SPARTNIK: ENGINEERING CATALYST FOR GOVERNMENT AND INDUSTRY

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ABSTRACT

Industrial demands for highly motivated and competent technical personnel to carry forward with the technological goals of the US has posed a significant challenge to graduating engineers. While curricula has improved and diversified over time to meet these industry demands, relevant industry experience is not always available to undergraduates.

The microsatellite development program at San Jose State University (SJSU) has allowed an entire undergraduate senior class to utilize a broad range of training and education to refine their engineering skills, bringing them closer to becoming engineering professionals. Close interaction with industry mentors and manufacturers on a real world project provides a significant advantage to educators and students alike. With support from companies and government agencies, the students have designed and manufactured a microsatellite, designed to be launched into a low Earth orbit. This satellite will gather telemetry for characterizing the state of the spacecraft. This will enable the students to have a physical check on their predicted values of spacecraft subsystem performance. Additional experiments will also be undertaken during the two year lifetime, including micro-meteorite impact sensing and capturing digital color images of the Earth.

This paper will detail the process whereby students designed, prototype and manufactured a small satellite in a large team environment, along with the experiments that will be performed on board. With the project's limited funds, it needed the support of many industry companies to help with technical issues and hardware acquisition. Among the many supporting companies, NASA's space shuttle small payloads program could be used for an affordable launch vehicle for the student project.

The paper address these collaborations between the student project and industry support, as well as explaining the benefits to both. The paper draws conclusion on how these types of student projects can be used by industry as a feasible resource for developing small platforms for space based experiments, as well as increasing the practical experience and engineering knowledge of graduating students. These benefits to industry and universities, can lead to a close working relationship between the two. These types of projects can facilitate the development of low-cost space rated parts to be used by the industry and university projects. It can also help with the understanding and use of acceptable risk non-space rated parts reducing the cost of the spacecraft. This will lead to the development of low cost platforms for space based experiments, providing research companies an inexpensive, long duration platform to conduct their in-space experiments, while better preparing engineering undergraduates for their transition into the work force.

INTRODUCTION

The concept behind the SJSU microsatellite project is to provide an environment in which senior undergraduates can develop a better understanding of the design, manufacturing and operational process of a microsatellite. This practical knowledge that the students gain will become invaluable to them and to the companies that they will work for. The students have gone through the entire process in a large team environment with students managing and making important decisions for the design team. To help the students manage and address design issues properly, volunteer industry mentors interacted with each of the subsystem groups. The mentors gave constructive criticism of the students' design and helped each student understand the engineering concepts behind the design parameters. The industry mentors passed on their practical knowledge to the students, increasing the educational quality of graduating engineering students, and ensuring that the design was reliable. This environment allowed the students to gain knowledge based on the extensive experience only available through long term industrial design.

SJSU is located in the heart of Silicon valley, a dense area of aerospace industries that have resources which are not generally available in academia, which include real world design, prototyping, manufacture and operation facilities. This allowed the SPARTNIK project to receive hardware and access to testing facilities through donations from the local companies. This also helped in developing and maintaining close working relationships with the industry mentors.

This type of project is not just for the benefit of the students, but for the aerospace industry and other research companies interested in space exploration. SPARTNIK is the initial design for a platform that industrial and research companies can use for inexpensive, extended-period space-based research. By funding a similar student project, the companies can employ senior undergraduate students to design the payload integration, manufacture and operate the satellite inexpensively compared to hiring one of the large aerospace companies.

The following will explain what senior aerospace engineers did at SJSU before the SPARTNIK project, the project process that the students went through to build SPARTNIK, and how the Space Shuttle Hitchhiker system can be one of the many lift systems that is used for launching the university built microsatellites, and the benefits to both the students and industry.

BACKGROUND

In the past SJSU has offered an undergraduate senior design class which normally provides for a paper design of a complete spacecraft. In the fall of 1994 the spacecraft design instructor decided to take the concept further. Utilizing local industry support the class was given the opportunity to design on paper, then prototype, test and manufacture a spacecraft destined for orbit. By the end of the fall 1994 semester the SJSU micro-satellite development center was underway, with a completed paper design. Using industry collaboration during the early stages of the design, enabled the prototyping and manufacturing of the satellite to progress quickly. The collaboration continued through all stages of the project. which allow for the exchange of new ideas and experience between mentors and students.

DESIGN PROCESS

The design process at SJSU has been consistent for a number of years. Students enrolled in the senior spacecraft design class are given general parameters from which they generate a mission plan, and then design hardware to satisfy that mission. The fall 1994 class was given a more specific mission--Build a microsatellite which will:

Generate its own power.
Maintain two-way communication.
Carry at least one experimental payload.
Fit as a secondary payload in any launch vehicle.

Given these general mission goals, the process took shape as follows.

Mission parameters were first determined after an extensive research on past university built microsatellites. These parameters gave the design team a basis from which to construct a preliminary mission plan. The research of past successful projects gave baseline design constraints on size, weight, power as well as payload considerations. With this baseline the design team formulated a mission plan for the SPARTNIK project, which is as follows;

- To manufacture and secure the launch of a reliable, low-cost satellite, which may be used for both scientific research and educational purposes.
- To provide practical design experience in a team environment for preparation of senior students to integrate into the industry work-force.
- To show the feasibility of a cooperative effort between academia and industrial sectors in space vehicle and mission design.
- To demonstrate the ease and low-cost of satellite imaging technology and how it can be used in our everyday lives.

- To provide a mobile and versatile platform from which to demonstrate scientific techniques and theory to encourage students and others to become involved in aerospace education and research.

Given the mission plan and the scope of the project, the class of 21 students formed subsystem design teams. These teams consisted of 3-4 students, one of which acted as the subsystem manager. Each team was required to solicit the help of at least one industry mentor, who was well versed in their particular subsystem. During the Preliminary Design phase of the project, these mentors provided invaluable insight into the design process. Mentors worked closely with students to guide them away from blind research, and towards mature designs. They were able to share 15+ years of experience and point out pitfalls which might have hampered speedy development.

Development fell into two phases; preliminary and critical design. At the end of the first semester (four months) the design team held a preliminary design review, where industry mentors where able to be briefed on the design status and give feedback to the student team. This also allowed the students to show consistent progress, while keeping the subsystems focused on the scale and integration into a larger design. The same was done for the critical design period at the end of the second semester.

The Preliminary design was the first decision point. This design was the product of academic research, mentor guidance, trade studies and subsystem design and integration meetings. These meetings were held throughout the entire project, insuring that the design of the different subsystems integrated properly. Students were allowed to formulate their preliminary designs, and based on those designs, choose the equipment and materials for each of their subsystems. The Preliminary Design Review (PDR) was the point at which funds were committed for the purchase of material. Specific hardware requirements were well documented by PDR, and those purchases were approved, while the design moved into the second phase.

The Critical Design Review (CDR) process began with the second of the two semester senior design project. The students returned to class with a PDR which required substantial refinement before manufacturing could begin. During the CDR phase, students began in-depth debugging of hardware and software. Detailed structural, thermal, and EM modeling began, with mission specific parameters being refined. Each subsystem made significant changes and improvements to accommodate integration requirements.

In parallel with the CDR progress, a payload launch adapter (PLA) team was formed, which went through an abbreviated PDR process. The PLA team continued initial research into launch environments and secondary payload systems on every commercial booster available, as well as the Hitchhiker platform offered by the Space Shuttle Small Payload Program. This team defined the ejection system hardware and process for launch from the payload bay of the launcher. Once this was well under way work began on launch verification testing and documentation.

The CDR process continued until the Final Design Review (FDR). At this point many of the subsystems had prototyped key components for testing. A design freeze was in effect, which prevented any major changes to the spacecraft and allowed integration. Subsystem fabrication began in earnest for all subsystems, including software development for the onboard computer.

Once the subsystems were substantially prototyped and the on-board computer built and programmed, the students began operational testing of the systems. By running each of the components through a rigorous testing scheme the students qualified each system as flight ready. If any anomaly was found the students assessed the problem and reevaluated their design and made changes where necessary. Structural testing was also conducted on the satellite bus. A aluminum prototype was built and tested on a shake table to qualify the general structure of the satellite in the various launch environments that it would encounter. With acceptable results on the prototype design, the team progressed to manufacture the flight structure and began to integrate the other subsystem components. Once the flight model was assembled with all the actual flight hardware installed, a second shake test was performed to qualify the flight structure and wash out any minor anomalies.

At the completion of the second shake test, a verification manual was compiled to report the readiness and reliability of the satellite to survive the launch environment of any launch vehicle. This document will be turned over to the launch vehicle company that SPARTNIK will be using, for their approval of flight readiness.

Students will also work closely with the launch vehicle company to ensure that the satellite will integrate properly with the launch vehicle, and convey the procedures for a successful launch. Once the satellite is in orbit the student team will maintain and operate the various housekeeping and data collection procedures for the satellite via a ground station at SJSU. The students will compile experiment data and forward them to the respective research company for their use. The students will also maintain the satellite and deal will any anomalous contingencies that might arise while on orbit. The projected operational life time of SPARTNIK is a minimum of 2 years.

The collaboration that came about between NASA engineers, industry engineers and students is phenomenal. SJSU is located in downtown San Jose, within 20 miles of numerous aerospace companies that have extensive experience in the design and manufacture of all types of spacecraft. Industry mentors collaborated throughout the design process, and allowed their experience to fertilize the education of the student-engineers. This industry collaboration extended to hardware and financial donations for the different phases of the project, which allowed for prototyping of key systems with actual flight hardware. The commitment from local industry did not end with mentors, hardware and money. Systems engineers from several companies evaluated the design at PDR, CDR and FDR to act as a sounding board for the overall system, and evaluate the student project as if it were being manufactured in-house.

HITCHHIKER

With the limited budget of the student project, a discounted or donated launch as a secondary payload is needed. There are many different launch vehicles that can be used by the student projects. Pegasus, Delta, Ariane IV, Lockheed Launch Vehicle and the Space Shuttle. The Space Shuttle program provides the Hitchhiker for experimental payloads, and offers this system to university programs for $10,000. Although, the GAS can system normally ejected microsatellites from the Space Shuttle, this is no longer done and the size constraint of the GAS system is to small for SPARTNIK. The Hitchhiker, to date, has not launched any micro satellites, but the SPARTNIK team believes that it would be a good launching system. The team has developed a system to be used with the Hitchhiker and the other possible vehicles for launching student built microsatellites.

Figure 1 shows the possible locations where the microsatellite could be attached to the Hitchhiker. The spacecraft would be attach to the various pallets by the payload adapter system, figure 2. The launch vehicle would supply a 28 V DC signal to the satellite to activate a release mechanism. A non-explosive separation nut and bolt system will be used for launching SPARTNIK. This assembly will be self-contained so that the separated parts will not float away and become a hazard to both the spacecraft and the astronauts. Once the main bolt is separated a spring will push the satellite away for the Hitchhiker, the resultant velocity of the satellite from the spring can be varied by installing different springs that have different spring constants before launch. This will enable the design team to ensure that the resulting orbit of the satellite will not come back around and hit the space shuttle. The base plate and stand-offs (figure 2) of the PLA will remain with the Space Shuttle after the launch, and will remain a rigid body throughout the entire mission.

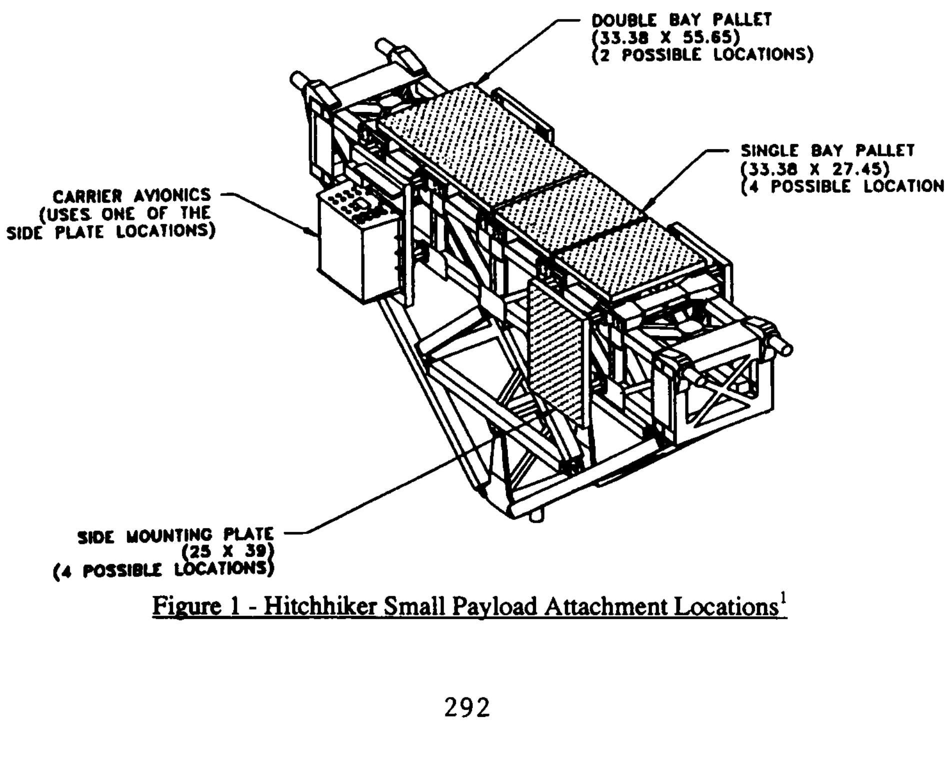

Figure 1 - Hitchhiker Small Payload Attachment Locations[1]

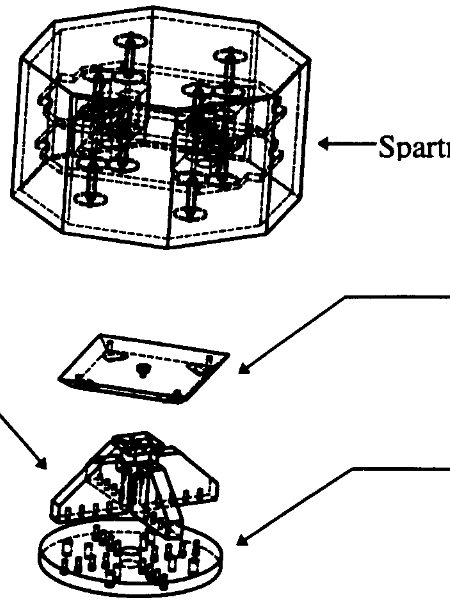

Figure 2 - SPARTNIK with Payload Adapter System

BENEFITS

This type of collaboration is beneficial to both parties, and will continue to be so. The primary benefactors were the students of the class, who received direct exposure to engineering as it is practiced in industry. Approximately twenty percent of the AE students at SJSU get internships at local companies which specialize in the aerospace industries[2]. That is four students in a senior design class of 20 which can expect to work in some capacity on significant design project during their tenure as an AE student. This collaboration allowed 100% of the design class to have exposure to a large project, and work closely with mentors in their area of interest. Additionally, the collaboration allowed various companies to evaluate designers before they graduate in a project which tests engineering skills, documentation, and interpersonal communication abilities.

Beyond the potential personnel evaluation, companies have a platform to test new ideas and hardware effectively. New battery, solar cell or computer technology can easily be tested on a microsatellite. The small scale of the project allows for simplified testing on an actual orbiting spacecraft. The SPARTNIK project is testing commercial grade NiCd batteries in a space environment. In exchange for the donation of the cells, the SJSU Aerospace Engineering Department will document performance of the batteries over the lifetime of the spacecraft. This data will be downloaded as part of the normal housekeeping telemetry for the microsatellite, and forwarded to the donating company.

This type of collaboration should be encouraged by government and industry sponsors to entice university programs to develop their academic programs into a forum for new ideas and techniques for the entire aerospace industry.

CONCLUSION

As SJSU becomes a development center for microsatellites, graduating engineers will be getting practical engineering knowledge that they will be able to use in industry. Thus, providing industry with better educated and prepared entry level engineers to contribute quickly to the aerospace industry. The industry mentorship will lead to a close working relationship between local industry companies and the universities, which will help with making the design more robust, the practical education of students, and the communication of industry needs to the university for trained engineers and direct the process in which this is done at the university level.

The student-run project will be an inexpensive way for research companies to perform space environment experiments for long durations and for the aerospace industry to test and qualify new satellite technologies for a low monetary risk. These projects can also be used to increase the understanding and use of acceptable risk non-space rated parts which lead to reliable, low-cost spacecraft.

The microsatellites will provide the research and industry companies with an orbiting test platform for a minimum of 2 years, inexpensively ($10,000 for launch, plus hardware funding) compared to what they would normally get for launching permanently attached to the Space Shuttle bay for up to three weeks for several millions of dollars.

REFERENCES

[1]Space Shuttle Small Payloads Hitchhiker Users Guide, 1994
[2]Professor Hunter, Aerospace Engineering Department, San Jose State University