Technical Report

Explorer Class

GALILEO

Submitted by the

Eastern Edge Robotics Team

The Eastern School District, NL, Canada

to the

Marine Advanced

Technology Education (MATE) Center

Team members:

Beau Callahan, Ben Cole, Adam Downton, Gina Doyle, Scott Follett, Jason Forbes, Andrew Furneaux, Justin Higdon, Renée Hodder, David Hornell, Sarah Howse, Zachary Hynes, Matthew Jenkins, Meghan Keating, Kimberly Maher, Sheldon Murphy, Paul Neal, Philip Nugent, Andrew Osmond, Jon Petten, Renée Quick, Daniel Ryan, Scott Stevenson, Jacob White

Team Management:

Gina Doyle, Renée Hodder, Sarah Howse

Teacher Mentors:

Clarence Button, Tom Donovan, Diane Howse, Corrina Mercer

External Mentor:

Dwight Howse, M. Eng, MBA

Table of Contents

Abstract

This Technical Report describes the Remotely Operated Vehicle Galileo, built by the Eastern Edge Robotics Team of the Eastern School District, Newfoundland and Labrador, Canada.

Galileo was created to compete in the 2005 MATE (Marine Advanced Technology Education) Center/ MTS International ROV Competition, hosted by the Johnson Space Centre, Houston, Texas.

Galileo's mission is to simulate exploration and conduct research on the unexplored terrain of Europa, one of Jupiter's four largest moons. Four tasks are to be completed within 30 minutes.

The tasks Galileo was designed to complete include:

i. Re-establishing the communications link to a science package
ii. Retrieving data probes located within a drawer on a science package
iii. Collecting a sample of red fluid from a crevice
iv. Measuring the temperature of some venting fluid

This report also includes a description of the design specifications and rationale, challenges, lessons learned, schematics, budget, acknowledgements, troubleshooting techniques, and future refinement possibilities. For more information on this project, please consult http://easternrobotics.dyns.cx.

Team Introduction

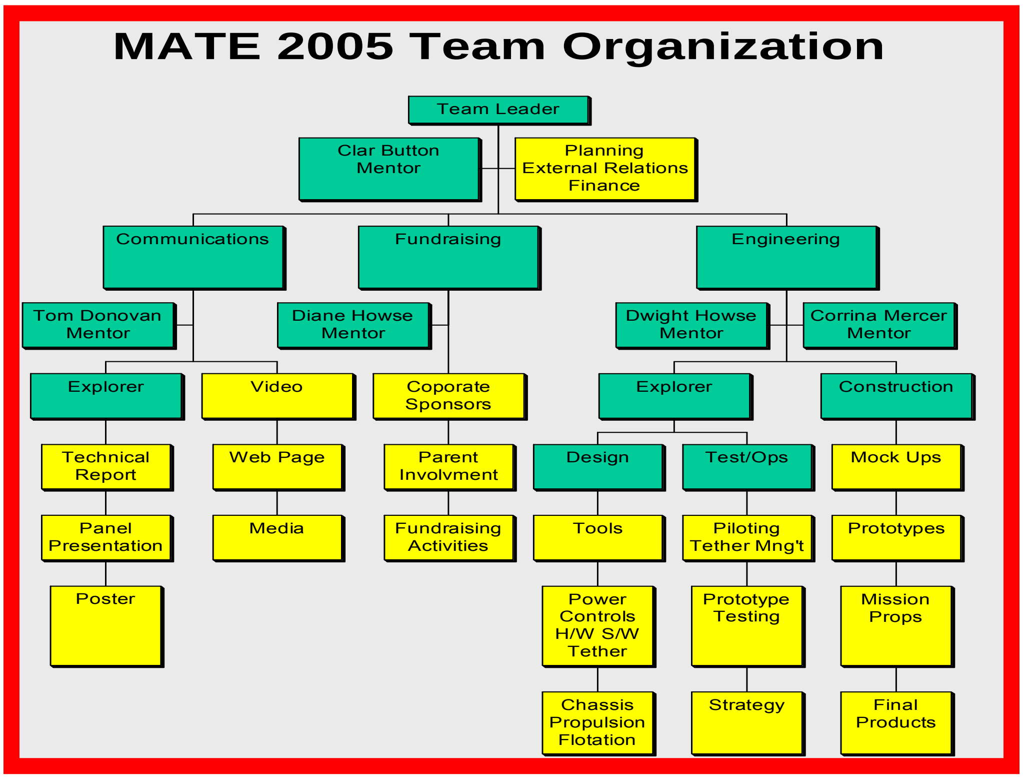
The Eastern Edge Robotics Team (Explorer Class) is composed of students from five high schools and one university in the St. John's, Mount Pearl and Conception Bay South areas of Newfoundland and Labrador, Canada. Since January, 15 students from Gonzaga High, Carbonear Collegiate, O'Donel High, Queen Elizabeth Regional High, Prince of Wales Collegiate and Memorial University have been working together to develop a Remotely Operated Vehicle for the 2005 MATE ROV Competition.

The team decided to name the ROV Galileo for two reasons: firstly, the scientist Galileo is credited with the discovery of Jupiter's four largest moons, one of which is Europa. Secondly, the spacecraft Galileo is currently orbiting Jupiter, partially focusing on Europa, and will be sending back information for the next few years. The name seemed very appropriate for an ROV which was built for a mission to Europa.

Project Management

Having such a large team, it was important to devise a way to manage members ensuring each person was included in a job. We decided to create a Team Organization Chart, dividing the team into three smaller categories: Communications, Fundraising and Engineering. Each group was run by a mentor and a responsible team member. This ensured that the group was productive.

Eastern Edge Robotics Organizational Tree



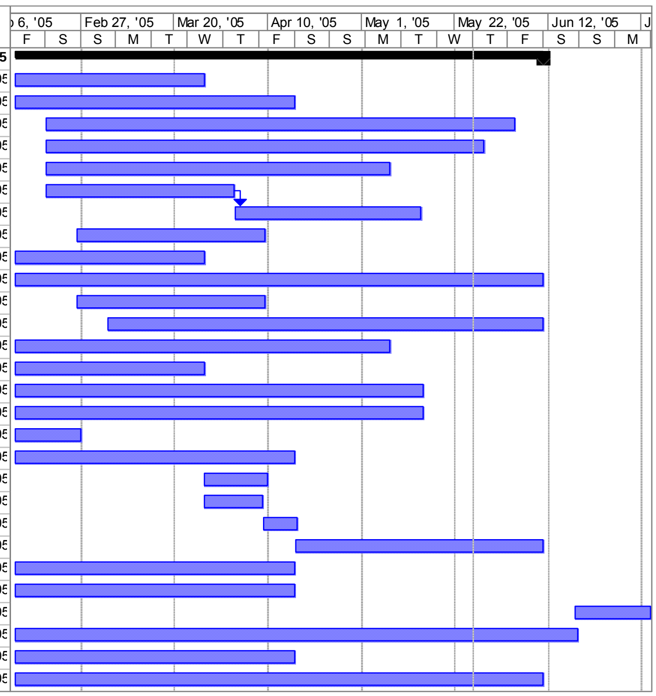
The largest group was Engineering, which designed, planned and built the ROV over a period of six months. It was divided into several subgroups, called "working groups," that developed and built the different components of the ROV. The fundraising group raised money for the trip, organized fundraising efforts and petitioned companies for donations. They also took charge of planning the trip and booking accommodations. The remaining team members worked in the Communications group, taking responsibility for everything under communications. This included the Technical Report, organizing the Engineering Panel presentation and the Poster Display.

The Engineering and Fundraising groups helped the Communications group by filling out weekly planners. These planners listed plans for the day, materials needed, and issues or concerns discovered over the course of the day. This made it easier to plan and write the Technical Report.

A project management program called Microsoft Project was used to create a list of tasks that needed to be completed and expected date of completion. This allowed us to delegate specific people to each task ensuring the construction of the ROV progressed efficiently. This ultimately saved time each meeting that would have been spent assigning people to jobs.

Our Gantt Organizational Chart

ID		Task Name	Duration	Start	Finish
1		**Build Mock Ups**	**20 days**	**Sat 2/12/05**	**Sat 6/11/05**
2		Build Probe with cable	7 days	Sat 2/12/05	Sat 3/26/05
3		Build Junction Box	10 days	Sat 2/12/05	Sat 4/16/05
4		Build holding device for	18 days	Sat 2/19/05	Sat 6/4/05
5		Develop releasing mech	17 days	Sat 2/19/05	Sat 5/28/05
6		Build drawer box with dra	13 days	Sat 2/19/05	Sat 5/7/05
7		Build 4-5 probes	7 days	Sat 2/19/05	Sat 4/2/05
8		Develop Drawer handle	7 days	Sat 4/2/05	Sat 5/14/05
9		Develop drawer opening	7 days	Sat 2/26/05	Sat 4/9/05
10		Develop probe collector	7 days	Sat 2/12/05	Sat 3/26/05
11		Build liquid container with	20 days	Sat 2/12/05	Sat 6/11/05
12		Build holding unit	7 days	Sat 2/26/05	Sat 4/9/05
13		Build Fluid Extractor	17 days	Sat 3/5/05	Sat 6/11/05
14		Build Fluid venting unit	14 days	Sat 2/12/05	Sat 5/7/05
15		* Develop hose hookup	7 days	Sat 2/12/05	Sat 3/26/05
16		Attach Temperature sens	16 days	Sat 2/12/05	Sat 5/14/05
17		Develop temperature rea	16 days	Sat 2/12/05	Sat 5/14/05
18		Order Materials	3 days	Sat 2/12/05	Sat 2/26/05
19		Await Arrival of Materials	10 days	Sat 2/12/05	Sat 4/16/05
20		Build First Prototype	3 days	Sat 3/26/05	Sat 4/9/05
21		Test Prototype	2 days	Sat 3/26/05	Sat 4/9/05
22		Refine Prototype	2 days	Sat 4/9/05	Sat 4/16/05
23		Build Final Product	10 days	Sat 4/16/05	Sat 6/11/05
24		Develop Web Page	10 days	Sat 2/12/05	Sat 4/16/05
25		Arrange Travel	10 days	Sat 2/12/05	Sat 4/16/05
26		Travel	8 days	Sat 6/18/05	Sat 7/23/05
27		Documentation	22 days	Sat 2/12/05	Sat 6/18/05
28		Fundraising/ Sponsorship	10 days	Sat 2/12/05	Sat 4/16/05
29		Accounting	20 days	Sat 2/12/05	Sat 6/11/05



Design Specifications and Rationale

1. Structural Frame

The chassis was created from 0.48 cm Lexan plastic bent into a trapezoidal shape. Two horizontal thrusters are mounted on its sides and two vertical thrusters are mounted on the sides at a 30º angle to the vertical axis.

Lexan is used for the frame, as it is durable, lightweight, and sturdy. It is easily conformed by heat allowing the creation of a machine specific to the tasks required of it. Lexan is clear, thus providing maximum visibility in an underwater environment. Using two vertical thrusters on a 30° angle to the vertical allows motion in the sway direction, giving the ROV more freedom underwater. The surface area of the frame was minimized to reduce resistance, increasing speed.

2. Video Switching Multiplexer

The video switching multiplexer takes in four video inputs and allows selection between four camera signals by changing two switches. As a switch is opened or closed, the selected view is sent to the display. This is accomplished by using two relays. The outputs are sent to one video output.

The video switching multiplexer allows the use of four camera views, increasing the pilot's awareness of obstructions, boundaries and other concerns in maneuvering the ROV. This ensures that the pilot does not overlook anything important and provides for precise positioning at the required targets.

3. Power Supply

The power supply has variable voltage output, ranging from 12-48 V, so that it can power both teams' robots: Ranger at 12 V and Explorer at 48 V. The power supply uses four 12 V spill-proof batteries (gel cells), connected with10 gauge hook-up wire, three double pole double throw switches, an ammeter, a voltmeter, banana jacks for 12 V output and a commercial electrical plug (rated at 50 A) for 48 V output and a 40 A circuit breaker.

This power supply was created by the Eastern Edge Robotics team, who upon entering two different classes this year, required a source of power that both classes could make use of. The Eastern Edge Robotics Team, as well as participating in the MATE ROV Competition, also holds summer Robotics Camps for Junior High students. This particular configuration permits four ROVs to operate simultaneously.

4. Video Cameras

Four Supercircuit PC169XS cameras were purchased for the ROV. These cameras are approximately 3.9 cm in diameter with a 1.0 lux low light rating, and contain a very high, 460 line resolution. These cameras operate on 12 volts DC, 110 milliamps, and have a 53 degree field of view in water. A local company called Lotek Wireless potted (waterproofed) the cameras. LEDs, also potted by Lotek, were placed in various locations on the ROV.

Supercircuit cameras were purchased for use in this year's competition. Lotek Wireless, a company focused on tracking marine life through electronic means, donated materials used in the waterproofing of these cameras. This allowed funds to be used in different sectors of the project. Adding LEDs provides extra light, increasing visibility in a light-deficient environment.

5. Remote Control System

The control system is an Isaac 16 system from IFI robotics. This system can read four analog inputs and eight switches. It is capable of driving eight pulse with modulated (PWM) Victor 883 motor controllers and four spike (on/off) reverse polarity relays. For our controller we require four pulse modulated motor controllers and two spike relays. User interface is through two joy sticks each of which has x-y motion, one wheel motion and two switches. The controller uses a STAMP processor that is programmed through a Windows™ based utility application. The programming language is similar to BASIC. A relay driver controls a pump and solenoid for the fluid sample while the PWM units are used to power variable speed thrusters. Electronics are housed in a watertight compartment that also serves as buoyancy for the ROV.

The remote control system is one that the team has used for several years and finds very effective. It is easily programmed to perform different tasks, which allows it to be reused and reprogrammed as often as necessary. It uses Pulse Width Modulation for variable control of the motors. As a result, precise control of our ROV's movement was achieved. This is crucial in an underwater environment.

6. Tether

The 75' tether uses three 12 gauge wires for Ground, +12 V, and a +48 V. A shielded 24 gauge twisted pair carries the communications signals and a 75Ω coaxial cable carries the video signal.

The tether is a very high quality product that is very visible in water. It was selected to provide maximum flexibility. Power lines are 12 gauge to reduce voltage drop in the tether. Shielded communications lines and a coaxial video cable are selected to reduce electrical interference

7. Thrusters

Four 48V thrusters from Inuktun drive the ROV. Two of these thrusters are used for horizontal movement and two for vertical movement. The vertical thrusters are positioned at 30º angles to the vertical axis and embedded in the sides of the chassis, while the horizontal thrusters are embedded in the sides of the chassis in the horizontal plane. The angled vertical thrusters are independently controlled to allow sway motion while also providing thrust in the heave direction.

Separate Tools for the Tasks

1. Re-establish the communications link

To re-establish the communications link, we constructed a device to hold the probe and release it at the appropriate position. The device is constructed from three pieces of Lexan. The main structure in 22.9 cm tall and incorporates a 16.1 cm prong to guide the tool to the correct position. A 16.5 cm trigger mechanisms is activated when the probe is lowered into place. The trigger releases a spring-loaded pin that drops the probe.

To re-establish the communications link, team members designed a simple and effective tool. The guide on front ensures that the ROV is directed toward the science package and the Lexan frame ensures that the pilot's view is not obscured. Having a trigger as a release mechanism guarantees that the probe is not accidentally dropped before the ROV reaches the Science Package.

2. Retrieve the data probes

To retrieve the data probes, two Lexan rakes were created. Each rake has three prongs. The prongs measure 8.25 cm, with 2.54 cm between each prong. The underside of each rake is angled toward the back of the ROV, which allows them to open the drawer. The rakes are placed on either side of our ROV, and are on sliders so that they can move up and down with ease.

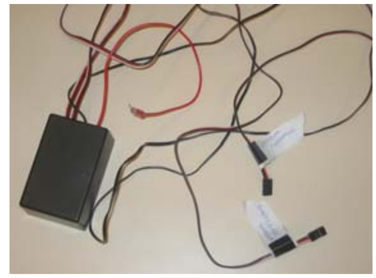
Using a rake, two tasks can be completed with one tool: opening the drawer and then picking up the probes. Also, a rake allows multiple attempts at retrieving the probes. Lexan is the best plastic for the rake because it is easily manipulated and more durable than other materials.

3. Collect a sample of fluid

Fluid is tested using a 12V, 750 GPH Mayfair Livewell through-hull aerator to pump the fluid sample out of the "crevice." The input bore of the Livewell aerator measures 1.9 cm and is fed by means of another flexible pipe, which has a bore measuring 0.95 cm. The top of a 2L soda bottle was used to create a funnel over the tube protruding from the crevice, as this will guide the hose. The funnel is connected to the pump's input with a brass female-to-female garden hose coupler. When the hose is in position, the pump is turned on to lift the fluid sample from the crevice. When the operator sees the sample flowing, a solenoid is activated to redirect to flow into the collection bag.

This design used in testing the fluid allows you to see when you have reached the fluid sample. At this point the solenoid valve is closed off forcing open the one-way valve and venting the fluid into the sample bag. A solenoid was used because it is a failsafe way to shut off the flow of fluid.

4. Measure the temperature of the venting fluid



The ROV incorporates a waterproof thermometer to measure water temperature over a range of 0°C to 40°C. The thermometer is based on a negative temperature coefficient thermistor with a nominal resistance of 10kΩ at 25°C. This thermistor is placed in series with a 13.2kΩ resistor to form a voltage divider. This divider gives a voltage range of 2.125V over the expected temperature range. This voltage is fed into an amplifier that uses two TL074 operational amplifiers to provide a voltage gain of 2.2. The amplifier output is sampled by an 8-bit analog to digital converter with a 0-5 V dc range on the Isaac 16 controller and then transmitted serially over an RS-232 bus to the computer at the surface. The surface computer reads the signal and displays temperature after applying a user-selected gain and offset that is used to calibrate the thermometer.

To measure the temperature of the venting fluid, a thermistor was used because it is easily connected to an Analog-to-Digital converter to allow the temperature reading to be transmitted to the surface.

Challenges

Many challenges were faced this year when building the ROV. The first problem faced was organizing a large team. There were so many new members that even the mentors found it difficult to remember their names. This resulted in the decision to hand out Personal Information sheets during the initial meetings. These questionnaires recorded each member's name, date of birth, phone number, etc., and facilitated easy contact with members when necessary.

Another problem was the task of occupying all team members. There were too few jobs for so many people. This prompted the decision to enter two teams into the competition this year, one into the Ranger class and one into the Explorer class. This meant that mentors spent significantly less time with each team. Due to this, both teams had to become independent and make many minor decisions on their own.

Planning the trip to the competition posed a significant problem, as the size of the team and number of mentors meant an expensive venture. Living on an island in Eastern Canada, it is costly to fly to Texas. To offset the cost of flying, our Fundraising group planned flea markets, bottle drives and other fundraising events. Air Canada was approached to give the team a discount on a group rate, and the team attempted to book the hotels in advance to obtain a cheaper rate.

Lesson Learned/Skill Gained

There are many lessons learned while planning and building an ROV. Many times this year, we encountered new tools, materials and designs, and were unsure of how they worked. In past years, mentors were able to spend more time with individual team members. However, due to the size of this year's team, our mentors had to divide their attention between the Ranger and Explorer teams.

Using our experience from past years, we were able to overcome most of the logistical problems. New team members relied on the advice and knowledge of more experienced team members and also took the initiative to work through problems independently.

We decided to hold a Team Meeting each week before breaking off into our smaller groups to discuss new designs and offer team members an opportunity to ask questions. We also set up a schedule for our mentors so that each group could discuss problems and ask questions.

Troubleshooting Techniques

There were several troubleshooting techniques that the team employed during the building of Galileo. For example, one problem we encountered involved Galileo's programming. During the initial meetings, the decision was made to base the program on one written last year. The program was modified by separating the controls for the two vertical thrusters, creating a sway control on Galileo. After these modifications were made, only one vertical thruster was working, even though the same program was created for both thrusters.

To isolate this problem we interchanged the thruster power wires. After doing so, the opposite thruster worked and the other did not. Then we exchanged the pulse width modulator controls and the same event occurred. We realized that we did not have a problem with hardware rather a problem concerning the program. Upon close examination of the program, it was verified that we had identical code for both thrusters. If the code was the same, we assumed that both thrusters should behave in the same manner but still only one thruster worked.

We decomposed the program into small units and tried controlling the thrusters individually. We then found that the program was able to control both thrusters independently.

Our conclusion was that the controller used was limited to 26 variables. When we added the fourth thruster, new variables were added, exceeding the controller's limit. The final solution was to create a more efficient program allowing the thrusters to be controlled using fewer variables.

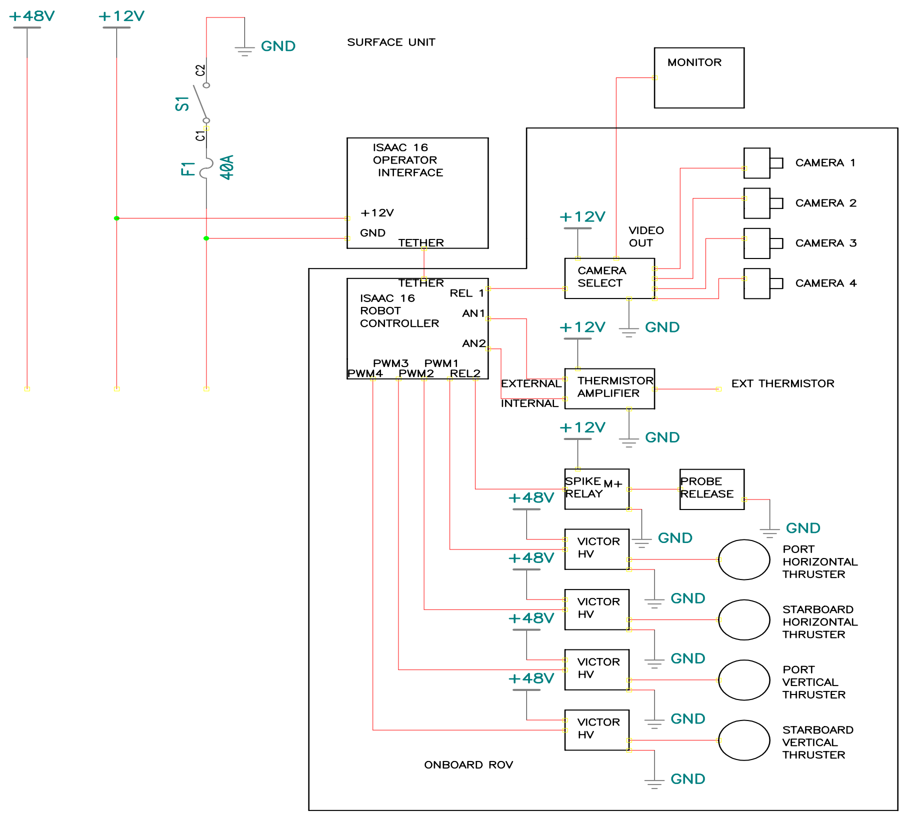
Future Improvements

Galileo is continuously being modified. Generally, we would like to refine and decrease the size of our tools. With the chassis, we want to try more designs and see which is most efficient. For the task involving re-establishing the communications link, we would like to perform more tests.

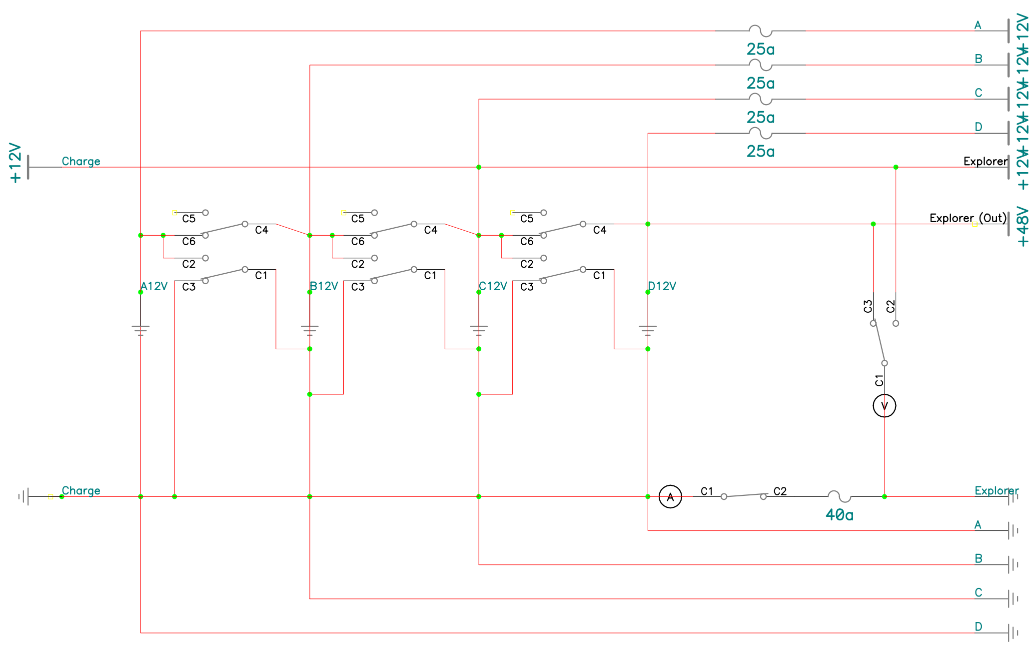
The task involving fluid extraction is the one we feel would benefit most from additional refinements. It would be beneficial to design our tool to be more streamlined. There is a risk that our fluid sample may become diluted during the process of extraction. We want to develop a more failsafe way to sample the fluid without this possibility. We recently considered some new designs that we believe would be more effective than the one we are currently using, and in the future would like to test some of them.

Schematics

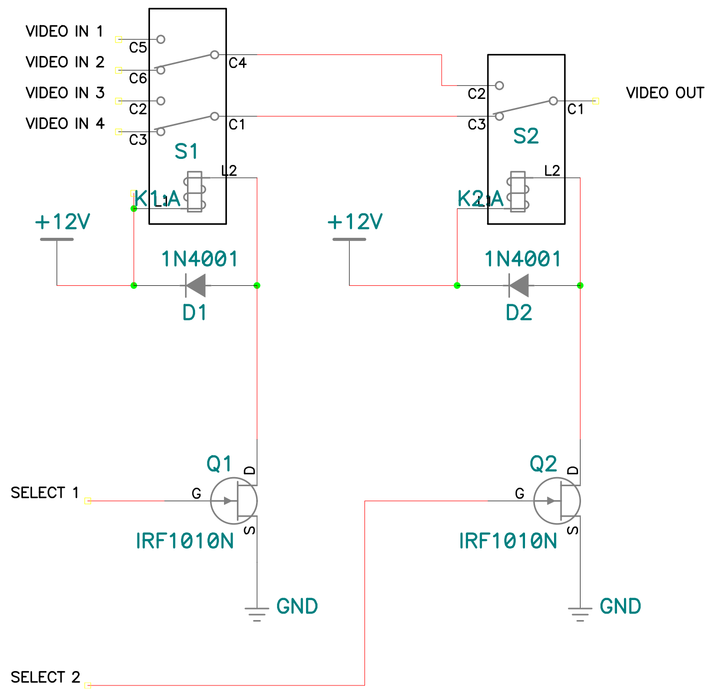
Galileo Schematic



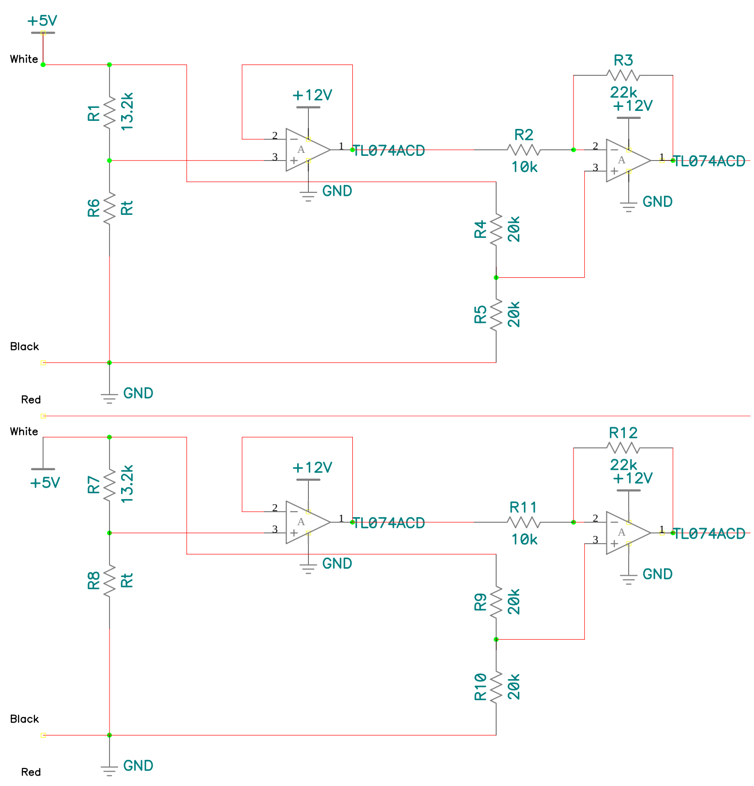
Power Supply



Video switch



Thermistor amplifier



Geophysics: How it will help us on Europa

Imagine a world where night was brightened dimly by fire. There were no electric lights, no oil lamps, and no “modern technology” of any sort. With the drilling of the first oil well in 1859, people began to understand that there was a substance in our earth possessing the potential to change the way we live. Shortly after, the invention of the motor car made it even more apparent that understanding what lay beneath the surface of our earth would be vital if our society was to continue advancing at its current rate. Today, we cannot imagine a world without oil, gas, coal and other minerals. But with such a large demand for petroleum products, how do we continue to find more within our earth? The answer lies in geophysics.

Geophysics is the physics of the earth. Geophysicists can focus in many different areas, such as oceanography or seismology, and study them using physics. They work alongside Geologists, Petroleum Engineers and other professionals in many different job scenarios. Discoveries in geophysics have led to some of the most amazing developments in science in the last century, including our current understanding of plate tectonics. (http://www.seg.org/)

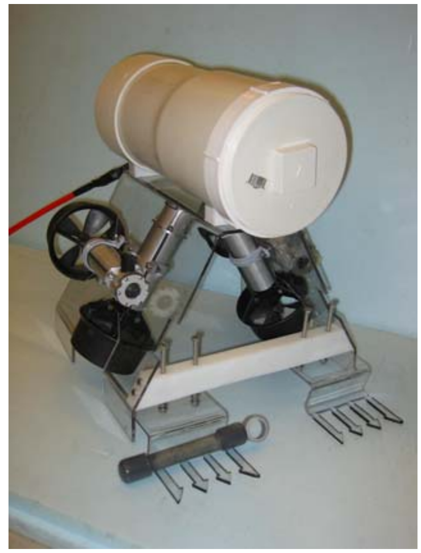
There are two main groups of geophysicists: solid-earth and exploration. Solid earth geophysicists use their knowledge of plate tectonics to explore the inside of Earth and other planets. Exploration geophysicists utilize geophysical theory to locate reserves of petroleum and other mineral resources. They are of the most interest to us as their research leads to the discovery and eventual drilling of oil.

Exploration geophysicists use a variety of methods to discover oil. They study the properties of the soil around a potential oilfield using gravimetry and magnetometry, which inform them of its density and magnetic field. They then send shockwaves into the ground, which reflect off different layers in Earth’s strata and return to the surface. They collect these seismic recordings and deposit them into computer-simulation programs. These provide a physical picture of what is underneath the surveyed area. They then collaborate with Geologists and Engineers to determine whether it is likely that oil exists, and whether it is financially practical to extract it. (http://science.howstuffworks.com/oil-drilling1.htm)

Newfoundland and Labrador, the eastern-most province in Canada, is home to several oilfields. One of the largest, Hibernia, has been in production since 1997, and Geophysicists were instrumental to its discovery and consequential success (http://www.hibernia.ca/.) Before any drilling could take place in the oilfield, Geophysicists analyzed it using seismic data to determine which area would be most productive. Without this knowledge, time and money would be wasted looking for a successful oil field. Geophysics is linked to the third task of our Mission to Europa, in which we must extract red fluid from a crevice. In order to accomplish this, we must first locate it and decide how and when to begin extraction. In real life, this would be the job of a geophysicist.

Our ROV, Galileo

Construction of the chassis

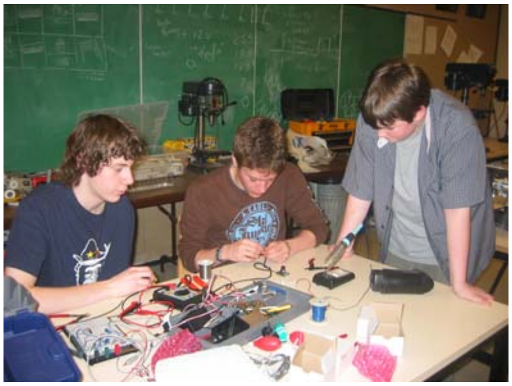


Latest model of Galileo

Our Team

The Eastern Edge Robotics Team (Explorer Class)

Team Photo Album



Wiring cameras

Shaping Lexan

Programming the thermistor

Working on electronics

Budget and Financial Statement

Expenses

ITEM	COST ($ CDN)
AIRFARE (Return St. John's to Houston)	
14 students @ $798.50(tax-in)	11179.00
2 mentors @ $798.50(tax-in)	1597.00
ACCOMODATIONS	
14 rooms/7 nights @ $90 US per person	1260.00
GROUND TRANSPORT	
Van rentals @ $85/day + gas and insurance	1900.00
MEALS	
16 people x 5 days @ $25 US/day	2800.00
AIR FREIGHT	
Return air freight St. John's- Houston	450.00
MATERIALS & FABRICATION COSTS	
Parts, motors, wiring, Lexan, electronics, cameras	2500.00
Promotional items (banners, t-shirts, plaques, etc.)	1200.00
TOTAL	27746.00

Revenues

ITEM	FUNDS ($ CDN)
Private Sector Contributions	7000.00
School Board Contributions	0
Public Sector Contributions	0
Team member contributions	
14 students @ $1481.86 each	20746.00
TOTAL	27746.00

Donated Materials

COMPANY (ITEM)	EST. COST ($ CDN)
Lotek (potted cameras)	50.00
Inuktun (four 48 V thrusters)	4000.00
Dominion (food for fundraising)	35.00
Aliant (team t-shirts)	200.00
Marine Institute (team t-shirts = 200.00) (monetary travel allowance = 2500.00)	2700.00
Leoni Elocab Ltd. (tether)	1000.00
TOTAL	**7985**.00

Acknowledgements

The Eastern Edge Robotics Team would like to thank the many contributors who helped make this project possible. We would especially like to thank the following:

Aliant, St. John's, NL. (donation of T-shirts.)

Dominion Grocery Stores (food donation for fundraising efforts.)

Eastern School District, NL. (use of facilities and personnel.)

Inuktun, Nanaimo, B.C. (donation of thrusters, cameras and tether.)

Leoni Elocab Ltd. (donation of tether.)

Lotek, St. John's, NL. (donation of materials.)

MATE, Monterey, Ca. (monetary travel allowance)

Marine Institute of Memorial University, St. John's, NL (donation of T-shirts, use of test facility and financial aid.)

O'Donel High School, Mount Pearl, NL. (use of facilities.)

Our parents (for their generous support)

Our mentors: Clar Button, Tom Donovan, Corrina Mercer, Dwight Howse and Diane Howse (for their guidance, patience and dedication)

APPENDIX A: Team Members

Beau Callahan, Level 3 at O'Donel High School
Ben Cole, Level 2 at Queen Elizabeth Regional High School
Adam Downton, Level 3 at Bishops College
Gina Doyle, Faculty of Biology at Memorial University
Scott Follett, Faculty of Engineering at Memorial University
Jason Forbes, Level 3 at O'Donel High School
Andrew Furneaux, Level 4 at Gonzaga High School
Justin Higdon, Level 3 at Prince of Wales Collegiate
Renée Hodder, Faculty of Engineering at Memorial University
David Hornell, Level 2 at Queen Elizabeth Regional High School
Sarah Howse, Faculty of Engineering at Memorial University
Zachary Hynes, Level 3 in Home-schooling
Matthew Jenkins, Level 3 at Gonzaga High School
Meghan Keating, Level 2 at Booth Memorial High School
Kimberly Maher, Level 3 at O'Donel High School
Sheldon Murphy, Level 3 at O'Donel High School
Paul Neal, Level 2 at Queen Elizabeth Regional High School
Philip Nugent, Level 2 at Queen Elizabeth Regional High School
Andrew Osmond, Faculty of Engineering at Memorial University
Jon Petten, Level 2 at Queen Elizabeth Regional High School
Renée Quick, Level 3 at O'Donel High School
Daniel Ryan, Level 1 at Carbonear Collegiate
Scott Stevenson, Level 2 at Gonzaga High School
Jacob White, Level 2 at Gonzaga High School