



# Proposal for the Development of an Infant Monitoring System

*For the Purpose of Preventing Sudden Infant Death Syndrome (SIDS)*





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## Executive Summary

Many more children between the ages of one month and one year die of Sudden Infant Death Syndrome (SIDS) each year than all who die of cancer, heart disease, pneumonia, child abuse, AIDS, cystic fibrosis and muscular dystrophy combined.<sup>1</sup> The cause of SIDS is still unknown, however the effects are real, as an alarming number of seemingly healthy babies quietly die in their sleep. The families of SIDS victims are left in a state of shock, confusion, and helplessness.

Many of the current SIDS monitors available are expensive, difficult to use, and trigger numerous false alarms. Most of these monitors involve some type of probe, electrode, or wire that must be attached directly to the infant. Improper connections, probe damage, and probe misplacement render monitoring systems ineffective. Additionally, apprehensions about "wiring up" the baby steer parents or babysitters away from using these types of monitors.

This document proposes the development of a monitor that is integrated into the baby's mattress, thereby eliminating the need for direct connections to the baby. Such a monitor would be easier to use than currently available monitors, removing almost all chance of human error. The less-invasive nature of the system will eliminate any concerns the parent may have about connecting the baby to the monitor.

ZenTech consists of five senior engineering students with experience in signal processing, circuit design, prototyping, and board layout. The schedule for researching, designing, and building the monitoring system encompasses a period of thirteen weeks, with a working prototype scheduled for completion by April 8, 1999. The project is currently budgeted at \$900, which we will raise through a variety of sources.



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## Introduction

Sudden Infant Death Syndrome (SIDS) is the "sudden death of an infant under one year of age which remains unexplained after a thorough case investigation, including performance of a complete autopsy, examination of the death scene, and review of the clinical history"<sup>2</sup>. In Canada, 400 infants die each year of SIDS, which means it is the leading cause of death among children among the ages of one month and one year.<sup>3</sup>

SIDS was recognized before this century, but, until recently, preventative monitoring systems were not extensively researched. Development of home monitoring systems began in the mid-1970's and since then, there have been many attempts to develop a reliable and acceptable home monitoring solution. Unfortunately, many of the available monitoring systems are extremely expensive: It costs \$2000-\$3000 US to purchase a monitoring unit or \$200-\$300 US per month rental.<sup>4</sup> Another problem with current home monitoring systems is unreliability. Systems often give false alarms or, conversely, do not trigger an alarm in an emergency situation. Difficulties also arise in properly applying sensors to the infants. Until now, infant monitoring systems required that most of the system sensors be physically attached to the child. Other significant problems with current systems include human error in operating the equipment and interpreting the feedback.<sup>5</sup>

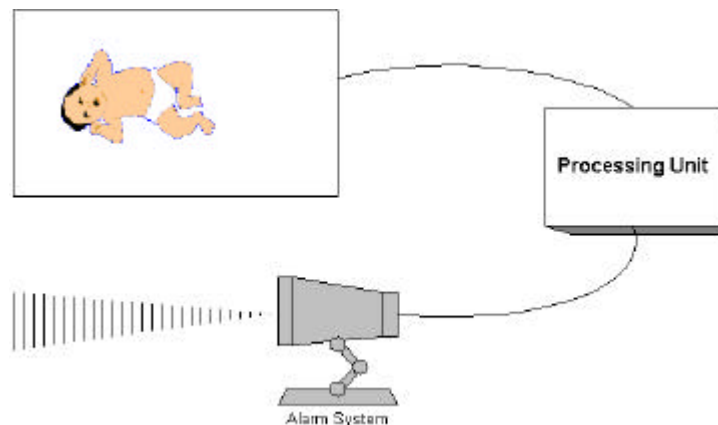
The decision to monitor an infant is an intense psychological experience for parents. The monitoring equipment may become a constant reminder of a possible infant death, or may imply the notion that the baby is 'abnormal' in some way. Another difficulty for the entire family becomes the task of finding baby sitters who are willing to apply and operate the monitoring equipment.<sup>6</sup>

The objective of this project is to design a reliable, minimally invasive monitoring system for infants. Our system will have no devices or probes needing attachment directly to the infant and will be extremely easy to use. Hopefully, by creating such an affordable system, we will ultimately be able to help in the fight against SIDS.

This document presents an overview of the proposed system, as well as implementation schemes that we have rejected. We also outline a proposed budget, discuss sources of funding, present the timeline in which the project will be completed, and define our group structure.

## System Overview

One of the fundamental design criteria for the Infant Monitor System (IMS) is minimal invasion. This is to prevent psychological stress for the family, errors due to misuse or misapplication of sensors, and to preserve the comfort of the infant. Clinical research has determined that parents and other caregivers are reluctant to use devices that must attach directly to the baby under their care.<sup>7</sup> By eliminating sensors that attach directly to the baby, the IMS will help alleviate any reservations that parents may have concerning the decision to monitor their child. The delivered IMS will be no more intrusive than the infant's crib. **Figure 1** shows a pictorial representation of the IMS.



**Figure 1 – IMS System Overview**

The IMS will initially use only the infant's respiratory acoustics as the input to the system which is represented in block form in **Figure 2**.



**Figure 2: IMS System Block Diagram**

The respiratory sounds of the sleeping infant will be acoustically amplified through a special architecture built into the mattress. Note that the sounds emitted from the child will include the heartbeat, breathing sounds, and miscellaneous noise. The signal processing unit, consisting of hardware and software components, will filter out any noise or unwanted signals from the acoustic signature gathered from the child. The remaining signal will then be analyzed to determine the condition of the infant. Should analysis show abnormal breathing or heart rate, the parents will be notified via an alarm system.

## Design Issues

### Possible Design Solutions

Despite considerable investigative and clinical attention directed towards SIDS, there is currently no clear indication of what causes SIDS, nor is there currently a fail-safe method for determining infants who are at high-risk of experiencing SIDS. From sleep studies performed on infants over the past 30 years, two possible theories have arisen explaining how SIDS occurs. One cause may be sleep apnea (cessation of breathing during sleep) characterized by an inability to revive oneself (believed to be due to the absence of certain neural transmitters, resulting in a brain 'glitch').<sup>8</sup> The other cause may be carbon dioxide poisoning which could theoretically occur due to sleeping materials such as blankets or the mattress which, in close proximity to the infants mouth, could collect toxic concentrations of carbon dioxide.<sup>9</sup> Slowly, the baby asphyxiates and as areas of the brain become deprived of oxygen and breathing slows, brain damage occurs and eventually breathing ceases.

We performed research on potential conditions and physiological observations that may be present directly before a SIDS death. There are several physiological systems and other observations that may be monitored in varying combinations in a home monitoring system. These include ambient and localized carbon dioxide concentrations, chest expansion and contraction (as a result of respiration), pulse (heart rate), breath (exhaled air with heat and moisture), acoustic signatures of breathing and heart pulses, and blood oxygen saturation. These solutions are further discussed in this section.

#### Ambient and localized carbon dioxide concentration

Although high carbon dioxide concentrations in the vicinity of the infant's sleeping quarters is unlikely, toxic concentrations would lead to asphyxiation. If a blanket or other material in the crib constricted the infant's exhaled air, there could theoretically be a build-up of carbon dioxide near the baby's nose or mouth. This high concentration of CO<sub>2</sub> could potentially cause asphyxiation.<sup>9</sup> Thus, by monitoring localized CO<sub>2</sub> levels, we would be able to detect such a situation and trigger an alarm.

#### Monitoring chest movement

The act of breathing involves the contraction and relaxation of the diaphragm muscle, which is observable as movement of the chest area. By simply observing the motion of the infant's chest, we would be able to determine whether breathing was occurring properly. Possible methods of monitoring chest movement include pressure, vibration, or acceleration sensors attached to the baby by a chest strap; motion sensors attached to the crib in a grid formation; or volume displacement measurements of the mattress in the crib.





### Pulse monitoring

A simple approach to monitoring heart rate would be to use a bracelet equipped with a sensor and a transmitter, and to have the infant wear this bracelet. A processing station similar to modern pulse monitors would then identify any pulse irregularities and trigger an alarm when an emergency condition is identified.

### Breath monitoring

Current research tends to indicate that the onset of SIDS is often accompanied by apnea (cessation of respiration). Thus, by monitoring the expelled breath from the child, we would be able to ensure that breathing did not cease for an extended period of time and that the periodicity of the breathing was regular. Three methods of monitoring respiration are monitoring the airflow out of the baby's mouth/nose, monitoring the heat signature of the breath from the baby, or monitoring the moisture content of the breath.

### Acoustic signature

By using the acoustic signatures of breathing and heart movement, we would be able to combine the heart rate monitoring and breathing rate monitoring design solutions into one. Central to this design is the simple fact that the action of breathing produces an identifiable sound in the body, as does the pulsing of the heart. By monitoring these sounds, we would be able to track the breathing rate and the heart rate, and thus be able to detect any problems.

### Blood oxygen saturation

Another method for monitoring the condition of the baby would be to measure the blood oxygen saturation of the infant. This measurement would be made with the standard hospital recovery room pulse oximetry equipment, with the finger probe sized for an infant (such units are commercially available). Normal saturation levels of oxygen in blood are well above 90%, and in the case of carbon dioxide asphyxiation, this level would almost immediately drop below 80%.

## Proposed Design Solution

Although every design solution outlined above would certainly accomplish the task of infant monitoring, there are benefits and drawbacks associated with each of them.

Localized carbon dioxide monitoring would require many sensors around the baby and the crib to pinpoint the location of high concentrations of carbon dioxide, due to the number of potential positions the infant can assume while in the crib. In addition, we would need a method of determining the location of the baby relative to any dangerous concentrations of carbon dioxide in the crib. Similarly, expelled breath monitoring would require numerous sensors to detect the source of the breath in the crib. Thus, we felt that these solutions would be too complex and expensive.

Chest movement monitoring would allow us to determine the cessation or irregularity of breathing in the baby. However, our research shows that the relative movement of an infant's chest due to breathing is much less than that of an adult.<sup>11</sup> Thus, the precision of the measurements would need to be extremely high. Also, all methods of chest movement monitoring proposed are subject to high levels of noise. This solution would be subject to numerous false alarms, thereby violating original system requirements.

Pulse monitoring requires a sensor to be attached to the infant. This violates our desire to keep the system as non-intrusive as possible. As well, in some cases, breathing can cease before the heart stops. Thus, by the time the pulse became irregular, the baby's breathing may already have ceased. Similarly, monitoring blood oxygen saturation requires pulse oximetry probes which are attached to the infant. Again, this solution would be intrusive and is therefore not desirable.

Based on the above information, we decided that the acoustic signature monitoring approach is the best solution. Our aim is to keep all sensors off the infant (that is, the sensors will be on the crib or mattress). Initially, we will design the system to monitor the acoustics of the infant's breathing and detect any irregularities indicative of the possible onset of SIDS.

### Project Enhancements

If time warrants, we would also like to incorporate heart rate monitoring into the system as our research indicates that the heart can slow to dangerously low levels even while breathing remains constant. We feel this would not be too difficult to monitor once we have filtered out the sound of breathing from the transmitted signal. To simplify operation, the ON/OFF switch will be replaced with an automatic pressure sensor switch, which will detect when the baby is on the mattress. As a safety precaution, a back-up battery power source and battery indicator will be added to guard against power failures. Final modifications could also include a temperature sensor and second-hand smoke detector because our research has shown that other, less probable causes of SIDS include body overheating and second hand smoke inhalation.<sup>3,4</sup>

## Sources of Information

Information regarding the implementation of the IMS will be collected from a variety of sources. These sources include Dr. Rawicz and Steve Whitmore (course instructors) and course TA's. We will also be consulting with Dr. John Dill concerning system usability. Outside of the school, we will be speaking with researchers, doctors, and other medical personnel at children's hospitals and SIDS awareness organizations.

Textual information will be gathered from medical and engineering textbooks in addition to related articles, books, journals, and presentations. Further reading will be carried out at numerous websites on the Internet which are concerned with our project concepts. Presently, we have made extensive use of the Canadian SIDS organizations and the SIDS Network.

Should we have time to incorporate the proposed design enhancements into our project, along with the aforementioned information sources we will be consulting members of the Kinesiology department at Simon Fraser University concerning various sensors. We have already consulted with Rick Hall, a graduate student in the department, who has completed research on force sensing resistors. In addition, we will be consulting other 370 groups who have completed projects related to our possible enhancements, such as the second hand smoke detector.

## Financial Issues

### Forecasted Costs

**Table 1** presents our forecasted materials costs.

**Table 1 – Forecasted Prototype Development Costs**

<b>Materials</b>	<b>Cost Estimate</b>
Custom mattress and mattress accessories	\$200
Sensors	\$130
Encasement	\$20
Microprocessor and evaluation board	\$200
Various electronic devices	\$150
Project Enhancements (time permitting)	\$200
<b>Total</b>	<b>\$900</b>

### Proposed Sources of Funding

To finance this project, we will be applying to student project funds in addition to soliciting funds from various health foundations and health organizations. We plan to apply for the Wighton Engineering Development Fund, which is a fund administered by members of the Simon Fraser Engineering faculty for the purpose of funding student projects. We also plan to apply for the Engineering Undergraduate Student Society endowment fund, which is another fund administered for the purpose of funding student projects. Finally, we will be appealing to Canadian SIDS organizations and various health centers to provide funding for our project.

We are confident that we will receive the funding necessary to complete this project from these various sources because this project, when complete, will offer a great benefit to society.

## Project Scheduling

Our proposed project scheduling is shown in the Gantt and milestone charts in **Figure 3** and **Figure 4** respectively.

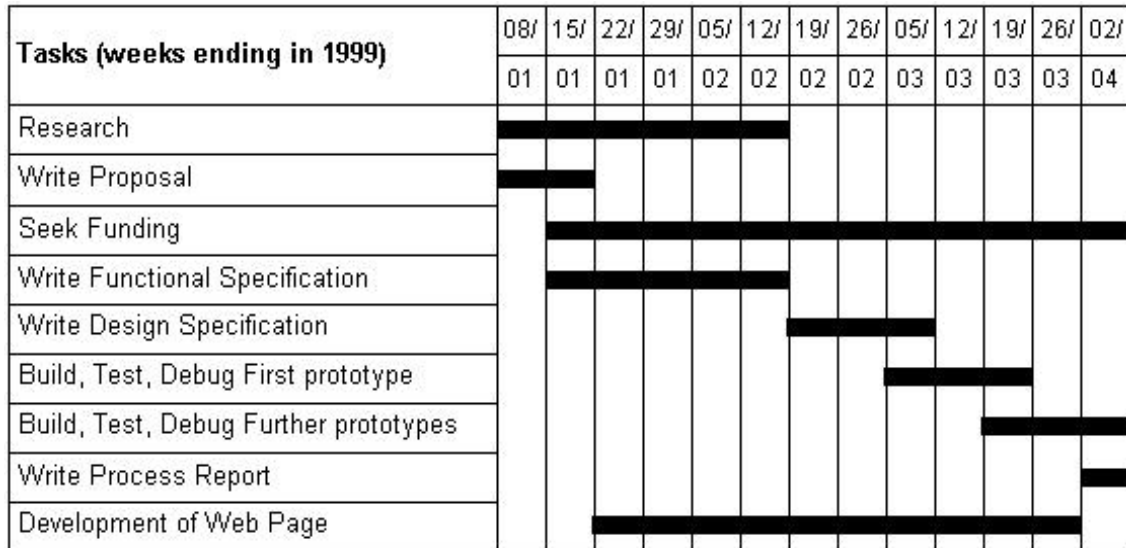


Figure 3 – Gantt Chart displaying proposed timeline

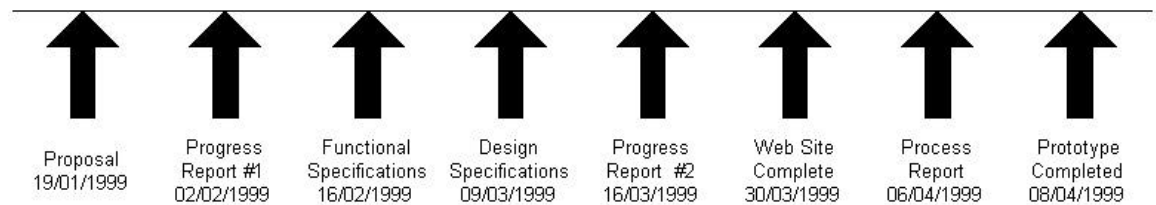


Figure 4 – Proposed milestone completion dates



## Team Organization

ZenTech Canada is a project group that has been formed for the purpose of developing an infant monitoring system. We believe that our team philosophy of distributing each of the positions of Project Leader, Marketing Department Head, and Director of Research and Technology among most or all of the team members promotes good morale, more effective decision-making, and overall team security. Our goal in team organization is to involve as many members as possible in each area of project development to ensure the equal distribution of an in-depth understanding of the project and project components. We primarily wish to avoid the problems sometimes apparent in industry today such as uninformed decision-making and project delays due to unexpected absences of key players or department heads.

The members of the group have worked well together previously on a variety of laboratory projects. The number one goal in our group interactions is clear and effective communication between group members. We have scheduled morning meetings twice each week in the ZenTech main office to ensure that product development is adhering to the timeline. Email will otherwise be our primary communication tool.

A. A. Rhiannon Coppin, Scott D. Kulchycki, Mike Sjoerdsma, Robert Trost, and Tim Wilder, the five founders of ZenTech, are all senior students at the School of Engineering Science, Simon Fraser University. For this project we plan to make use of our variety of expertise that each of us has gained through coursework and co-op experiences. Appendix A consists of copies of our resumes.



## Conclusion

We see the development of an infant monitoring system as a serious challenge for our skilled team. But, at the same time, we know that our team possesses the abilities required to successfully complete the project on time. We look forward to the numerous challenges that will be presented by this project and we are confident we will produce a system which will help alleviate the fears of parents.

The challenge of creating a new device that can assist in saving the lives of infants worldwide, while at the same time being affordable, simple to use, and extremely reliable, is one we shall strive to meet.

## References

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10. "SIDS and Apnea: Difference of Opinion", <http://sids-network.org/apneadiff.htm>, January 1999.
11. "Physiologic Differences Between Adult and Pediatric Airway, Breathing, Circulation, Neurologic & Misc Structures", <http://www.wf.net/~wiz4648/pedidiffs.htm>, January 1999.

### Patents Consulted:

1. US4146885: Infant bed and apnea alarm.
2. US5853005: Acoustic monitoring system.
3. US4438771: Passive contactless monitor for detecting cessation of cardiopulmonary.
4. US5515865: Sudden Infant Death Syndrome (SIDS) monitor and simulator.
5. USRE032180: Composite sheets constituting electromechanical transducers and transducers equipped with such sheets.





Appendix A

# Resumes