Piezoelectric Harvesting

A sustainable approach to clean energy generation in airport terminals.

Airport Environmental Interactions

Christopher Scholer, Undergraduate
Jeffrey Ikeler, Undergraduate
Joshua Ramirez, Undergraduate
Sarah Jen, Undergraduate

Glynn Falcon, Faculty Advisor
San Jose State University

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Executive Summary

In this era of increasing energy costs and decreasing supplies of fossil fuels, emphasis on protecting the environment and creating sustainable forms of power have become vital, high priority projects for modern society. Airports are no exception in this race to discover and implement new energy technologies to bring the United States into the 21st century and beyond. It is imperative that clean, renewable sources of energy be put into practice if we are to wean ourselves off of more traditional sources of power such as fossil fuels.

Airports in the United States are vital transportation hubs that will greatly benefit from new energy technologies. Lower costs along with cleaner day-to-day operations from green forms of energy will allow airports in the United States to operate more efficiently and effectively. Furthermore, implementing these technologies at airports could have the added benefit of improved relationships with airport neighbors; the green technology used at the airports would set an example for the surrounding communities and would show that airports are concerned about the environmental impact that they have on the surrounding areas. One such idea that will fit well in an airport setting is the capturing of kinetic energy from passenger foot traffic. This novel idea is not only clean but it is also renewable.

Problem Statement

Currently, there is a need to utilize alternative forms of energy at airports across the United States. Cleaner, more sustainable forms of electrical power are needed in order to keep costs lower, to maintain positive and productive relationships with airport neighbors and to insure a healthier environment for future generations. The use of piezoelectric devices installed in airport terminals will enable the capturing of kinetic energy from foot traffic. This energy can then be used to offset some of the power coming from the main grid. Such a

source of power can then be used to operate LED lighting systems, since LEDs use far less energy than more conventional (fluorescent and incandescent) bulbs. "LEDs are about four times more efficient than conventional incandescent lights and more environmentally friendly than compact fluorescent bulbs" (Purdue University, 2008). This will help to decrease energy consumption and environmental impact even further.

Background

PIEZOELECTRIC DEVICES

Using the floor space in airport terminals allows for a large source of otherwise wasted energy to be captured and utilized as an alternative form of energy for the lighting systems within airports. In order for the energy from walking motion to be captured, piezoelectric devices must be installed underneath the floor in terminal buildings.

Piezoelectric devices are implements that use materials exhibiting piezoelectric effects. "Piezo," in Greek, means "pressure," which explains that when you apply pressure to piezoelectric materials, you get a charge separation within a crystal and a voltage across the crystal that is sometimes extremely high (How Stuff Works, 2000). Quartz, Rochelle salt, and certain ceramics all exhibit piezoelectric behaviors. Placing piezoelectric devices that are used to capture energy from foot traffic underneath airport terminals can effectively capture electrical energy and send it back to the power grid through inverters, which are needed in order to convert the DC power, from the piezoelectric, into AC power used by terminal lighting systems (Inverters for solar panel installations work just as well for piezoelectric devices).

> An example is a BBQ lighter, the popping noise you hear when depressing the lighter button is a little spring-loaded hammer hitting a crystal and generating thousands of volts across the faces of the

> crystal. A voltage this high is identical to the voltage that drives a spark plug in a gasoline engine. The crystal's voltage can generate a nice spark that lights the gas in the grill (How Stuff Works, 2000)

Similar to the BBQ lighter, shoes striking a piezoelectric pad underneath a floor tile act like a hammer hitting the crystal material inside the pad. This energy from the shoe then creates a voltage that can be used to power lighting systems. Hundreds or even thousands of these piezoelectric devices would be installed underneath flooring to capture the kinetic energy from walking.

EXAMPLES OF CURRENT USES

Electricity generated through piezoelectric devices has many applications; the BBQ lighter mentioned above is one of many uses. One use, comparable to an airport application, is the implementation of piezoelectric generators at a nightclub. "The dance floor makes use of a piezoelectric system that produces electricity as the dancers jump up and down, which charges some batteries that are used to power parts of the club" (engadget, 2008).

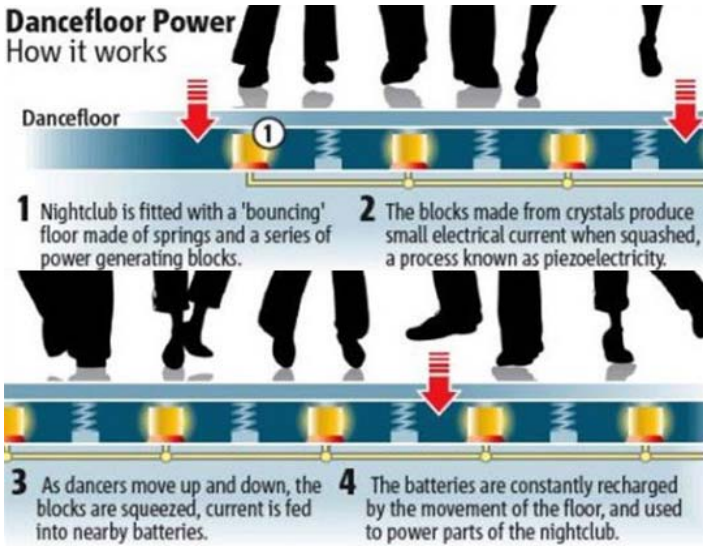

Figure 1 – How a piezoelectric flooring system generates electricity through kinetic energy. Courtesy engadget.com.

This example of piezo electricity would be similar to one installed at airports except that springs would not be needed, thin, piezoelectric pads would be installed underneath the floor material. The pressure placed upon the pads as people walk will generate the needed force to create an electrical charge; the charge will be sent to an inverter and then directly to the airports main power grid thus avoiding the need for batteries.

Another example of piezo electricity in action is the experimental installation of these piezo electric devices at a train station in Japan:

> The East Japan Railway Company (JR East) conducted a demonstration experiment from January 19 to March 7, 2008, at Yaesu North Gate, Tokyo Station, on a new power-generating floor. Installed at the ticket gate area, it generates electricity from the vibrations created by passengers walking through the ticket gates.
>
> The power-generating floor is embedded with piezoelectric elements, which are 35 millimeters in diameter, and disc-shaped components used for loudspeakers. It uses 600 of these elements per square meter. While the loudspeaker creates sound by converting electric signals to vibrations, the floor adopts the reverse mechanism that produces electricity by harnessing the vibrational power generated from passengers' steps. It is being developed by JR East with the aim of making stations more environmentally friendly and energy efficient (Japan for Sustainability, 2008).

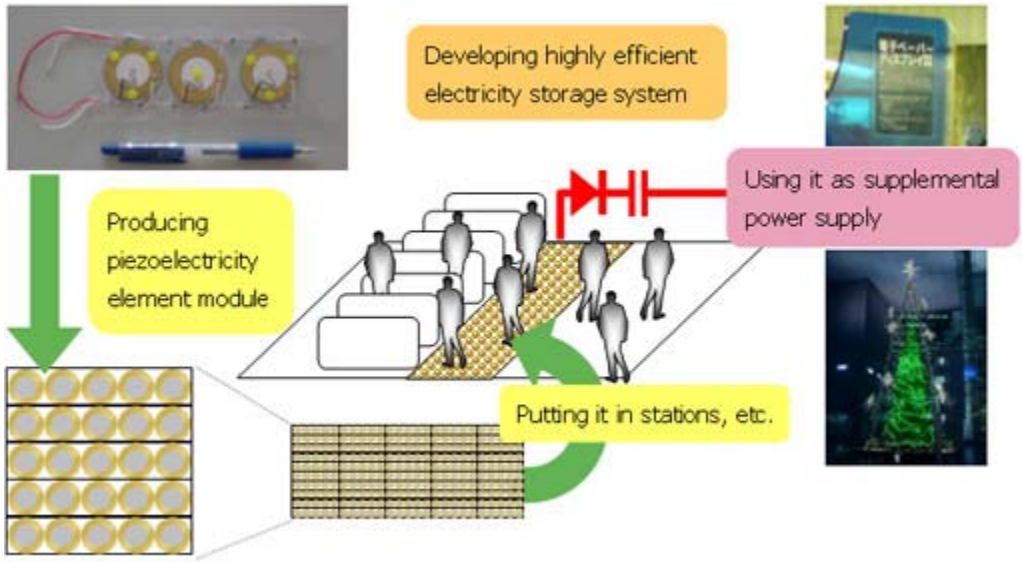

Figure 2 – Tokyo Train Station and how it generates electricity through piezoelectrics installed at the ticket area. Courtesy Japan Railways Group.

This particular application would resemble airport applications the closest. Train stations are much like airport terminals in that high volumes of traffic come and go in waves depending upon when Flights/Trains are arriving or departing. The Japanese rail station intends to use the power for station facilities such as automatic ticket gates or electric displays (Japan for Sustainability, 2008). Implementation in airports could also use the power for displays and lighting in terminals.

INSTALLATION

The installation of the piezo devices requires that flooring be removed. This process can be done as old, worn flooring is replaced or in certain high traffic areas as an experiment for determining feasibility in airport terminals, a similar option to the implementation in the Tokyo train stations. The piezo devices, due to their small thin shape, could be placed underneath floor tiles or carpet with few complications. In order to harness the power a capacitor could be used to store the electricity like in the train stations or inverters, like ones used to convert solar electricity from direct current to alternating current, could be installed in the terminals to convert the DC power from the piezo devices into AC power used in the lighting systems at airports. The power could then be routed directly to specific electrical devices such as lights or billboards or it could be sent to the main power grid at an airport in order to supplement the main power supply. There are many installation options and applications of these devices; the specific type of installation will depend upon the intended use of the piezo devices within the terminals.

LOCATION WITHIN TERMINAL BUILDINGS

Locating piezo electric flooring in airports is dependent upon how much traffic, on average, certain parts of a terminal receive in a given day; the higher the averages the higher the potential for energy production. Based on this it is important to locate high traffic areas to gain the most benefit out of the power generating floor.

One such high traffic area is the check-in station, these areas often have large lines of passengers waiting to check in baggage and obtain boarding passes. Piezo devices could also be installed under the baggage weighing scales in the check-in areas to harness the energy from placing luggage on these platforms. Another high traffic area is the security line; the piezo devices could be located under the floors along these lines to capture the foot traffic in these lines. Concession areas and advertising signs would also benefit from having the power-generating floor. Billboards could be light up by people passing by and lighting in the concession areas could be partially powered by the flooring. Experimentation with different areas and by observing locations of high foot traffic in airport terminals are important in determining the optimal locations for capturing kinetic energy from walking.

Figure 3 - Baggage check-in area where piezoelectric flooring could be implemented. Courtesy Flight Data Management.

Literature Review

PIEZOELECTRIC TECHNOLOGIES

According to How Stuff Works, piezoelectric materials create a positive and a negative end when work is done to deform their original shape. The International Harvest Tribune claims that "energy harvesting", more commonly referred to as "crowd farming", has been in existence for as long as 10 years. An electrical charge flows across the material once pressure is relieved from them. While they usually provide very low currents, they can generate extremely high voltages. Harvesting energy from piezoelectric flooring is said to be impractical in residential applications due to the high cost of implementation and small amount of electricity generated in these settings. Common piezoelectric materials include quartz, Rochelle salt, and some ceramics. The New York Times also claims that harvesting energy from piezoelectric materials is inefficient, converting only a small amount of kinetic energy into electricity.

The Christian Science Monitor claims that a single footstep could potentially generate enough electricity to power two 60-watt incandescent bulbs for one second, while the International Herald Tribune claims that the technology were implemented in a busy train station that the energy captured could power 6,500 LED lights for an unspecified amount of time.

LED TECHNOLOGY

Light-emitting diodes, or LEDs, show promise for replacing traditional lighting sources. According to the Christian Science Monitor, the European Union has banned the sale of incandescent light bulbs because of their inefficiencies, with BBC News stating that

Australia has followed suit and banned them as well. Specifically, they cite that the standard incandescent light bulb converts only about five percent of the electricity it uses into usable light, with the rest being converted into heat. LEDs are approximately four times more efficient than incandescent light bulbs and currently as efficient as fluorescent lighting without the environmentally harmful mercury content that they contain according to Purdue University.

LEDs also carry the benefit of providing high visibility in signs, some of which can be seen from up to 1.5 kilometers away, claims Wallstreet Pit. The New York Times states that a new LED sign in New York City will be bright enough to be readable even during high noon. Philips claims that their current state-of-the-art Luxeon K2 LEDs have outputs of at least 200 lumens at 12 volts DC with a current as little as 350 mA. Further, they dim far less than traditional lighting sources, with some experiencing only a 10% loss of light output after as many as 1,000 hours, and last for as long as 15 years under normal usage conditions. Several cities are considering switching from high pressure sodium lighting to LED lighting, including a pilot program of 34,000 street lamps slated for testing in Lansing, Michigan.

APPLICATIONS

Club Watt in Rotterdam, The Netherlands utilizes a spring-loaded flooring system of independently moving tiles. Inhabitat claims that each tile can compress up to 2cm, activating a flywheel mechanism which powers a small electrical generator. It also claims that LEDs embedded in the floor are sustained entirely by the approximately 20 watt generated by each dancer. The owner is said to have paid $257,000 for the 270 square foot floor. While he does not expect to recoup his investment through energy generation, he expects to recover 10% of the club's electrical requirements through the flooring system.

Engadget covered a similar club in the United Kingdom. Named Club4Climate, it utilizes piezoelectric materials in the flooring to generate higher amounts of electricity. Harvesting power from the dancers, the energy is stored in batteries, which are emptied into the grid to help directly offset the costs of electricity usage. Mail Online cited the owner, Mr. Charalambous, claiming that vigorous dancing could generate as much as 60% of the energy needs for the club.

Problem Solving Approach

The original design idea for our team was an ice detection system for runways and taxiways at airports; we wanted to incorporate infrared cameras into current detection equipment. Through our research we discovered that the use of infrared technology for ice detection was not a very practical idea. Ice forms on runway surfaces that are at or below water freezing levels, using an infrared camera to pick up ice patches would not work for this type of scenario. The infrared picture would show the ice and surface it is forming on as the same making these infrared images non-useful for spotting ice.

After realizing that our first design would not be practical, we brainstormed for ideas and eventually came up with the plan of harnessing energy from walking to supplement the main power for airport terminals. We discovered that the idea of using energy from walking or dancing was already under trials at various places such as the train station in Japan and several nightclubs in Europe. As a group we felt that this technology could be utilized at airports much like it is used at the train station in Japan. High levels of foot traffic inside terminals would allow for the potential of high energy acquisition from a renewable, clean resource. This adopted idea will provide for a safe, clean and renewable supplemental source of power for airports; it will help promote the FAA's move towards safer, cleaner technologies for airports across the country.

Safety Risk Assessment

The safety risks associated with this design proposal are minute. The installation of the kinetic flooring in terminals will not affect safety within the buildings. Passengers will not be able to tell that this technology is in use, the piezo devices used to harness the power from foot strikes will be installed under the flooring and so will not interfere with walking. The very low risk associated with this technology is in line with the FAA Safety Management system, it provides little to no increased risk, insuring that passengers and employees remain safe in airports that would use this technology (Federal Aviation Administration, 2008)Benefits

Interview

On November 24th 2008, an interview was conducted with the Facilities and Engineering Senior Manager for San Jose International Airport. Patrick Crowley is the current Facilities and Engineering Senior Manager and oversees the maintenance and development at the airport. San Jose International Airport is owned by the city of San Jose and Mr. Crowley is a city paid employee. He has been the senior engineer of SJC for the past five years. Mr. Crowley was previously employed in a different department of the city of San Jose, the division of Public Works. The interview provided our team with valuable information necessary for the proposal for the installation of the sustainable floor tiles. Below are the relevant questions asked, and answers Mr. Crowley provided.

- "What is the square footage of all the terminals?"

According to Crowley the square footage of terminals A and C is 420,000 and the new terminal currently under construction will have a square footage of 389,000.

- "How much traffic in passengers does the airport see yearly, monthly, daily?"

San Jose International sees 10 million passengers a year. This past June, SJC had 915,000 passengers for the entire month. On average, that equates to 30,500 passengers each day.

- “What kinds of overhead lighting are used throughout the terminals?”

Almost all of the overhead lighting of the terminals is provided by 25 Watt T8 fluorescent bulbs.

- “What was last year’s budget for the Facilities and Engineering Department?”

Mr. Crowley stated that last years budget for the Facilities and Engineering Department was 22.2 million dollars.

- “How much money is spent each month on electricity for the terminals?”

308,000 dollars was spent on electricity alone for the operation of the terminals.

- “Are the lights in the terminal on 24 hours a day?”

Overhead fluorescent lights in the main part of the terminal are on 24 hours a day however lighting in other places are either on clock timers or are motion activated.

- “What type of flooring is in each of the terminals?”

In the security checkpoints, terminal A and the new terminal under construction, the flooring is terrazzo (strong faux stone flooring). Terminal C is all carpeting and requires the most maintenance with removal and replacement approximately every 5 years.

- “Are any LED type lighting used at the airport?”

LED type lighting is used only on the airside of the airport and is used for the directing of aircraft, i.e. taxiway and runway lighting.

From the information gleaned from the interview, a sustainable flooring installation into the terminal buildings would decrease the amount of electricity used by the airport and decrease floor maintenance when replacing carpeting with piezoelectric flooring. According

to the team's research, installing piezoelectric flooring and replacing overhead fluorescent terminal lighting with LED's would greatly reduce the electricity required to light the terminal buildings. Our team would like to graciously thank Mr. Crowley for taking time out of his busy schedule to allow the interview. Crowley was quite interested in the design for the sustainable floor tiles and looks forward to hearing the FAA's response to the proposal.

Appendix A

Faculty Advisor:

Glynn Falcon, Director of Aviation
One Washington Sq.
San Jose, CA 95192
Glynn.Falcon@sjsu.edu
(650) 323-0333

Team Leader:

Christopher Scholer
23760 Alamitos Road
San Jose, CA 95120
krittir@aol.com
(408) 717-3319
(408) 268-1461 FAX

Team Members:

Jeff Ikeler
1919 Fruitdale Ave. Apt. K766
San Jose, CA 95128
Jeff.Ikeler@gmail.com
(530) 295-7822

Josh Ramirez
433 S. Navarra Dr.
Scotts Valley, CA 95066
Chevydelrey55@yahoo.com
(831) 588-7339

Sarah Jen
116 Brighton Ave.
San Francisco, CA 94112
Sjen991@yahoo.com
(415) 505-4763

Appendix B

SJSU'S MISSION

In collaboration with nearby industries and communities, SJSU faculty and staff are dedicated to achieving the university's mission as a responsive institution of the State of California: To enrich the lives of its students, to transmit knowledge to its students along with the necessary skills for applying it in the service of our society, and to expand the base of knowledge through research and scholarship.

GOALS

For both undergraduate and graduate students, the university emphasizes the following goals:

- In-depth knowledge of a major field of study.
- Broad understanding of the sciences, social sciences, humanities, and the arts.
- Skills in communication and in critical inquiry.
- Multi-cultural and global perspectives gained through intellectual and social exchange with people of diverse economic and ethnic backgrounds.
- Active participation in professional, artistic, and ethnic communities.
- Responsible citizenship and an understanding of ethical choices inherent in human development.

CHARACTER AND COMMITMENT

San José State University is a major, comprehensive public university located in the center of San José and in the heart of Silicon Valley. SJSU is the oldest state university in California. Its distinctive character has been forged by its long history, by its location, and by its vision -- a blend of the old and the new, of the traditional and the innovative. Among its most prized traditions is an uncompromising commitment to offer access to higher education to all persons who meet the criteria for admission, yielding a stimulating mix of age groups, cultures, and economic backgrounds for teaching, learning and research. SJSU takes pride in and is firmly committed to teaching and learning, with a faculty that is active in scholarship, research, technological innovation, community service and the arts.

Appendix C

No non-university partners were utilized in the creation of this proposal.

Appendix D

FAA Design Competition for Universities
Design Submission Form (Appendix D)

Note: This form should be included as Appendix D in the submitted PDF of the design package. The original with signatures must be sent along with the required print copy of the design.

University San Jose State University
List other partnering universities if appropriate N/A

Design Developed by: ☐ Individual Student ■ Student Team

If Individual Student

Name _____
Permanent Mailing Address _____

Permanent Phone Number _____ Email _____

If Student Team:

Student Team Lead Christopher Scholer

Permanent Mailing Address 23760 Alamitos Road, San Jose, CA 95120

Permanent Phone Number (408) 717-3319 Email krittir@aol.com
Competition Design Challenge Addressed:

(Airport Environmental Interactions) Piezoelectric Harvesting

I certify that I served as the Faculty Advisor for the work presented in this Design submission and that the work was done by the student participant(s).

Signed _____ *Date* _____

Name Glynn Falcon
University/College San Jose State University
Department(s) Aviation & Technology (AvTech)
Street Address One Washington Sq
City San Jose State CA Zip Code 95192
Telephone (408) 924-3203 Fax (408) 924-3198

Appendix E

1. **Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?**

All team members agreed that the Design Competition presented the opportunity for a "meaningful learning experience." Each member found the required format of the proposal to be conducive, though there was often discussion among team members regarding minor details of its layout.

2. **What challenges did you and/or your team encounter in undertaking the Competition? How did you overcome them?**

The largest challenge that the team overcame during the Design Competition was researching the first few proposals that were created. The first iteration of the team's proposal was cancelled because of a surprising lack of available research that was published in accessible formats. Without a sufficient amount of data readily available to support the proposal, the team decided that it would be a more efficient use of time to change the proposal a bit. The second iteration of the proposal appeared very promising on the surface, due to its simple practicality and vast amount of research available. However, the topic was dropped when an industry expert revealed that he was already working directly with the FAA with regards to the exact same idea.

3. **Describe the process you or your team used for developing your hypothesis.**

The hypothesis of applying sustainable floor tiling in the terminals was developed through the combining of two team members idea. The first was to utilize environmentally friendly materials in the terminal building, and the second was to find a way to create electricity for the terminal without the use of solar energy. While researching electricity generation and

sustainable buildings our team discovered the sustainable dance floor which gave us our idea to install the piezo floor tiles in the terminal buildings, our hypothesis.

4. **Was participation by industry in the project appropriate, meaningful and useful? Why or why not?**

Participation with industry leaders was appropriate, meaningful and useful for purposes of the Design Competition, but only within the aviation industry. One of the team's contacts, an employee of Norman Y. Mineta San Jose International Airport was very helpful in providing a context for the efficiencies of the airport, as well as its various fragments. However, contacts with industry experts in piezoelectrics and sustainable nightlife turned out to be very unreliable. Several times the only responses received were form letters which gave no useful information, while the times when people were reached, they were not able to provide any meaningful information for the purposes of the Design Competition.

5. **What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?**

Jeff felt that while the project helped hone both his writing and analytical skills, it did not prepare him for successful entry into the workforce any more than a typical senior project would have. Most classes that he has taken have had semester-long projects similar in nature to the Design Competition, but which provided a higher degree of freedom in proposal criteria, allowing for more flexibility in writing. In the way of further study, he believes that the Design Competition functions as a great preview of the process and dedication required to successfully complete a thesis for a Master's degree.

Sarah learned many things from this project, and felt that it definitely helped to prepare her for the future work force and further study. She especially enjoyed the aspects of brainstorming ideas for the proposal, but also enjoyed researching the topic at hand. She found that problem solving was required for the project and said that she learned how to better work with team members. Since teamwork is very important in Aviation when it comes to safety, she was glad to have successfully collaborated to reach the goal.

Josh discovered that coming up with an original design idea is a challenging and time consuming process. He felt that the project did help him prepare for the workforce in that it gave him a valuable team building experience.

Crit stated that it was extremely difficult to find a topic for the design competition that had not been previously submitted. When ideas were voiced by students, on the third day of class, over 5 students had almost the same proposals. Crit was excited that his team found a topic that was on the cutting edge of new technological development and had not been proposed to the FAA previously. According to Crit, the researching and team involvement in the project taught him the importance of accurate

Exhibit E

(Advisor/Instructor Portion)

1. *Describe the value of the educational experience for your student(s) participating in this Competition submission.*

Entering this competition has proven to be an excellent Capstone experience for our graduating seniors. They have now experienced "real-world" deadlines, planning, schedules, teamwork and personal commitment, personal and group conflicts, interfacing and consulting with aviation experts, and preparing and editing a professional report. As their professor, I was able to observe their growth throughout the process, and see how they overcame problems which, in other college courses, would have left them stymied and looking to their instructor for resolution. Not here, as I was able to act merely as facilitator for access to information and expertise, and left these student competitors to find their own solutions.

2. *Was the learning experience appropriate to the course level or context in which the competition was undertaken?*

Yes, as we restricted the college-sponsored applications only to those Capstone enrolled, graduating seniors. In this way, we believe we could witness their culminating learning experience and, hopefully, successful outcomes.

This belief proved to actually be true. This year, without exception, each of our seniors demonstrated maturity and educational excellence and competence in their approach to submitting their designs to the FAA, and also in their work ethic.

3. *What challenges did the students face and overcome?*

They faced too many challenges to adequately list them all, here. But the most significant challenges seemed to be adaptability to working efficiently within the group dynamic, and in developing sufficient knowledge and expertise within their proposed design submissions to appreciate flaws or limitations with their proposals.

I also placed an additional requirement upon their work, and that was to document on video their group's progress and setbacks, and then compile and edit the video into a 10 to 15 minute presentations to be submitted with their designs. This will be played for faculty review, and at graduation to the families of our graduates.

4. *Would you use this Competition as an educational vehicle in the future? Why or why not?*

Yes. As a "competition," I previously commented upon some inequities and unfairness that existed under the former rules which had caused us some concern. Those comments appeared to be taken to heart by the Design Committee, and are no longer an issue. As a "learning experience," this program remains an outstanding opportunity to have our senior class demonstrate their readiness to join government and industry employment.

5. *Are there changes to the Competition that you would suggest for future years?*

Yes. Instead of having one "annual" competition, divide it into 2 (for semester programs) or 3 (for quarter programs) so that within the university, we are not competing one class against another. We believe that the Spring submissions have an advantage in the competition, as not only to they have several additional months to research and prepare, but (at least within the university) they have the advantage of witnessing the work, designs, and deficiencies of the Fall class's submissions.

Thank you for providing this excellent program to our students.

Respectfully submitted:

April 13, 2009

/s/

Glynn Falcon

Director of Aviation
Aviation & Technology Dept.
College of Engineering
San Jose State University

Appendix F

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