ArachnoBotics Research Inc.

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January 18th, 2010
Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Capstone Project: *Proposal for a Lightweight Robotic Spider*

Dear Dr. Rawicz,

Please find attached the document *Proposal for a Lightweight Robotic Spider*, for our ENSC 440 Capstone Engineering Project. Our objective is to design a spider robot that is capable of traversing a pre-programmed trajectory. This is part of a larger research project headed by Dr. Carlo Menon for the European Space Agency.

The attached proposal outlines the overview of our design, the design parameters, sources of information and funding, as well as a proposed budget. We also discuss the company structure and the proposed schedule for completing the project. Finally, our references include other similar robotic projects, which serve as an important background and are critical in making this project a success.

ArachnoBotics Research Inc. consists of five highly motivated, innovative and talented fifth year engineering students experienced in a wide range of technical disciplines: Cristian Panaitiu, Daniel Naaykens, Pavel Bloch, Pranav Gupta and Stefan Strbac.

If you have any concerns or questions regarding our proposal, please feel free to contact me by phone (778.893.3303) or by email (pranav_gupta@sfu.ca).

Thank you very much for your consideration.

Yours sincerely,

Gupta

Pranav Gupta
Chief Executive Officer
ArachnoBotics Research Inc.

Enclosed: *Proposal for Lightweight Spider Robot*

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Proposal for a Lightweight Robotic Spider

Project Team:
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Created For:
ENSC 440 - Prof. Andrew Rawicz
ENSC 305 - Steve Whitmore

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Executive Summary

"Engineers, scientists, and business people are increasingly turning toward nature for design inspiration" [1]

Through biomimetics, robotic implementations of natural organisms bring many benefits to society and technology. Scientists and Engineers are better able to understand the behavioral and functional mechanisms of organisms by designing them in electromechanical form. Furthermore, studying organisms in their natural surroundings allows researchers to identify possible advantages the creatures might have and apply these mechanisms to a scientific end. For example, Arachnids have excellent balance and are able to traverse the most difficult of terrain, often including perpendicular surfaces. This is an interesting physical property that can lend many positive benefits to exploration in outer space.

As part of ongoing research in robotic space exploration, the European Space Agency has commissioned research for the development of robotic spiders that will be used for travel and construction in outer space. One of the requirements of these robots is to climb walls vertically, a functionality that will be extremely useful in unexplored terrain. To this end, the spider robot must come equipped with a chemical adhesive that allows the robot to attach to any surface.

This proposal outlines a unique implementation of the robotic spider, the ArachnoBot™. The design philosophy will be to mimic an actual spider as closely as possible while bearing electrical and mechanical limitations in mind. Spiders are autonomous, free moving, and intelligent creatures, and as such ArachnoBotics Research Inc. plans to develop technologically advanced robotic spiders that contain much of the advantages of real spiders. Future generations of the ArachnoBot™ will involve wireless control from an external user as well as implementing basic intelligence to carry out tasks such as surveillance and construction.

ArachnoBotics Research Inc. is comprised of five innovative Engineering students from Simon Fraser University. With diverse backgrounds in Electronics, Systems, and Computer Engineering the group is well suited for designing a robotic spider, a truly multi-disciplinary project. Further assistance will provided by Dr Carlo Menon and Dr Lesley Shannon, Professors in the School of Engineering Science at SFU. Past projects will further serve as references and will enable us to successfully complete the task and enhance the functionality of this next-generation robotic spider.

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List of Acronyms

DC - Direct Current
DOF - Degrees of Freedom
ESA - European Space Agency
FPGA - Field Programmable Gate Array
HES - Hall Effect Sensor
IC - Integrated Circuit
PCB - Printed Circuit Board
PID Controller - Proportional-Integral-Derivative Controller

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1. Introduction

The study of Biological systems and methods has long intrigued Scientists and Engineers in their quest for a greater understanding of the world. Biological systems have managed over thousands of years to evolve many methods for completing tasks that are naturally impossible for humans such as re-growing missing limbs, breathing underwater and even flying. Although humans have managed to mimic some of these abilities through the inventions of submarines and airplanes, there are still many areas of engineering that these biological marvels can be applied to. Biomimetics, the study of Biological methods and systems and their implications toward robotic systems and engineering problems, is the term applied to this ancient art, and has gained prominence in recent years for its novel solutions.

Using the art of biomimetics, ArachnoBotics Research Inc. is proud to present its proposal for ArachnoBot™, a lightweight robotic spider. The ArachnoBot™ is based on a project commissioned by the European Space Agency (ESA) whose main aim is to design a spider robot prototype to be used in outer space travel [2]. Its small, lightweight form factor is based on both the weight requirement for launching it into space, as well as that of its biological counterpart: the Arachnid.

Figure 1: Proposed ArachnoBot™ Design

While technically a hexapod, the ArachnoBot™ will have 6 legs, each with 3 degrees of freedom (DOF). This allows ArachnoBotics Research Inc. the opportunity to take advantage of the many research papers outlining hexapod gait, as well as reducing both the weight, and complexity of the ArachnoBot™.

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The research and development of the ArachnoBot™ will be split into three phases; Component Selection and Hardware Design, Prototype Construction and Testing, and Integration and Completion. The three phase development process is expected to last for three months, after which possible enhancements to the ArachnoBot™ will be outlined, attempted, or set aside for future development. These enhancements include wireless user control, automated environment traversal, and internal battery power.

This proposal outlines ArachnoBotics Research Inc.'s design, electrical and mechanical characteristics of the ArachnoBot™, as well as resources, funding outlines, and project schedules. As a finished product, the ArachnoBot™ is expected to be a platform for further development and expansion.

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2. System Overview

The basic function of the ArachnoBot™ is to move in a coordinated manner. Much like real spiders, the ArachnoBot™ should be designed to facilitate vertical motion. The most common solution to this requirement is making the design both lightweight and by using an adhesive substance on the feet.

The important functional requirements are listed below:

1. Six legged
2. Three degrees of freedom on each leg
3. Lightweight
4. Coordinated Movement in forward direction
5. Coordinated movement in a variety of directions
6. Ability to stick to surfaces
7. Ability to climb a perpendicular surface
8. User controlled

The aim of this project is to accomplish requirements 1 through 4, with the possible expansions to requirement 5 through 8. The implementation of this robotic spider will be as modular as possible to allow room to expand the abilities of the spider for user control (requirement 8) and beyond without violating the previous requirements.

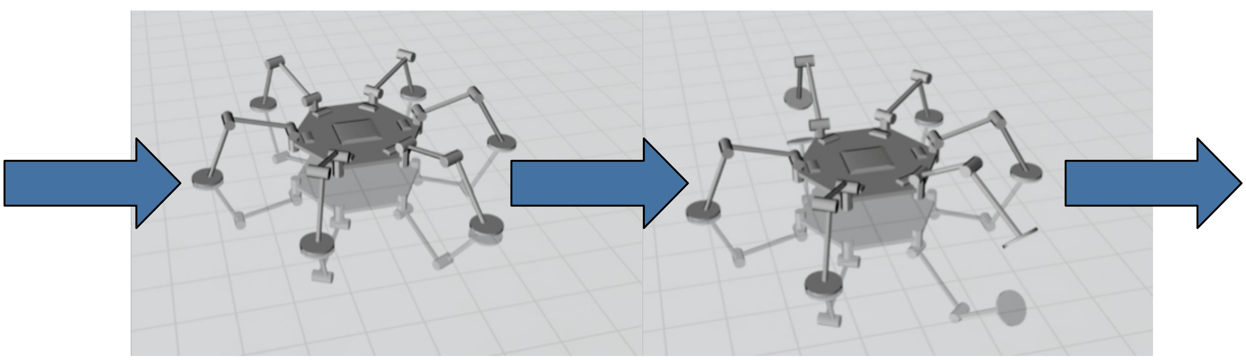

Figure 2: Example Leg Movement

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3. Proposed Design Solutions

The proposed mechatronic system for our robotic spider will involve a low form and low weight mechanical frame that encompasses a low power embedded digital control system. Low power, weight, and form are prerequisites to a battery-powered spider with the ability to walk on vertical surfaces while supporting its own weight. The electronic components, integrated circuits (IC), and drive actuators that make up the control system of the robot will have to meet these same specifications. The ArachnoBot's™ control system will be designed and built onto a multi-layer printed circuit board (PCB), while the mechanical frame, legs, motor joints, and PCB chassis, will be built through rapid prototyping material.

Currently ArachnoBotics Research Inc. is researching the advantages and disadvantages of two proposed designs solutions. Both designs share common elements, such as the frictionless Hall Effect Sensor (HES) used to derive the current position of each leg joint, while the major differences are in the choice of processor to control the mechatronic system.

To minimize the number of components on the PCB, a Field-Programmable Gate Array (FPGA) can be utilized to implement a system-on-chip directly on the PCB. A FPGA will allow reconfigurable logic to be added to the system; as well as allowing Feedback and PID control to be implemented in hardware logic. However, due to the slow clock speed of the HES, as well as its high digital output voltage, signal interfacing will still have to be converted outside the FPGA chip, and thus will require voltage convertor ICs.

An alternative to the FPGA design is to build the control system from an array of microcontroller ICs. The tradeoff here is that microcontrollers will most likely increase weight and form of the system but will make design considerable simpler. Because of time and resource constraints this option may end up more feasible, although it reduces the number of future enhancements.

Both of these two options will be considered, and the final choice will depend on the low form, low weight, the overall cost of system, and design simplicity.

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4. Research

Several sources of information will be used for the design of the ArachnoBot™. The Internet will be frequently used to find electronic periodicals, research articles, and datasheets and specification documents of both electronic and mechanical components. These references will be invaluable when deciding between specific design implementations for our robot.

Before identifying the final design implementation, preliminary research will be used to determine the functional design of the ArachnoBot™. A variety of past SFU projects exist on robots including a wall climbing robot [3], and a spider robot project [4].

Additionally, Dr. Carlo Menon and Dr. Lesley Shannon will be offering further assistance with the mechanical and processing aspects of the project. They will no doubt be of invaluable help to the project and will provide both time saving advice and critical feedback and important milestones of the project.

Finally, as mentioned, this project is part of a larger project for the European Space Agency [2]. The ESA has sponsored Dr. Menon to come up with a creative design for a robotic spider that will ultimately be used in space exploration. Dr Menon will serve an important role in clarifying goals and requirements of the robotic spider

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5. Budget and Finances

Our primary source of funding for this project will come from the Engineering Science Student Endowment Fund, with additional funding from the Wighton Engineering Development Fund, The School of Engineering Science and Dr. Carlo Menon.

Based on ESSEF Awards from recent semesters, we expect to receive between $700 and $900. We also plan to make use of the School of Engineering Science's $50 per ENSC 440 group funding to purchase all parts required during testing.

At the end of the project we plan to apply for the Wighton Engineering Development Fund. As this project is part of Dr. Carlo Menon's research, he has generously offered to cover the remaining costs.

Table 1: Estimated Budget for Robotic Spider

Part	Part Number	Quantity	Price
FPGA [5] / Microcontrollers [6]	XC6SLX45 / STM32F103CBT6	1 / 7	$200.00
Adaptors			$300.00
Hall Effect Sensors [7]	KMA200	20	$200.00
H-Bridge [8]	MPC17550	6	$40.00
Voltage Translator [9]	GTL2010	4	$10.00
DC Motor [10]	GH6124S	20	$250.00
PCB Manufacturing		1	$1,000.00
Rapid Prototyping			$100.00
Miscellaneous			$50.00
Overflow			$150.00
		Total:	$2,300.00

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6. Project Timeline

The Gantt chart seen in Table 2 below displays the timeline distribution for all tasks in the project. The project is split threefold, beginning with component selection and circuit design, then with building a working prototype using inexpensive proto-board to test circuit elements and layout, and ending with full PCB integration. We have allotted two weeks in April should any unexpected problems arise, or for adding further functionality.

Table 2: Gantt chart of Tasks

Task	January				February				March				April			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Documentation Deliverables																
Project Proposal	■	■	■													
Functional Specification				■	■											
Oral Progress Report						■										
Design Specification							■	■	■							
Written Progress Report										■	■					
Demo Presentation												■	■			
Post Mortem														■	■	
Component Selection and Design																
Finalize Part Selection and Order	■	■	■													
Mechanical Design			■	■	■											
Electronic Circuit Design			■	■	■											
Software Design				■	■	■										
PCB Layout Design						■	■	■	■	■						
Prototype Construction and Testing																
Mechanical Construction						■	■	■								
Proto-board Construction							■	■	■							
Mechanical Testing								■	■							
Software Testing										■						
Integration and Completion																
PCB and Hardware Integration										■	■					
Software Calibration										■	■					
Completion												■				

We have also noted a number of important milestones to our project work, including the highly important PCB Design and Construction. These milestones are shown on page 8 in Table 3.

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Table 3: Project Milestones

January 2010		**February 2010**		**March 2010**		**April 2010**
18	*Project Proposal*	**07**	Electronic Design	**08**	*Design Spec*	*Group Demo*
22	Begin Mechanical Design	**07**	Mechanical Design Completed	**10**	Software Integration Complete	*Professional Journal*
22	Order Components	**08**	*Functional Spec*	**15**	PCB Fabricated and Populated	*Post Mortem*
25	Begin Software Design	**15**	*Oral Progress Report*	**15**	*Written Progress Report*	
		18	Proto-board Assembly Complete	**25**	Project Complete	
		21	Spider Robot Prototype	**31**	Demo Presentation Complete	
		21	Begin Software Integration			
		30	PCB Layout			

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7. Company Profile

Pranav Gupta	Chief Executive Officer	CEO

Pranav Gupta has a strong background in Computer Engineering along with two years in Chemical Engineering. His experience in embedded firmware programming and digital system design make him an excellent contributor to the ArachnoBot™. He has had the opportunity of living in three culturally diverse countries, offering an excellent insight onto the business markets that he has observed throughout his experience.

Pavel Bloch	Chief Operations Officer	COO

Pavel Bloch is completing his BaSc degree concentrating in Electronics Engineering at Simon Fraser University. Through his work in the industry, Pavel brings with him expertise in analog circuit and firmware design, a strong background in various software languages including C/C++ and problem solving in the engineering context. Pavel's past work experience includes PMC-Sierra Inc, a silicon vendor and global leader in Integrated Circuit design in the Telecommunications industry.

Daniel Naaykens	Chief Mechanical Officer	CMO

Daniel Naaykens is a self-taught jack-of-all-trades with notable skills and interests in a wide variety of areas within Engineering. His natural interpersonal skills make him a great communicator and team member, and as a Systems Engineering Student his previous work includes practice in mobile robotics, computer-aided design, and rapid prototyping.

Cristian Panaitiu	Chief Technical Officer	CTO

A fifth year Honors Electronic Engineering Student, Cris brings experience from various fields such as negative feedback control, precision digital position control of electrical motor systems, and industrial automation equipment. He also has experience programming digital logic and is excited about fulfilling his role at ArachnoBotics Research Inc.

Stefan Strbac	Chief Research Officer	CRO

Stefan Strbac is a fifth year Electronics Engineering Student with an interest in robotics and intelligent systems. In addition to his work in Engineering, he is also actively pursuing a minor in the Physics. Stefan also has a variety of practical skills from his Co-op Work Terms, including PCB fabrication and assembly from his time at an electronics manufacturer.

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8. Conclusion

ArachnoBotics Research Inc. is aggressively pursuing the development of the ArachnoBot™ fully mobile hexapod. Our current objective is to make the ArachnoBot™ capable of walking on any flat surface, based on a preprogrammed trajectory stored in robot's memory. However, research to develop an efficient algorithm that will allow ArachnoBot™ to navigate any surface and obstacle is also underway.

We believe that the development of ArachnoBot will lead to new inroads towards a new class of walker vehicles, capable of exploration or delivery in difficult environments, delivering a robot that can navigate any terrain not traditionally reachable by wheeled vehicles and possibly inaccessible to humans. The development of advanced AI algorithms and providing a flexible programming framework will enhance the functionality of the robot, thereby making the ArachnoBot™ to be a truly versatile walker platform suitable for adaptation into a wide variety of applications.

By combining our expertise in mechanical, electrical and software design, the ArachnoBotics Research Inc. team will be successful in their endeavor of creating a small lightweight robot while minimizing cost ushering in a new era for outer space exploration.

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9. References

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Photo References

Spider Picture © Daniel Naaykens, January 2010.
Proposed ArachnoBot™ Design © Stefan Strbac, January 2010
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