: ENSC 440 – Functional Specifications for a Voice Activated Control System

Dear Mr. One,

Attached, please find our Functional Specifications Document for ENSC 440: Capstone Engineering Project. The included document is a summary of functional requirements for Freedom Voice Control™, an expansion of ProBed Medical Technologies Inc.'s existing "Freedom Bed™: a programmable, automatic, laterally rotating bed." More specifically, the product expansion includes an add-on device implementing voice control to allow disabled patients unable to operate the button-based user interface to control the bed and gain independence.

The purpose of this document is to encapsulate the deliverable project. Specifically, the document outlines the necessary aspects and additional features to be included in both the prototype and commercially available versions of Freedom Voice Control™.

The Dokkō Design team members include five energetic, talented, and hardworking senior engineering students: Natisha Joshi, Jessica McAlister, Loïc Markley, Nick Meisl, and Adam Stefanski. If you should have any comments or queries about the included document please feel free to contact me by email at jmcalist@sfu.ca or the team at lannj-440@sfu.ca.

Sincerely,

Jessica McAlister

Jessica McAlister
President & CEO
Dokkō Designs

Enclosure: Functional Specifications for a Voice Activated Control System

Freedom Voice Control™
Functional Specifications

Submitted to: Lakshman One – Ensc 440
Steve Whitmore- Ensc 405
School of Engineering Science
Simon Fraser University

Released: January 20th 2003

Revision History

Version R0.9	02/17/2002	• Created by entire project team. • Project Team: Natisha Joshi Jessica McAlister Loïc Markley Nick Meisl Adam Stefanski • Initial draft release

Executive Summary

Decubitus ulcers, more commonly known as bed sores, are caused by pressure or friction against the skin and can range in severity from a slight pink discoloration to a deep wound extending through internal organs to the bone. Patients who suffer from a lack of mobility and spend much time in bed are at a high risk of developing bed sores unless they are rotated at regular intervals. This work is usually performed by a care aide. The patient is dependent upon another individual.

ProBed Medical Technologies Inc., has developed the Freedom Bed™, "a programmable, automatic, laterally rotating bed designed to meet the needs of those patients with, or at risk of developing bedsores and other complications of immobility". The bed may be programmed to perform a series of rotations or controlled in real time using a series of buttons. Many patients are physically unable to operate the bed controller and therefore someone must still control the bed for them. The patient is still dependent upon another individual.

Dokko

Self-reliance, autonomy, independence

Independence is a luxury often taken for granted. When reduced or limited, independence becomes a great desire. This document proposes an add-on device to Pro Bed's Freedom Bed™ aimed to greatly increase the independence of the user. Using speech recognition technology, all the functionality of the Freedom Bed™ will be put at the disposal of the user. In order to operate their bed and prevent bed sores and improve comfort, the patient will have no dependence on another individual.

Dokko Designs is composed of five senior engineering students whose chosen study concentrations and work experience cover a wide range of engineering fields: computer, biomedical, physics, electronic, and systems integration. The pooled skill sets of its members include signal processing, analog/digital circuit design, microprocessor programming, and hardware design.

The development of this project will take place over a 13-week period, culminating with a working prototype by April 1st 2003. This will be accomplished on a projected budget of just over $700 with funding coming from Pro Bed Medical Technologies Inc.

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1. Introduction

Immobile patients who spend much of their time in bed are at a high risk of developing *bed sores* and accumulating unhealthy amounts of fluid in their lungs. To overcome these health risks, it is routine to physically rotate the patient regularly over a 24-hour period. Traditionally, this is done by hand, forcing the patient to be dependent on a caregiver.

ProBed Medical Technologies Inc. is a young company based in Abbotsford, British Columbia that recently released the Freedom Bed™. The Freedom Bed™ is a computer controlled, laterally rotating bed designed to meet the needs of those patients with, or at risk of developing, pressure sores and other complications of immobility. The Freedom Bed™ may be operated in either manual or automatic pre-programmed mode and is smooth and silent so as to provide the user with a good night's sleep while preventing bed sores and excessive fluid build up in the lungs.

Unfortunately, many users are physically unable to operate the button-based control wand for the bed and, therefore, are still dependent on someone's aid.

This document outlines the functional specifications for a device that will give autonomy to the user when operating their self-turning bed: the Freedom Voice Control™. Freedom Voice Control™ will be a stand-alone, plug-in addition to the Freedom Bed™ and will implement most of the features of the conventional button-based user interface using speech recognition technology.

This document begins with a description of the unique user groups and particular needs that the product is designed for. With these needs foremost in mind, functional specifications are outlined. These functional specifications must be met in order to ensure that the Freedom Voice Control™ will meet the needs and requirements of the user.

2. Target User Groups

Since the Freedom Voice Control™ is being designed to extend the existing user interface of an existing biomedical device, it is important that the potential user's and their needs be defined.

2.1. The Operator

Freedom Voice Control™ is designed to provide autonomy to a specific user group that will be referred to as the *Operator*. The Operator is the individual using the Freedom Bed™ who finds the current button-based *wand* controller cumbersome or impossible to use and is still capable of speech. The Operator would be someone who is highly immobile and therefore still at a risk of developing bed sores. Such individuals would include quadriplegics and those suffering from muscular dystrophy. The Operator may be using a respirator.

To the Operator, any degree of autonomy is highly desirable. Their condition dictates that in order to complete tasks, a Caregiver must be relied on for assistance. Freedom Voice Control™ has been designed with the needs and constraints of the Operator foremost in mind to deliver their desire of self-reliance.

2.2. The Caregiver

Since Freedom Bed™ users are generally in such a state of physical immobility, they require assistance in daily activities which is provided by a *Caregiver*. The Caregiver is responsible for ensuring the Operator's basic needs are met. In a healthcare setting, the Caregiver is often a nurse or other medical aide, whereas in a household setting, the Caregiver could be a family member or hired help, such as an in-house nurse. The technical knowledge base and familiarity with medical equipment of the Caregiver ranges from beginner to expert.

When caring for a patient using a Freedom Bed™ with Freedom Voice Control™, the Caregiver's tasks include helping the Operator program and *train* the Freedom Voice Control™. This task is critical to the use of the voice control feature; without the Caregiver's aid, the patient cannot fully utilize the features of the bed that will add comfort and quality to their daily life. Due to the wide user base, the technical knowledge of the Caregiver is assumed to be minimal; therefore, the Freedom Voice Control™ must be designed so that the Caregiver can easily program and operate the bed as required.

3. User Needs and Expectations

The Operator expects to control the bed using the Freedom Voice Control™ with as much functionality as a more mobile patient using the control wand. If a voice command is successfully recognized, the bed will move, providing feedback to the Operator. If the voice command is not recognized, the Operator will expect some form of feedback.

Potentially, the voice pattern of the Operator may be strained and irregular. Therefore, the Operator desires a verbal command set that is easy to say and remember. Additionally, the Freedom Voice Control™ should be highly reliable to alleviate Operator vocal discomfort caused by unnecessary command repetition.

Unlike the patient, the Caregiver views their interaction with the Freedom Bed™ as a systematic task or process. Like programming a VCR, the Caregiver wants the programming of the Freedom Bed™ to be intuitive, simple, and quick. Since their technical knowledge base may be limited, the user interface should be straightforward and not require the use of a technical manual.

The Caregiver needs a user interface that is easy to learn and operate, a fast method of recording voice tags for the Operator, and a responsive feedback system to indicate the success of voice tag recording and storage.

4. User-defined Functional Specifications

4.1. User Services

The services that the system, Freedom Voice Control™, must provide to meet both the Operator and the Caregiver's needs are very different.

The system provides the Operator with one essential service:

- Responsive bed movement upon recognition of valid commands.

The system provides the Caregiver (and indirectly, the Operator) with several related services:

- Command voice tag programming and training.
    - Delete voice tags for all commands.
    - Record voice tags for all commands.
    - Select a command for voice tag editing.
    - Delete a voice tag for a single command.
    - Record a voice tag for a single command.

4.2. User Interface

4.2.1. General Overview

There will be two user interfaces (UI), one for each of the specific user groups the product has been designed for: the Operator UI and the Caregiver UI.

For the prototype, both UIs will incorporate the most usable designs devised by Dokko designs. It should be noted that the final product may contain modified UIs based on field testing and further research.

The Operator UI will by based on speech input from the Operator and sound or mechanical feedback from the interface.

The Caregiver UI will be based upon button inputs with both LED and sound feedback from the interface.

The Freedom Voice Control™ will store in its flash memory voice tags that code for several different verbal commands. When successfully recognized every command causes the bed to perform a different task.

Shown below is the command set. Beside every task is listed a brief description of what it entails along with the suggested verbal command that has been chosen to provide the highest accuracy in voice recognition.

4.2.2. Command Set

Command Name	Description	Suggested Vocal Command
Trigger Word	Used to begin a session in the Operator UI	"Freedom Bed™"
Tilt Bed Right	Moves the Operator further on their right side	"Tilt Right"
Tilt Bed Left	Moves the Operator further on their left side	"Tilt Left"
Flatten bed	Removes all tilt from the bed, puts the Operator flat on back	"Level"
Trendelenburg	Adjusts the frame of the bed such that the head board is higher than the footboard	"Trend"
Reverse Trendelenburg	Adjusts the frame of the bed such that the footboard is higher than the headboard	"R Trend"
Remove Trendelenburg	Flattens the frame of the bed	"Flat"
Bed up	Moves the frame of the bed up	"Bed Up"
Bed down	Moves the frame of the bed down	"Bed Down"
Head up	Inflates bellow under head to tilt the head up	"Pillow Up"
Head down	Deflates bellow under head to tilt the head down	"Pillow Down"
Feet up	Inflates bellow under legs to tilt the feet up	"Feet Up"
Feet down	Deflates bellow under legs to tilt the legs down	"Feet Down"

Any of the above commands that invoke motion, with the exception of "Flatten Bed" and "Remove Trendelenburg" will cause motion in an incremental – or latched- fashion to provide the safest possible operation.

Using the Caregiver UI, the Caregiver navigates through a defined training process that has the Operator say the suggested verbal command while the voice controller records a voice tag.

Using the Operator UI, the Operator will control the bed by saying one of the voice commands.

4.2.3. Caregiver User Interface

Figure 1 below illustrates a mock-up model of the programming UI that would most likely be used exclusively by the Caregiver:

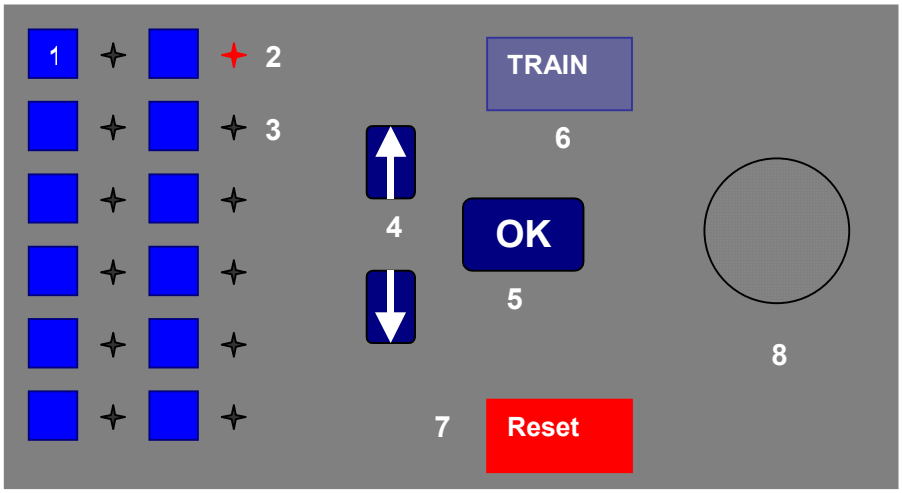

Figure 1: Mock-up Model of Programming UI.

1. Labels: There will be one label per command. Each label will name the command and show a diagrammatic representation of the function carried out by the command
2. On LED: When on, an LED will be red showing that that command specified by the label beside the glowing LED is currently selected.
3. Off LED: When the LED is off, the command specified by the label beside the LED is not currently selected.
4. UP/Down Arrows: Buttons that when pushed allow the Caregiver to select a specific command.
5. OK Button: Pressing this button will move the device into the training sequence for the selected command. This button will also be used during the training sequence itself.
6. Train Button: Pressing this button will activate the Caregiver UI. Before this button has been pressed, no LEDs will be on signaling that the UI is currently not in use. This button will be implemented using a slide type control such that the current state will be obvious.
7. Reset: Pressing this button clears all voice tags stored in the device. This button will be have a cover such that its unintentional use will not be possible.
8. Speaker: Used to relay voice feedback from the UI.

A flow diagram in Figure 2 indicates the process by which the Caregiver would operate the Caregiver UI:

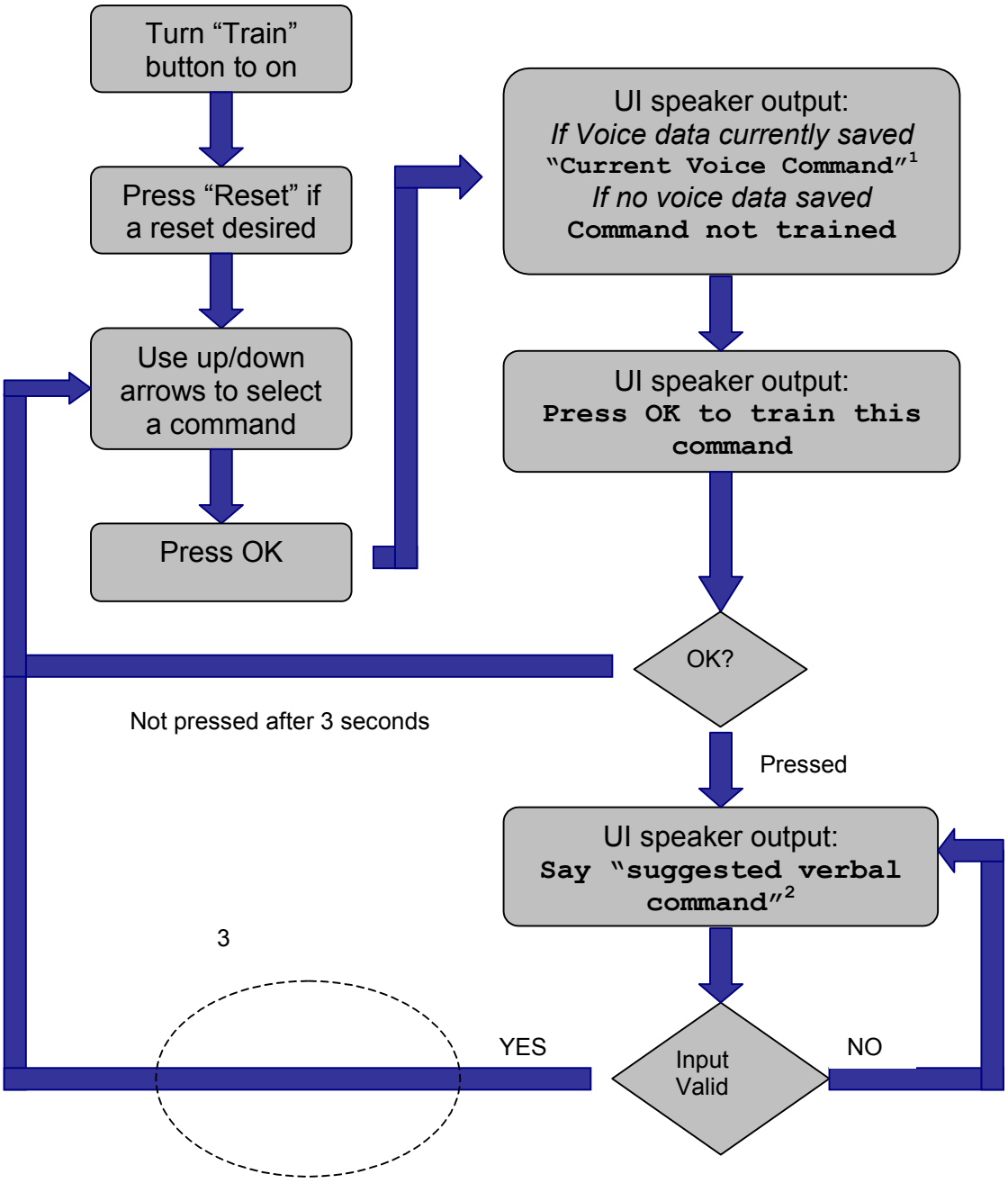

Figure 2: Flow Chart Model of Programming Process

1. Current Voice command refers to a recorded voice tag from a previous training session.
2. Suggested verbal command refers to the suggested phrase for a specific command that will produce highly reliable speech recognition.
3. In this region the UI speaker will output "Please Repeat" and addition two times. This is done in order to store additional voice tags for the command such that voice recognition will be highly reliable.

4.2.4. Operator User Interface

The Operator UI will consist of inputs form the Operator in the form of verbal commands picks up by a microphone and sound and spoken outputs from the speaker contained on the Caregiver UI module.

A trigger word command will be used to begin a controlling session in order to increase the reliability and safety of the Freedom Voice Control™.

Unless disabled, the Operator UI will silently cycle waiting for the trigger word command to be recognized. Once the trigger command has been recognized, a beep will sound.

Upon hearing the beep the user may then say previously trained verbal commands in order to operate the bed.

If a command is recognized, the bed will perform the specified function.

If a command is recognized, but that command has been locked out by the Caregiver in the main control module (not a part of the Freedom Voice Control™), then the UI will inform the Operator that this command has been "locked out"

If an error occurs in voice recognition or if recognition was uncertain as to the stated command, the UI will instruct the Operator to please repeat the command.

The UI will stay in the controlling state until a command has not been said for a period of one minute after the completion of the last command. At this time, the UI will issue three beeps. After this time, the Operator will need to say the trigger command in order to begin controlling the Freedom Bed™ once again.

5. System-defined Functional Specifications

The following functional specifications define the system characteristics needed to effectively, safely, and reliably deliver system services to the user in timely, and economically feasible manner

5.1 Physical and Environmental

5.1.1. Embedded Board

The board will fit into a 5”×3”×1” plastic enclosure.

The board will be powered by 12V supply lines from the CAN Network.

The board will be mounted inside the footboard.

The board will operate with the noise generated by medical equipment

The board will operate at the normal consumer room temperature of 0°C to 40°C.

The board will operate under all commercial humidity and pressure ranges.

The board will dissipate heat of no more than 10°C.

5.1.2. User Interface

The user interface will be a maximum size of 5”×3”×2”.

The user interface will be powered from the embedded board.

The user interface will be mounted on the existing Freedom Bed™ footboard.

The user interface will be durable and resistant to impact.

The user interface will not be susceptible to moisture or dust.

The user interface will operate at the normal consumer room temperature of 0°C to 40°C.

The user interface will operate under all commercial humidity and pressure ranges.

The user interface will dissipate heat of no more than 10°C.

5.1.3. Microphone

The microphone will be a maximum size of 1”×1”×3”.

The microphone will be connected to the embedded board using a wire.

The microphone will be mounted on the Freedom Bed™ frame.

The microphone will be durable and resistant to impact.

The microphone will not be susceptible to moisture or dust.

The microphone will operate at the normal consumer room temperature of 0°C to 40°C.

The microphone will operate under all commercial humidity and pressure ranges.

The microphone will dissipate heat of no more than 10°C.

5.2. System Interfacing

As the Freedom Voice Control™ will be used in conjunction with the Freedom Bed™, we intend that the integration of the two systems be seamless.

5.2.1. CAN Network Interface

The Freedom Voice Control™ will interface to the Freedom Bed™ via an existing CAN Network.

The Freedom Voice Control™ will connect to the CAN Network via two RJ11 connectors.

The Freedom Voice Control™ will send out commands via a microcontroller.

The Freedom Voice Control™ will use the existing Freedom Bed™ command set.

5.2.2 RS-232 Interface

The Freedom Voice Control™ will be flash upgradeable via a 9-pin RS-232 port.

The Freedom Voice Control™ will be flash upgradeable at 11500 bits per second.

5.2.3. Microphone

The microphone will connect to the embedded board via a single analog I/O pin.

The microphone will be controlled by the Sensory Inc. microcontroller.

5.2.4 User Interface

The user interface will connect to the embedded board via a maximum of 16 digital I/O pins.

The user interface will be controlled by the Sensory Inc. microcontroller.

5.3. Standards

The Freedom Voice Control™ will be fully compliant with the V2.0A and V2.0B standards for CAN Networks

The Freedom Voice Control™ler will be fully compliant with the EIA-562 and EIA-574 standards for RS-232 serial networks.

The Freedom Voice Control™ler will be fully compliant with all FCC standards for electronic emissions.

5.4. Reliability

The Freedom Voice Control™ will be user-dependant: adjustable to the unique speech needs of the Operator through speech programming.

The Freedom Voice Control™ will be able to function in a moderately noisy environment.

The Freedom Voice Control™ will wait for a trigger word before responding to executable commands.

The Freedom Voice Control™ will only execute commands after the trigger word has been recognized.

The Freedom Voice Control™ will not stay triggered indefinitely.

The Freedom Voice Control™ will be controlled by a suggested set of simple, easy-to-remember phrases.

The suggested command phrases will be sufficiently different to avoid erroneous execution of commands.

The Freedom Voice Control™ will not execute a command without significant confidence of phrase recognition.

In trigger mode, the Freedom Voice Control™ will provide feedback to the Operator if recognition fails.

The Freedom Voice Control™ will allow for some variance in Operator's voice, tone, and volume through strategic assignment of confidence levels and averaging.

The Freedom Voice Control's™ microphone will be strategically placed such that performance will not be compromised with the changing positions of the bed and Operator, and such that the Operator's comfort will not be compromised.

The Freedom Voice Control™ must be able to operate over extended periods of time; most Freedom Bed's™ are continuously operated and the Freedom Voice Control™ must comply.

The Freedom Voice Control™ will be powered by the Freedom Bed's™ power source so power reliability is built-in.

The Freedom Voice Control™ will have a mean time between failure exceeding 100,000 hours.

The user interface buttons should have a duty cycle of at least 1,000,000 cycles

5.5. Performance

The Freedom Voice Control™ will supply real-time feedback for triggering through a single beep when trigger word is recognized.

The Freedom Voice Control™ will supply real-time feedback for a recognized executable command in trigger mode through execution of the command.

The Freedom Voice Control™ supply real-time feedback for an unrecognizable command in trigger mode by replying "please repeat."

The Freedom Voice Control™ will supply real-time feedback for a recognized locked-out command in trigger mode by replying "command is locked out."

The Freedom Voice Control™ will supply real-time feedback when exiting the trigger mode after a time-out period through three beeps.

5.6. Error Handling and Extreme Conditions

The Freedom Voice Control™ must ensure that bed movement occurs in response to only valid commands spoken by only the user of the bed.

If the Freedom Voice Control™ is being used in a facility among other Freedom Bed's™ using Freedom Voice Control™, the voice recognition must distinguish between its unique Operator's commands and other Operators of Freedom Beds™ in the same setting.

The Freedom Voice Control™ must allow the user to correct or change incorrect command inputs.

The Freedom Voice Control™ must ensure that the voice recognition system is updateable should the Operator's voice change sufficiently.

The Freedom Voice Control™ should default to the existing error handling and extreme condition logic in the Freedom Bed™ in situations of voice recognition disabling, bed movement disabling, emergency conditions, error handling, and extreme conditions (such as external physical obstructions to the bed)

5.7. Safety

As a biomedical application, the Freedom Voice Control™ will be used to control the movement of the Operator. As such, it will be designed with the safety of the user paramount. There is a potential for the user to be placed in very uncomfortable positions and there also is a potential for injury if a movement is imposed when the patient is in an awkward position. The functional specifications for safety are as follows:

All Freedom Bed™ movements will be limited to 3 seconds in length.

An Emergency Stop command will instantly halt all Freedom Bed™ movements.

The Freedom Voice Control™ must hear the trigger word and enter Command Mode before allowing any commands to be processed.

Command Mode will expire 1 minute after the last command has been spoken.

There will be a Disable/Power switch on the Freedom Voice Control™ to prevent commands from being processed while activated.

The Freedom Bed™ will not move unless the voice command has been recognized at a sufficiently high confidence level.

The microphone will not be attached to the patient or anywhere it can obstruct patient movement.

The microphone wire will not be of length to emit harmful electromagnetic radiation.

The Freedom Voice Control™ will have no sharp corners and will be electronically shielded to protect the Operator and Caregiver.

5.8. Documentation

When this device becomes a market product, it will require documentation to provide an explanation for all features, training process instructions, user interface explanations, as well as documentation explaining what to do if something goes wrong.

A concise but thorough manual will be written with three main sections. The first section of the manual introduces the Freedom Voice Control™ and its features and outlines the command set used for bed control. The second targets the Caregiver, the third targets the Operator.

The Caregiver section of the manual provides an explanation for the training of the Freedom Voice Control™ module. It provides example scenarios with ample written and pictorial illustrations for ease of understanding.

The Operator's section of the manual will explain the feedback and command responses to expect from the Freedom Voice Control™ module when in normal use. It will also briefly cover the general particulars of voice recognition.

FAQ and troubleshooting sections will also be included in the manual.

A laminated one-page quick reference sheet will be provided for display near the Freedom Voice Control™ for use by the Caregiver.

The product website will also contain a documentation section where the manual's FAQ will be displayed as well as contact information for Dokko Designs support staff.

6. Test Plan

This section outlines the goals and methods for testing the functionality of the Freedom Voice Control™. Testing of the system will begin with thorough component testing and once resolution of any component failures has been completed, the software will undergo integration and system testing.

The functional specifications are essential in system testing. They identify what services and system responses must be present and to what degree, and stand as a specification and checklist for system testers.

6.1. Test Overview

The system must provide two classes of functionality, depending on the active user. The most complex functionality of the system concerns the actual programming and training of the system by the Caregiver. The system must be able to support the selection, deletion, addition of one or more voice tags to bed movement commands by the Caregiver. The system should also allow the Operator of the bed to control the bed movements through the confident recognition of the Operator's voice commands. The focus of the testing will be to ensure that the system correctly identifies the Operator's commands and performs the corresponding bed movements, and that the user interface used by the Caregiver in training is intuitive and lends itself to correct, quick, and concise programming by the most inexperienced technical user.

6.2. Testing Strategy

The Freedom Voice Control™ consists of four main components: 1.) physical user interface, 2.) embedded user interface, 3.) filtering, voice recognition and encoding module, and 4.) CAN bus interface. In relation to the functional specifications, the first three components need to be tested thoroughly to ensure that the requirements are met.

After initial component testing, drivers will be written for components 2 and 3 and black-box testing will be performed; the user interface components will be user tested through scenarios, mock-ups, and path testing.

Equivalence testing will be used to represent system's response to the possible sets of input to the system. In our system, the uniqueness of the Operator and the variance in the voice capabilities and pronunciation of commands provides a strong case for performing extensive equivalence testing. Our testing will include providing various samples, signals, and other noise inputs to test the output response of the system. Final testing would include gathering varying voice samples from typical users, taken at different times of the day, in different sitting/lying positions, and from individuals with various

medical histories to test as many variations in input as possible. Boundary cases will also be examined and tested to ensure that the system correctly handles these cases.

Following component testing, integration testing and overall system testing will be performed. Integration testing will test the functionally of the subsystem as a whole and ensure that the modules communicate and interact with each other correctly, and that they provide the rest of the system with appropriate services when required. Should the integration testing uncover any system failures, these failures must be resolved, the testing performed again until valid results are received. Finally, after thorough integration testing, the system will be tested for overall high-end, user functionality. The functional specifications will act as a checklist for how well the system corresponds to the users' requirements. Should the system fall short of the requirements, the shortcomings will be thoroughly documented and used to alter the design of the system in the following product iterations.

7. Conclusion

The functional specifications outlined in this document were created to serve the specific needs of the two user groups of the Freedom Voice Control™: the Operator and the Caregiver. For the Caregiver, specifications have been created to ensure that training the device is straightforward, easy to use, and requiring a minimal time commitment. For the Operator, special steps have been taken to ensure that the specifications will ensure that the device will meet their needs and desire for a greater sense of autonomy when operating their Freedom Bed™.

Glossary

Bed sore - A pressure-induced ulceration of the skin occurring in persons confined to bed for long periods of time. Also called decubitus ulcer

Caregiver – An individual who provides basic assistance and medical care for individuals who are not completely autonomous.

Operator – An individual who uses the bed during daily activities.

Train – Refers to the setup process of dependent voice recognition systems; usually requires recording a set of training words.

Voice tag – A stored voice recording that is mapped to a specific bed movement command.

Wand – Existing physical user interface for the Freedom bed; remote control.

Acronyms

CAN – Controller Area Network
EIA – Electronic Industry Alliance
FAQ – Frequently Asked Questions
FCC – Federal Communication Commission
I/O – input/output

