The Western Michigan University Launch Initiative: Challenges and Opportunities for a New University Small Satellite Team

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Abstract

University small satellite programs have grown dramatically in the past decade. More than 100 universities now host small satellite programs and more than 50 universities have launched multiple satellites. These programs offer opportunities for students to build research skills, enhance learning through application of engineering concepts, and improve job preparation.

This paper presents lessons learned on starting a new student small satellite organization within the environment of a new aerospace engineering program. In the last three years, the Western Aerospace Launch Initiative (WALI) team was established as a student organization at Western Michigan University dedicated to small satellite design and other high-altitude flight experiments. As a new program, WALI has faced challenges in maintaining student involvement and cultivating student leadership. This paper presents preliminary results on the effectiveness of several methods, including enrollment tasks, hands-on technical workshops, and student travel and presentation opportunities, for recruiting and training engineering students for leadership in the small satellite team.

Introduction

This work-in-progress paper considers the Western Aerospace Launch Initiative (WALI) organization at Western Michigan University (WMU) as a case study in establishing a new university-based small satellite team. Small satellite programs have proliferated rapidly in recent years. Inexpensive hardware, government funding, and low-cost launch opportunities have brought satellite design programs within reach for many colleges and universities. These programs can provide valuable learning and professional development opportunities for students.

On the other hand, designing and building a small satellite is a difficult engineering project. University teams that are new to this field face a number of challenges, both technical and programmatic. This paper presents several lessons learned in the three years since the WALI team was founded. We focus specifically on team management and student learning, which are key areas that may be overlooked by new small satellite team leaders, who are often focused on research plans and funding acquisition. We have found that the team's technical success depends greatly on personnel management. In the university environment, where student researchers are typically volunteers and annual turnover is high, a careful strategy for recruiting, training, supervising, and retaining team members is critical to successfully building a small satellite.

WALI's programmatic challenges fall into three categories: (1) recruiting and retaining qualified student members, (2) training students in key technical skills, and (3) directing and supervising student work. We find that student team members are most interested in building their technical skills and improving their career prospects; team management strategies that address these objectives are most effective in keeping students engaged.

Background: Small Satellite Programs

Small satellites are generally classified as satellites under 500 kg. CubeSats – satellites built in a form factor of one or more 10 cm x 10 cm x 10 cm cubes [1] – are a common type of small satellite. Some university programs focus specifically on CubeSat design, while other programs address a broader range of small spacecraft. Many university small satellite teams also pursue other high-altitude vehicle projects, such as payload design for suborbital rocket tests and high-altitude balloon flights. WALI's founding members deliberately chose the team name and mission statement to encompass all types of high-altitude projects.

More than 100 universities currently host small satellite programs and more than 50 universities have launched multiple satellites. At the time of this paper, 166 university-class CubeSats have been launched [2]. In the last decade, an industry has emerged around small satellite design, with many startup and large companies entering the market. Many of the students who participate in university small satellite teams hope to work at one of these companies upon graduation, and student leaders from successful teams are often highly recruited.

Literature on Small-Satellite-Based Education Programs

Swartwout and Jayne examined the history of university-class spacecraft and categorized programs as *flagship universities*, *prolific independent universities*, and *hobbyists* [3]. New university programs enter the field in the *hobbyist* category, which is characterized by low flight rates and high rates of on-orbit failure. When a university establishes a new small satellite team, it is important to be aware of these risks.

Berthoud and Schenk provide a review of "lessons learned" papers from many student CubeSat projects and present the results of a survey of 40 CubeSat teams [4]. The paper contains an excellent summary of program management advice from experienced CubeSat teams.

Several universities address small satellite design in a one- or two-semester course – typically an upper-level, lab-based course in which students work on a satellite or subsystem for a specific mission. Kroeker *et.al.*provide a detailed description of this type of course at the University of Illinois [5]. A satellite design course is an excellent way to provide hands-on, project-based education in space systems engineering, but it requires dedicated faculty and a sufficiently large, well-trained student cohort. Also, as noted in [5], a dedicated course is not a reliable method to guarantee progress on a nanosatellite design.

Western Michigan University's WALI Team

This paper addresses the case of a university that has recently entered the field of small satellite design. WMU is a public university in Kalamazoo, Michigan, located in southwest Michigan, midway between Chicago and Detroit. WMU is a doctoral university with approximately 23,000 students, including about 17,000 undergraduates and 3,400 graduate students on the main campus [6]. Approximately 2,700 students are enrolled in WMU's College of Engineering and Applied Sciences, which houses 14 undergraduate engineering, technology, and applied science programs.

In 2013, WMU's undergraduate program in Aeronautical Engineering converted to Aerospace Engineering. New space-focused courses were introduced and two new faculty members were hired to specialize in space-related research. In 2015, a Master of Science program in Aerospace Engineering was added.

The WALI team was founded in fall 2014. The team was originally proposed by two faculty members and a small cadre of interested students. Since that time, the team has grown to approximately 20 active members, most of whom are undergraduate students from many different engineering majors, including aerospace, mechanical, and electrical engineering, as well as computer science.

For the first year after its founding, WALI struggled to define a specific, unique satellite mission. Early meetings focused on introducing the concept of small satellites to new students. In the first year, the team performed two high-altitude balloon flights, which aimed at simply developing balloon launch and tracking capabilities. The first balloon was lost due to a tracking equipment failure (the payload was later returned by a local farmer), but the second balloon payload was successfully tracked and recovered.

In fall 2015, the team submitted a successful proposal to the Air Force Research Laboratory University Nanosatellite Program (UNP). This project has given WALI a clear objective; the group is currently designing a CubeSat mission to demonstrate on-orbit plasma plume diagnostics. The programmatic structure required by the UNP guidelines has been invaluable for the WALI team; it is highly recommended that new small satellite teams pursue UNP projects or follow a similar program structure with regular reviews and documentation requirements.

Challenges

Since WALI was founded, its membership has fluctuated widely, from more than 60 students to less than 10 at different times. Peak membership is typically early in the fall and spring semesters, when many students attend mass meetings, and then membership dwindles as the semester progresses. The summer term – which is an important time for outdoor testing (e.g., balloon flights), hardware development, and travel – is often the time of lowest participation, as most students accept off-campus internships.

Engineering students have many demands on their time, including coursework, extracurricular activities, and personal responsibilities. Many WMU engineering students work part-time jobs to cover their tuition and expenses while carrying a full course load. WALI also competes with several other student teams at WMU for membership; students with strong technical and leadership skills are recruited by the Solar Car, Formula SAE, and AIAA Design/Build/Fly teams, among others.

To address ongoing challenges in student recruitment, training, retention, and engagement, WALI's faculty and student leaders initiated several new strategies in the 2016-17 academic year. First, to identify new members with strong potential and to filter less-serious students from the initial recruiting pool, the WALI project manager assigned enrollment tasks to all interested new students. The tasks were individually designed to fit each new student's area of interest and incoming skill level. For example, a first-year student interested in structural design was

assigned to develop a CAD model of a 1U CubeSat structure, while an advanced undergraduate interested in orbit determination was assigned to develop a presentation on determining the relative position of two satellites using GPS data. Students were granted official membership in WALI upon successful completion of their enrollment tasks.

Second, WALI students were encouraged to participate in several hands-on workshops. Three students participated in a sub-orbital rocket payload design workshop at NASA Wallops Flight Facility [7]. Four students attended a Satellite Fabrication course as part of the UNP program. A group of 10 students participated in a three-day "CubeSat Bootcamp" workshop, led by an engineer from the Jet Propulsion Laboratory, on-site at WMU. These workshops were well received by WALI students; they found the hands-on activities highly engaging and reported greater interest in space system design after each workshop.

Finally, several key subsystems were designated as capstone senior design projects for mechanical, electrical, and aerospace engineering students. Delegating these projects to students in the capstone course (many of whom were not previously involved in WALI) provides accountability for key tasks, as the students are required to complete the projects to pass the class. In a university that does not offer a designated spacecraft design course, these individual design projects can serve many of the same functions.

Preliminary results of these initiatives are positive. There are currently more than 20 active WALI members and 10 senior design team members working on CubeSat-related projects. The team has made substantial progress in technical design and documentation; WALI's UNP project recently successfully completed Preliminary Design Review with AFRL.

WALI Team Activity Evaluation Survey

In January 2017, a survey was conducted to evaluate the effectiveness of WALI's recruiting and training activities. The survey questions were distributed at one of WALI's weekly team meetings and results were anonymous. A total of 16 students responded. Results are shown in the Appendix. The students were also encouraged to add comments and suggestions to improve WALI. From the question responses and the comments, several themes emerged.

1. **Students are most interested in technical skills and resume building**

In response to the question, "What do you want to get out of your participation in WALI?" most students responded that they want to gain new skills, build their resumes, and/or gain job opportunities/networking. When asked what types of team activities would interest them most, 14 of the 16 respondents were interested in more hands-on workshops. Social events are of lesser interest, although a substantial portion of students mentioned that friendships and getting to know other students with similar interests were a benefit of WALI participation.

2. **Clear direction is important**

Half of the students responded that they do not have enough direction within WALI and several comments emphasized this theme. Comments included, "*I'm fairly new to WALI and I personally find it a little hard to get started. There isn't much direction…*" and "*I feel we are loaded with a*

bunch of tasks to do with a certain direction, then it seems we change the goal and have to do over activities."

Some discomfort with lack of direction is an inevitable, and even desirable, consequence of the small satellite design process. For most of the team members, it is their first experience with designing a completely new system, and it is quite different from solving well-defined problems in engineering classes. However, going forward, the team leaders will put more emphasis on directing new team members' work and minimizing direction changes.

3. **Travel and presentation opportunities are not widely popular**

Less than half (44%) of respondents were interested in travel opportunities and very few wanted to present to industry leaders. A significant fraction of WALI members have expressed needs to stay near home for work and family reasons; others may simply not be interested in making such a large time commitment to travel for an extracurricular activity.

The lack of interest in presenting to industry leaders is potentially troublesome, particularly because this is one of the best ways for students to network in the small satellite field. This result indicates a need for greater mentoring. In the future, WALI's faculty mentors will emphasize that presenting results is an important aspect of a professional engineering career. Also, presentation at design reviews may be stated upfront as a requirement for all subsystem leadership positions. At WALI's recent Preliminary Design Review, 15 students presented their work to AFRL reviewers. As the group matures, we hope to build a culture that encourages and supports student design presentations.

Conclusions and Future Work

This work-in-progress paper discusses our experiences starting a student small satellite team at WMU. The team is still quite new, but we believe that the lessons learned to date may be helpful to other universities starting similar programs. From survey results and experience to date, we recommend that new university small satellite teams consider the needs and constraints of their student populations, particularly when designing training and team-building activities. At WMU, hands-on workshops have been the most successful activities, as students are most interested in technical-skill building and job preparation. Travel and presentation opportunities are not incentives for many students, perhaps due to work obligations.

Recent initiatives aimed at recruiting, training, and retaining WALI students have seen positive preliminary results. The long-term effects of these efforts on WALI participation, learning outcomes, and professional placement for student members will be assessed in upcoming years. WALI membership will be logged at the beginning and end of each semester, and the numbers of students who request and complete enrollment tasks will be tracked. We will also request that all students leaving WALI complete an exit survey, which will be used to track job outcomes for graduates and may provide insights about other students' reasons for leaving the team. As WALI becomes a well-established organization with several members graduating each year, we will begin tracking anonymized GPA data for members. We will compare GPA outcomes to students who did not participate in WALI, controlling for incoming standardized test scores, to determine whether WALI participation is correlated with improved academic performance.

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Appendix: Survey Results

Table 1. Results of WALI evaluation survey. A total of 16 students responded; multiple responses were allowed for each question, so percentages do not total 100%.

	Number Selected	Percent
1. How did you become interested in WALI		
a. Word of mouth	7	44%
b. Advertising (email, flyers, splash screen)	8	50%
c. Faculty/advisor discussion	2	13%
2. What are the best aspects of participating in WALI		
a. Technical skills training	9	56%
b. Leadership skills development	5	31%
c. Career networking	2	13%
d. Social (getting to know other students with similar interests)	7	44%
3. What are the worst aspects of participating in WALI		
a. Workload	4	25%
b. Not enough direction, don't know what to do	8	50%
c. Meeting times are inconvenient	2	13%
4. What additional activities would interest you most?		
a. Hands-on workshops	14	88%
b. Opportunities to present to industry leaders	3	19%
c. Travel opportunities	7	44%
d. Tutoring/homework help	1	6%
e. Social events	2	13%
5. What do you want to get out of your participation in WALI		
a. Learn new skills	11	69%
b. Build resume	9	56%
c. Friendships	6	38%
d. Job opportunities/networking	8	50%