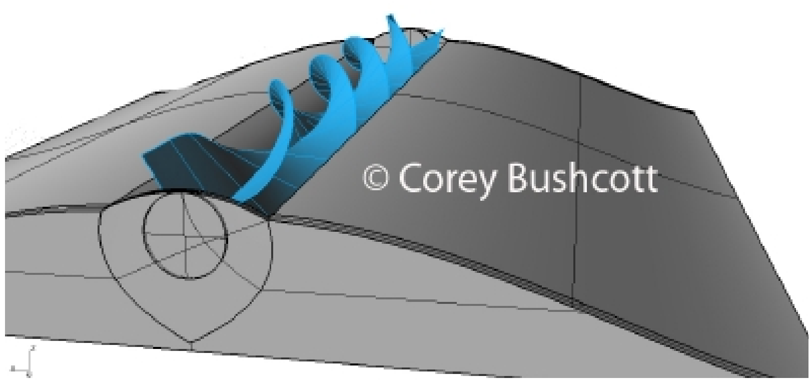
Illinois Institute of Technology

IPRO 323: Design of a Wind Energy Module for Buildings

Project Plan
Spring 2011



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ABSTRACT:

In recent years, interest in extracting significant amounts of electrical power from large wind turbines has increased significantly. However, as simple as these devices may look to the layman's eye, designing a device which efficiently and reliably converts wind into electrical power represents a highly non-trivial challenge. Further complications come about when this green energy is expected to work as a module on the top or the side of a building. Extracting the maximum amount of energy from wind flows whilst transforming mechanical energy into electrical power and then feeding this energy into the electric grid of a building while sustaining minimal losses and maintaining reasonable machine production and installation costs is a fully innovative and extraordinary proposal and objective. This inter-professional project team (IPRO 323 for Spring 2011) understands that the full undertaking of this idea would last, at the very least, five to six semesters of highly efficient work and research. ? Furthermore, is the geometrical design of the entire wind turbine which, is a project in itself.

Therefore, the main objective of this semester's IPRO is designing the shape of an urban rooftop that will harness an amount of wind which will induce optimal turbine work. This part of the project will be aided through wind tunnel testing and computer assisted analysis. Once a tentative shape has been obtained, 323 IPRO progeny could evaluate the economic feasibility of the project by installing several existing or new wind turbines designs into the modular shape provided by the Spring 2011 team.

Somewhat further explaining this semester's work: On the supposition/knowledge that different inlet and outlet geometries to the wind turbine will affect the power output, this team will perform wind tunnel studies of various wind turbine inlet and outlet sections along with a wind turbine analogy (a porous plate in place of the turbine will simulate the pressure drop of a random or particular turbine, as

shown by Aubrun, Loyer, Espana, Hayden and Hancock on the AIAA paper "Experimental study on the wind turbine wake meandering with the help of a non-rotating simplified model and of a rotating model"; so that the analysis can be simplified). This is in order to better understand the power output behavior of such systems in complex flow situations. These tests and analysis shall have as an outcome the conception and final design of a modular wind turbine inlet and outlet sections, which can be further analyzed with real turbine simulations to determine the viability of placing modular wind turbines on buildings.

As the New Green Revolution sweeps over the world and we all become more conscious of our impacts on the environment the quest for new forms and sources of clean energy ramps up. This project intends to take the first steps on creating a new opportunity for wind power transformation in cities, a windy environment underutilized as a source of energy where it is used most.

Team Charter

Under the guidance of:

Dietmar Rempfer Ph.D.

Candace Wark Ph.D.

The group assembled for this semester of work consists of Architects and Engineers. This is a group of students with entirely different skill sets. Attached are the team rosters as well as what each member of the team is bringing to the group as a whole.

Purpose and Objectives

Design and engineer a shape that can be implemented into a modular wind turbine

In this project we will pursue two major goals: On one level, the team will contribute to educating future engineers on the efficient use of wind power by exposing them and have them work on a practical problem of wind energy converter design. On the more concrete level, we are interested in evaluating the pressure drop (which relates to power output) across wind turbines models in the search of an “ideal” inlet and outlet wind turbine shape. Several possible shapes will be evaluated inside the MMAE department’ Mark V. Morkovin wind tunnel to look for pressure drop differences across a porous metallic plate (to simulate the wind turbine load). Finally, all data will be analyzed in the lookout of the “ideal” inlet-outlet wind turbine geometry.

Find the most favorable location of the wind turbine on the designed shape in order for the geometrical definition to be complete, the turbine location must be defined. On the experiments described above, to be performed on the wind tunnel, the location of the porous plate would change in order to get a broader amount of information that will ultimately allow for the determination of the best location for the turbine.

Background:

The design, science, and engineering of wind turbines is still a very young art. Over the last few decades wind farms have gone from outrageously expensive and inefficient rarities to an art that has created new ways of harnessing the planets energy. A conceptual design has been developed by Corey Bushcott with the help of Professor Land in the College of Architecture. Under the guidance of Dr. Wark and Dr. Rempfer, and thanks to the grant received by the MMAE department from the Department of Energy, this IPRO team will have the opportunity to use the MMAE department's apparatus to test this concept. The MMAE department is equipped with a subsonic (below speed of sound) wind tunnel in which experimental analysis can be carried out.

Problems:

For this project, instead of having a strict design to build and test, we will be designing shapes and conjuring ideas for a proper wind turbine. The plan is to optimize a new shape for the wind power device we are trying to design. This IPRO will rely heavily on experimental and computational testing of different design shapes. It is vital that the testing and analysis of data can be conducted in a timely manner.

This IPRO contains a highly technical engineering side where there has been much research and work done with the existing structures. To improve upon these structures, the instructors who laid out their own framework for the project proposed creating an environment where different setups for current and near future wind turbines could be tested. The ideas presented within this were highly technical and involved many hours of fabrication and testing, with a large emphasis on essentially decoding the data and making what a scale model experienced relevant to full sized, real world machines.

The second side of this project was born from the creative mind of one of the IIT's architecture students, Corey Bushcott. His idea was to incorporate the energy of the wind into the design of buildings. By studying how sand Dunes are formed, and how the wind naturally flows over surfaces, the student devised a basic design which could harness the turbulent flow of air in cities.
By combining this novel design, the technological aspects of wind turbine design, and the resources of the MMAE department these ideas can be tested and realized to their fullest potential.

Technological Considerations:

This IPRO is faced with an engineering heavy problem. The amount of data that will be gathered and subsequently analyzed will be staggering. The MMAE wind tunnel facilities will be a vital tool in the development of this project. This IPRO is composed by undergraduate students from the MMAE department with both technical and practical experience in wind tunnel testing, and along with guidance of the project advisers, this research will be able to be conducted in a timely manner.
As mentioned earlier the science of wind turbines is very young. Novel ideas for wind turbine design have come and gone through the years. In general the failure of these designs is because of monetary troubles. There has been growth in the field over the last few decades, the size and efficiency of wind turbine power stations has grown and improved over this period of time. Currently the most effective

way of capturing wind is having a very open area with large axial turbines to catch the wind. It is also a staple of wind turbines to have large “farms” of wind turbines. One of these wind farms could cover dozens of square miles and in this area, while wind power is clean, the sound pollution can be intolerable.

The development of wind turbines to be used in an urban environment has grown in the last decade. These structures can be seen in most major cities and like their larger, axial cousins are incredibly expensive. The deployment of these facilities in a large scale has yet to occur. The way air flows through a city is impossible to track. Placing devices is extremely difficult because of how turbulent the air becomes in a city. The slightest disturbances in the atmosphere could distort the airflow over that particular part of the city and yield that machine totally useless.

Currently the cost and noise produced by wind turbines are hampering their use in large urban environments. This projects development of small scale wind turbines that can easily be placed on current structures will try to negate these issues. The wind turbines developed in this IPRO will be specifically designed to accommodate the turbulence found in cityscape.

The design that results from this IPRO could be built into a useable prototype, and then deployed on a small scale. As invaluable as controlled wind tunnel testing will be to this project, actual implementation and observation of a prototype unit will supply the data that can make or break this project.

Lastly, it is important to mention that the wind turbine prototype for this IPRO will be a perforated plate. The perforated plate is replacing the turbine for various reasons: cost efficiency; maneuverability; last but not least, astonishing results obtained from research on wind turbines. Much research has been conducted by the AIAA committee, which came up with the conclusion that a plate with a specific perforated configuration would simulate the flow behavior around a regular wind turbine. This advantage of using the perforated plate to simulate the air flow over the turbine will greatly facilitate our experiments, where the difference in pressure between the two faces of the plate, thus the energy supplied by the "turbine", will be easily obtained.

Team Values Statement:

- All team members are asked to appear on time having prepared ahead of time for their assigned tasks. If you are having difficulty performing your tasks, for whatever reason, inform the group ASAP so that group progress may continue steadily.
- Any group member who will be missing a scheduled meeting which includes them must inform the respective group members ASAP.
- All university rules regarding lab time will be observed.
- When communicating through email, use the “Reply All” feature so as to include the entirety of the group in the discussion. This will provide ample opportunity for members to voice their suggestions or support another.
- All data and literature concerning IPRO 323 will be posted to iGroups to make access easy and reliable for all members.
- Conflicts among members should be dealt with quickly. If the conflicting members are unable to resolve their problem with a discussion amongst themselves then they should bring it to the attention of the group leader whom should then address it at the beginning of the next general body meeting.
- All members must be willing to accept constructive criticism from other group members and faculty advisers.
- All members will show decorum in scheduled meetings and will respect the leadership of the designated leader.

Project Methodology

Project Breakdown:

This project has three main structural units; one team will test the tentative designs, another team will analyze the data obtained from testing, and a final third team will perform CFD analysis of the designs so that comparison between virtual and real tests can be made.

The design team will come up with candidate shapes for the wind turbine module. This will consist of deciding on an initial design shape. Using known resources a shape for the 'hill section can be designed. With the hill section a mesh could be created to simulate the effects of a moving turbine. The mesh will consist of a porous material to let an ideal amount of air pass through. The mesh will also simulate the downstream effects of any such wind turbine.

The design team will then work with the engineering (prototyping) team to create a physical model of the design that will be tested in the wind tunnel. Foam will be cut using a hot wire cutting device, and as the design progresses the shape of the 'hill' can be modified. After testing the model in the wind tunnel, the data can be analyzed by the data analysis Team. At the same time the CFD and design team will work together to generate a virtual model of the test. This test will help to analyze the results from the physical test. The CFD will be tested against a known test so that the team knows that the code is functioning properly. When there is an anomaly between the CFD and the physical test data there can be more analysis and testing done to ensure that all is functioning properly.

This analysis can then be used to give feed back to the design team. The design team will take what was learned in the tests and adjust the design accordingly.

This outlined in the attached Gantt Chart

Expected Results:

With the implementation of a method of testing and analyzing test data through the semester there should be timely results delivered on an almost weekly basis. Ideally there would be a turn over cycle of about one week between testing and data analysis. This will ensure that no team member is ever without work.

By the end of the semester a functioning 'hill' shape should be in place to begin testing different shapes for the actual turbine section. The idea configuration for the turbine will be tested with the use of the mesh, and the findings on proper placement and ideal energy transfer will translate to another semester of another component design.

In the case of the deliverables, this project team has the advantage of having a portion of its students come from IPRO 397. There has already been significant time spent preparing for the project and all of the progress reports that come with it. The group members are varied enough such that there should be little trouble in creating explanatory and interesting presentable materials.

Budget:

See attached Budget Sheet.

Multi-semester Planning:

This project will incorporate a long cycle of testing. Over the course of multiple semesters the machine as a whole could be assembled and tested as a cohesive unit. In each semester a new component could be designed, prototyped, and tested.

The work done with the mesh can be directly translated to creating an ideal turbine. The placement and maximum amount of energy transferred will be found this semester and that work will be easily transferable to work on more components of the device.

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	Major	Year	Email
Taylor Dizon	Mechanical Engineering	3rd	tdizon@iit.edu
Tom McManus	Aerospace Engineering	4th	tmcmanus@iit.edu
Jonathan Swanson	Mechanical Engineering	4th	swannyjss@gmail.com
Thiago Jardim	Architecture	5th	tjardim@iit.edu
Nyla Husain	Aerospace Engineering	3rd	nhusain@iit.edu
Lucas Pfiffner	Aerospace	6th	lucaseng22@comcast.net
Jose Luis I. Amodio Leon	Aerospace engineering	4th	jamodiol@iit.edu
corey bushcott	architecture	5th	redjadestudios@gmail.com
Antonio Gonnella	Aerospace and Mechanical Engineering	4th	antoniogonnella@gmail.com
Edward Ciciora	Aerospace Engineering	4th	eciciora@gmail.com
Kent Hoffman	Architecture	5th	khoffman730@gmail.com
Jaeyoung Kim	Architecture	5th	itsaquarius@gmail.com

	Strengths	Weaknesses	Expectations
Taylor Dizon	dedicated, detail-oriented, friendly	confrontation, opposition	I hope that working with a team for an extended amount of time will improve my communication skills and enhance my relationships with both professors and fellow students.
Tom McManus	I'm decent at math, I have some computer experience, I enjoy learning, and I'm a friendly person.	I am a bit of a procrastinator, and sometimes I have issues with punctuality.	I expect that we will all come together as a team and that we will meaningfully progress towards the goal of a novel wind energy solution.
Jonathan Swanson	Wind Tunnel Experience, Research Experience	Time, Delegation	To improve Team skills, delegation skills, and to see design improvement
Thiago Jardim	Committed to progress, rational, creative and hard working. I am skillful with diverse modeling softwares and informative graphic design.	Lack of mechanical knowledge	I expect that the group achieve efficient results to be applied to real world urban landscapes
Nyla Husain	Wind tunnel experience and basic research experience, knowledge of fluid mechanics.	No IPRO or CFD experience.	To design something that works or at least gather useful information. To develop better team skills.
Lucas Pfiffner	Innovative and I like to look at the big picture thereby providing forethought as well as playing the devil's advocate.	Procrastination	To gain an understanding of some practical engineering methods as well as how to work amongst varied professions.
Jose Luis I. Amodio Leon	Responsible. Dedicated. Eager to learn. Ability to speak a lot, but also give crucial info in a short amount of time.	Computer software. I can be late sometimes.	Learn many things related to team work, CFD analysis and how to work in a lab. Also learn more about wind turbine modules performance and get a useful result.

	Strengths	Weaknesses	Expectations
Corey Bushcott	design, concept, visuals	pre-stressed, rigor, patience	to produce a proof of concept prototype.
Antonio Gonnella	good leadership, good drive to success, goal oriented, great adaptability to different situations, hard worker, time management, detail oriented.	short temper, easily stressed, over achiever.	I would like to accomplish great things with this IPRO. I would like to gain wind tunnel testing and CFD experience. This IPRO is just a stepping stone towards my goal of working for a company that deals with wind turbines and renewable energy.
Edward Ciciora	Works best under stress, will do what it takes to get the job done, eye for detail	Time management skills, patient	I really want to see what happens when a group assembles one solid idea and makes it work. I am very interested in anything that has to do with the aerospace field and this project is an opportunity to put all I have learned into practice.
Kent Hoffman	Good time management skills, ability to lead a group and make tough calls, can work under stress, quick learner	Lack of knowledge in mechanical engineering and fluid dynamics	I expect to work within my IPRO group on a project that I've never tackled before. I would like to gain a greater knowledge of wind technology and a greater ability to work with individuals outside my major coming from completely different backgrounds.
Jaeyoung Kim	3D Modeling. Good Time management. Friendly	Lack of knowledge about f=ma(physics). Shy.	I expect that have diverse experiences. I'm interested in applying technology in architecture.

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Expense Category		Amount	Percent of Total
Equipment (Describe **briefly** below in Justifications area.)	$	-	0.00%
Materials and Supplies (Describe **briefly** below in Justifications area.)	$	1,500	14.52%
Publications and Communications (Describe **briefly** below in Justifications area.)	$	180	1.74%
Student Stipend(s) - ***May not exceed $2,500***	$	-	0.00%
Faculty Stipend(s) - ***May not exceed $8,000***	$	8,000	77.44%
Other Stipend(s) - (translator, advisor from field, support from someone outside your institution, etc.) (Describe **briefly** below in Justifications area.)	$	-	0.00%
Travel Expenses (Describe **specifically** below in Justifications area - re: # of trips and # of people traveling.)	$	-	0.00%
Prototyping	$	500	4.84%
Other Expenses (Describe **very specifically** below in Justifications area.)	$	150	1.45%
Total	$	10,330	**100.00%**

Total budget may not exceed $12,000. If you have received or plan to receive other funding for this project, please note this in a separate budget document.

Justifications - ***Use the space below to describe expense line items above.***

1) A major component of this IPRO is wind tunnel testing and as such there will be several items that will need to be purchased for the construction of the model as well as the testing of the model. The materials & supplies that will be needed to perform the wind tunnel tests include foam (to make the façade), glue, tape, goo-gone/degreaser/solvent, MDF (for the façade template), tape (scotch super 88), wire (for cutting the façade), perforated plate for modeling the wind turbine and miscellaneous parts to secure, position and provide ease of movement of the models in the tunnel. The planform of the test section in the wind tunnel is 4' wide and approximately 5' in length so the single biggest expense in this category will be the purchase of relative large pieces of good quality foam to investigate several different models.

2) $180 for posters and brochures. Some funds may be needed for the purchase of publications.

3) $500 for prototyping. For this project there will be several "models" of building facades tested in the wind tunnel. There will also be "models of wind turbines that need to be fabricated to use in the wind tunnel tests.

4) Other Expenses: Students wanted two pizza working dinners. I am not sure if this is at all allowed but I have put it in. Mike Gosz did say something about pizza when he was describing the "other expenses" category: I am not sure if he was joking or not. I have calculated three large pizzas per dinner at $16 per pizza + soft drinks + tax + tip. If this isn't allowed then take it out of the budget

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	Week 1	Week 2		Week 3		Week 4		Week 5		Week 6		Week 7		Week 8		Week 9	
ACTIVITY		18-Jan	20-Jan	25-Jan	27-Jan	1-Feb	3-Feb	8-Feb	10-Feb	15-Feb	17-Feb	22-Feb	24-Feb	1-Mar	3-Mar	8-Mar	10-Mar
Finalize Project Plan		Project plan team		IPRO team													
Design Research				Design Team													
Mesh modeling+1st model				CFD team													
Wind tunnel calibration				Wind tunnel team													
Wind tunnel mesh testing								Wind tunnel team									
Model 1 manufacturing											group 1						
Test 1												group 2					
Analysis 1														group 3			
CFD 2nd model														CFD team			
Model 2 manufacturing															group 1		
Test 2																group 2	
Analysis 2																group 3	
CFD 3rd model																CFD team	
Model 3 manufacturing																	
Test 3																	
Analysis 3																	
CFD 4th model																	
Model 4 manufacturing																	
Test 4																	
Analysis 4																	
Midterm Review										Sub Team		IPRO team					
CFD 5th model																	
Model 5 manufacturing																	
Test 5																	
Analysis 5																	
Interpret overall results																	
Finalize Model																	
Small Scale prototype																	
Poster/Abstract/Report																	
Prepare for IPRO Day																	
Final Project report																	

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	Week 11		Week 12		Week 13		Week 14		Week 15		Week 16			Week 17
ACTIVITY	22-Mar	24-Mar	29-Mar	31-Mar	5-Apr	7-Apr	12-Apr	14-Apr	19-Apr	21-Apr	25-Apr	26-Apr	28-Apr	29-Apr
Finalize Project Plan														
Design Research														
Mesh modeling+1st model														
Wind tunnel calibration														
Wind tunnel mesh testing														
Model 1 manufacturing														
Test 1														
Analysis 1														
CFD 2nd model														
Model 2 manufacturing														
Test 2														
Analysis 2														
CFD 3rd model														
Model 3 manufacturin	group 1													
Test 3		group 2												
Analysis 3		group 3												
CFD 4th model		CFD team												
Model 4 manufacturing			group 1											
Test 4				group 2										
Analysis 4					group 3									
Midterm Review														
CFD 5th model					CFD team									
Model 5 manufacturing						group 1								
Test 5							group 2							
Analysis 5							group 3							
Interpret overall results								IPRO team						
Finalize Model						IPRO team								
Small Scale prototype								IPRO team						
Poster/Abstract/Report							Poster team		IPRO team					
Prepare for IPRO Day									Sub Team		IPRO team			
Final Project report										Sub Team		IPRO team		

Primary Activity
Secondary Activity
Final Cut

Group 1	Manufacturing team
Group 2	Testing team
Group 3	Analysis team