RamanFlex
School of Engineering Science
Burnaby, BC
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September 16, 2002

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Dear Dr. Rawicz,

A copy of our proposal for a Gas Analyzer using Raman Spectrometry is enclosed for your consideration. RamanFlex' goal is to complete the exploratory phase of this technology to a level at which the design of a commercial prototype can begin.

The proposal outlines a high level design of our product, an examination of other solutions, budget and funding considerations, and a tentative design schedule.

While our primary focus is SCUBA Diving applications, we believe that the technology to be developed by RamanFlex will have far-reaching uses in various fields and applications. Possible uses will be in such applications as anaesthetic mixing, environmental monitoring, and in superchargers and afterburners.

Our team consists of four intelligent, innovative, and motivated engineering students with a broad range of skills and experiences. Members have worked with each other in past projects and through their experiences have developed effective team dynamics.

If there are any questions, concerns, or comments, do not hestitate to contact any member of the Design Team. Our contact information has been included in the first page of our proposal.

Sincerely,

Graeme Smecher
Project Lead
RamanFlex

RamanFlex

Project Proposal

Simon Laalo
Jon Jolivet
Graeme Smecher
Bernard Smit

The Fine Print

This document reflects the plan for a four-month project, and is accurate to the best of our abilities. The project is, however, a moving target. Therefore, this document is subject to revision.

The RamanFlex team may be contacted en masse at `ensc340-napiform@sfu.ca`. Alternately, our individual contact information is as follows:

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This is Version 1 of this document, prepared on September 16, 2002. Please check for newer versions with one of the above contacts.

Executive Summary

Imagine breathing from the tailpipe of a running car. With every breath, a deadly soup of soot, hydrocarbons, sulphur dioxide, carbon monoxide, and countless other toxins are introduced to your lungs — and from there, perhaps to your bloodstream. It's a good way of getting sick, but a miserable way to do anything else.

Now, imagine breathing from the same tailpipe while performing a strenuous, dangerous activity. Try doing a fireman's job — which is difficult enough — with nothing but engine exhaust to breathe. Try surviving, to say nothing of enjoying, a SCUBA diving trip with poison rather than air in your tank.

Firemen and SCUBA divers are among many hobbyists and professionals who require compressed breathing gases. Compressing air sounds like a simple enough proposition: compressors have been refined for centuries, and air is hardly expensive or difficult to collect. However, there are many more details standing between safe air and the air inside of a compressed-gas cylinder.

Compressors are complex. They require constant maintainance and careful operation. If they operate while hot, lubricants can combust or be vaporized, introducing toxins into the compressed air. A compressor's air intake must be carefully isolated from the rest of the machine, especially its engine. Sometimes, the best indication of bad air, available to the user, is a rotten taste or smell. Smell and taste, however, are incredibly poor indicators of safety. Furthermore, many divers will use air from a cylinder that smells bad anyways.

All of these dangers can be removed with an analysis of what is in each tank of breathing air. Analysis equipment is commercially available — however, until now, it has been based on laboratory technology and has been too expensive to bring to the average compressor site. There are many technical difficulties that prevent simpler solutions from completely analyzing the gases within a mixture.

We propose a device which performs two functions. Firstly, the device measures the concentrations of the major constituents of safe breathing gas (O_2, CO_2, N_2, and He). Secondly, it recognizes threshold levels of common contaminants and toxins (e.g. CO, hydrocarbons, and organic materials).

For the four-month development cycle presented in this document, we propose a proof-of-concept: that is, either a refutation or a confirmation of the feasability of such a device. We intend to evaluate whether the technology exists to produce a functional product on an extremely low per-unit cost, which is several orders of magnitude beneath the price of a laboratory-grade unit based on the same principles.

We anticipate an operating budget of $2,500, a figure which includes a reasonable margin for contingencies. With a project as technically ambitious as this one, we do not expect to produce a prototype unit. Instead, we intend to

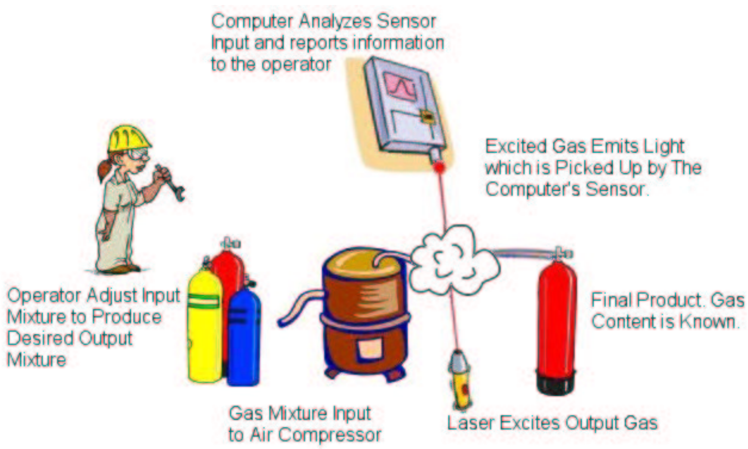

Figure 1: The Gas Analyzer, in broad strokes

complete the exploratory phase to a point at which we could begin the design of a prototype device.

The following document provides some market details and the requisite technical introduction to our project. We have included some budgetary projections, as well as an introduction to the development group.

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1 Introduction

That safe breathing air is essential for survival needs no evidence. Polluted air has received a lot of attention: airborne mold, pollen, and industrial and car exhaust are among the myraid of worries that have led to daily smog reports, medical papers, perscription drugs, and class-action lawsuits.

The same health concerns require a careful look at the quality of air in compressed-air applications. However, in these cases, the pollutants are often worse, the monitoring is spotty, and the consequences can be fatal. An underwater athsma attack aggravated by pollen would be fatal.

The project outlined in this proposal, though it has applications ranging far beyond SCUBA diving, was primarily intended to afford divers and compressor operators some immediate feedback on the quality of their air mixtures. During a SCUBA dive, pollutants are more damaging due to the strenuous nature of the sport. Worse, any reduction in the alertness of a diver can create an extremely dangerous situation. Divers must carefully monitor both their equipment and the amount of time and depth at which they have been diving. A moment's disorientation can bring a diver down to a lethal depth — or, might send the diver shooting uncontrollably to the surface. Both situations are deadly.

Even pure breathing gas (carbon dioxide, oxygen, nitrogen, and perhaps helium) presents major physiological risks to divers. Underwater, a high concentration of oxygen is toxic. At greater depths, nitrogen becomes a narcotic, causing disorientation and confusion. Excessive concentrations of helium or carbon dioxide lead to asphyxiation. Days after a diver has surfaced, nitrogen which was absorbed by the diver's tissues while underwater reenters the bloodstream and is eventually exhaled. If the diver does not plan carefully, this nitrogen can instead form bubbles in the bloodstream. These bubbles collect in a diver's joints, resulting in an excruciating, often lethal condition known as decompression sickness (DCS) or "The Bends."

An in-situ analysis of breathing gas would be extremely useful in two situtions with respect to SCUBA diving. First, compressor operators could analyze the air entering a tank at the time of filling. Secondly, the contents of a cylinder could be verified after it has been filled. Not only are these analyses useful during a simple air fill — they are essential when divers begin modifying the oxygen, nitrogen, and helium levels in breathing gas.

Currently, compressor operators are encouraged (though not required) to send in a gas sample for testing several times per year. However, those shops which do elect to send in samples for analysis (at a cost of around $200 per sample) are most likely to do so as part of a regular maintainance schedule. This means that the samples sent to be tested are likely to have been taken immediately after the compressor has been lubricated and has had its seals and filters replaced. The sample, therefore, reflects a sample quality that can be of much higher quality than most divers will receive from the same compressor.

There are many ways in which air quality can degrade after a compressor is maintained. For example, compressors used for breathing gas always contain filtering stages. These filters remove pollen and other particulate materials, as well as some of the chemical pollutants that can be found in even relatively safe air. However, these filters are easily destroyed by water — and if the compressor's water trap is not emptied every fifteen minutes, the filters are ruined. If, immediately after being maintained, the compressor is used to fill a sample canister for analysis, there is no indication that the filters might be ruined by fifteen minutes of careless operation at any point afterwards. Worse yet, the filters would then remain useless for several months, until the next regular maintainance. Because every analysis comes up clean, an operator would have no way of discovering their mistake. They might make it repeatedly, until an accident occurs.

This undetected failure assumes a reputable, knowledgeable compressor operator. However, many shops that sell compressed gas are not aware of the maintainance and safety procedures that keep divers breathing. Often, for example, floating gas stations — generally aimed at dive charters and tourists — offer to fill SCUBA tanks as a side business. They fill tanks with a compressor which is infrequently used and even seldom maintained. The operators of these compressors might not even realize that regular maintainence is required, and they are extremely unlikely to send in samples for periodic analysis.

Given this reality, why haven't inexpensive gas analyzers been marketed? The answer is simple: they have. However, technological barriers have limited inexpensive analyzers to one or two gases; the concentrations of some, such as nitrogen or helium, have been totally inaccessible outside of a laboratory environment.

Our goal is to design a gas analyzer that provides near-instant feedback on gas contents. This analyzer must be inexpensive to encourage those with compressors, such as dive shops or fire stations, to use it. The targeted cost for such a device is between $1,000 and $2,000.

The remainder of this document contains the details of our product, its competition, and the design process that we will undertake in the coming months. Financial sources and a team overview are also included.

2 Possible Solutions

The problem which we hope to solve is the sale, in good faith, of dangerous compressed air or improperly mixed gas. Therefore, when searching for existing or potential solutions, we must not restrict our focus to competitive products alone — the primary alternative for most compressor sites is by shipping a sample canister to a third party for analysis.

The alternatives which we identified are described in the following sections.

2.1 Third Party Analysis

Several firms, such as Lawrence Factor, provide gas compliance testing against a number of standards. This testing procedure, depending on the provider, costs in the neighbourhood of $200 per sample.

Because this is a periodic test, it is a poor indicator of the range of air qualities that may be produced by a single compressor over a short time period. The turnaround time makes this a totally inapplicable analysis tool for anything other than air — mixed gases are produced on a tank-by-tank basis, and vary for different dive and equipment types.

The chief advantage of this analysis tool is the excellent quality of analysis and the relative lack of effort required to obtain data. However, particularily because the analysis costs are incurred on a tank-by-tank basis, there is little incentive for compressor operators to frequently and regularly have their air analyzed.

2.2 Electrochemical Analysis

The physical behavior of some gases makes it possible to determine their concentrations electrochemically. The sensors themselves operate in a similar fashion to batteries. However, parts of the sensor wear out and require periodic replacements.

Electrochemical sensors are extremely simple, well-understood, and effective. However, only oxygen concentrations are readily measurable using these sensors. Therefore, as part of a set of several sensors, electrochemical analyzers are valuable tools. They are unable to provide a comprehensive gas analysis tool by themselves.

2.3 Infrared Absorbtion Analysis

Infrared absorbtion tools take advantage of the fact that several gases absorb some types of light. In these sensors, a beam of infrared light is shone through the sample. The amount of light which is absorbed by the sample can be used to determine the concentration of a particular gas.

However, as with electrochemical sensors, only a few gases (such as carbon dioxide or monoxide) respond readily to this sort of analysis. Additionally, each gas responds to a different frequency of light, and some of the sensors are expensive to produce.

Some gases, such as oxygen, nitrogen and helium, remain totally inaccessible to this type of analysis.

2.4 Combinational Analysis

By combining infrared and electrochemical analyzers, it is possible to determine concentrations of most of the gases of interest to gas mixers and compressor operators. The remainder can generally be determined with careful assumptions and a little bit of math.

Sometimes, however, the assumptions that are made by gas mixers are not safe. Combinational analysis does not always take into account all of the pollutants that can be present in air.

Also, the sheer number of different sensors greatly increases two types of error: firstly, the failure of a single analyzer to produce valid results might go completely unnoticed. Secondly, the chances of human error are greatly increased when the operator must perform all of the required calculations by hand.

Finally, the combination of several analyzers increases the odds of equipment failure. This problem is excaberated by the fact that some of the analyzers require electrode replacement and regular maintainence. Each must be individually tuned to maintain accuracy.

Combinational analysis is the only solution currently available to gas mixers, for reasons explained above. However, it has many problems; we feel that a more comprehensive solution can be produced at a competetive price, and with fewer points of failure.

The following section details our proposed solution.

3 Proposed Solution

The design solution we propose is to perform gas analysis using Raman spectroscopy. Raman spectroscopy has three major benefits over the previously mentioned designs. First of all, more gases exhibit Raman effects allowing for the design of a generalized gas analyzer, capable of meeting the needs of many markets. Secondly, although the design process may be complicated, the apparatus, once constructed, will be simple and will contain few active components. Lastly, Raman spectroscopy does not require parts to be replaced

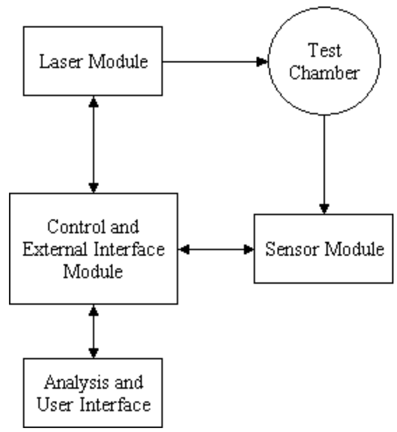

Figure 2: A broad overview of the gas analyzer

as part of a regular maintainence schedule. These benefits allow us to design a reliable, flexible gas analyzer.

Raman spectroscopy takes advantage of an effect known as Raman scattering. A gas, when a very intense light is shone through it, absorbs an extremely small amount of energy from some of the light. This changes the colour and direction of a miniscule fraction of this light subtly. The differences created by this process are unique for each molecular compound and may be likened to a fingerprint. By subjecting a sample of gas to a beam with carefully controlled characteristics, it is possible to determine the relative levels of gases contained in the sample. Unfortunately, this effect is extremely faint and requires some very sensitive equipment to detect.

The gas analyzer may be divided into 5 modules (Figure 2). The first is the laser module, consisting of the laser, its temperature control system, and the optics necessary to remove unwanted characteristics of the laser beam. The second module is the test chamber which will contain the gas to be analyzed, and house the required optics to maximize its efficiency. Third is the sensor module, consisting of some conditioning optics, the sensor, and its temperature control system. Next is the device controller and interface module which controls the laser and sensor modules as well as providing an interface for an external computer. The final module provides analysis and a user interface. This module consists of software for a PC, which performs the analysis and allows the user to monitor system performance and view results of the analysis.

Thanks to the optical storage and communications markets, the required optics, laser, and sensors have very recently become mass-produced and readily available. This new product availability and affordability also exists for the thermal management systems thanks to the new concern for thermal management in the home PC market. Combined, these two factors enable the development of an affordable, consumer grade gas analyzer using Raman spectroscopy.

4 Budget

A high-level summary of the budgeted amounts for various component types are detailed in Table 1. These cost estimates have been attained through an examination of component price lists from various suppliers. Efforts will be made to seek components from, for example, sample programs in order to minimize costs.

Component costs vary widely depending on a number of factors. These are closely related to the final design parameters and requirements which are not yet completely defined. In order to accomodate for cost estimation error and development mishaps, a contingency fund of $700 is also included. In addition, each of the prices below allow at least a 15% overhead to account for fluctuations and replacements. In the unlikely event of a budetary underrun, we intend to follow policies detailing the return or handling of extra money.

Equipment	**Estimated Cost**
Laser	$500.00
Sensor	$500.00
Optics	$200.00
Microprocessors	$100.00
Cavity	$100.00
PCB	$200.00
Discrete components	$200.00
Subtotal	**$1800.00**
Contingency	$700.00
Total Cost	**$2500.00**

Table 1: Budget Estimation

4.1 Funding

Due to the high cost of this project, a number of sources will need to be sought. Several opportunities are available: Engineering Science Endownment Fund (ESSEF), the Wighton Development Fund, and local high-tech companies. While defence funds and government grants might prove valuable sources of funding, the limited time available to us precludes the long application and screening process they require. RamanFlex is in the process of applying to a number of these funds as well as searching for more possible sources.

Members of the team have held a comfortable relationship with Microchip

Inc. in the past. Microchip has expressed interest in the product and is willing to provide RamanFlex with several of the components which will be required to bring the project to a successful conclusion. We expect to be able to cover around $100 in parts expenses through this partnership.

If we cannot raise sufficient funding through other means, the Design Team is willing to bear the cost of components. We understand that the onus to ensure the completion of this project rests on us, and we realize that we have selected a potentially expensive project. The RamanFlex design team is confident that the project has potential to cover a portion of the design cost in prize monies earned from Engineering Competition such as WECC and CEC. In addition, its potential as a thesis project validates a higher level of individual expenditure than would be appropriate for an isolated project.

5 Schedule

The completion deadline for this project is in early December, 2002. This deadline neccessitates an extremely aggressive development schedule. While a number of the tasks evident in the following Gantt chart (Figure 3) may be moved to a later starting date without holding back the project as a whole, we are certain that time will become increasingly scarce as the semester moves along.

Because of the technical complexity of this project, we have designed our development schedule such that it provides several appropriate points at which the project might conclude its four-month development term. Of course, our preference would be to see the project through to completion — however, in the brief time available to us, we must plan for contingencies. The greatest risk, however, is that we meet an insurmountable roadblock. It is entirely possible that we may conclude that such a project is either technically or economically infeasible for us to complete. However discouraging such an outcome is, it still answers our feasability question, (albeit with a resounding "no,") which was the initial purpose of our project.

Our milestone plan is shown in Figure 4. Both technical milestones and logical milestones are shown together, because our technical progress is an integral part of the planning process and project development.

6 Team

The RamanFlex team consists of four engineering undergrads with a diverse skill set. The following sections provide some information on the experience and roles attributable to each.

Our organizational structure is, by neccessity, loose. We have too much ground to cover to uphold strict task boundaries. However, we have assigned the oversight of each of several major tasks to individual group members. While they are not expected to carry out the entire task individually, responsibility for steering the task falls to an individual rather than a committee.

We anticipate that a high degree of task overlap will occur during the actual completion of the work. Should one group member fall sick, for instance, another member should be familiar enough with the status of the project that progress should not be unduly hampered.

Meetings are more formal. A strict time limit is enforced to keep meetings on-track, and an agenda is circulated prior to each meeting. We maintain official meetings once per week. Research meetings and laboratory sessions are informal.

6.1 Simon Laalo, Optics Developer & Interface Guru

Simon Laalo brings years of experience in the high technology industry to RamanFlex. He gained experience in user interface design, a key factor in the success of any technical product, while working with Rockwell Software's award winning HMI team. Simon also brings experience with lasers, optics, and design for manufacturability. He gained these skills at Creo Products, working on the design of a high precision laser profiling tool.

6.2 Jon Jolivet, Software Developer

Jon Jolivet is the official geezer of the team, bringing with him over 20 years of experience working in the technology and IT sectors. With his biomedical background, Jon brings a strong understanding of gas chemistry and fluid mechanics. His years of experience in the areas of technical support, product documentation, and customer service have granted him a unique perspective on usability. This perspective will ensure that all system controls, user interfaces and documentation will be approached in a manner appropriate to the user base, making RamanFlex stand out against all competition as the company with a firm understanding of the users of its products.

6.3 Graeme Smecher, Project Lead & Raman Researcher

Graeme Smecher, an avid SCUBA diver, provides the application-domain knowledge vital to ensure that this product is as useful as possible for our target market. Graeme has practical fabrication experience, including schematic capture and PWB design and fabrication. As our chief researcher and project lead, he is responsible for ensuring that no technological stone is unturned, and that the project proceeds as smoothly as possible.

6.4 Bernard Smit, Hardware Lead & Documentation Supervisor

Bernard Smit is a Third Year Electronics Engineering Student with strong interests in physics and analog circuit design. Bernard will bring his knowledge from various physics courses to the group as well his experience from past projects: the design and implementation of a pacemaker, an in-depth analysis of the dynamics of a jumping mechanism, and the development of a faux perpetual motion machine. His experience in mathematical modeling and the application of those models to real world devices will be an asset to the goals of this project. Participation in extra-curricular activities such as Rugby, and the EUSS makes Bernard an excellent team player.

7 Conclusion

RamanFlex is committed to improving the safety of breathing gases by bringing affordable, reliable, and convenient gas analysis to the consumer market. Our hope is that this will result in the implementation of regulated standardized testing, ensuring that breathing gases are of the highest quality possible. An indication of success would be a significant reduction in needless deaths due to toxic or poorly calibrated mixtures.

Our design will provide the best combination of longterm cost efficiency, reliability, convenience, and flexibility available in the consumer gas analysis market. The SCUBA market is ready for such a valuable product which presents a stable base from which we may explore other markets.

We recognize that this is an extremely ambitious undertaking, especially considering the limited time available to us. We do not anticipate the completion of a prototype unit; instead, we intend to either demonstrate or refute the possibility of a product that meets our requirements, including the low cost required to achieve the market coverage that such a safety product deserves.

8 Sources of Information

The following individuals, companies, and organizations have provided invaluable information in the preparation of this document. We appreciate their

help and anticipate their continued assistance as the project continues.

- DAN (Divers Alert Network)
- Dr. Curtis Smecher
- Dr. John Ogivilny
- PADI (the Professional Association of Diving Instructors)

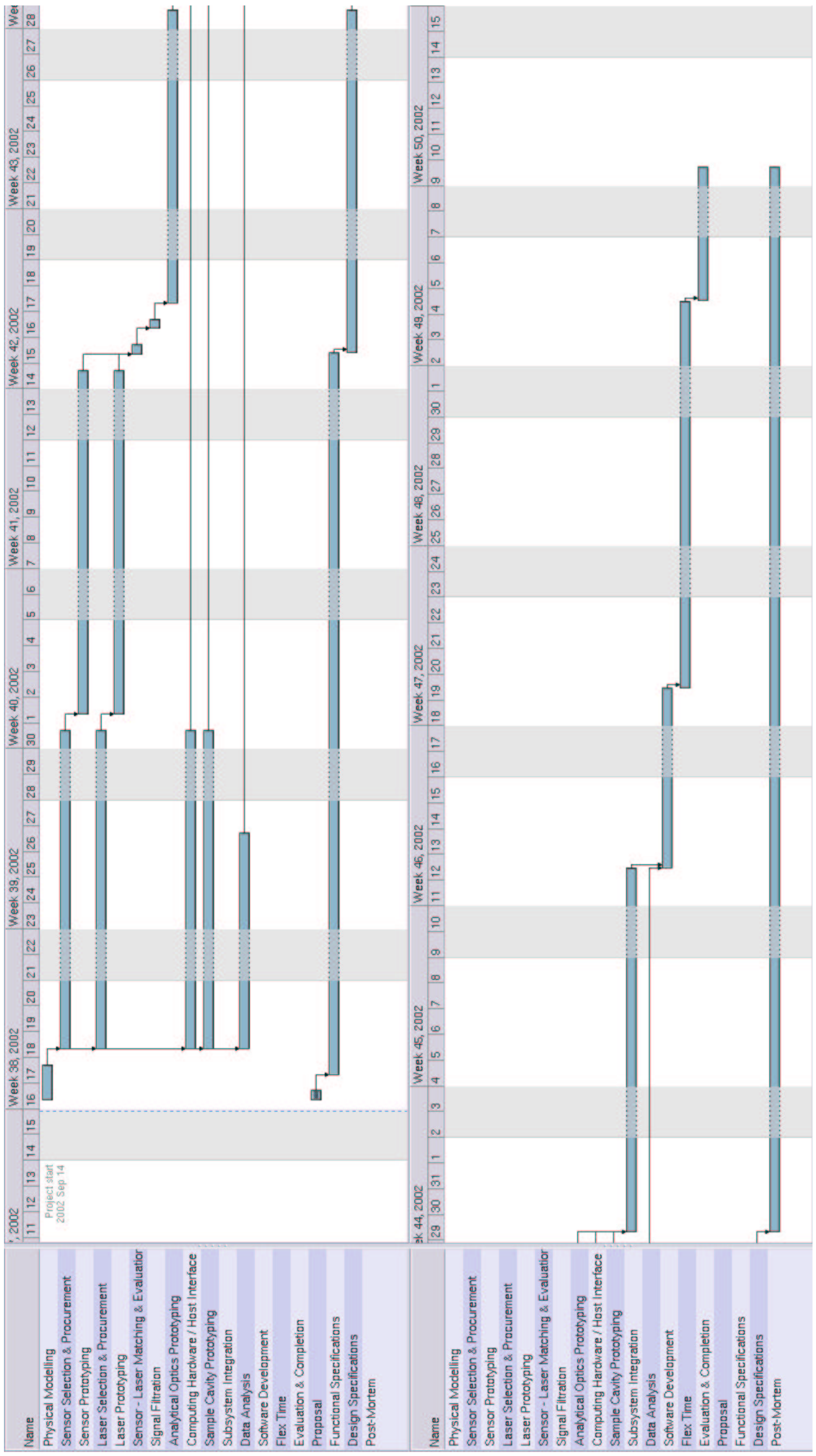

Figure 3: Gantt chart for the RamanFlex project

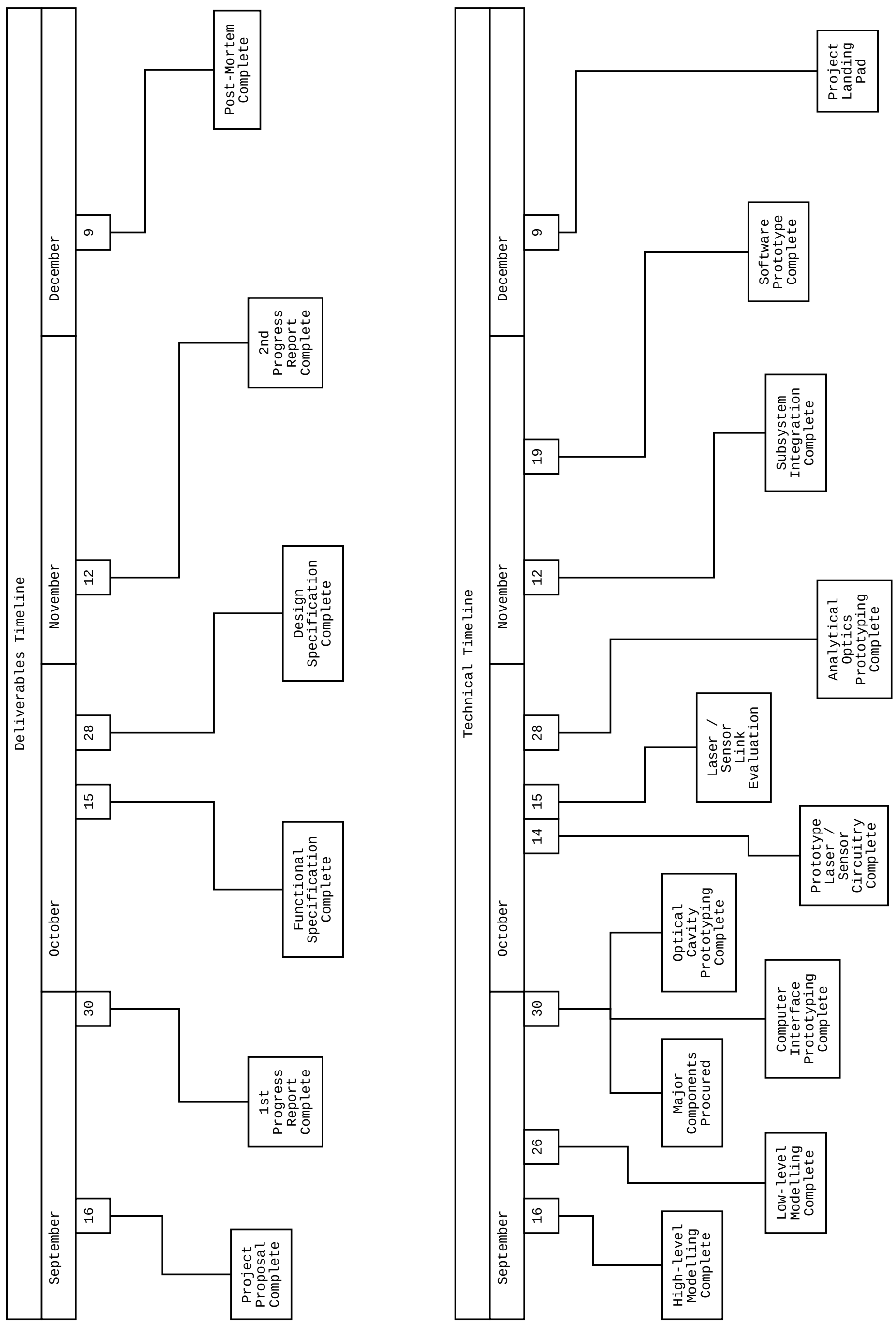

Figure 4: Milestone charts for the RamanFlex project