2014 Hawaii University International Conferences
Science, Technology, Engineering, Math & Education
June 16, 17, & 18 2014
Ala Moana Hotel, Honolulu, Hawaii

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Synopsis:

Students from five international universities collaborate together on designing and building competition robots. This paper showcases the design outcomes and highlights the key lessons from this collaboration.

Fostering Global Collaboration Between Engineering Students Through a Robotic Design Competition

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Abstract

Global collaboration is becoming increasingly integrated in engineering activities. Companies such as Boeing have distributed engineering centers across the world that must work together seamlessly to build safe and reliable products. The necessity of global collaboration motivated us to expose university students to such environments, allowing them to experience first-hand the unique challenges that arise. Toward this goal, engineering students from the Georgia Institute of Technology teamed with students in Europe and Asia to participate in the 2013 Rescue Robot Competition. This paper details the rules and objectives of the competition and showcases the design outcomes from this collaboration. More importantly, it highlights key lessons that both faculty and students learned from this challenging experience.

I. INTRODUCTION

Global collaboration is becoming increasingly common in engineering activities. However, most engineering students have no international collaboration experience when they graduate and enter the workforce. They have not encountered the benefits and difficulties first-hand, and have not developed the necessary communication and interpersonal skills. It is our view that engineering students can benefit greatly by working in multi-national groups.

To address this goal, engineering students from the Georgia Institute of Technology teamed with students in Europe and Asia to enter the 2013 ARLISS[1] Rescue Robot Competition. This design contest requires the students to build a robot, launch it up to approximately 12,000 feet over the Black Rock Desert in Nevada, and then have the robot navigate autonomously to a target in the desert. Figure 1 shows the contest launch area. The contest provides a fun and challenging goal for collaborators to work toward. It also required hands-on interdisciplinary design and construction, which is another area often lacking in undergraduate engineering curricula.

[1]A Rocket Launch for International Student Satellites [1], [2]

Figure 1. Launch site in the Black Rock Desert, Nevada, USA

(a) Machine is loaded into a rocket cargo bay

(b) Rocket is launched, and machine is ejected at 12,000 ft.

(c) Machine autonomously travels to target location

Figure 2. Major Components of the Rescue Robot Competition

Section II explains the rules of the competition. Section III describes the international teams that were formed, and their methods of collaboration. Section IV presents the development of autonomous machines: from conceptual designs, to working prototypes, to final contest-ready machines. Section V gives the results of the contest and Section VII draws conclusions about the project.

II. COMPETITION RULES

The ARLISS Rescue Robot is a design competition held annually. Teams build small machines that compete by completing the steps shown in Figure 2. First, a machine is loaded into a model rocket, as shown in Figure 2(a). Next, the rocket blasts off and ejects the machine at approximately 12,000 feet, as shown in Figure 2(b). Finally, the machine must navigate to a target location on the ground[2], as shown in Figure 2(c). The machine can fly to the target, it can land on the ground and then travel overland to the target, or it can use a combination of approaches.

The machine must meet the size restrictions shown in Table I. Note that there are two classes. Machines in the CanSat class are substantially smaller than Open Class machines and are launched in smaller rockets.

[2]The GPS coordinates of this target location are provided at the beginning of the competition.

TABLE I. Machine maximum dimensions and mass

	Open Class	CanSat Class
Diameter	5.75 in	2.6 in
Length	9.5 in	4.75 in

The goal is for the machine to get as close to the target as possible.

In order to win the contest, the machine must stop within 10 m of the designated target, and the students must prove that the machine used controlled guidance to get to the target – the machine must log data of the machine's measurements and control decisions. This is to prevent the possibility of a team winning through pure luck.

There are numerous challenges that make it difficult for machines to succeed. For example, machines experience large accelerations during launch and when they are ejected from the rocket. The desert terrain can be challenging, depending on the weather conditions. These terrain variations can significantly affect the land-based machines. Strong winds at high altitudes can push the machines far away from the target, which is especially challenging for flying machines.

III. INTERNATIONAL TEAMS

Students at the Georgia Institute of Technology have been competing in the ARLISS Competition for more than a decade [3]. This extracurricular design club serves as an optional follow-up to the sophomore-level course in mechanical design [4]. Due to substantial sponsorship from Boeing in 2013, the design club was expanded to include four additional foreign universities. The participating institutions were:

- Georgia Institute of Technology (Atlanta, USA)
- Budapest University of Technology and Economics (Budapest, Hungary)
- Kumoh National Institute of Technology (Gumi City, Korea)
- Indian Institute of Technology Madras (Madras, India)
- University of Patras (Patras, Greece)

In January 2013, new universities were introduced to the competition and encouraged to generate conceptual ideas through brainstorming sessions for the first two months. This helped instill a sense of ownership and value among all of the students. Once the concepts were narrowed down to the most promising ideas, two separate international teams were formed, with each team focusing on specific design concepts. The grouping of these two teams is shown in Figure 3.

Both teams were led by mechanical engineering Ph.D. students at Georgia Tech. There were approximately 20 active members on the two teams. However, this number varied greatly throughout the year. Teams included a mix of undergraduate and graduate students. Each team had participants from 3 different continents, and minimum time zone differences of at least 11 hours.

All international teams were supplied with the same mechatronics kit that included a microcontroller, GPS receiver, data logger, motor drivers, motors and servos. This allowed the electronic and programming platforms to be standard across the collaborating institutions.

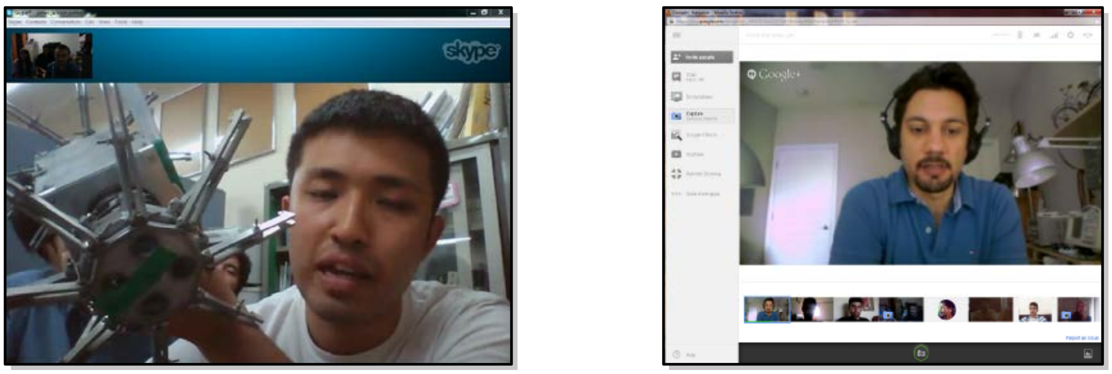
Georgia Institute of Technology
Budapest University of Technology and Economics
Kumoh National Institute of Technology

(a) Team Red

Georgia Institute of Technology
Indian Institute of Technology Madras
University of Patras

(b) Team Blue

Figure 3. Rescue Robot 2013 Team Organization



(a) Skype (b) Google+ Hangouts

Figure 4. Transcontinental video conferences

COMMUNICATION

To enable effective communication between the different teams in different parts of the world, a number of cloud-based project management services were evaluated. An online service called Basecamp was eventually selected as a tool to share ideas and ask questions on a day-to-day basis. The tool allows for sharing of messages, pictures, files, and each team or sub-team can have a dedicated project space within the site. Teams also often conducted video conferences to share updates at key design stages. As shown in Figure 4, Skype and Google+ Hangouts were used for this purpose. Video conferences were extremely useful in connecting team members, regardless of their location.

The collaboration took the form of tasked subgroups among the two teams. For example, individuals from India were tasked with building software modules for reading the GPS data, parsing it, and creating software interfaces for easier integration to the full robot codes. A group from the Greek team was tasked with reviewing the electronic board designs prior to fabrication. Another sub-team from Greece was tasked with carrying out drop tests with the parachute. This was in addition to the internal tasks generated within each university's team.

In addition to the online collaboration between the universities, the faculty advisor from Georgia Tech visited the Hungarian and Greek teams during the Spring 2013 semester. Furthermore, the faculty advisor from Budapest University of Technology and Economics visited the American and Korean teams. The interim visits helped facilitate knowledge transfer between the teams.

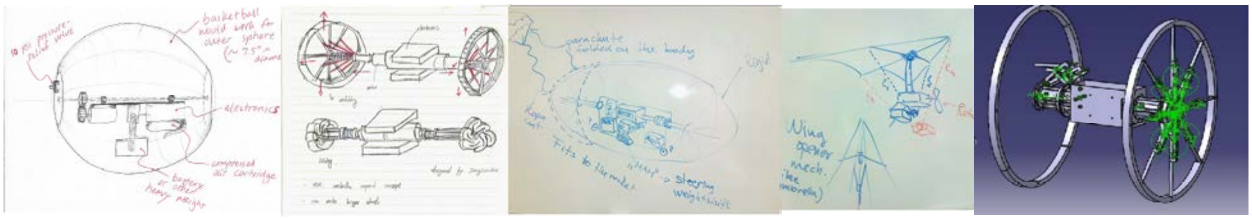


Figure 5. Conceptual design work

IV. MACHINE DEVELOPMENT

The teams started working on the project in January 2013 and the contest took place in September 2013. The design started with the concept-generation-and-selection phase, which lasted two months. The system-level-design-and-prototyping phase followed, and lasted through July. The detailed-design-and-construction phase then continue right up until the competition time.

CONCEPT SELECTION

During the concept-generation-and-selection stage, the team members were encouraged to submit as many concepts as possible. Traditionally, the most common design entry by competitors were two wheel rover based designs; however, our team members were encouraged to come up with novel concepts. A large number of concepts were received from all countries. The concepts were screened through multiple iterations and a few were selected for validation and further design. Figure 5 shows examples of the submitted concepts.

SYSTEM-LEVEL DESIGN & PROTOTYPING

During the system-level design phase the emphasis was on testing the functionality of the selected concepts. Sub-teams were formed to focus on each concept, generating working principles and prototypes. An electronics design sub-team was formed to carry out the design of the electronic board and software. It was envisioned that a common electronic platform should be designed that would be cross-compatible with the different concepts.

In creating the prototypes, students utilized the different facilities available at each university such as laser cutters, 3D printers, and water jets. Figure 6 illustrates the conversion of a detailed CAD design of a self-inflation mechanism to a working prototype using a 3D printer.

Students performed a number of component-level function tests across the different concepts such as parachute drop tests, rover wheel material testing, bump and incline drive tests, and propeller thrust tests.

DETAILED DESIGN & TESTING

Four working principles were chosen for the competition. Figure 7 shows photographs of these 4 robots. The first robot was a cylindrical rover with variable wheel size, it featured a long life battery and a novel drive mechanism. The second entry was a solar rover with a one-way bearing that could theoretically have unlimited supply of power during the day. The third was a quadrotor with folding arms, it featured a rugged design with powerful motors and did not require a parachute. The fourth robot was a two-wheeled

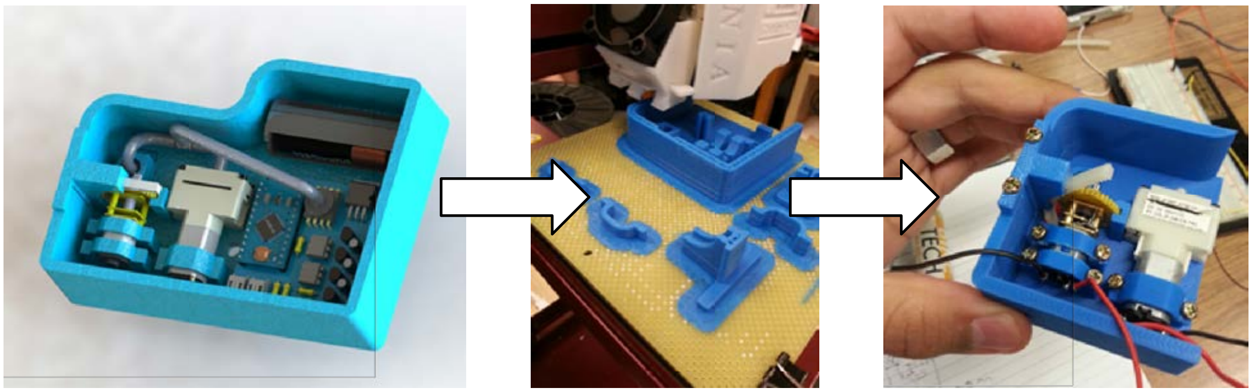
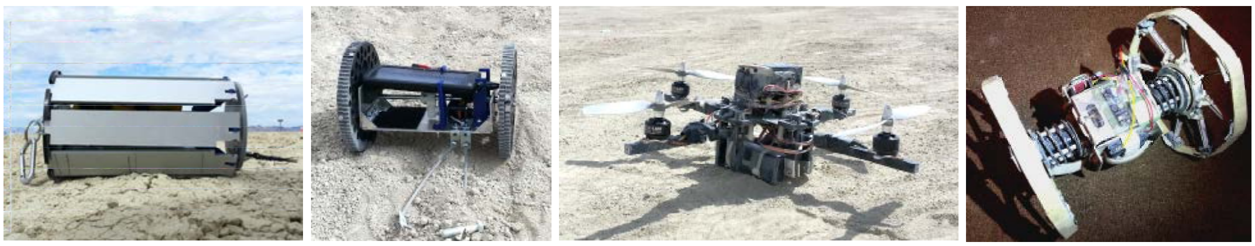


Figure 6. Rapid prototyping machine



(a) Cylindrical rover (b) Solar rover (c) Expanding quadrotor (d) Expanding rover

Figure 7. Final machines for the contest

rover with an umbrella-inspired mechanism to expand the wheels. It featured a rugged design and a long life battery. The rovers were designed to hit the ground softly using a parachute, and then detach the parachute before driving to the target. The quadrotor was designed to fly to the target without touching the ground.

V. COMPETITION RESULTS

During the 2013 competition, an unusual amount of rain made ground conditions difficult, and forced rocket launches to stop early on one of the three competition days. Therefore, only three of the four robots were launched. The quadrotor performed the best and landed 800 m from the target as shown in Figure 8(a). This was not close enough to win, but it was an impressive achievement. The expanding wheel rover and cylindrical rover both detached prematurely from their parachutes. They did not land safely, as shown in Figure 8(b), and they were unable to drive to target. The plot in Figure 9 shows the altitude of the cylindrical rover during launch. Table II gives the statistics for one launch as recorded by the on-board microcontroller.

VI. CHALLENGES IN INTERNATIONAL COLLABORATION

The international collaboration between students posed several challenges. One of the main challenges faced was the time difference between the collaborating teams. It was often hard to assemble a meeting between teams in the USA, Hungary and Korea for example, with times that would suit them all. This limited the ability to collaborate in real time. A partial solution to this problem was found by using Google

(a) Quadrotor

(b) Cylindrical rover

Figure 8. Landings after falling from rocket

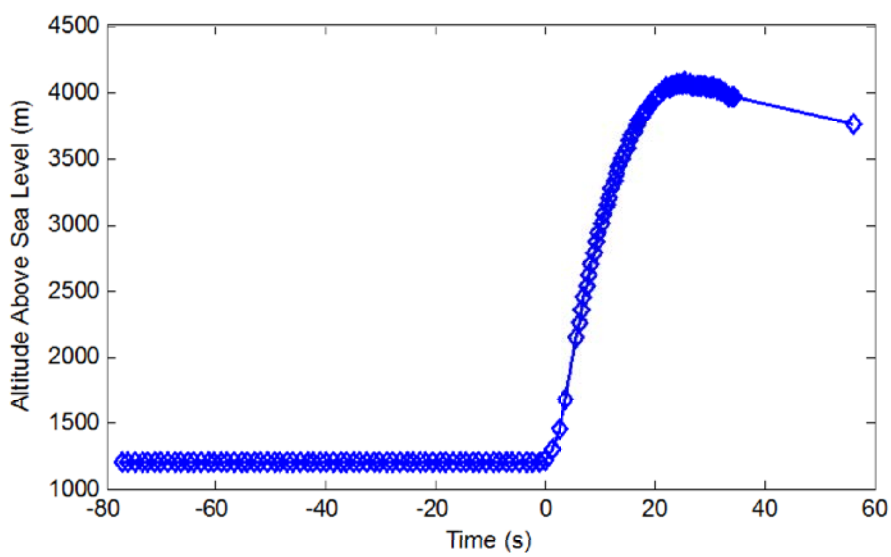


Figure 9. Altitude data recorded by cylindrical rover

TABLE II. Launch statistics

Time from machine initialization to launch:	70 min
Time from launch to maximum altitude:	25 sec
Initial altitude (above sea level):	1120 m
Maximum altitude (above sea level):	4071 m
Maximum velocity:	242 m/sec
Maximum acceleration:	5 g

Hangouts, which is a video conferencing tool that allows many users to join a video chat through their mobile phones or personal computers on the go. This eliminated the requirement of having to physically gather team members in one location.

Another factor that impeded the design process was that some teams used a language other than English in producing their engineering work. This caused confusion when files were transferred. Furthermore, some documentation was not translated and; therefore, not shared as well. Video calls worked well because each team had people that had sufficient English skills.

Another challenge faced was in supply chain management. In addition to the different engineering standards used in different countries, at times it was not possible for vendors to deliver certain parts to other countries. This restriction, combined with the long international shipping times, made it challenging to share physical components with all the different teams.

Finally, given that students volunteer their time to this activity, mandating that certain tools or software packages, such as CAD tools, be used by all team members was not realistic. Such standardization was compromised for the sake of encouraging students to volunteer their time and effort to this activity.

Students are likely to face such challenges during their careers and exposing them to such challenges is a key part of the learning objectives of this activity.

VII. CONCLUSIONS

The Rescue Robot design competition provided a unique platform for international collaboration between undergraduate and graduate students from five different universities spread across three continents. The students were exposed to the full engineering design cycle from problem understanding to concept generation to physical construction and testing. Students gained a practical appreciation of the benefits and challenges of working with multidisciplinary and multi-cultural teams. Students found the contest to be interesting and that encouraged them to invest their time in the project. This intentional collaboration also provided a realistic evaluation of engineering collaboration tools. Finally, it provided an invaluable experience to the students and the faculty advisors.

ACKNOWLEDGEMENTS

We would like to thank The Boeing Company, the Georgia Space Grant Consortium, and the Georgia Tech student government for their financial support of this project.

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