February 18, 2008

Patrick Leung
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 – Functional Specification for a Wheelchair Stability and Pressure Relief System

Dear Mr. Leung:

The enclosed document, *Functional specification for a Wheelchair Stability and Pressure Relief System*, outlines the features that will be available upon completion of our project. The goal of our team is to design a system that has the ability to move the body sideways and out of danger in a tipping situation and provides substantial and effective controlled pressure relief for disabled people with limited upper body mobility.

From the feedback collected through meeting with some disabled people and a physiotherapist at GF Strong Rehabilitation Center, we have generated a set of functions and requirements that our system must meet. The purpose of this document is to ensure our product will meet the needs of its users. We will be using these set of requirements to guide our design phase of development.

Safe Sense Technologies consists of three hard working fifth-year engineering science students: Jamie Westell, Arash Jamalian, and Shadi Agha Kazem Shirazi. Please feel free to contact me with any questions or concerns regarding our functional specification. I can be contacted by phone at (778)889-2310 or by email at saghakaz@sfu.ca. Our team can also be contacted via email at ensc440-spring08-safesense@sfu.ca.

Sincerely,

Shadi A.K Shirazi
President and CEO
Safe Sense Technologies

Enclosure: *Functional specification for a Wheelchair Stability and Pressure Relief System*

FUNCTIONAL SPECIFICATION FOR A WHEELCHAIR STABILITY AND PRESSURE RELIEF SYSTEM

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Date: February 18th, 2008

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EXECUTIVE SUMMARY

Many experts and scientist are convinced that the human balance system is our true sixth sense. Most people do not give their sense of equilibrium a second thought, but without balance, it is almost impossible either to get around or to live in an independent fashion. Safe Sense Technologies is confident that *Equipoise* can assist wheelchair users who are prone to falling as a result of impaired upper body balance. As well, we believe that *Equipoise* has the facility to alleviate the development of pressure sores. *Equipoise* will provide its users a higher degree of comfort and security, and allow incapacitated individuals to engage in their day to day activities with a greater sense of comfort and liberation.

The development of *Equipoise* will occur in two main stages. In first Stage we will construct the operational prototype for proof of concept and in second stage we will present the manufacturing model for commercial use. The prototype model will be used to demonstrate the idea but it will be crude in terms of aesthetic. Phase one will be targeted for completion by April 2008, and will posses the following main features:

- *Equipoise* will be able to move the user's upper body sideways and out of danger in a tipping situation in a fast response manner.
- *Equipoise* will provide substantial and effective, controlled pressure relief in a very slow fashion.
- *Equipoise* will be capable of enabling and disabling the above functions.
- *Equipoise* will be much lighter, cost effective and consume less power than its rival designs.

The timeline for the second stage of development will depend on technical and market factors, and will be determined after the successful completion of the first stage.

This document is dedicated to the detailed discussion of functional specification for stage one and partially for stage two of development. The listed specification for the second stage, represent our current understanding of what our customers demand and will be modified upon further researches.

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1. INTRODUCTION

Equipoise is an active system which has the ability to move the inert body sideways and out of danger in a tipping situation. It is common for wheelchair users to be involved in tips and falls. Tipping occurs when navigating over sidewalk curbs, when meeting an immovable obstacle, when the user is reaching awkwardly and when the user suffers from sudden muscle spasms. In any one of these circumstances, the individual is rendered helpless and the accident inevitably follows. *Equipoise* has the facility to reduce these innate dangers by moving the person in the opposite direction of the tip and in so doing, help prevent the fall.

Equipoise, over the longer term, provides substantial and effective, controlled pressure relief. Pressure relief comes naturally to able bodied individuals. By moving the helpless individual's body, very gently, from side to side, *Equipoise* can help prevent skin break down, as well as keep the skin tissue healthy.

Figure 1 illustrates the two main functions of *Equipoise*.

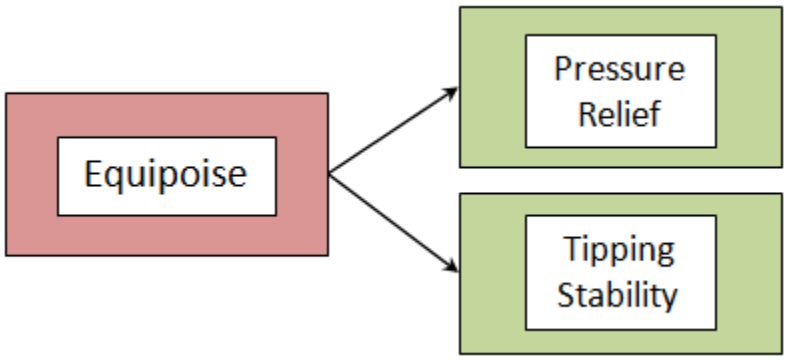

FIGURE 1 EQUIPOISE MAIN FUNCTIONS

Equipoise requires less power than products currently on the market which are designed on the tilt and interpolation of the chair itself. The latter are large and heavy and require an excessive use of power. *Equipoise* simply moves the body rather than the chair and therefore does not consume as much electricity as its rival designs. The *Equipoise* apparatus is much smaller and lighter than any other present design; as a consequence, *Equipoise* has proven to be far more cost effective for both the manufacturer and the consumer.

The task of developing *Equipoise* is divided in to two stages: the proof of concept stage and the production model stage. The proof of concept stage will extend over a 13-week period, beginning on 9th of January 2008; with April 6th, 2008 as the scheduled completion date for prove of concept prototype. The timeline for the second stage of development will depend on technical and market factors, and will be determined after the successful completion of the first stage.

1.1 SCOPE

This document describes the functional requirements that Equipoise must satisfy. Through meetings with Walt Lawrence, spine peer mentor, who has been paralyzed for over 40 years and suffer form limited upper body mobility and Ian Denison, physiotherapist and equipment evaluator at GF Strong Rehabilitation Center, we have generated a set of functions that our system must meet.

The functional specifications listed in this document, fully describe the proof of concept model and partially describe the production model requirements. The listed production model specifications represent our current vision on what customers demand and will be modified upon further tests and studies.

With a clear set of objectives in mind, we can then proceed to design Equipoise to efficiently meet these requirements.

1.2 INTENDED AUDIENCE

This functional specification is intended for use by Safe Sense technologies members. It is intended to ensure that the development of *Equipoise* is following the correct path. This document will be used by designers, engineers and project manger within Safe Sense Technologies.

Designers and engineers will use this document as guideline during the development process of *Equipoise*.

Project manger will use this document for project performance estimation and milestone scheduling.

In overall this document will be used as a measure of success in designing *Equipoise*.

1.3 CONVENTION

Throughout this document, each functional specification will be assigned a requirement number with the following convention

[*R*n-*X*] A functional requirement

Where n is the functional specification number and X represents the priority of each functional requirement, which will be one of the following two values:

I The Requirement applies to proof of concept model

II The requirement applies to production model

2. System Overview

Figure 2 shows a general system overview of *Equipoise*.

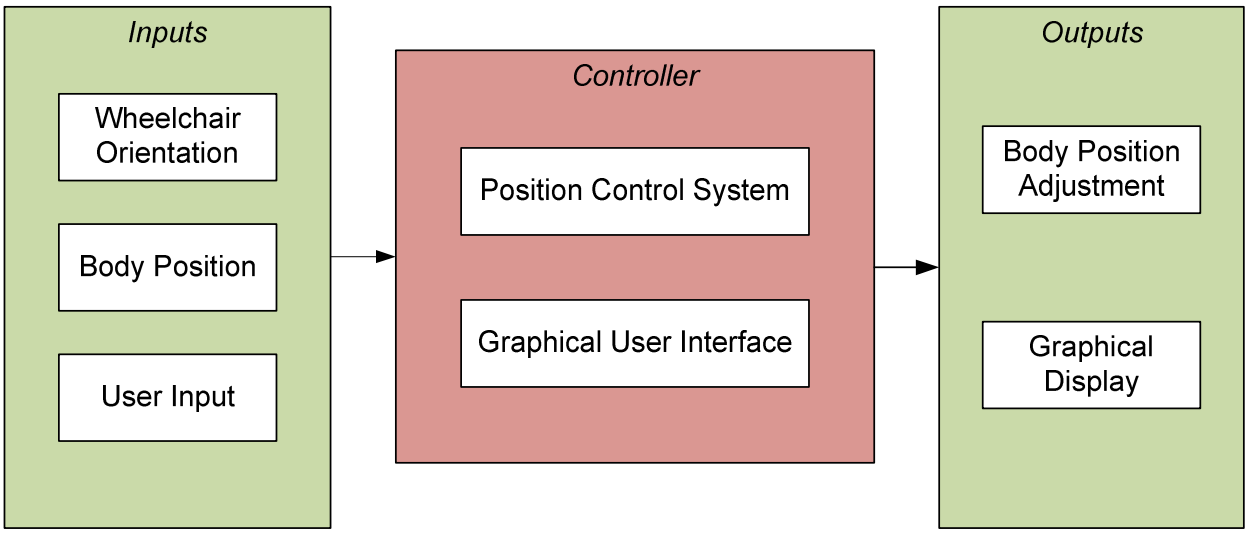

FIGURE 2 SYSTEM OVERVIEW BLOCK DIAGRAM

The three fundamental system inputs will be the orientation of the wheelchair, the position of the body within the wheelchair, and any input given through the user interface. The controller will then use these inputs to generate appropriate outputs for the wheelchair stability and pressure relief functions. These outputs will come in the form of a body position adjustment along with a corresponding graphical display.

Figure 3 demonstrates an example of the system response specifically for the wheelchair stability mode.

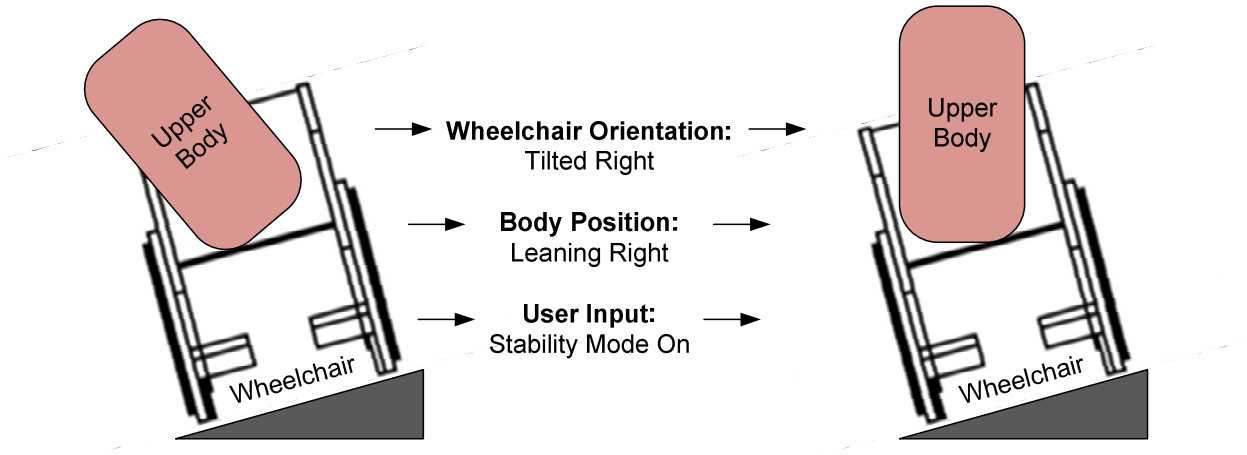

FIGURE 3 WHEELCHAIR STABILITY CORRECTION

In the leftmost image in Figure 3 the wheelchair is tilted to the user's right, the upper body is leaning to the right and the user has requested the stability mode to be on. Based on these

inputs, the controller generates a desired body position adjustment output in order to move the upper body to a safer position.

Figure 4 shows the state diagram for switching between different modes of operation.

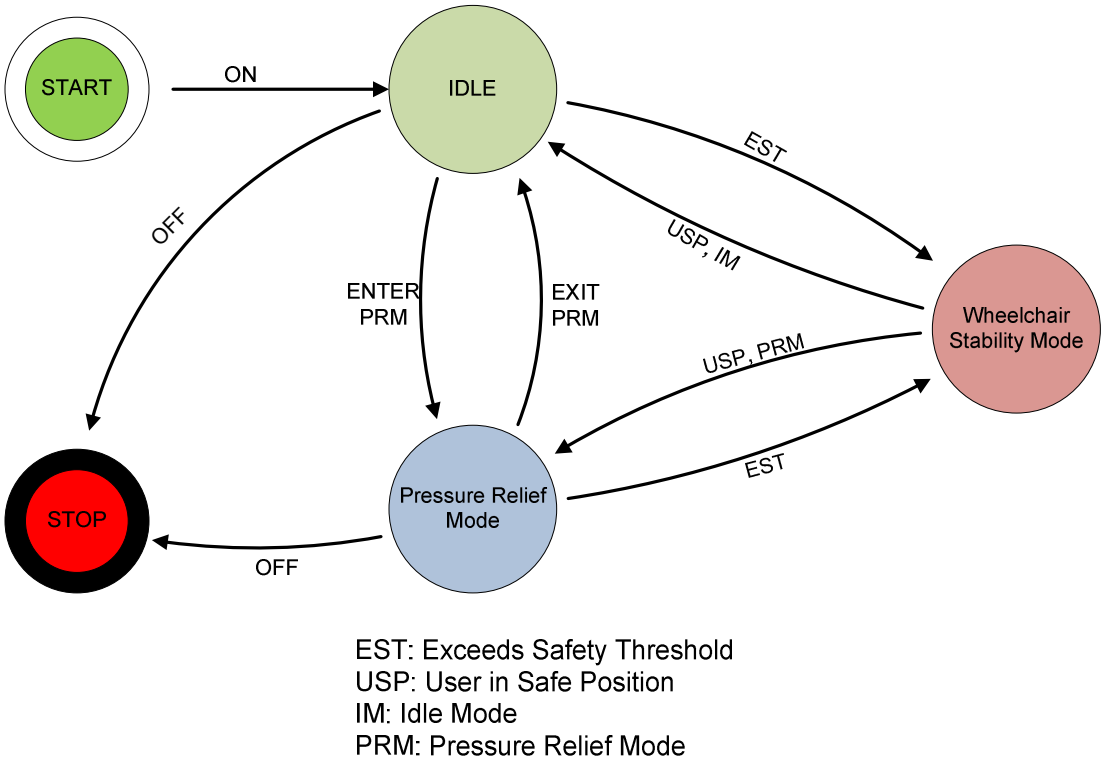

FIGURE 4 STATE DIAGRAM

The system begins in an idle mode and depending on either user input or sensor input the state will change to either the Pressure Relief Mode (PRM) or the Wheelchair Stability Mode (WSM). When in WSM the system will exit this state only when the user is in a safe position (USP). The user will have the option to turn on or off the pressure relief mode and upon exit of WSM the system will return to the state it was previously in before entering WSM. The system may be turned off in PRM or IDLE modes however when in the WSM mode, the system will ensure that the user is in a safe position before turning off.

3. System Requirements

3.1 Mechanical

[R1-I] The structure will not increase the physical dimensions of the wheelchair.

[R2-I] The structure will not block the user's view.

[R3-II] The transfer of mechanical power will be efficient and quiet.

[R4-I] The mechanical components will require little maintenance and can be easily replaced.

[R5-II] The mechanical components will be reliable from -10 to 40 degrees Celsius.

[R6-II] The system will weigh less than 100N.

[R7-II] The system components will be strong enough to move a 100kg body.

[R8-II] The system will be customizable so that it can be used on any type of motorized wheelchair.

3.2 ELECTRICAL

[R9-I] The system will use a portable power supply.

[R10-II] The portable power supply will be capable of supplying power to the system for 8 hours without fail.

[R11-II] The electrical components will be reliable from -10 to 40 degrees Celsius.

[R12-I] The power consumption will be kept at minimum when the upper body is not being moved.

[R13-I] The heat dissipation of the system will not affect the chair and chassis temperature.

3.3 COST

[R14-I] The overall cost of the system is less that $2000.

3.4 SAFETY

[R15-II] The system will follow the requirements for wheelchair tie down and occupant-restraint system as outlined in ISO 10542-1:2001.

[R16-I] The failure of mechanical and electrical components will not cause any danger for the user.

[R17-I] The system will not impose any restrictions on moving the wheelchair forward or backward.

[R18-II] The system will turn off in the case of low power supply.

3.5 User

[R19-I] The exertion of force will not cause any discomfort or pain for the users.

[R20-I] The system will respond to user input immediately.

[R21-I] The user will be able to turn off/on the pressure relief mode or the stability mode.

[R22-I] The user will be able to manually adjust the posture of his/her upper body via the user input.

[R23-II] The system will display relevant information to the user via the graphical user interface.

[R24-I] The use of the system is intuitive enough to be learned independently.

3.6 Operation

3.6.1 The pressure relief function

Figure 5 shows pressure map when sitting straight.

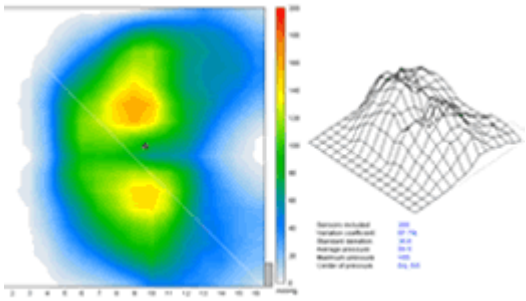

FIGURE 5 PRESSURE MAP OF SEATED PERSON (WWW.VITAFOAM.CO.UK)

The red area on the top section of the map shows a pressure peak which will create pressure ulcers over time. The *Equipoise* system will provide effective weight shifting by moving the upper body sideways according to the requirements suggested by Ian Denison, a physiotherapist and equipment evaluator with the GF Strong Rehabilitation Centre (GFS).

[R25-I] The system will begin moving the user to a side every 15 minutes.

[R26-I] Movement will begin from neutral position and end when the upper body is moved 12 centimeters to one side.

[R27-I] The upper body will be moved left and right in successive manner.

[R28-I] The duration to move the person from neutral position to one side will be between 20 seconds to one minute.

[R29-I] The speed of the movement will be made constant as well as independent of body weight and external disturbances.

[R30-I] The speed of the movement will be kept very slow so that it is unobtrusive to the user.

[R31-I] The upper body will be kept at leaning position for 2 minutes and then moved back to neutral position.

[R32-I] The system will retain knowledge of the position of the upper body after power reset.

Figure 6 demonstrates the functional requirements specific to the pressure relief function.

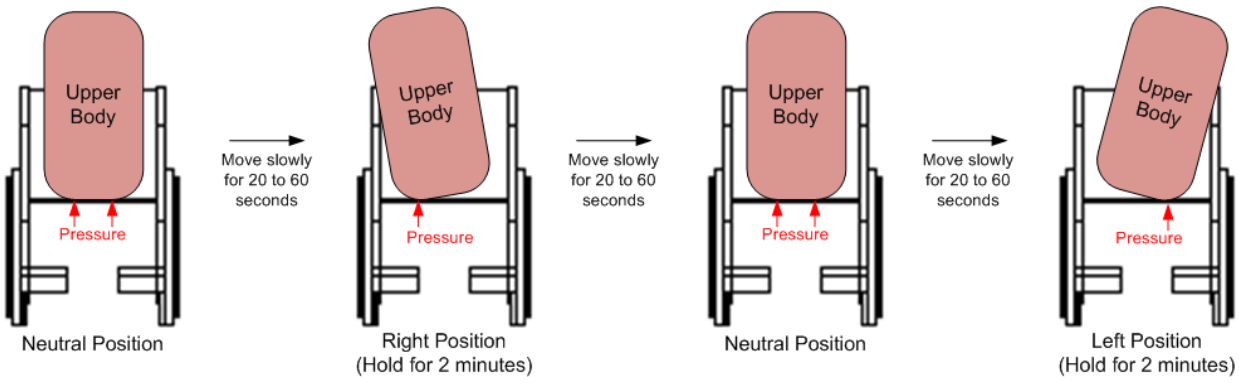

FIGURE 6 PRESSURE RELIEF DIAGRAM

The red arrows above the word ‘pressure’ show where the pressure is concentrated between the user and the seat. The movement of the upper body from the right to left positions through the neutral position alters the force distribution on the seat and thus relieves the concentrated pressure on the user’s body.

3.6.2 STABILITY FUNCTION

When the wheelchair gets tilted, the user's body mass must be shifted to opposite side to keep the overall centre of mass within the wheelchair foot print. This function ensures stability for wheelchair users driving on terrains and sidewalks. The functional requirements of the stability feature are as follows:

[R33-I] Once the wheelchair tilt angle from ground is greater than a certain threshold, the system will start moving the upper body in opposite direction.

[R34-I] The upper body will be moved to the opposite direction for *X* centimeters where *X* is the distance between the current position of the body and the final position. *X* will be proportional to the tilt angle.

[R35-I] The final position of the upper body will be updated in real time corresponding to the current tilt angle of the wheelchair.

[R36-II] The system will ensure that overall center of mass is within the wheelchair footprint at all times independent of height of the person.

[R37-I] The speed of movement will be proportional to the tilting speed of the wheelchair.

[R38-I] The response time will be sufficient to prevent tipping or injury from tipping.

[R39-II] The response time will be less than 10ms.

[R40-I] The upper body will be kept at the final position corresponding until the danger of tipping is removed.

[R41-I] The upper body will be moved to the neutral position once the wheelchair's tilt angle becomes less than threshold.

[R42-II] The threshold angle will be adjustable to take into account the person's height and the wheelchair's structure.

4. TEST PLAN

There are four major test plans for Equipoise system:

1) Pressure relief: Upon the completion of the system prototype, a pressure mat will be borrowed from GF strong Rehabilitation Centre to measure the pressure distribution on the chair as the upper body is moved sideways. The data gathered from this test will be used to enhance the efficiency of the system.

2) Wheelchair tipping:

   - Static stability test:
     A fully loaded wheelchair is placed on an adjustable platform. The wheelchair will be slowly tilted sideways and the stability limit will be recorded. The stability limit is defined by the tilt angle at which the wheelchair is about to tip over.

   - Dynamic Stability test:
     This test will be similar to the static test with the exception being that the wheelchair is accelerated while it will hit obstacles, side walk curbs or make sharp turns. The stability limit is again defined by the tilt angle at which the wheelchair is about to tip over.

3) Safety: To ensure the system will follow the requirements for wheelchair tie down and occupant-restraint system as outlined in ISO 10542-1:2001, the system will be tested according the procedures mentioned in the standard. Note that this test will be done once the system is ready to be manufactured.
   In addition, the required tensile, bearing, and shear strength of the mechanical components depend on the design of the mechanical structure. Upon the completion of the prototype, the mechanical components will be tested by exerting 9800N on the structure. Different parts of the structure will then be examined for possible deformation and failure.

4) Usability: To make sure the system is user friendly, the prototype of the system will be examined by Walt Lawrence who suffer form limited upper body mobility.

5. CONCLUSION

The listed functional requirements of Equipoise system has been carefully reviewed within Safe Sense Technologies and discussed with some disable people and a physiotherapist at GF Strong Rehabilitation centre to address wheelchair stability and pressure relief issues in the most efficient way. All these set of specification has been cautiously chosen based on feasibility, practicality and usability factors. The listed specifications will ensure that the operation of the system will be safe, reliable and follows the standards.

The ultimate goal of Safe Sense Technologies is to make *Equipoise* a major break through in the lives of all those people who are forced to spend their days in a wheelchair and make a significant difference in the lives of people who endure limited mobility. We want to provide more comfort and safety in a most cost effective manner.

By April 2006, the first stage of the project, the design and creation of the proof-of-concept model will be developed which will include all the requirements labeled with **[Rn-I]**.

Upon the successful completion of the first stage, the development of the production model encompassing all the requirements mentioned in this document will be completed at a later date.

6. REFERENCES

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5. ISO 10542-1:2001. Technical systems and aids for disabled or handicapped persons -- Wheelchair tie down and occupant-restraint systems -- Part 1: Requirements and test methods for all systems < http://www.iso.org >

6. Li, W. A Study of Active Shifting of Human Driver for Improving Wheelchair Tipping <Stabilityhttp://www.ensc.sfu.ca/research/erl/med/>