April 28, 2011

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby BC
V5A 1S6

Re: ENSC 440/305W Post Mortem for ArcTech's Integrated Climate Evaluator (ICE) system

To Whom It May Concern:

We enclose a post mortem for ArcTech's Integrated Climate Evaluator (ICE) system that outlines the current status of the project as well as some higher level details. The system currently meets its critical design requirements as a working demonstration prototype and further work will be completed to ensure it meets all design requirements.

This document outlines which specific requirements have been met and which will be met in future versions of the system. It also provides scheduling and budget details, describes any changes that have been made to the design and addresses challenges faced during the project. Finally, each member provided some general comments about the design process and what we took away from it.

ArcTech consists of five senior engineering students with a wide range of expertise in both technical and non-technical areas. If you have any questions about this document, please contact me by email at bjm11@sfu.ca.

Sincerely,

Brendan Moran
CEO, ArcTech

encl: Post mortem for ArcTech's Integrated Climate Evaluator (ICE) system.

Post Mortem for GPS Ice Tracking System

Project Team:
Andrei Simion
Brendan Moran
Conrad Lichota
Gianmarco Spiga
Lydia Zajiczek

Submitted to:
Dr. Andrew Rawicz
ENSC 440
Mr. Michael Sjoerdsma
ENSC 305W

ARCTECH

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

Submitted: April 28, 2011
Revision: 1.1

Contents

1 Introduction

We have successfully produced a demonstration prototype of our Integrated Climate Evaluator (ICE) system. This system is to be used in climate change research to track the movement of ice floes in the Canadian high arctic but is designed for more general tracking purposes. The project was completed on time and on budget and all group members worked well together to produce a working prototype, having some fun along the way. This document will outline which requirements have been met and which will be met in future versions of the system, as well as any changes that have been made to the design specification. A general summary of high level project details will also be given along with some reflections on the process and possible areas for improvement.

2 Current Status

This section will detail the functional requirements that have been met and those that will be met in future versions of the prototype.

Figure 1: Demonstration prototype of the ArcTech ICE System showing enclosure and internal electronics

2.1 General Requirements

The ICE system is currently an an autonomous, self powered tracking system capable of determining its location through a GPS receiver and broadcasting it to an end user via an Iridium modem. It also collects data about its surrounding environment and communicates this information along with its location. The system is capable of withstanding a marine environment and maintains functionality at temperatures as low as -20° Celsius.

2.2 Physical Requirements

As shown in Fig. 1, the system is housed in a cylindrical aluminum container that is approximately 20 inches in length and 5 inches in diameter to conform with the end user's installation equipment. It is rated to IP-67 standards, i.e. the enclosure is submersible in water up to 1 metre. [1] The sensor pod on the end cap, however, is not submersible but the unit will not be submerged in water at any time during its operation thus this is not a functional requirement. The threaded rods provide sealing and mechanical stability for the electronics and battery pack.

2.3 Sensor Requirements

The unit provides information about the following environmental conditions:

- Air temperature in cap of unit
- Relative humidity
- Barometric pressure
- Temperature of ice below unit

Production units will provide information about the following environmental conditions:

- Heave (via a three-axis accelerometer with the output filtered and integrated twice)
- Fall through detection via an abrupt change in the ice temperature

The unit does not provide information about air temperature in the bottom of the unit as this was determined by the client to be unnecessary.

2.4 Communication Requirements

The unit is capable of determining its GPS location with accuracy of 1-2 m and sends data messages to an end-user email address via the Iridium satellite network. The update frequency can be adjusted at the request of the end user and currently requires some fine tuning in the area of GPS timeout e.g. if the GPS receiver cannot get a fix to a satellite, the update frequency is affected.

2.5 Performance, Reliability and Durability Requirements

The system has an air temperature measurement accuracy of $\pm 0.5°$ Celsius. All units were purchased with storage temperature ranges exceeding -40° Celsius thus we expect the unit to maintain functionality to this temperature. Given our power budget estimate and allowing for overshoot, with Tadrian Lithium Primary cells installed, we expect the unit to last 13 months. This provides a reasonable margin for error in the case of battery failure that will allow us to meet the design requirement that the unit be self powered for an eight month deployment.

2.6 Usability Requirements

Our system was constructed using sensors that are fully calibrated, thus providing a working production unit to a customer will only require the inclusion of a magnetic switch circuit. As for end-user data processing, in the interests of reducing power consumption and processing time, there is a possibility that we provide raw sensor data via the email message and allow the end user to perform their own processing for increased flexibility. This may be implemented on production units. The data will still be provided to an email address.

3 Deviations from the Functional and Design Specifications

Design

We did not implement a flotation collar as described in the design specification as the end user will almost definitely not be recovering the units after the ice floes melt. However, this is a possibility that will be considered if the product is ever to be used for more general tracking of marine assets.

While we have a fully functional, working three-axis accelerometer, the processing required to calculate the heave of the device proved to be quite difficult and taxing on the microcontroller. As described previously, several measurements of the acceleration may be provided to the end user to allow for calculation of heave on their end rather than by the unit itself, however it may be implemented on future prototypes.

As per the functional requirements, our temperature sensor had to be accurate to $\pm 0.5°$ Celsius. However, the SHT15 loses accuracy at the extreme ends of its operating temperature range, thus we implemented a post-processing algorithm to maintain the required accuracy. We obtained this post-processing algorithm from the sensor's manufacturer, Sensirion.

For the mechanical enclosure, additional sealing is provided on the threaded rods via Teflon tape. In addition to conformal coating of the external PCB, it was placed in a small plastic box with ventilation holes to allow for the sensors to be exposed to the air. These holes are slanted to minimize the amount of particulate matter coming into contact with the sensors. To avoid condensation buildup, the box also had a small hole drilled in the bottom to allow for drainage.

Finally, we chose a different antenna that was slightly more expensive (approximately $200 which was within our original budget) but offered better dual-band performance. We selected a 2.6 inch diameter Antcom S2IR16RR-P-XTB-1 antenna as we encountered problems with our previous choice of model.

System Testing

Our system has two main functional requirements, that it determine and communicate its position and that it withstand and provide information about an arctic marine environment. Testing the GPS and communication capabilities of our device was relatively simple as we received messages via the email and compared the GPS measurement to our known location via Google Maps. Our system works as expected in this aspect.

The sensors were purchased on the grounds that they are calibrated to provide accurate results, thus our testing of the air temperature, relative humidity and barometric pressure involved comparing the measured data to reasonable known values and placing the unit in a standard household freezer. It withstood the test appropriately.

Given the timeframe of this project, we were unable to complete any significant testing regarding the longevity of our system in a marine environment, either in terms of corrosion or battery life. More extensive testing will be performed after our demonstration prototype is received by the end user and feedback is received.

4 High Level Details

4.1 Budget

We were fortunate to have a client funding our project so development budgetary concerns were not a problem. We did select components based on price but were not limited in purchasing multiple microcontroller development boards, sensors etc. The production cost of the enclosure due to the simple design and inexpensive material has been reduced to approximately \$100. The reduced cost of the microcontroller is due to the removal of the development board for a production unit. The resulting cost is less than \$1,000 which is well within the cost specified by our client.

Table 1: Estimated cost of components needed for GPS ice tracking system

Component	**Estimated Cost**	**Production Cost**
Enclosure	\$500	\$100
Satellite Modem	\$340	\$340
Antenna	\$200	\$200
Battery Pack	\$70	\$70
Accelerometer	\$50	\$50
GPS	\$45	\$45
Temperature/Humidity Sensor	\$40	\$40
Pressure Sensor	\$40	\$40
Microcontroller	\$20	\$10
Power Board	\$20	\$20
Total	**\$1,325**	**\$915**

4.2 Schedule

Our proposed schedule shown in Fig. 2 was largely accurate, with our demonstration occurring on April 26, 2011 due to conflicts with group members' exam schedules. Most of our timing setbacks were the result of external delays in fabricating the enclosure and client-requested changes to the functional requirements.

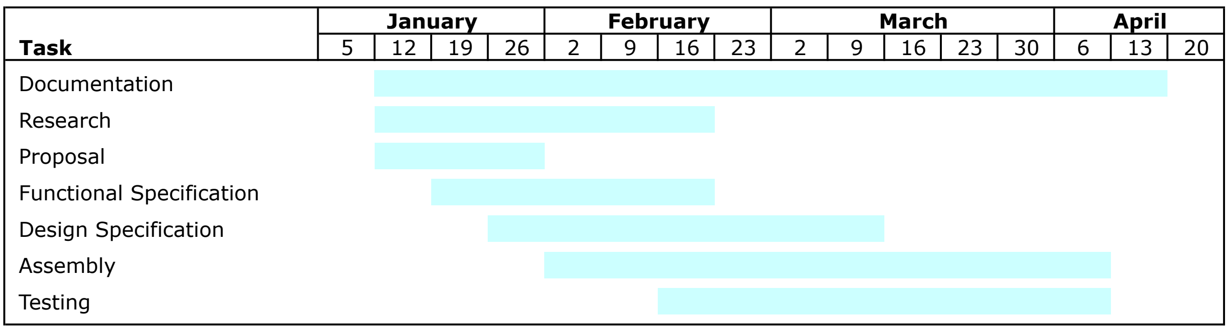

Figure 2: Gantt chart showing time allocation for principal tasks.

4.3 Team Dynamics

Given the diverse range of skill sets within the ArcTech team, we chose to operate with a top-down style of management with our CEO Brendan Moran as team leader. This decision was made in light of several factors:

- The complex nature of the project
- The relatively short timeframe in which to complete it
- Brendan's extensive experience in industry (approximately 6 years)

Once we chose this style of management, every group member had to maintain a high level of commitment and accountability to the project as the risk of allowing some members to do more work remained high. In addition, the top-down style of management led us to allocate specific tasks to each member based on their expertise, which necessitated constant communication and weekly emails to ensure everyone was up to date on the status of the project as a whole. Accordingly, the tasks were divided as follows:

Andrei Simion, VP Software Andrei was responsible for much of the software development on the microcontroller as he is a computer engineering student. He also developed a demonstration script to allow us to demonstrate the tracking ability of the unit via Google Maps.

Brendan Moran, CEO Brendan provided expertise in the power control aspect of the project, a critical design requirement for a self-powered system. He also designed the PCB layouts and wrote DMA drivers to interface with the sensors. He was instrumental in almost all aspects of the project.

Conrad Lichota, VP Hardware Conrad provided expertise in the mechanical design area of the project with Gianmarco and contributed significantly to software development.

Gianmarco Spiga, COO Gianmarco's wide range of experience allowed him to contribute to daily operation of the project in terms of coordinating schedules and even reminding his group members of a 305 meeting. He and Conrad were largely responsible for mechanical design, a significant and challenging portion of the project.

Lydia Zajiczek, Secretary Lydia provided leadership on most of the documentation for the project and took minutes at the weekly meetings from her experience as a secretary for companies and volunteer organizations. She also designed the PCB layouts and assisted with electronic design.

Common Tasks General research, mechanical assembly and testing, contribution to documentation, specific software development

5 Challenges

The main challenge of the project was not creating a unit capable of surviving an arctic marine environment or a unit that could measure GPS location, environmental data and communicate it to an end user. The challenge was designing a system that could do both at the same time. Connectors that are IP-67 rated are fairly easy to find and purchase, but the circular connector that connected the internal and external PCBs proved to be one of the most difficult components to install and seal. Our sealing method will have to be improved for future prototypes.

On the software side, actually having the microcontroller power down at the specified timing interval was complicated slightly by the GPS receiver if it was unable to fix to a satellite. We were unable to implement a timeout solution for the GPS to avoid affecting the microcontroller's sleep cycle but this will be present in future versions.

In terms of group dynamics, it was a challenge to ensure that members with more experience were not doing too much work. We initially tried to have everyone assist with all aspects of the project, but due to the complex nature this was not possible. We set somewhat ambitious deadlines that were much earlier than those specified by ENSC 440/305, and we were unable to meet them. Had we implemented more regular meetings and smaller deliverable deadlines this might have been possible and will be taken into account if this project is extended further.

6 Personal Summaries

Andrei Simion

Having undergone the full development cycle of a product with a small group of engineering students, I have learnt many lessons in teamwork, time management, and various technical issues over the past four months. This experience has provided me with new insight and appreciation into how products are developed in industry and showed me what it takes to bring a product from initial design, through research and development, to testing and preparation for deployment.

I am very thankful to have had such hardworking teammates! We had complementing strengths and this was an important factor in our success as a team. This allowed us to learn from each other in areas outside of our expertise and avoid situations where no one on would know how to solve a problem. My primary area of study is in digital design and software. As such, the collective experience of our team permitted me to learn about different aspects of an engineering product. Having had to make considerations beyond the microcontroller, namely, the mechanical and analog side of a product, I feel much more confident in applying my skills towards a product with real-world applications. Putting the microcontroller into a power-down mode proved to be troublesome; it was one of the biggest problems I encountered.

My advice for future groups taking ENSC 440: have structured meeting often - setting specific short-term goals, taking turns sharing the status of everyone's milestones, and holding a forum for any problems encountered in which everyone tries to provide suggestions. Utilizing software for sharing files and hosting a version control server is crucial. I think we could have benefited further by using even more online collaboration tools. I am quite pleased with the results of our hard work. I believe the project was a success both as a technical endeavour and as a milestone in our growth as engineering students.

Brendan Moran

When I initially heard about this project, it seemed to me that it would be a fairly simple project with just a few sensors in an enclosure. It turns out that taking that project from start to finish in an already busy semester was more complex than I had anticipated. While I have participated in many group projects before, this was the first group product design I have done and some of the team dynamics which came with this kind of project were very new to me.

The technical aspects of the project were not really the place where I learned the most. I now know more about using Real Time Operating Systems (RTOSs) in a microcontroller and I have learned how to build a low power sensor system, but I feel that my real lessons were more in group management. The single biggest lesson I have learned as a result of this project is that more small milestones are better than few big ones. Had we spaced milestones out better, I think we would have had a better picture of where we should be in the project at any given time. Because we failed to set enough milestones, we failed to meet our own desired large milestones, though we met the milestones required for the course.

From an electronic design standpoint, I've learned that it is important to make provisions for disconnecting untested circuitry in case it doesn't behave as expected and that making an air-tight container with electrical connections to the outside world is very difficult. I've also learned that it is important to go looking for errata notes at the start of a project and that a logically designed circuit may not work in real life, even if it works in simulation.

Overall, I consider our project a success. I believe that every group member learned some important lessons about the design cycle of a product and that we have created a useful product. We hope to see the ArcTech ICE deployed in the arctic this fall.

Conrad Lichota

I am very pleased with the way the project went overall. I think we were fortunate to find a project with an end goal of being deployed in the summer in that it gave us something concrete to work towards and made us be more accountable as it wasn't just a school project.

I learned a lot throughout this project and took part in the entire development cycle. It was really interesting to learn not only technical skills but also true group management skills. The project was run with a top-down approach led by Brendan who has had lots of previous industry experience.

If I could change anything about how the project went I would have liked to set more small deadlines to keep the project on pace. However keeping the project moving is always hard when each member has different classes and deadlines. I hope to see our system deployed to the Arctic this summer.

Gianmarco Spiga

The past four months have been challenging ones and have required a considerable effort from the team in terms of committment, intellectual engagement and time. Personally, I feel like I have gained much both in technical and interpersonal skills. After the initial brainstorming and the division of tasks, I could clearly perceive what my areas of strength/expertise were (mechanical), and where instead I was lacking (software/PCB design). Because of this, being able to relate to other teammates, and most importantly to ask for help when required, became fundamental for successfully completing the project. In this context, I discovered something about myself that surprised me. I now find myself being able to enjoy work in a greater way if said work is performed in small teams. In fact, I realized that I performed much better and was more motivated when doing manual/coding work with another teammate. That said, there are certainly areas in which our team dynamics could improve. While we did have some working meetings, in fact, these happened mainly very early and very late in the semester. In contrast, I think we would have benefited from weekly, day-long, working meetings throughout the whole course of the project.

On the technical side, I learned that building an airtight enclosure becomes a real problem when information has to be transmitted through the enclosure itself. In particular, it seems to me that the complexity of such enclosure grows exponentially with the number of through-communication lines required. I think that, in this context, we all learned the importance of considering several different designs and keeping them as realistic options, before settling with a final one. Also, a lesson I can take for the future is accounting for component failures throughout the design and making sure to have lots of spares for everything, especially cheap components such as connectors. All in all, I think taking care of the mechanical design also improved my visualization and fabrication skills.

Lydia Zajiczek

I headed into this semester knowing that it would be the most difficult undertaking of my engineering career. While it was a time consuming project, I did learn quite a bit about the design process in general and about more specific areas such as real-time computing and mechanical design. Overall it showed me how much more I have to learn about engineering before I can successfully take a project from start to finish. In particular, I wish I could have participated more in the software design process as I am quite inexperienced in this area. The development software for our microcontroller was not compatible with Mac OS X (my home operating system) and SFU was unfortunately unable to provide any Windows computers on which I could install LPCXpresso.

I also believe we could have met more frequently and set more small milestones in order to meet our personal goals for the project. In terms of what I would have done differently, I personally would have tried to rely less on other group members when I ran into difficulty. I learned a lot about PCB design and would be interested in further honing this skill. Finally, one of the biggest lessons I took away from this course other than the general mechanics of a group project is that making a mistake is not necessarily a failure. Choosing the wrong component or soldering something together by accident is not something to hide and should be addressed quickly. Overall this project was a success, although I am not entirely pleased with the tradeoff we had to make regarding finishing the project or everyone learning to do more than what they already had experience in. It has however piqued my interest in doing more engineering projects which will be helpful in the future. I am truly grateful to my excellent group mates for a successful semester.

7 Conclusions and Future Work

Our system meets the critical functional requirements outlined by our client and has the hardware in place to meet almost all of them. We worked well as a group and met all major deadlines for ENSC 305/440 and as described in the personal reflections, every group member learned a lot about design as well as about specific types of engineering. Overall we could consider the project to be a success. We will hopefully be implementing all the changes outlined in this document as well as some of the testing suggestions brought up at the demonstration. With continued work, we should have functional, tested units shipping by June 2011 for deployment at the end of the month.

References

[1] *Degrees of Protection Provided by Enclosures (IP Code),* ANSI/IEC Standard 60529, 2004.

[2] ArcTech Inc., *Proposal for GPS Ice Tracking System,* 2011.

[3] ArcTech Inc., *Functional Specification for GPS Ice Tracking System,* 2011.

[4] ArcTech Inc., *Design Specification for GPS Ice Tracking System,* 2011.

