School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6
ensc440-asaconcepts@sfu.ca

February 16, 2009

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

RE: Functional Specification for the Smart Crutch

Dear Patrick:

Attached is the functional specification document for the Smart Crutch system. The Smart Crutch provides a safe alternative to normal axillary crutch users by providing several levels of prevention and protection against user accidents such as falls and slips. The three levels of safety included in the Smart Crutch system includes the warning system for avoiding slippery surfaces, the fall-prevention mechanism for stabilizing user composure in case of small slips and the alarm system for notifying people of possible user accident.

The functional specification document provides a high level functional requirement for the Smart Crutch system. It elaborates the functional details of the mechanisms in the system which includes the friction sensor, the motion sensor, the fall-prevention mechanism, the warning system and alarm system, and the user interface and microcontroller unit. It will be a basis for design engineer during the product development and testing phase.

ASA Concepts is composed of 5 engineers with a diverse background on mechanical, electrical and software skills. The following tasks are assigned for each engineer as follows: Amir Sadeghi – friction sensor development; Ben Lush – fall-prevention system development; Kyle Lin – motion sensor development; Stan Lin – hardware and microcontroller unit design; James Guerra – software development.

For any further questions please feel free to contact us through email, ensc440-asaconcepts@sfu.ca or through my phone

Yours truly,

Ming-Cheng Lin
Chief Executive Officer
ASA Concepts

Enclosure: Functional Specification for Smart Crutch

Functional Specification for the Smart Crutch

Project Team: Ming Cheng Lin
James Guerra
Chien Wen Lin
Amir Sadeghi
Ben Lush

Submitted to: Patrick Leung - ENSC 440
Steve Whitmore – ENSC 305

Contact Person: James Guerra
jguerra@sfu.ca

Date Submitted: February 16, 2009

Executive Summary

The Smart Crutch is an alternative way of providing a safe assistive device for disabled persons. The Smart Crutch provides three layers of prevention and protection for crutch users against falling or slipping accidents. The features included in the Smart Crutch system are a warning system for cases where the user encounters slippery surfaces, a deployable stabilizing mechanism which helps the user to regain composure in case of a minor slip and a remote alarm system which notifies other people that an accident happened.

The smart crutch will contain a friction sensor which constantly samples the friction coefficient between the ground and the crutch, a motion sensor (accelerometer) which constantly monitors the angle between the crutch and the ground, a stabilizing mechanism which prevents the user from completely falling into the ground, a radio transmitter which sends distress signals to a remote alarm device in case of a user accident, a user interface, a microcontroller unit for main control of the system and a fall-prevention mechanism which automatically deploys in case of a minor user slip.

The tasks for product development are evenly divided as follows:

- Amir Sadeghi – friction sensor development
- Ben Lush – fall-prevention mechanism development
- Chien Wen Lin – motion sensor development
- Ming Cheng Lin – hardware and microcontroller unit development
- James Guerra – software development

For the first phase of our product development, each group member is responsible for the feature of the Smart Crutch assigned to them. Each member performs research, experimentation and design of his assigned feature. Working features are demonstrated among group members and evaluated for their proper functionality and the constraints involved.

The second phase of the product development will involve minor integration of individual features for testing. The motion sensor, for example, will be connected to the microcontroller unit and tested for proper data acquisition by the microcontroller. In case of conflicts for the design between features, the simplest but effective design approach always takes precedence.

The last phase of the product development involves full integration of the features and testing of the device. The last design phase also includes minor changes adjustments to the design like addition of a small structure to support the microcontroller unit and integration of a 6V power source for the whole system.

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Glossary

ISO	International Standards Association
CSA	Canadian Standards Association
LED	Light Emitting Diodes
RF	Radio Frequency
Axillary	Armpit

1 Introduction

The Smart Crutch is a pair of underarm crutches equipped with friction and motion sensors that will teach the user how to crutch properly to avoid sliding. With the friction sensing motor that measures the friction and the motion sensor that measures the angle position of crutches, the system will undergo a detailed calculation based on the measurement to conclude if the user has the tendency to fall. The Smart Crutch also has other security features including the extra mechanical support during the slip motion and the emergency alarm system if an accident occurs. The functional requirements for the Smart Crutch, as proposed by Asa Concepts, are described in the following functional specification.

1.1 Scope

The scope of this document is to outline the functional requirement of the Smart Crutch. This document describes the functionalities of the following fives major parts of the Smart Crutch: The overall system picture, friction sensor, motion sensor, fall- prevention mechanism, warning system, alarm system, user interface and microcontroller unit. This document also discusses all detailed function requirements which is used as a reference guide during the development.

1.2 Audience

This document is intended for all the Asa Concepts design engineers. They should refer to this document during all the development stage to ensure the design work meet all the function requirements. This document also helps the marketing manager to better understand our product and thus he can start looking for potential buyer and investors for the final product.

1.3 Classification

[Rn-p] A functional requirement specification.

In this convention, **n** means the functional requirement number and **p** stands for three different development phases in the timely order.

I stands for the proof-of-concept stage.
II stands for the ongoing developing stage.
III stands for the final production stage.

2 System Requirements

The following requirements are presented for the smart crutch system.

2.1 System Overview

The Smart Crutch system will have the following main features:

1. Preventive mechanism for extreme cases of possible user slipping.
2. Alarm system in case of user accident.
3. Accessible user interface for entering user identification information, weight and age.
4. Warning mechanism for cases of possible user fall.

The following figure shows how the features are implemented during system operation.

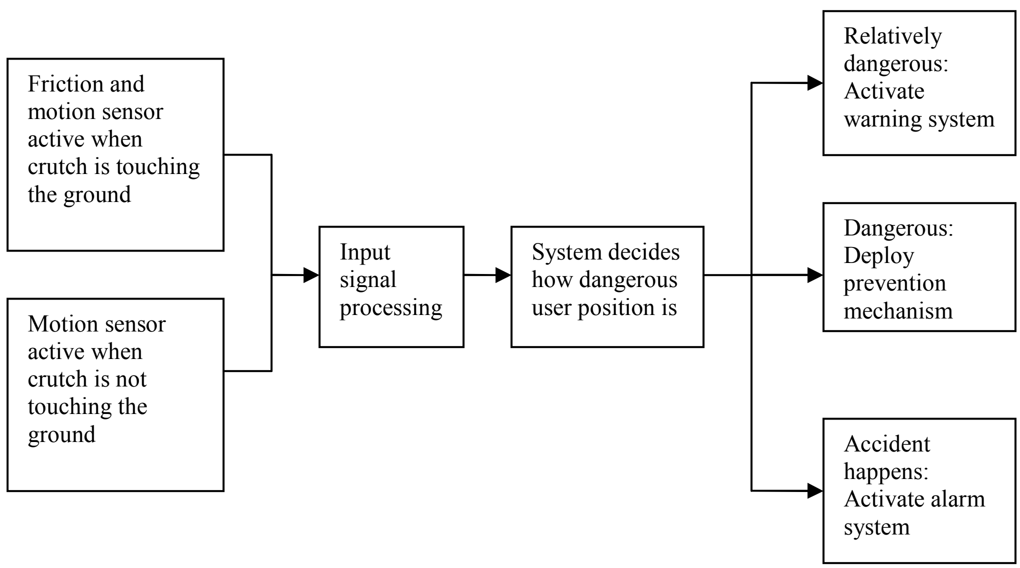

Figure 1: High level system block diagram

The Smart Crutch will not replace the proper usage of a normal axillary crutch. As recommended, the two-point, three-point and four-point gait procedure for using a crutch must still be used [1]. The Smart Crutch will only activate its warning mechanism and prevention mechanism in cases where there is possible slipping or when the ground is slippery or the user purposely increases the angle of between the crutch and the ground for increased propulsion. The alarm mechanism will only activate when the user falls.

The crutch must be able to detect different possible degree of danger for the user. The remote alarm system will be activated if the crutch is detected at a tilt position with angle greater than 80 degrees or less than 5 degrees with respect to ground or if there a sudden movement by the crutch. The prevention mechanism will deploy if there is a sudden movement with the crutch and the friction between the crutch and ground is detected as unstable. The warning system will only activate if the friction sensor detects a slippery ground.

Figure 2-3 shows the labeled features of the Smart Crutch system.

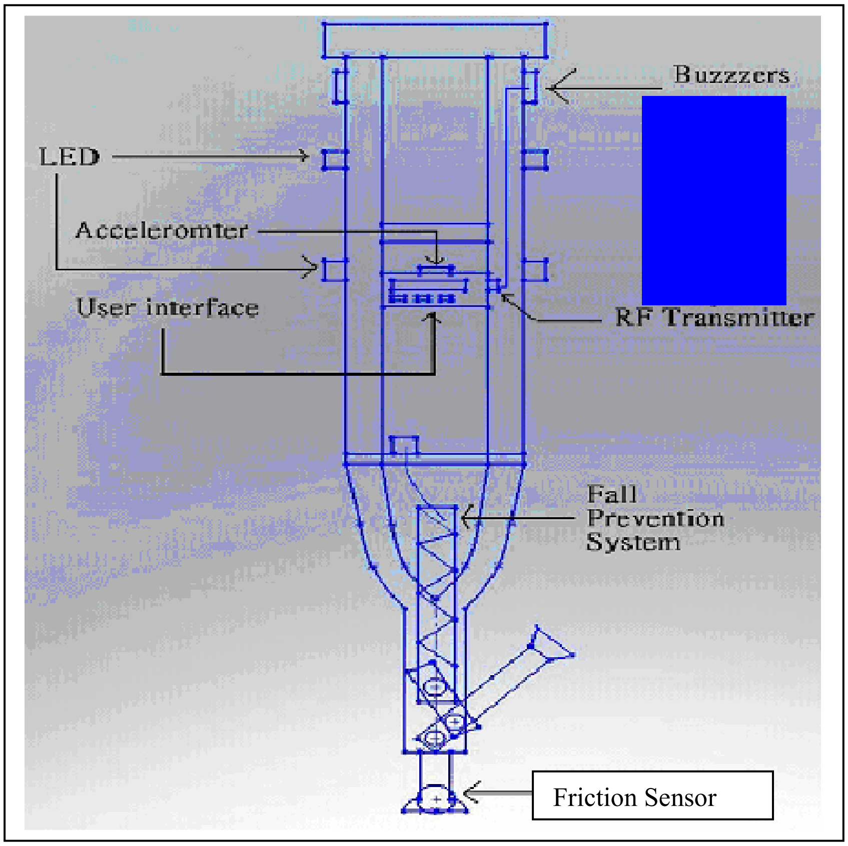

Figure 2: Smart Crutch system

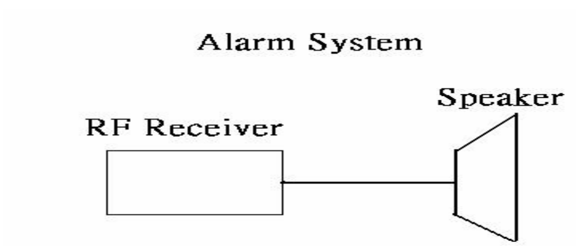

Figure 3: Alarm System

2.2 General Requirements

[R1-II] The crutches can be used as normal axillary crutches.
[R2-III] The crutch is adjustable for a user height of 5'1'' to 5'11".
[R3-III] The retail price of the crutch will not go over $125.
[R4-I] The added weight of the features will not exceed the total weight of the crutch.

2.3 Physical Requirements

[R5-II] The crutches will have an adjustable length of 52"-60".
[R7-III] The crutch structure will look like a standard axillary crutch.
[R8-II] Modules implementing each feature are independent and can be easily replaced.

2.4 Electrical Requirements

[R9-II] The onboard power supply will be made up of 6V rechargeable battery pack.
[R10-III] The battery pack can be recharged using a wall-to-wart power adaptor supplying 6V from a standard North American 110V/120V at 60Hz AC wall outlet.
[R11-III] The power adaptor will have a length of at most 3 m.
[R12-II] The crutch can enter a power saving mode after being idle for 10 minutes.
[R13-III] The battery pack can supply power at a minimum of 3 hours of continuous crutch operation.
[R14-II] An RS232 port will be available on the microcontroller board for firmware updates.
[R15-II] Voltage nodes near sensors (motion and friction sensor) and the microcontroller board will be available for testing and debugging.

2.5 Mechanical Requirements

[R16-III] All sensors are free of control and independently operating from one other.
[R17-II] All non automatic parts are controlled using springs, gears and pulley systems.
[R18-II] All automatic parts are electronically controlled from the microcontroller board.
[R19-III] Added features for the Smart Crutch must not obstruct the normal use of the handgrips and axillary rests.
[R6-III] The crutches will be made of metal with rubber padding for handgrips and axillary rests.

2.6 Environmental Requirements

[R20-I] The crutch can be operated normally between -12^oC to 45^oC.
[R21-II] The crutch can be operated normally on all walking surfaces.
[R22-I] The crutch will produce minimal noise of not greater than 50 dB during normal operation.

2.7 Standards

[R23-III] The crutch will conform to ISO 9999:2007 for the proper assistive product classification. [2]
[R24-III] The crutch will conform to CSA Electrical Aids for Physically Disabled Person Standard. [3]

2.8 Reliability and Durability

[R25-II] The mechanical components of the crutches can withstand a sudden fall.
[R26-II] The crutches can support up to 300lb person.
[R27-II] The electrical components of the crutches can withstand a sudden fall.
[R28-III] The crutches can be repaired by trained technicians.
[R29-III] The crutches firmware controlling the warning, preventing and notifying systems can be updated regularly or tailored to a particular user.

2.9 Safety Requirements

[R30-III] All electrical connections on the crutches will be insulated.
[R31-III] All mechanical aspects parts of the crutch must be rigid and strong.
[R32-III] Parts of the crutches will not interfere with the proper crutch usage.

2.10 Performance Requirements

[R33-III] The crutches system will initialize itself after power on for about 500ms.
[R34-II] The crutches will respond to possible slippage of the user within 1s.
[R35-II] The crutches will send an alarm signal to a remote alarm system during an accident within 1s.
[R36-II] The crutches will continue to monitor possible user slipping every 10ms interval.

3 User Interface and Microcontroller Unit

The microcontroller unit samples signals from the motion and friction sensor. It calculates the possibility of the user falling based on the weight of the user and gathered data from the sensors

The user interface provides a user-friendly interface to the crutch user. It will consists of 5 buttons and requires minimal technological knowledge from the user.

3.1 General Requirements

[R37-III] The user interface requires the user to enter its name or identification number.
[R38-III] The user interface requires the user to enter its weight and age.
[R39-III] The user interface must allow the user to activate normal operating procedure of the crutch.
[R40-III] The user interface must allow the user to deactivate normal operating procedure of the crutch.
[R41-III] The user interface displays the information provided by the user during system setup.
[R42-III] The user interface displays warning message in case of possible user slippage or user accident.
[R43-III] The user interface display normal operating message during normal operation of the crutch.
[R44-III] The user interface displays errors for malfunction detectable by the microcontroller unit.
[R45-III] The user interface must allow the user to disable remote alarm system feature.
[R46-III] The microcontroller unit determines possible user slipping based on user weight and input signals from sensors.
[R47-III] The microcontroller unit can activate and deactivate the warning system.
[R48-III] The microcontroller unit can send distress signal to a remote alarm system using an RF transmitter.

3.2 Electrical Requirements

[R49-III] The microcontroller unit detects electric signals from sensors.
[R50-II] The microcontroller unit requires 5V during system operation.
[R51-II] The microcontroller unit goes to power down state after 10 minutes of idle operation.
[R52-III] The microcontroller unit electrically controls the prevention mechanism.

3.3 Usability Requirements

[R53-III] The user interface must take into account all kinds of users.
[R54-III] The user interface will only have 3 step procedure to setup the Smart Crutch system.
[R55-III] The user interface will only have 5 pushbuttons for data entry.
[R56-III] The user interface will have a readable display written using English language.

[R57-III] The written user manual will use English, Chinese and Arabic languages.

4 Friction Sensor

Friction sensor is a newly designed active sensor to detect the coefficient of friction of the ground using a motor. The friction sensor is not a sensor that can be picked up from a shelf. It was designed by our team and serves the microcontroller with a very close approximation of the coefficient of friction of the ground.

To detect the coefficient of friction, a small motor that constantly rotates a small wheel that barely touches the ground provides the source of coefficient of friction between the ground and the crutch. The torque applied to the motor from the ground is proportional to the current drawn by the motor from the battery. By placing a resistor on the way of the input to the motor, the voltage across the resistor is measured. The varying electrical signal from the motor is fed to the microcontroller unit for interpretation.

The system has to be tested on different surfaces at the point of slip to find the linear relationship between the voltage across the resistor (the proportional value to the coefficient of frication of the ground) and the voltage out of the accelerometer (the proportional value to the angle of the crutch and the surface)

4.1 General Requirements

[R58-II] The friction sensor must constantly sample the coefficient of friction between the ground and the crutch.
[R59-III] The friction sensor must not be affected by the weight of the user.
[R60-III] The friction sensor must operate independently and only supply electrical signals to the microcontroller unit.
[R61-III] The friction sensor must send an activation signal to the microcontroller unit whenever the sensor touches the ground.

4.2 Electrical Requirements

[R62-II] The friction sensor requires an input voltage of 6V from the battery pack.
[R63-II] The friction sensor must not send a signal anything greater than 5V to 200 mA to the microcontroller unit.
[R64-III] The friction sensor must condition the signal before sending it to the microcontroller unit.

4.3 Physical Requirements

[R65-III] The wheel of the friction sensor must barely touch the ground.
[R66-III] The size and weight of the friction sensor must be minimal (not greater than 200g).
[R67-III] The friction sensor must not hinder crutch from properly having a normal grip on the ground.

4.4 Mechanical Requirements

[R68-III] The motor/wheel mechanism must be smoothly adjustable as the sensor tries to barely touch the ground.
[R69-II] The friction sensor must depend on mechanical systems such as springs, shafts and o-rings for the adjustable movement during contact with the floor.
[R70-III] The motor controlling the wheel of the friction sensor must have high torque.

5 Motion Sensor

The motion sensor is made up of an accelerometer measuring the angle of the crutch with respect to the ground. The motion sensor is another independent sensor feeding signals to the microcontroller unit.

5.1 General Requirements

[R71-II] The motion sensor provides measurements of the angle between the crutch and the ground.
[R72-III] The motion sensor must detect if the crutch is lying parallel to the ground.
[R73-III] The motion sensor is stable when the crutch is standing perpendicular with the ground.
[R74-III] The motion sensor must work independently from all other parts of the system, providing only signals to the microcontroller unit.

5.2 Physical Requirements

[R75-III] The motion sensor must be located near the microcontroller unit for a more compact system.
[R76-III] The motion sensor must be enclosed in rigid enclosure to avoid damage during falls.

5.2 Electrical Requirements

[R77-III] The motion sensor requires 5V from a power supply.
[R78-II] The motion sensor must not send any signal greater than 5V and 200mA to the microcontroller unit.
[R79-III] The motion sensor must send a large pulse lasting not less than 10 ms to the microcontroller unit whenever the crutch falls onto the ground.

6 Warning and Alarm system

The warning system will consists of 4 LEDs and 2 buzzers on the crutch and will only warn the user in case a slippery surface has been detected. The warning system is controlled by the microcontroller unit only.

The alarm system will consist of a transmitter and receiver devices where transmitter send distress signals to the receiver as controlled by the microcontroller unit.

6.1 General Requirements

[R80-III] The warning system will notify the user that the ground is slippery.
[R81-III] The warning system can be deactivated by the user through the user interface.
[R82-III] The warning system will be automatically deactivated when there is no more threat to the user.
[R83-III] The remote alarm system will be activated in case the user falls.
[R84-III] The remote alarm system can be turned off using a switch.
[R85-II] The buzzer for the remote alarm system will be quiet and only produce a beeping sound once the alarm is set off.

6.2 Physical Requirements

[R86-II] The antenna for the receiver and transmitter must be 17.2 cm in length for proper data transmission.
[R87-III] The receiver and transmitter is located closely the microcontroller unit for a compact design.
[R88-III] The buzzers and LEDs of the warning system are embedded on the crutch structure.

6.3 Electrical Requirements

[R89-III] The transmitter and receiver modules each requires 5V power supply
[R90-III] The transmitter and receiver operates using AM at 434MHz carrier frequency.
[R91-III] The buzzer and LEDs of the warning system requires 5V for power.

6.4 Standard Requirements

[R92-III] The RF transmission should conform to IEEE C95.1-1999, the human exposure standard for 3 kHz to 300 GHz. [4]
[R93-III] The RF transmission should conform to FCC regulation. [t]

7 Fall - Prevention system

The purpose of the fall prevention mechanism is to provide the user enough support to keep an upright position after the crutch has undergone a slip. It is necessary to have dimensions adjusted to provide the least stress on the user and maintain a reasonable stability. A pair of stabilizer bar will function as the support mechanism creating a tripod system with the third pod being the rubber contact of the crutch on the floor.

7.1 General Requirements

[R94-III] The support mechanism must be automatically activated by the microcontroller unit.
[R95-III] The support mechanism can be reset manually and mechanically.
[R96-I] The support mechanism must be deployed in less than 1s after the microcontroller unit detects a rubber contact slip.

7.3 Physical Requirements

[R97-III] Both stabilizer bar lengths should be such that it has contact with the floor when crutch is at 80 degrees with respect to the ground.
[R98-III] Both stability bars should be able to rotate between 0 – 70 degrees.
[R93-III] Both stability bars should have locking angle intervals < 10 degrees.
[R100-III] Both stability bars should have lengths < 10”.
[R101-III] Both stability bars must be parallel at all times.
[R102-II] Both stability bars should provide enough friction for a stable tripod system.
[R103-III] The mechanism must provide room for electrical connection between the friction sensor and microcontroller unit.
[R104-III] The mechanism must not interfere with the friction sensor.

7.2 Mechanical Requirements

[R100-II] The support mechanism can be reset using a pulley system.
[R100-III] The stabilizer bars must be held upright when not deployed using a

locking mechanism.

System Test Plan

The major goal for Asa Concepts with the Smart Crutches is to provide disabled people a safest walking assisting tool without worrying about jeopardizing their injured leg while walking. To meet such a high expectation, Asa Concepts come up with two lists of test plans. The first list applies to the individual part development stage which happens before the whole system integration. The second list applies to the whole system integration stage including the final product test plans.

Test plan for individual part development stage

1. The Friction Sensor: The friction sensor needs to predict the slip motion accurately based on the contact surface, user's weight, and the angular position of crutches. Our engineering team will conduct several tests in different contact surface, ranging from the most slippery one to the least slippery one. They will make sure the sensor measures the friction accurately and consistently through out different contact surfaces.
2. The Prevention Mechanism: When the prevention mechanism receives a slip detection message from the microcontroller, it needs to release the extra mechanical support fast enough so that crutch users do not fall down. Our engineer team will verify the validity of this part by checking the response of prevention mechanism with different angular position and contact surfaces during the slip motion.
3. The alarm system and the motion sensor: the alarm should be off during the safe operation and on when it receives an emergency message. The motion sensor should be able to measure angular position of crutches accurately.

Test plan for the whole system integration stage

1. The prototype construction: The prototype construction will start once we finish testing all the individual part and verifying their interaction with the microcontroller development board. We will conduct a series of hardware test by probing the ICs to verify the correct functionality of the prototype circuitry. We will also do a current draw measurement on our power circuitry to calculate the battery life of Smart Crutches.
2. The weight endurance: We will test the weight endurance of crutches and the friction sensor by applying a large magnitude of forces and then put a maximum weight endurance label on crutches.
3. Normal crutch operation: Our engineering team will compare the user experience of using Smart Crutches and normal crutches. We will make sure the users do not feel much difference during the normal crutch operation. Our added features and

extra supports should be positioned in adequate place and also with minimized size and weight so that users do not have troubles carrying our Smart Crutches.

4. User-friendly interface: Our engineering team will make sure Smart Crutches are easy to use with clear labeling on the user input buttons and also the understandable message on the LCD display. We will find some other people who are not involved in the development cycle and ask for their feedback on this.
5. Overall system response: Once we finish prototyping our Smart Crutches, we will conduct an overall system test including the accuracy of the slip motion detection, the validity of the prevention mechanism, and the proper response of the alarm system during the emergency.
6. The prototype protection guard: The prototype protection guard should be strong enough to protect all the electronic parts reside in the crutch during the falling motion. We will conduct this test by purposely dropping the crutch with different angular position to verify the expected result.

Conclusion

This document outlines the functional requirements for the Smart Crutches to be a safe and easy-to-use walking assisting tool for the disabled people. This document also includes the system test plan that will be followed by Asa Concepts design engineers to manufacture a fully functioning product. The product development takes place in three stages: proof of concept stage, ongoing development stage, and final product integration stage. Our design team is currently on the ongoing development stage with off-the-shelf items considered as on the final stage of development. We are confident that the Smart Crutches will meet all the functional requirements specified in this document and the final product can be delivered in time by our target date of April 14, 2009.

References

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