AC 2009-382: DESIGN AND FLIGHT TESTING OF AN IN-FLIGHT DEPLOYABLE PARACHUTE SYSTEM FOR A SMALL UNMANNED AERIAL SYSTEM (SUAS)

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Design and Flight-testing of an in-flight Deployable Parachute System for a small Unmanned Aerial System (sUAS).

Abstract - Students in the Freshman Spring 2008 design course were challenged to engineer a deployable parachute system for a model aircraft that could be used on a small Unmanned Aerial System (UAS) platform. The primary design requirement of the project was the need for the parachute system to be able to deploy in the event of communications malfunction, loss of control or any other critical failure that could impact the safety of persons or property on the ground. Project requirements stipulated that the design focused primarily on safe, successful recovery of the given airframe. Team members were given the opportunity to suggest alternative materials or changes in design that may yield increased performance benefits for future prototypes.

Students utilized a model Piper Cub and were able to meet the minimum design specifications articulated by the customers. The aircraft would fly with a suitable center of gravity (CG) and could manually deploy the parachute while killing power to the model aircraft's electric motor.

This paper discusses group dynamics and leadership as applied to a freshman engineering design project solution.

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 was kept as a whole with one defined project leader who oversaw several project teams. 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.

Students engaged in team work in a multidisciplinary team environment such that the reality of cooperation in a global economy became a lesson realized early in their freshman engineering year in college. With a dynamic market place, graduates need to be able to interact effectively in diverse fields. 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 [2] 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" [1] Students partaking in the engineering exercise are forced to confront concepts outside of their normal field of expertise in the short span of a semester and make decisions on a cost and design schedule.

ENGAGING STUDENTS WITHIN THE ENGINEERING DESIGN PRINCIPLES

Students in the Spring 2008 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 deployable parachute system for a model aircraft. 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. Their interaction with the client at this stage is also viewed as a process of fine tuning their communication skills. Throughout the course, students studied the design process 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 design team to offer design requirement clarifications and to check on student progress. This inherent bidirectional communication process provides the clients an in-depth evaluation of students participation as well as level of understanding as it relates to the project. Throughout the project, timelines were adjusted to meet unforeseen challenges. Group members kept a log book accounting for unpredicted progress and project setbacks.

Additional course assessments included 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.

BALLISTIC PARACHUTES FOR sUAVs

A system of ballistic recovery for small, local UAV operations has been cited for its potential to mitigate the risk of a ground collision to local populations and structures [4]. The capability to deploy a ballistic parachute upon the loss of UAV control should result in a lower descent rate and therefore less energy to contribute to injury or damages on the ground. A deployed parachute, combined with a slow descent should also give persons on the ground a greater chance of seeing and avoiding the disabled aircraft.

One major challenge for the freshman team was deciding upon a parachute type, size and material. The teams researched these issues and decided on a nylon material parachute designed for model rockets. The parachute size was chosen based on the projected weight of the finished design.

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 an historically black university (HBCU) providing a rich and diverse project team. One team was comprised of the whole class due to the limiting size of participants. The sub-groups were self-selected by team members at the onset of the project.

PARACHUTE DESIGN

The parachute group utilized a nylon dome canopy design for its strength, lightweight characteristics, fire resistance and ease of packing (Fig. 1). Additionally, students discovered nylon is mold resistant and less expensive than silk.

Two design challenges included 1) engineering a system that was strong enough to handle the CO_2 exhaust blast without damaging the parachute and 2) calculating the drag force on the airplane created by the parachute.

Fig. 1 Parachute packed in the Parachute deployment unit

PARACHUTE DEPLOYMENT

Students focused on parachute deployment were concerned with anchor strength and line strength required. Unable to find supporting data in their research efforts, students utilized the model aircraft's existing attach points used to secure the wing to the fuselage (Fig.2). This proved adequate to handle deployment forces but the configuration did have some problems. Although field tests did show that the nylon string did adequately handle deployment loads, the parachute chords became tangled after release. To mitigate this problem, students designed a collar device out of two metal brackets to keep the strings from twisting freely in the wind. The final design utilized a single plastic collar which had a lighter weight.

Fig. 2 Parachute mount design

TRIGGER AND SYSTEM INTEGRATION

The trigger and system integration team was responsible for determining the position and angle on the aircraft where the parachute would deploy from and what mechanism would be utilized. The CO2 unit and the remote controlled trigger was placed in the fuselage of the aircraft (Fig. 3) and under the wing where the two wing roots met. Plastic tubing was run to the empennage of the model aircraft to the parachute launching device.

The triggering device underwent many design changes after numerous testing activities. Initially, students utilized a pellet gun trigger device but found the weight of the aluminum very restrictive. Team members were able to replace the equipment with a lighter-weight plastic Gallo gun used for cleaning industrial drains. A servo was used to receive the signal from the remote control unit's fourth (4^{th}) channel. Early attempts at turning the servo resulted in increasing the arm size for greater mechanical advantage which increase the success of the remote operation. A wire was connected to the servo and the Gallo trigger device. Additionally, trigger team members were able to install an electric kill switch for the model aircraft's motor that would activate simultaneously with the parachute deployment.

Fig. 3 Space utilization

Some additional changes were needed to increase the effectiveness of the overall integrated design. Wires were replaced with stronger cables to decrease likelihood of servo failure. The piston used to fire the parachute was altered from a "U" shape to an upside-down "V" shape to focus the charge firing from below and to reduce wasted air pressure. In addition, bullet connectors were utilized to allow future disconnection/removal of the firing device from the model aircraft fuselage. The parachute location was moved aft to the empennage to avoid a nose heavy center of gravity (CG).

TEAM PROJECT'S EVALUATION

The design team was expected to present a final design to the "clients" at the end of the course, during the time allotted for final exams. Other than this final testing during design presentation, rigorous testing was not completed. The parachute system did integrate successfully with the remote control model aircraft and proper center of gravity location did allow for sustained flight. Due to a change in the model aircraft power-plant, the device was able to maintain altitude but not climb. The students were able to remotely activate the parachute mechanism which killed the engine and gently carried the aircraft back to the surface intact. Students were asked to complete a final written group report which was analyzed by the faculty.

TEAM LEADERSHIP IMPLICATIONS

The group dynamics found in most freshman design courses can be framed in the context of the Leader-Member Exchange Theory [3] where it is assumed that leaders do not treat all followers in the same manner. Through the presence of a dyadic relationship, some group members are bound to find themselves in the out-group. The mere fact of being in the out-group does affect the member's perception of group performance and ability. The ability to accomplish group goals is affected by the group member's position in or out of the group. In group members are likely to work outside of their job specifications to get the job done, while out-group members are likely to stay within their rigidly defined roles. These dyadic relationships were observed to exist in the freshman design process in the form of design groups. The Integration group and the trigger design group worked closely together with the project manager to the point that the manager was able to assume a monitoring role of their progress. A clear in-group dynamic had formed. Faculty observers taking on the role of clients observed a personal and professional distance between the project manager and the Parachute design group. Clearly, members in the parachute design group were in the out-group and as a result, the project manager was more heavily involved (more than he cared for) in overseeing the progress made on their portion of the assignment. Artifacts collected from their project report identified the outside relationship of the parachute team.

"The Parachute team *stayed intact* as a foursome with responsibilities more specific to each person."

"Being a member of the parachute team was a little more difficult".

"…someone suggested that we make (a)….collar device…"

Clearly, there was a sense of disconnection from the greater group and an overall sense of having a more difficult time being in this sub-group. Additionally, the group was described as more individualistic in its function. Faculty observed that attendance at lab and field testing activities had fewer representatives from the parachute sub-group.

These responses can be compared to the impressions of the identified in-group participants that mentioned in their section of the report more positive team oriented responses.

"As a group (trigger team) we have accomplished a lot throughout the semester."

"Groups were created to make the process more organized and …speed up the process…"

"I went around and assisted any group that need(ed) any extra help…"

"This was overcome by Pete's (manager) help…"

"Credit for the switch and its integration goes to James and Pete".

Examples of a closer dyadic relationship is apparent from the projects own self reporting. Members from the in-team were quick to report the ease of group collaboration and openly gave credit to others who helped from outside of their own sub-group.

"Three members of the class found it unnecessary to attend class and the group formed closer without them."

"I learned that working your part on an engineering team pays off very well and those willing to work their part will connect better."

"Omissions noted here are the results of lack of participation in the classroom and on the project. The slack was picked up by team members that were eager to see the project through to its fruition. The real engineers of tomorrow!"

The above statements highlight the fact that this inside and outside relationship exists and that there is a perception from the in-group that the out-group is a result of not doing their part in the project.

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