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February 16, 1999

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
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Re: ENSC 370 Remote Transcranial Doppler Ultrasound Orientation Device Functional Specifications

Dear Dr. Rawicz,

We are submitting the document entitled, *Remote Transcranial Doppler Ultrasound Orientation Device Functional Specifications*. Our intention is to design an electromechanical means of adjusting a Transcranial Doppler Ultrasound transducer used in measuring blood velocity in a cranial artery. Remote adjustment will allow the operator to find an optimal signal without having to be at the subject's side. The attached document outlines the requirements and specifications of our system. The main components of our system are an input device, a control unit, and an actuating mechanism.

KineTech Solutions consists of four engineering science students at Simon Fraser University: Cyrus Sy, Carmel Cinco, Kevin Ko, and Michael Ilich – each with an interest in electronics as well as in the field of kinesiology. If you have any questions or concerns, please contact Michael at (604) 944-6302 or via email at ilich@sfu.ca. Contact *KineTech Solutions* directly by email at kcmc-ensc370@sfu.ca.

Sincerely,

Michael Ilich
KineTech Solutions

Enclosure: *Remote Transcranial Doppler Ultrasound Orientation Device Functional Specifications*

Submitted by	KineTech Solutions Cyrus Sy, Carmel Cinco, Kevin Ko, Michael Ilich
Contact	Michael Ilich School Of Engineering Science Simon Fraser University ilich@sfu.ca
Submitted to	Andrew Rawicz School of Engineering Science Simon Fraser University Steve Whitmore School of Engineering Science Simon Fraser University
Date	February 16, 1999

Executive Summary

Over the last 20 years, the development of Transcranial Doppler (TCD) sonography has allowed researchers, such as those at Simon Fraser University's Aerospace Physiology Lab, to use noninvasive techniques to assess intracranial circulation. Data collected from TCD can help researchers understand the physiological effects of extreme environments such as high and low altitudes. Within the rest of the medical community, TCD has proven to be useful in helping to predict strokes.

The problem with existing TCD ultrasound systems is that the ultrasound sensor must be manually positioned by hand. Each time the transducer needs to be repositioned, someone must be present at the side of the test subject to make the appropriate adjustment. The problem is exacerbated when experiments need to be done in a hypo-hyperbaric chamber, which simulates high and low altitudes. The data-analyzing computer must remain outside of the chamber — for safety purposes. It would be inconvenient and even dangerous to always have the test operator and test equipment inside the pressurized chamber to adjust the position of the sensor.

KineTech Solutions has decided to design and prototype an electro-mechanical system which can alter the position and orientation of the transducer from a remote location. Our primary goal is to create a remote control system that would provide the same level of accuracy and user intuitiveness as the current manual positioning system. Additionally, our remote system will be designed to withstand the extreme environmental conditions inside hypo-hyperbaric chambers.

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1.0 Introduction

The Transcranial Doppler (TCD) ultrasound is a noninvasive technique used to measure blood flow velocity in cranial arteries. In this system, a crystal transducer emits ultrasound pulses towards the target artery and measures the reflected ultrasound. The velocity of blood is then calculated using the Doppler shift in the reflected waves. The TCD ultrasound is used widely in the medical community and in human physiology laboratories. Knowing the speed at which blood is traveling through intracranial arteries can help detect signs of stress, as well as prevent deaths due to stroke and anemia.

In its current state, a trained operator must manually position and orient the TCD transducer such that it points precisely at the artery to be observed. This not only calls for a steady hand and experience in finding the artery, but most importantly, it requires the presence of an operator at the side of the subject when repositioning and reorienting is necessary.

KineTech Solutions Remote Transcranial Doppler Ultrasound Orientation Device will allow test operators and researchers a way to remotely orient the transcranial Doppler transducer. Its uses become obvious when trying to measure intracranial blood flow of subjects in a hypo-hyperbaric chamber (where test subjects are exposed to very low or extremely high atmospheric pressures).

This document provides the functional requirements of our proposed Remote Transcranial Doppler Ultrasound Orientation Device. The intended audience for this paper is Dr. Andrew Blaber, Dr. Andrew Rawicz, Mr. Steve Whitmore, and the team at KineTech Solutions.

2.0 Background

Extensive research is currently being conducting in the Environmental Physiology Unit (EPU, est. 1981) at SFU to examine human physiological response to extreme environmental conditions. Components of the research apparatus include a climatic chamber, hot and cold immersion tanks and an altitude/diving chamber. The EPU allows simulation of a variety of temperatures and pressures under wet and dry conditions, below and above sea level.

The component that most concerns our project at hand is the altitude/diving chamber. It consists of an entrance lock, wet chamber and living chamber. The living chamber can accommodate up to four divers and includes four beds, a table, and systems for communication and fire detection/suppression as well as breathing masks. The chamber is rated to a pressure of 305 meters and an altitude of 12,000 meters. Internal and external doors allow separate pressurization or evacuation of either the wet chamber or living chamber. Each chamber is controlled from a central console that monitors air purity, temperature and water filtration. The altitude/diving chamber will also be referred to as the hypo-hyperbaric chamber.

Dr. Andrew Blaber, the Kinesiology professor who we approached for this project, is concerned with the analysis of blood cell velocity through the major cranial arteries when humans are subjected to extreme depths and altitudes. His analysis is achieved using DWL Electronic Systems, MultiFlow® TCD Ultrasound Monitoring System (see Figure 1) . MultiFlow consists of a Doppler Ultrasound sensor connected to a dedicated 486-based computer. The MultiFlow computer has a built in display, stereo-loudspeakers and FFT (Fast-Fourier-Transform) for signal analysis. Test operators monitor pulses received from the ultrasound probe at the terminal. The operator can adjust the probe by hand while looking at a graphical and audible representation of the signal from the terminal to find the optimal signal.

Figure 1: TCD Ultrasound Monitoring Unit[1]

[1] Photo taken from DWL Electronic Systems website http://www.dwl.de/home_e.html

3.0 System Overview

The Remote TCD Ultrasound Orientation Device begins with an input from the test operator— likely through a joystick or mouse. The operator input is processed and control signals are sent to the sensor actuating mechanism to move the Doppler sensor to the desired position. Based on the audible feedback from the TCD ultrasound system, the operator will adjust his/her input as needed. The system process is depicted in Figure 2.

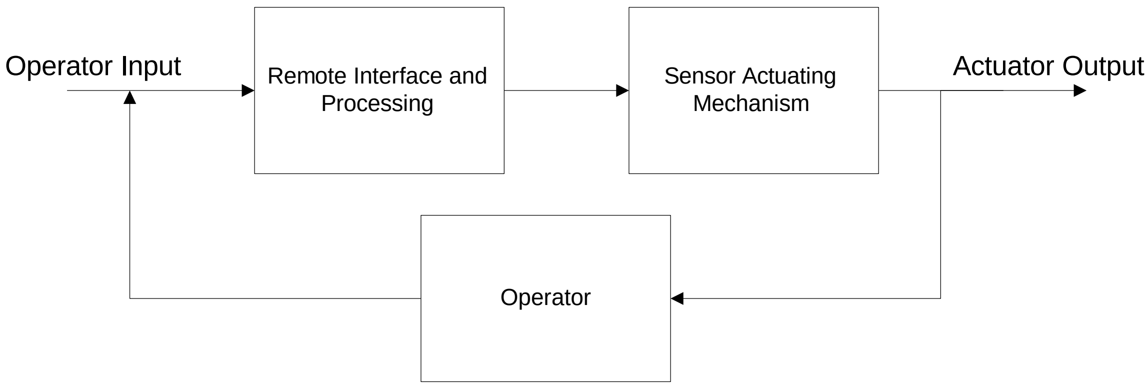

Figure 2: System Diagram

The Remote Interface and Processing Module (RIP) will consist of a suitable input device, and a PC or microcontroller based control unit which reads the test operator's input, converts the signal appropriately, and sends control signals to the Sensor Actuator Module.

The Sensor Actuator Mechanism Module (SAM) consists of the actuating mechanism to control the Doppler sensor and all other necessary components and packaging.

4.0 Remote Interface and Processing (RIP)

4.1 Hardware Requirements

Remote hardware required for site installation will include a 486 or Pentium computer with a minimum of 16MB RAM and an external parallel port and serial port. A custom made cable will be required to connect the PC to the data communications interface of the hypo-hyperbaric chamber. This cable patch will use one standard IBM Centronics attachment (to be connected to the parallel port, ISO9000 compliant) and two BNC coaxial connectors .

User control of the sensor actuators will be accomplished by means of a suitable input device. Hardware drivers specific to the input device will be provided in addition to the controller software.

4.2 Software Requirements

The 486/Pentium computer must be equipped with either the Windows 95 or Windows 98 32-bit operating systems. The software will be written in Borland C++ 4.52 as a 32-bit executable specifically for a 486 based platform. Also included will be drivers for the input device, such that the device may be calibrated within the Windows environment as well as within the controller software.

The software will consist of a calibration screen as well as coordinates that track the position of the sensor. The initial calibration will establish a reference from which to calculate coordinates of the sensor’s traversal. Extensive use of the Windows 95/98 parallel communications facility will ensure accurate transmission of position instructions.

Figure 4 is a screenshot of the proposed calibration screen that will include real-time coordinate display and graphical representation.

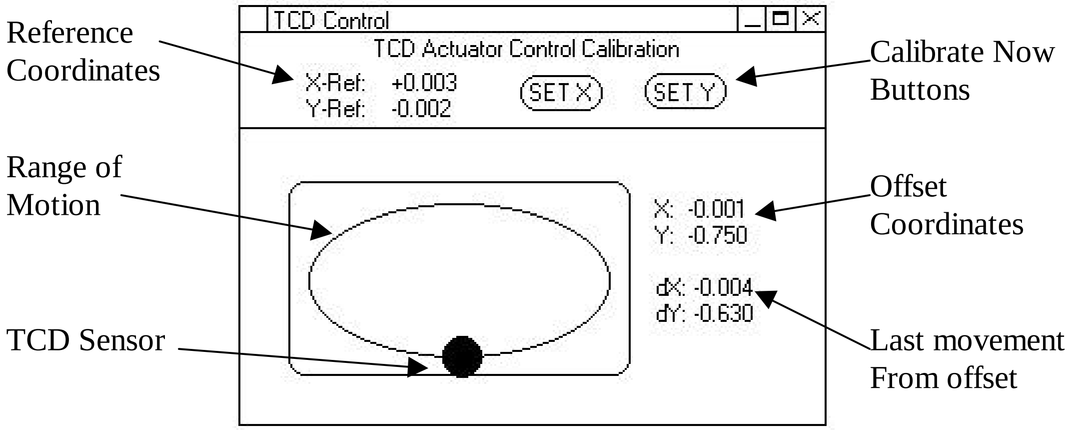

Figure 4 TCD Control Screenshot

4.3 User Interface Requirements

Ideally, the RIP interface will mimic the current manual positioning method. At all times, the test operator must be informed of the TCD's current position. In addition, any GUI or console interface must be designed for optimal comprehensibility. This would include a well-organized layout of the required data and easy to use tool bar and/or command line.

The manual positioning method involves grabbing the spherical back end of the crystal unit and rotating the crystal unit about its cup as illustrated in Figure 5. Figure 6 shows the existing TCD Ultrasound Mounting mechanism as it would be attached to the test subject's head.

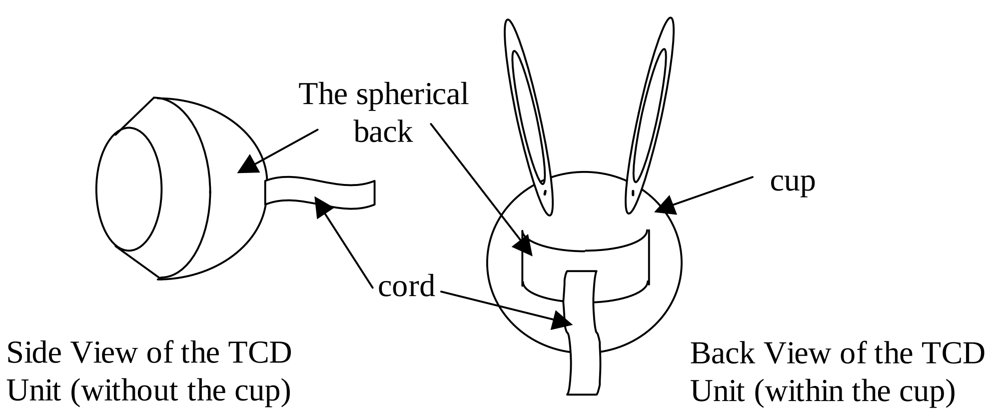

Figure 5: Side view and Back view of the Crystal Unit

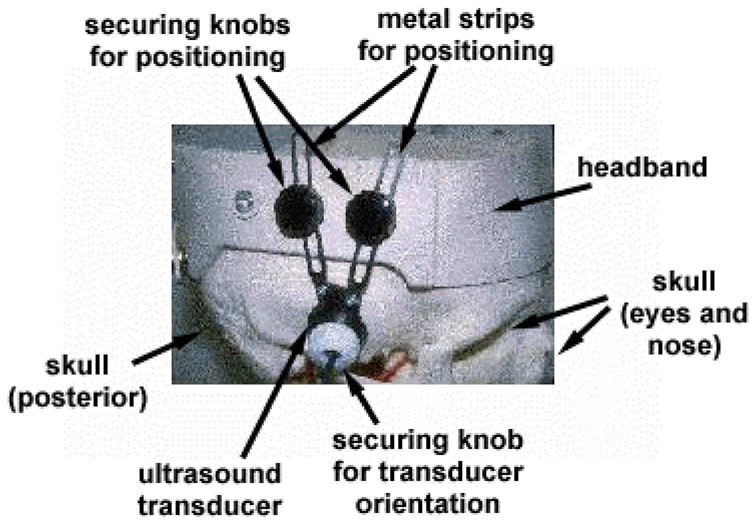

Figure 6: The Existing TCD Ultrasound Sensor Mounting Mechanism[2]

4.4 Physical Requirements

Since the RIP consists of standard computer components and devices, the physical requirements will be subject to the manufacturer's specifications. Ideally, the whole system will be able to fit on a work table next to the existing TCD Monitoring unit.

[2] Photo taken from Sana-Med website: http://www.sana-med.com/frames/fixation.html

4.5 Environmental Requirements

The RIP will be designed to operate under normal office/laboratory conditions.

4.6 Safety Requirements

Since the RIP will not be used in the hypo-hyperbaric chamber, the RIP need not follow the chamber's pressure safety standards. However, the RIP will follow the CSA safety standards outlined in document CAN/CSA-C22.2 No. 601.1-M90.

4.7 Electrical Requirements

If a PC will be used to control the RIP, it will use the standard 110V electrical outlet. In addition, the cable connecting the RIP to the hypo-hyperbaric chamber will supply the SAM with, at most, 24V.

5.0 Sensor Actuator Mechanism (SAM)

5.1 Hardware Requirements

Our selection of Sensor/Actuator hardware must allow full freedom of circular movement of the TCD ultrasound probe within its bowl-shaped track. The electromechanical implementation should allow an accuracy to within 2 degrees, which will eventually be designated the smallest unit of movement within the semi-circular plane. The actuators must be rated to draw a minimal amount of current, dissipate a minimum amount of power and operate at a DC voltage of less than 24V. The packaging used for the orientation unit should shield all components from electrical noise as well as pressures experienced within the hypo-hyperbaric chamber.

A BNC coaxial cable that is both pressure and noise resistant will be employed to ensure that a clear signal is transmitted from the remote PC, through the data communications interface, and into the chamber directly to the orientation unit.

5.2 Physical Requirements

The enclosure for the Sensor Actuator Mechanism will be light-weight and as unobtrusive as possible to the person taking the Doppler Ultrasound test.

Table 1: SAM Physical Requirements

Height	70 mm maximum
Length	70 mm maximum
Width	50 mm maximum
Weight	500 grams maximum

5.3 Environmental Requirements

Table 2: SAM Environmental Requirements

Pressure Range	Diving Pressure - 305 m below sea level Altitude Pressure - 12000 m above sea level
Temperature Range	-40°C to +80°C
Humidity	ambient conditions present in hypo-hyperbaric chamber
Heat Dissipation	Minimal

The enclosure and components of the SAM will be chosen to withstand the extreme conditions of the hypo-hyperbaric chamber.

5.4 Safety Requirements

The actuating mechanism of the orientation device must be enclosed in a package such that no protruding features may harm the test subject. Electrical components will meet CSA biomedical standards and be able to withstand the wide range of pressures in the altitude/diving chamber (pressures of 305 metres and altitude of 12,000 metres). Any sparks or electrical mishaps taking place under extreme pressures may end in fatal results. Likewise, all wires carrying currents should be safely concealed in a pressure resistant packaging. Heat generated from the system should be kept to a minimum and dissipated as quickly as possible.

5.5 Electro-Mechanical Requirements

The maximum potential difference allowable through a BNC cable is 24 V; therefore, all electro-mechanical components must run efficiently given this upper limit. Audible noise should not interfere with the transducer's performance, and electrical noise should be reduced to a minimum.

Response time (from the user input to the sensor movement) should be less than 1.5 seconds. As well, a high level of actuator resolution is necessary for optimal operation — ideally, resolution allowing movements as fine as 2°. The movement of the sensor should, at a bare minimum, include the motion obtainable with the currently-used manual device.

5.6 Standards

All components and connections to be used inside the hypo-hyperbaric chamber will follow CSA medical standards with respect to electrical and safety requirements.

5.7 Potential Limitations

Due to the cost of high quality materials and components, the device enclosure or components may not be able to withstand the entire range of chamber pressures. This area will be improved upon in the future should it appear to be a problem. Other areas may be subject to limitations due to component costs are resolution and accuracy.

Although this device will solve the problem of orienting the sensor towards the target artery, the test operator must initially adjust the sensor position to an acceptable proximity before the test subject enters the hypo-hyperbaric chamber. (i.e. in the approximate vicinity of the artery).

6.0 Testing

To ensure the proper function and safety of the Remote TCD Orientation Device, all the functional requirements must be tested. All the functional requirements listed in this document can be verified or tested using standard procedures.

Pressure robustness tests will be carried out on the electrical components to be used in the hypo-hyperbaric chamber. This involves observing the behavior of each electric component when subjected to the pressures created in the chamber. The current SFU TCD engineer has carried out pressure robustness tests and has offered to aid us in conducting our own pressure tests within the hypo-hyperbaric chamber.

Operation of the SAM in different orientations will also be tested. The SAM will work no matter if the test subject is standing, sitting, or lying down. The operation of the SAM in different orientations would depend on its mass and component organization. More testing would need to be done in the future if the users of the Remote TCD Orientation Device would like to use it for underwater research.

The RIP and SAM will also be tested for communication reliability. This would involve testing each position and each movement combination of the RIP with the corresponding position and movement of the SAM.

7.0 Conclusion

This document has detailed the functional considerations of constructing the Remote Doppler Ultrasound Orientation Device. These functional specifications were developed in conjunction with Dr. Andrew Blaber and the Aerospace Physiology Lab. Since this project is being funded by Dr. Blaber, KineTech Solutions has entered into an Intellectual Property agreement with Dr. Blaber. David Foord of the University Industry Liaison Office (UILO) has agreed to draft a standard intellectual property sharing agreement between Dr. Blaber and KineTech Solutions. KineTech solutions is expected to retain rights to the original design and any profits from commercialization.