AC 2010-126: DESIGN OF A BUNGEE LAUNCH SYSTEM TO SUPPORT A KITE-BASED LIFTING PLATFORM FOR AERIAL IMAGING

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Abstract

Freshman engineering design students were given the problem of designing a bungee launch system to support a kite-based lifting platform for aerial imaging. The unique nature of the project lies in its support of precision agriculture efforts on campus by reducing cost and difficulty of operation for aerial imaging platforms in little to no wind situations.

The students were given a set of criteria which required them to employ engineering principles as well as leadership skills in team building and management. The problem statement was for the students to design a bungee launch system for a kite-based lifting platform that incorporates a camera system for aerial imaging purposes. The requirement was that the delivered product should meet the following criteria:

- Must be able to launch winds less than 7knots, more than 3 knots.
- Mechanism must be static (anchored) in nature and weigh less than 15 lbs.
- Be able to launch kites of various sizes weighing less than 5 lbs.

A successful launch was defined as being able to sustain flight for more than 120 seconds

Students competed on two separate teams that designed independently of each other. This paper examines the similarities and differences in the final design product, the process in completing the assignment and leadership variables involved in project management.

Index Terms – engineering, bungee launch, kite, aerial imaging.

Introduction

One of the issues confronting learning environments is the ability to integrate diversity of approach both in teaching and learning modalities. With the freshman engineering course we have attempted to use the diverse faculty in the department which has both engineering and aviation sciences programs to structure projects related in some ways to both programs. This is done to advance engineering principles as well as proof of concept, as the case may be in its application to the aviation program.

The benefit for students is that they are able to engage the faculty both as clients and instructors that result in a variety of learning modes. For this project, the class groups of two distinct teams that completed identical projects for the same client. Engineering design concepts with emphasis on various aspects of planning, developing and product design via hands-on approach was the key to this course experience. It also enhanced the students' communication skills and teamwork. Product visualization utilizing computer software such as word processing, Power Point, and spreadsheet enhanced the students' ability to collaborate in defining, developing, and designing a working prototype. Students learned the components of product development such as brainstorming, time allocation, project management, alternative designs, and cost constraints.

The use of multidisciplinary team projects ensures students the opportunity to be exposed to the realities of today's work environment. The ability to be able to interact with complimentary fields is quickly becoming a necessary skill. One important goal of multidisciplinary design is to identify the many solutions needed to solve a single problem while keeping in mind the many differing objectives of the overall project [1]. A multidisciplinary approach to engineering design is valuable in that it asks that students make certain that, "…advances in performance,… technology, or discipline(s), must be much more highly integrated than in the past" [2]. The Freshman Engineering course at the University of Maryland Eastern Shore is designed to expose students to challenging problems that require them to gain experience and increase their knowledge outside of their normal field of expertise while practicing decision making skills necessary to stay on time and on budget.

Engaging students within the engineering design principles

Students in the Spring 2009 Engineering Design course were given a written design problem statement and presentations by two of the Aviation Sciences faculty in their Department. Students were asked to design and build a bungee launch system to support a kite-based lifting platform for aerial imaging. The initial meeting included a question and answer period where student could ask key design questions to the faculty members playing the customer role. This session is initiated only when the class has fully researched the project by reviewing previous work done in the subject area. It is intended to provide students with a knowledge-base from which an intelligent discussion about the project can begin. Students interaction with the client in the initial stage is also viewed as an opportunity for students to work on developing their communication skills. Throughout the course, students studied the design process through regular lectures with their course instructor which included key concepts such as team design, understanding the client's needs; functions and design specifications; generating design ideas; connecting design concepts to engineering objectives; outcome reporting; oral presentation skills and final report elements.

Throughout the semester, aviation faculty met with the two design teams to offer design requirement clarifications and to check on student progress. By adopting a bidirectional communication process, the clients were able to gain additional insight by conducting an in-depth evaluation of student's participation. Additionally, the clients were able to gauge the student's level of understanding as it related to the project. Throughout the project, timelines were adjusted to meet unforeseen challenges. Team members were required to keep a log/journal book accounting for any unpredicted progress and project setbacks.

In addition to the aforementioned assessments, students were also evaluated by the following tools: 1) applying knowledge of math, science and engineering; 2) design, construct experiments and, analyze and interpret data; 3) design a system that meets the client's needs; 4) identify, formulate and solve engineering problems; 5) communicate effectively within the group and to the client; 6) utilize knowledge of contemporary issues; and 7) utilize techniques, skills and modern engineering practices. The class project was evaluated by the instructor with input from the faculty clients utilizing assessment of weekly reports, final project product, project report and group presentation including a question and answer session. Clients completed an evaluation of both the team's oral presentations on the last day of class for the semester.

Bungee launch system basics

A bungee launch system allows for the launch of a flight device from a static position using the build-up of tension in the bungee cord to jettison the kite into the air. The clients needed the freshman design class to develop this device in order to facilitate the launch of aerial imaging system in support of data collection of the university's agricultural fields on days where there was little to no wind present.

Students had to review Hooke's Law (F=K*X) in order to determine the right amount of line tension needed to keep their device aloft without causing breakage in the line. Additionally, students were required to gain insight into Newton's first and third laws of motion, Bernoulli's principles of fluid motion, as well as concepts of kite stability in flight. Students relied heavily on NASA's Glenn Research Center's site on *Forces on a Kite*. In order to achieve stable flight, students were required to maintain that the vertical pull (P_v) plus the weigh (W) minus the lift (L) was equal to zero (0).

$$P_v + W - L = 0$$

Group one relied more heavily on the NASA kite site and utilized its online kite modeler. Group one determined to use the Winged Box Kite after entering their variables into the Kite Modeler. Group two chose a simple delta wing design but did not state the reason for the decision.

Student population

Students were comprised of freshman engineering majors in the Department of Engineering and Aviation Sciences from the University of Maryland Eastern Shore (UMES). UMES is a historically black university (HBCU) providing a rich and diverse project team. Two teams were selected by splitting the class in half. Each team self-selected its team leader and devised the work according to their needs.

Bungee launch design

Group 1- The first group indicated in their weekly journal that there was a plethora of launch system information found on the World Wide Web (www). The group agreed on a ramp type design using a bungee cord as the launch mechanism. PVC piping was used to build the frame of ramp for its light-weight and sturdy characteristics. Additionally, materials were inexpensive and easy to construct with basic tools. Group 1 provided the customer with an initial design sketch (Fig. 1), a final side-view CAD drawing (Fig. 2), front view (Fig. 3) and overhead view (Fig. 4).

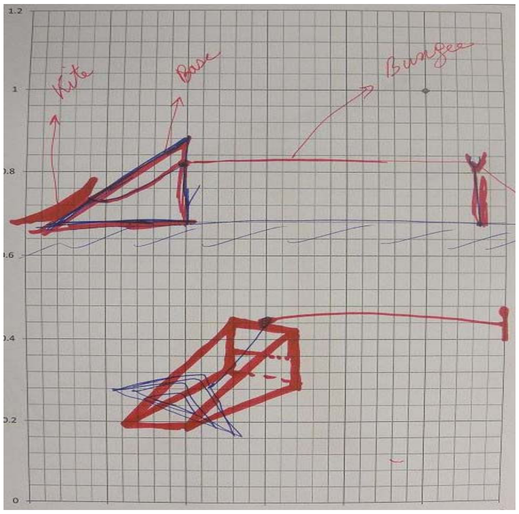

Fig. 1 Group 1 Initial design sketch

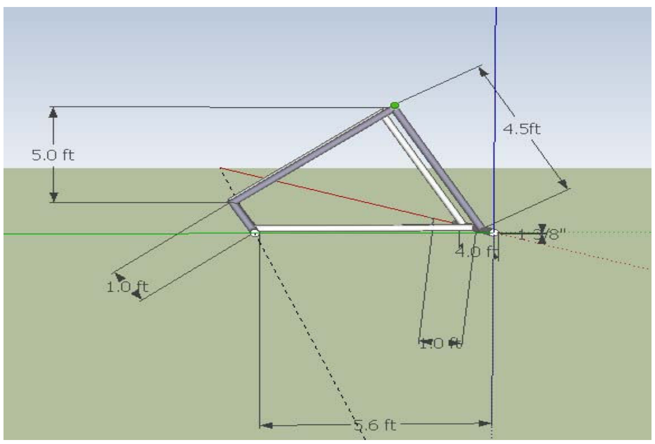

Fig. 2 Group 1 Final design sketch. Side View

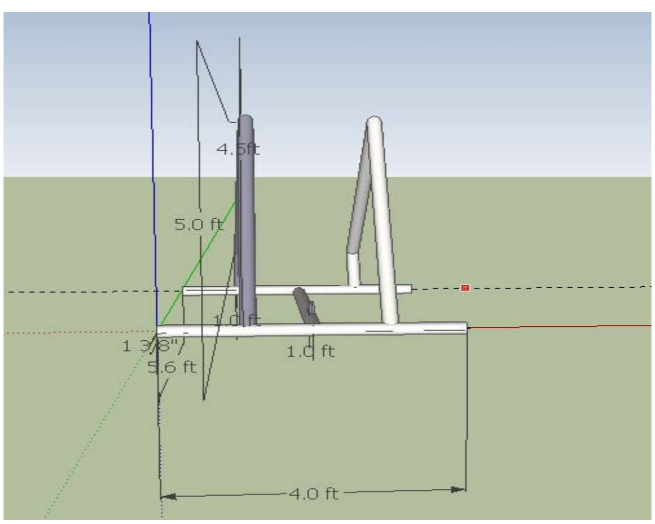

Fig. 3 Group 1 Final design sketch. Front View

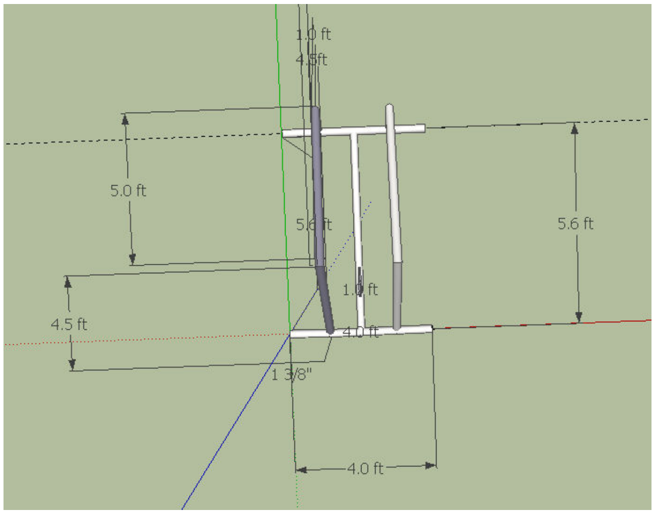

Fig. 4 Group 1 Final design sketch. Overhead View

Group 2 – The second group did not present the customers with an initial design sketch. Additionally, no schematic of the final design was created before product construction.

Final Design

Group 1 – The platform was designed with a sixty degree (60) incline to allow for a larger angle of incidence (Fig. 5). The platform utilized a simple release mechanism which included a small hook at the bottom of the platform approximately 24" from the leading edge of the platform. The bungee has a metal attachment ring at the end of the line which is released from another ring when pulled by the operator. The team used PVC piping for the frame, foam padding, rope, metal hooks and rings in the construction of the platform.

Challenges – The angle of the platform had to be increased in order to successfully launch the kite. Also, students miscalculated the cord strength. The group found that a heavier string was needed to withstand the forces encountered at launch time.


Fig. 5 Group 1 Final product A

Fig. 6 Group 1 Final product B

Group 2 – Group 2 also utilized PVC piping. An innovative design was used to solve the problem of the kite hanging up on the launch surface was employed. Group 2 decided to heat a piece of PVC tubing to make a bend (Fig. 7) instead of using a pre-constructed elbow.

Fig. 7 Group 2 Final product

Kite Deployment

Students in both groups were able to test their design periodically throughout the design phase. Group 1 routinely journaled their experience both in their group journal exercise as well as by video. All group members can be seen participating in the experience.

In stark contrast, there was no evidence of journaling from Group 2. The final oral presentation did not highlight any evidence of group participation. Additionally, the final written report indicates that the group leader carried most of the design and development burden.

Time Management

Group 1- Group 1 did not present a pre or post time management report (Fig. 8) in their oral or written presentation. Instead, the group chose to use a Project Schedule with seven key meeting outcomes. These included:

- First Group Meeting
- Task Allocation
- Literature Review/Design Proposals
- Analyzing Conceptual Design
- Material Acquisition
- Construction
- Testing/Proving

Group 2- Group two spent less time (Fig. 9) in consultation and more time in construction than previously planned.

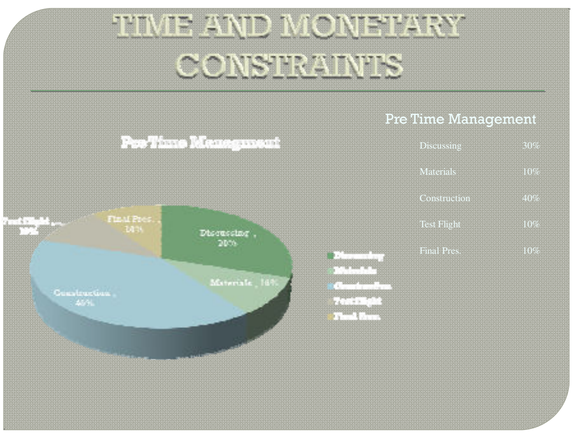

Fig. 8 Pre-Time Management Group 2

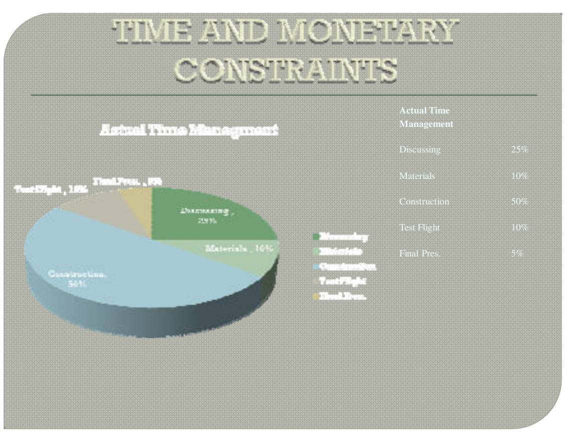

Fig. 9 Actual Time Management Group 2

Budget

Each team was given a budget of $105.00 to build the bungee launch system.

Group 1 – The team was able to stay within its budget (Fig. 10).

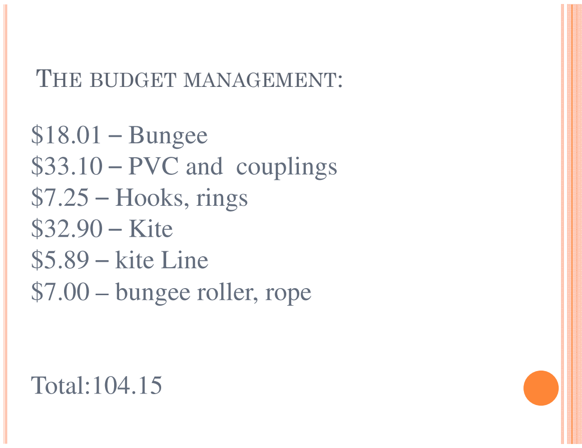

Fig. 10 Group 1 Budget

Group 2 – The team spent a bit more money (Fig. 11) on PVC and kite supplies putting them over budget by $12.87.

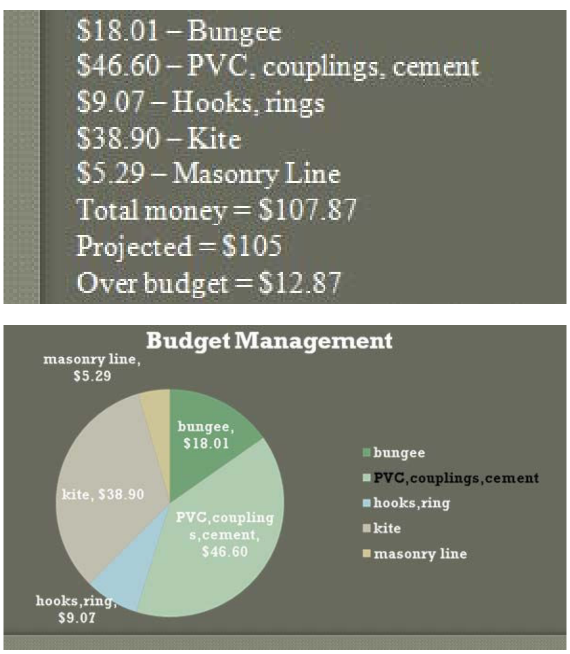

Fig. 11 Group 2 Budget

Team Project's Evaluation

The design teams were expected to present a final design to the "clients" at the end of the course, during the time allotted for final exams. Both teams did successfully launch their kites. However, due to the weather conditions during the evaluation day (heavy rain) the time aloft (120 sec.) criteria could not be demonstrated. The clients took this into consideration but found that all other requisites had been met.

Conclusion and Team Leadership Implications

Students were given a team formation survey and asked to select items that best describe them. Students were open to select as many as possible. It also asked if members lived on campus or off campus and asked them to describe their skill level in computing, building and analyzing. Group 1 was comprised of students with varying levels of engineering related experience. More than half the group indicated that they possessed all three skills (4/7). All of group 1 indicated that they possessed two of the three skills listed.

Group 1 had at least one student identify for each descriptor (Active Listener; Influencer; Analyzer; Innovator; Fact Seeker; Conflict Manager; Team Builder; Goal Director; Process Manager; Consensus Builder). All students in group 1 had a minimum of three of the attributes listed. One (1) indicated that he identified with all of the attributes, and two members identified with at least five.

Three (3) group 2 members indicated that they only possessed one skill group and one (1) member noted they possessed none of the skills. The one student that listed no skills also selected only two attributes that closely described her, that is 1.) Active Listener and 2.) Fact Seeker. No members of group 2 indicated that they possessed all three possible skill sets. In fact, only one student indicated they possessed *Good Computing Skills* and only two out of five indicated that they had *Good hands-on/Building* skills.

Group 2 had only one classmate identify in the following areas: Team Builder; Goal Director, Consensus Builder and Process Director. No one identified as an Influencer. Two group members out of the five lived off-campus.

Additionally, both teams were given a questionnaire to assess their perceptions of team leadership during the design project. The questionnaire was an adaptation of LaFasto and Larson's (1987) Team Excellence and Collborative Team Leader Instrument found in Northouse's Leadership: Theory and Practice text [3]. The in-class survey was designed to measure the group's effectiveness and outcomes using the framework of the team leadership model. The model has been found to be a useful tool in leadership selection and problem solving. It can be used to evaluate both leader and subordinates. In general, the team leadership model assists team leaders in making current assessments of team functioning. The leader's role becomes one of the tinkerer. The leader interacts with the group as a facilitator to help strengthen the team during times of need. These problems can be both internal and external. The leader needs to determine when it is best to take on one of three roles: Authority (internal, relational); Clarifier (internal, task); and Negotiator (external). In general, the leader must match their behavior with the nature of the problem.

Group 1's responses to the in-class survey indicated high (3 or more out of 4; Four indicating the statement is very true) perceptions of clarity, structure, competency, standards of excellence, commitment, collaboration, support/recognition, goal orientation, confidence, perceived technical ability, prioritization, and overall management.

Group 2's responses indicated low scores (2 or less out of 4; with scores of 1 indicating the operationalizing statement is false) in team structure, standards of excellence, support and recognition, member competency, external support/recognition, goal orientation, collaboration, confidence, prioritization and management performance.

The clear contrast between group's responses in surveys was evidenced by the oral and written project summary and final reports. In their final reports, group 1 explained how the group members, "*…enjoyed being part of a group designing and constructing projects that could possibly be used by future classes. The experience was great, learning the process to research a project and interact with the client to achieve a product that is feasible and meets or exceeds the client's expectations. The project is a success for the group and the client*."

In contrast, the team leader of group 2 indicated in his report that he and one other student had completed most of the necessary requirements for the project. His statement sums it up best, "*Although the course was designed to teach teamwork across all aspects of research, design and construction, it fell short…*". The report outlines a lack of participation and effort outside of the group leadership. The group leader did indicate that, toward the end of the assignment, he determined to communicate with the other team leader to brainstorm ideas with their design.

In retrospect, one might suggest utilizing both leadership assessments during the first week of class to gauge the student's skill and attribute levels prior to team formation to determine if a level of leader/team pre-selection helps mitigate outcomes as seen in group 2.

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