

APPLYING UNIVERSITY SMALL SATELLITE PROGRAM LESSONS TO A CAREER IN THE AEROSPACE INDUSTRY

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ABSTRACT

A senior manager in the satellite industry, a former member of the Cornell University Satellite (CUSat) team, and its former Principal Investigator discuss the professional relevance of the University Nanosat Program (UNP). Particular focus is given to the technical experience, leadership, and networking skills gained from working on small satellite systems. This paper explores how the aggressive UNP schedule exposes students to three major career paths: technical engineering, functional management, and program management, preparing them for cross-disciplinary roles. The authors assert that tackling the same issues encountered in industry-- performing to challenging schedules, managing subcontracts, motivating a team, and the intricacies of interacting with a customer--prepares new engineers to enter the workforce ready to challenge the industry's status quo. The UNP and similar university satellite programs train the next generation of scientists and engineers to begin a professional career and to immediately contribute innovative solutions benefiting their employer and the broader aerospace industry. This paper explores the correlation between university programs and the commercial satellite industry.

INTRODUCTION

Spurred by the Cold War, the twentieth century was marked by innovations from aerospace engineers and scientists. Aerospace systems and technology including GPS, mobile communication systems, and Teflon have transformed people's daily lives; changing everything from how people drive and communicate to how they cook eggs. This work inspired a generation of engineers to solve challenging problems. As these scientists and engineers begin to retire, a new challenge faces the aerospace industry.

Fifteen percent of the aerospace industry's technical workforce is currently eligible to retire and fifty-five percent will be eligible in the next ten years. This impending loss of the workforce is known as the "demographic cliff." Given that less than five percent of undergraduate degrees are awarded in engineering fields, it will be difficult for companies to fill these positions.¹ Replacing experienced, senior engineers will require new aerospace engineers to quickly integrate into their roles and achieve technical expertise faster than ever. American universities have responded to this

challenge by creating new engineering programs that combine theory with practical laboratory and manufacturing experiences that culminate in spacecraft launch opportunities.

The University Nanosat Program (UNP) is one such program. Sponsored by the American Institute of Aeronautics and Astronautics (AIAA) and Air Force Research Laboratory's (AFRL), the program's primary objective is to strengthen educational and workforce development for undergraduate students. Secondary goals include developing low-cost technology and supporting university spacecraft-hardware laboratories. More than 4500 undergraduates from 28 universities have participated in the program in the last ten years.² From Hawaii to Florida, university students are collaborating to design, build, and launch small satellite missions.

The UNP sponsors an aggressive two-year design cycle competition where ten to twelve university teams design, build, and test satellite systems. The competition requires teams to complete six design

reviews, participate in several outreach events, and demonstrate consistent progress on a problem of immediate technological relevance to the United States' Air Force. Successful teams may also have an opportunity to launch their satellite.² Figure 1 shows CUSat, winner of the UNP-4 competition, which is expected to launch in 2013. Cornell's UNP-6 entry, Violet, which is expected to launch in 2016, is shown in Figure 2. The competition teaches students to overcome technical engineering challenges while balancing functional and program management responsibilities.

Although several papers have explored the academic and mission relevance of the UNP and its university participants, few papers have addressed the professional benefits. This paper will use the UNP as a case study to reflect on how the experience gained through university small satellite programs impacts students' transition from academia to industry. This topic will be presented from three perspectives: Cornell University's (CUSat) UNP principal investigator, a former CUSat student participant, and an industry manager responsible for leading the development of next generation satellite systems for a major aerospace corporation. The authors investigate how dealing with the technical and managerial challenges of building satellites in college drives UNP graduates to disrupt the industry status quo. The UNP trains students to innovate and to challenge, in contrast to traditional academics or industry learning processes. As the aerospace industry trains the next generation of engineers, the role and impact of programs like the UNP will grow in importance.

A PRINCIPAL INVESTIGATOR'S PERSPECTIVE

A university professor leads each UNP team as a Principal Investigator (PI). Models for this leadership vary. Some PIs are largely hands off, some integrate the UNP projects into their core research, and others deeply integrate themselves into the team's decision making process. Many PIs blend these models.

At Cornell, the UNP-4 CUSat team (and the later UNP-6 Violet team) combines cutting-edge technology investigation suited to faculty and Ph.D. student research with undergraduate-focused experiential learning. Programmatically, the CUSat project includes research funding for key technology developments (such as the core flight experiment—software and hardware for a two spacecraft, GPS based relative navigation and satellite-to-satellite inspection system) and student-team funding for lab training, supplies, travel, and team learning activities. The PI sets expectations by frequent communication with the team leadership and by documenting the guiding principles of the team. The PI selects the initial student program manager and subsystem leads and mentors them

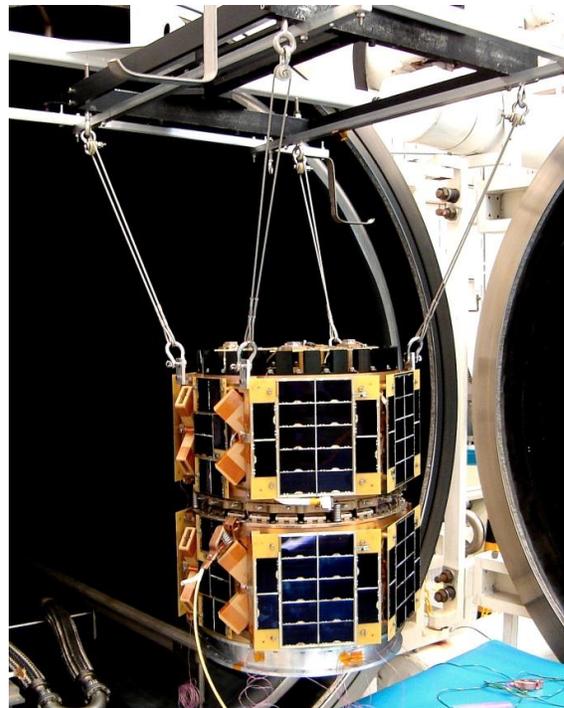


Figure 1: CUSat, winner of the AFRL UNP-4 competition, during environmental testing to prepare for its 2013 launch opportunity.



Figure 2: Violet, UNP-6 entry, in preparation for the Flight Competition Review.

continuously on leadership and technical matters. When the time comes for a transition of leadership, the student leader identifies a likely successor, which the PI approves. The transition takes several months, during which the outgoing leader trains the incoming leader.

The student program manager and subsystem leads are responsible for recruiting and staffing the team of students who will do the technical work. Student program managers always rise from within the team's ranks, often having joined as sophomores and sometimes freshmen performing technical tasks.

The PI establishes a team culture of professionalism and a degree of responsibility at a level uncharacteristic of typical student activities. The goal is for students to learn how to interact with vendors, the Air Force sponsor community, and other external stakeholders respectfully, honestly, and responsively. Generally the UNP experience is the first time students are asked to meet such high professionalism expectations. Students are only given the responsibility of serving as a point of contact for an external entity only after some

experience working with another mentor on the team. This model of ensuring that team members prove themselves before assuming greater responsibility is also used in industry.

This professionalism extends to all team members as well, despite that students are generally more comfortable speaking and interacting casually. Where possible, the team leverages these very effective informal practices (including interim documentation

Table 1: Student Performance Criteria for Cornell’s Spacecraft Technology Programs

Minimum Performance Criteria for a “B” grade

Meet all commitments: complete all work and attend all meetings.
Know the requirements for the work you’re expected to do.
Complete your tasks by the deadline you’re given.
If you can’t keep up, tell your lead early so that s/he can find someone else to take care of your work. Otherwise, the whole project may be delayed.
Admit mistakes. We all make them. Only hiding mistakes is a reason to be ashamed.
Do error-free work or fix your mistakes completely. If you don’t know how, ask before you do it.
Admit what you don’t know, and learn how to do it, either from existing documents or by asking more senior people. Everyone on CUSat has to learn sometime.
Document ALL your work, ideally in reports and/or on the wiki, not just in IMs, texts, et al.
Put in your time: 12-15 hours per week on average, every week. Not just 20 hours around design-review time and a couple of hours per week during the rest of the semester. If you don’t have enough to do, ask your lead to specify some tasks.
Be professional and respectful to team members, collaborators, vendors, and Cornell administrators. Follow the lab rules.
If you’re a lead: <ul style="list-style-type: none"> - Maintain a complete schedule showing all tasks, durations, and people working on them. - Know how your subsystem interfaces with and affects the rest (from both a design and I&T perspective) - Ensure people are putting in their time - Communicate with other subsystem leads constantly - Ensure documents and presentations follow the expectations established by the rest of the leads - Stick to the processes we’ve established over the years for CM/QA and I&T.

Minimum Performance Criteria for an “A” grade

Seek out problems: notice what’s wrong and go fix it without being told to do so first.
Solve problems with minimal hand-holding.
Create and document action items when you identify any a problem needs to be solved.
Know the requirements for other subsystems and propose changes when your work or theirs makes certain requirements invalid.
Follow up with people to be sure they give you what you need on time.
Always ensure that your work is coordinated with others; don’t expect anyone else to do it for you.
Recognize that every engineering decision on a complex system like CUSat is interdisciplinary and habitually consider the impact of your decisions on the rest of the subsystems.
Question everything: Ask “what can go wrong?” every time we think we have a solution to a problem, and act on that answer.
Lead trade studies to formally decide important matters.
Do more than what you say you will do, and have it done ahead of schedule.
Seek more responsibility rather than hoping someone else will take care of problems you notice.
Volunteer instead of waiting to be chosen by default.
Mentor others so that they can become more productive, faster.
Always be learning and absorbing more about the project than is necessary for your immediate technical issues.
Propose ways to change our processes or the design to make it faster, better, and/or cheaper.
Propose meetings among interested parties and volunteer to schedule them.
Be very familiar with the parts of the project schedule impacted by your work: what does your lateness cause, and what does others’ lateness do to you?
Aspire to lead your subsystem some day.
Get used to saying “I’ll take care of it.”
If you’re a lead: <ul style="list-style-type: none"> - Dynamically manage the schedule to pull in deadlines when work goes well or shift deadlines while accommodating the rest of the subsystems when things go wrong - Know what work needs doing, and be sure you have people to do it. Otherwise, negotiate with other leads to move tasks between subsystems. - Create document templates, I&T processes, lab-reorganization ideas, and generally improve the way we do things - Understand how spacecraft are designed & built professionally and try to make that happen here: make us do better

through emails and interaction through instant messaging), but formal deliverables, schedules, and decorum are ultimately required for all products. Leveraging social media and a wiki-based knowledge management system for space systems are disruptive practices (in the good sense) that benefit the team and will likely influence how these students impact their profession as they migrate to the workforce.

Students working on CUSat are not paid. However, they receive course credit. End-of-semester grades are determined by a combination of peer evaluations and the PI's assessment of a written report, which details their work completed during the semester. The criteria for the peer evaluations has evolved over the years into a detailed list of numerically ranked traits. The team refers to these as "B" behaviors and "A" behaviors. A student who achieves mostly "B" behaviors does work correctly, as expected, with no problems and no delays; and such a student likely receives a "B" grade. To receive an "A," a student must go above and beyond: work completed ahead of schedule, problems identified before they impact at the system level, process improvements offered, voluntary mentorship provided, problem-solving within a multidisciplinary environment that extends beyond the student's specific technical responsibilities, and so on. Students with an "A" reputation are just the sort that are highly sought after in the aerospace industry and that are likely to come from only a handful of educational programs, such as UNP. These criteria are listed in Table 1.³

Although UNP spacecraft are small—at most 50 kg—the challenges are great. Students address complex technical issues that require systems thinking of the kind they are likely to encounter in industry. The comparatively small scale of nano and microsatellites allows somewhat faster development: on the scale of 2-6 years of part-time work by a few dozen students, versus the up to a decade or more work by hundreds of full-time employees for contemporary national asset spacecraft systems. That shorter lifecycle offers students some hope of a cradle-to-grave experience, where a freshman may be involved from the proposal through flight operations before he or she graduates.

For example, CUSat's was ready for launch in the summer of 2008, about 2 ½ years after authorization to proceed. Subsequent changes in launch opportunities allowed the project to fully complete its development of the flight software to support the full mission objectives, with a launch expected in 2013. Students graduating from the CUSat program this year will have primarily focused on mission operations. A goal of Cornell's program in the future will be to choose

projects with lesser scope to help ensure students can experience the full lifecycle.

UNP STUDENT PERSPECTIVE

Undergraduate students working on UNP teams are faced with a challenging dilemma. They must build a satellite system that will provide compelling, relevant mission data to the AFRL, mentor other students on the fundamentals of spacecraft engineering, and meet an aggressive program schedule with heavy financial constraints. Student program managers and subsystem leads must learn how to be effective leaders, communicators, and take ownership of the technical tasks associated with their discipline. They must do this while still learning the fundamentals themselves. Balancing the expectations of their PI, external stakeholders, and schoolwork may seem overwhelming at times. However, students who are able to meet these challenges gain highly valued spacecraft technical experience, develop strong leadership and communication skills, and are prepared to contribute to the industry immediately after graduation.

Organization

The UNP organizational structure follows the industry model, which divides the workforce into three roles: technical leadership, functional management, and program management. Figure 3 illustrates these different paths as implemented at Boeing. It is important to recognize that the roles illustrated in Figure 3 are interrelated and that each role is critical to delivering a successful product.⁴

Engineers perform the technical tasks associated with their subsystem's area of expertise. The two management divisions focus on how the technical work is accomplished. Functional management oversees the "people" aspect of the project within a specific technical engineering discipline. Functional managers strive to match people with positions that fit their interest and skills. They face the challenge of training the workforce and ensuring that the engineering tradecraft is not lost. This is difficult because functional managers must also work to optimize program execution across multiple platforms. While functional managers focus on developing tradecraft engineers and supporting the execution of multiple programs, program managers focus on the successful execution of one project.

Students who are primarily doing the technical work for the project are grouped into subsystems, where each group is responsible for solving the specific challenges associated with their discipline. Due to the relatively small size of standard university teams (usually between 30 and 150 students), subsystem leads must

balance their program and functional manager roles by ensuring their subsystem successfully executes the technical requirements, as well as ensuring that subsystem team members are engaged in the overall project. Successfully managing this dual role is critical. Student leaders who neglect the functional management aspects of their job are likely to see high attrition rates between semesters and their program's schedule compromised.

In addition to managing the technical execution of the project, student systems engineers, chief engineers, and program managers must manage the internal and external interfaces of the project. Due to the small size of student teams, it is not uncommon for student leaders to assume multiple leadership roles, such as being program manager and chief engineer.

Managing the relationships with external customers is a key responsibility of student program managers. Like industry program managers, these students must develop stakeholder management skills. Good program managers must also learn how to actively look for and recognize areas of weakness in a project. Identifying potential problems early allows the team to mitigate them better by rearranging the project's resources and notifying the relevant external stakeholders of the issue's resolution. Although the engineering scope of industry projects is usually larger, the fundamental challenges facing UNP and industry program managers

are the same.

One challenge unique to student teams is that most students lack previous aerospace experience. While industry programs are able to cherry pick from a larger and more developed talent pool, student teams must invest significant effort and time teaching fundamental skills. This challenge is even more difficult given that a student's time on the team is limited to their time at the university. Therefore, even the most highly skilled and trained students will spend only one to five years working on the project.

High turnover rates pose a large risk to university teams and may lead to large losses of program information. Successful programs acknowledge this attrition-related risk and are scoped accordingly. Additionally, the need to constantly bring members up to speed slows down the progress of technical work making the team's continuity problems more significant.

Often students who did the initial design work have graduated by the time a launch opportunity becomes available. This was an issue that CUSat experienced. After completing hardware delivery to the AFRL in 2008, several electrical board problems were discovered during environmental testing, four years after the team members who did the electrical design had graduated. These hardware problems ultimately led to de-scoping the second half of CUSat's mission.

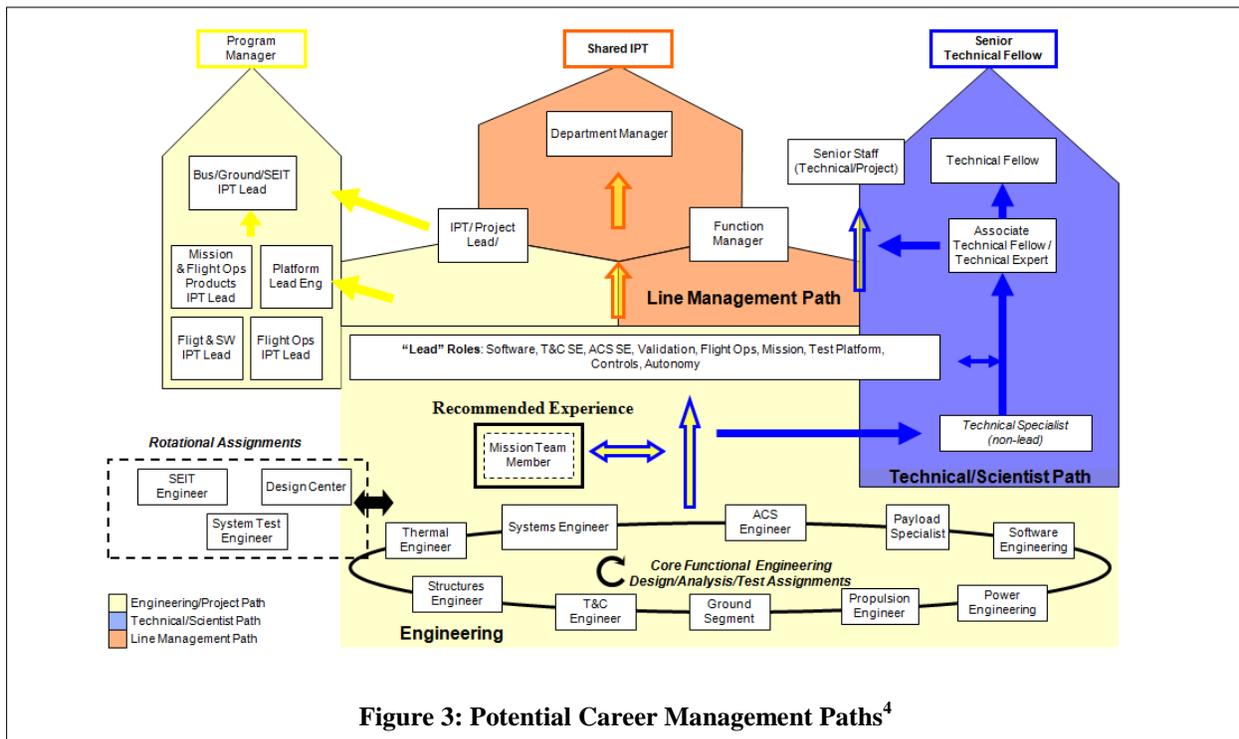


Figure 3: Potential Career Management Paths⁴

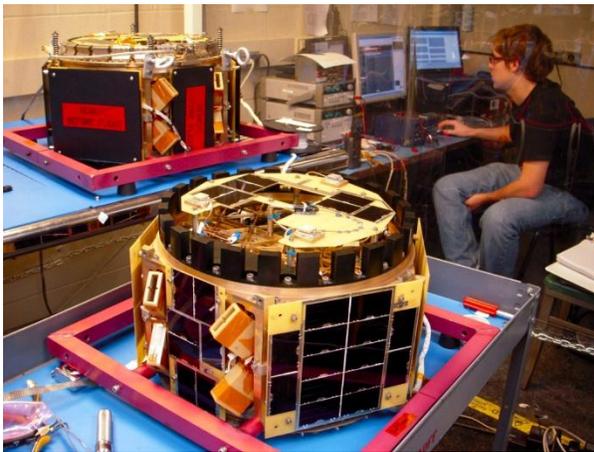


Figure 4: By participating in the UNP, students gain experience building and testing real satellite systems.

The fast paced UNP allows students to gain experience in multiple roles over a short time period. It is not uncommon for students who are on the team for two or more years to take on leadership positions. Gaining cross-disciplinary experience allows students to view the project from technical and managerial perspectives. Having the ability to think in this manner leads to better system level solutions when the students' program runs into problems.

This skill directly translates into industry once the student graduates. Making the transition from a subsystem engineer to subsystem lead, to system engineer, and finally chief engineer or program manager may be done in less than three years on a student team, while in industry the same career path usually takes more than a decade. Students carry this experience and perspective with them to industry. Students who participate in the UNP benefit from this advantage, which enables a UNP participant to easily move through the ranks on a program.

In industry settings, cross-disciplinary experience is highly valued. In small teams cross-disciplinary experience is valued because teams must still capture the necessary breadth and depth of experience with fewer team members. Cross-disciplinary systems engineers are essential. In larger, more complex systems this cross-disciplinary experience is valued since it allows information to be linked across different subsystems. Although technical depth is required for specific tasks, breadth across multiple subsystems also takes years of experience to develop. By already coming in with this cross-disciplinary mindset, new engineers contribute to solving these problems immediately.

Technical Challenges

The fundamental technical challenges for building spacecraft are common to both industry and student teams. Students solve these problems and participate in all portions of the design from writing requirements and running simulations to physically assembling and testing the spacecraft. Figure 4 shows students participating in CUSat's integration and testing activities.

A unique feature of university satellite teams is that the missions are designed to be cutting edge technology demonstrations with diverse applications. CUSat's mission was to demonstrate sub-centimeter accurate relative GPS algorithms, using those algorithms to perform relative navigation between two spacecraft, and providing an autonomous orbit, satellite-to-satellite inspection system. Meanwhile, Violet's main mission objective is to provide an orbit test bed for control moment gyroscope (CMG) steering laws, which will allow it to complete its secondary mission objectives of ultraviolet astronomy. Violet's array of high-agility CMGs will allow the spacecraft to rotate up to 40° per second. Once the spacecraft is launched, Violet will be the most agile spacecraft ever launched.⁸ The mission diversity among UNP satellites allows students to working on cutting-edge technology.

The difficulty of solving these unique problems is compounded by the limited availability of COTS products that fit the weight and volume constraints specified in the UNP competition guidelines.⁵ Yet, these missions often benefit multiple parties because they enable emerging spacecraft technology to advance to a higher technology readiness level (TRL), which is often a primary goal of spacecraft hardware vendors and university PIs. These groups would like to have their technology used on larger, more mainstream spacecraft. Therefore university teams often receive hardware or software donations from vendors interested in gaining flight heritage for newly developed units. Once the product has flight heritage, the vendor is better prepared to sell their product to traditional customers. Without the technology demonstration mission and donations from hardware vendors, university teams would not be able to afford the millions of dollars that it takes to build a typical spacecraft system.⁶

Universities that compete in multiple UNP cycles may also address reusability and maintenance. Commonly reused project elements include simulation code and ground station networks since these components are necessary even when the spacecraft have different missions.² Today, designing for maintainability is a key aspect of commercial satellites. Companies are investing effort into standardizing their product lines and minimizing the changes between individual spacecraft. Maximizing the commonality among spacecraft is recognized as a key step to reducing the cost of on-orbit access.⁷ Students who have experience designing for standardization and cost-reduction are highly valued by the industry once they graduate.

Meeting the technical challenges of designing spacecraft requires students to develop and improve their engineering skills. Students gain leadership and communication skills by collaborating with team members to solve these challenging problems.

Leadership

Although most students' first roles on these teams are technical in nature, many students move into key leadership positions. Students learn to dynamically manage a schedule and motivate their team members. These skills are important for students who are leading other students, since the lead assumes responsibility for the completion of all technical work associated with that aspect of the project. Working with other subsystem leads is important when addressing areas where subsystems have overlapping influences and constraints. Students learn how to prioritize their tasks and track the team's technical progress.

Student leaders face several unique challenges. Working as a technical leader is often the student's first team experience. Learning how to effectively interact with teammates, balancing their school work, and maintaining a healthy balance is difficult.⁸ These challenges are often compounded by the fact that teams have to deal with students constantly moving on and off the project.

However, this challenge reemphasizes the importance of the students' leadership role. Student leaders must quickly integrate new team members into their existing team. Subsystem leads are able to do this by providing reading material, formal training sessions, and having new team members demonstrate proficiency on their newly learned skills. Holding these training sessions in team settings also helps new team members socially integrate into the group. These activities enable students to become productive faster.

While traditional university programs provide the technical principles necessary to build complex aerospace systems, they lack practical experience in implementation. These experiences are important because they teach students how to be effective technical team members, while also providing many students with leadership education. As the "demographic cliff" approaches, early career professionals will have to assume leadership roles as well as serving as contributing team members. The leadership skills necessary to drive a successful execution cannot only come from lectures and coursework. Leadership, project management, teambuilding, partnership and collaboration are best learned by doing, not from reading. UNP gives new hires an advantage because it allows students to assume multiple roles: as individual contributors, team contributors, and team leaders. These experiences make it easier for new employees to join existing teams and contribute to its success. The leadership and communication skills learned while participating in the UNP improve team performance at all levels.

Communication

In 2010 Christina Chaplain, Director of Acquisition and Sourcing Management for the Government Accountability Office, testified before the Senate's subcommittee on Strategic Forces to address the Department of Defense's problems with overrun space system budgets. During the testimony she remarked that budget overruns are a major problem for nearly all large-scale space systems, with some programs facing overruns of more than 300% of their initial estimate. Along with the additional cost, these projects have faced large schedule slips, higher technical risks, and reduced capabilities from programs' initial scope. Their

study cited that the program management and communication between stakeholders as a major weakness.⁹ This example illustrates that communication skills greatly impact program execution and are not limited to microcosmic internal team relations. Early career training to develop effective communication skills will directly contribute to lower cost systems and better program execution success.

Students who participate in the UNP develop strong communication skills. The educational diversity in student teams makes effective communication an important skill in experiential learning. Figure 5 shows examples of UNP activities that require teamwork and effective communication.

UNP often practice several disruptive styles of communication. Student subsystems make a deliberate effort to ensure that they work physically close together. This is done by subsystem leads scheduling two to five working meetings a week where members are co-located. This close style of interaction makes it easier for members to ask questions and collaborate with each other. Working closely together strengthens team relationships and helps students feel more connected to the project's success, improving member satisfaction and team retention. Although each lead can choose the meeting schedule that works best for their team, subsystems who more spend more time working together tend to accomplish more throughout the semester compared to teams that meet less frequently. Physically close collaborations helps to ensure that all subsystem members understand the team's priorities, deadlines, and critical path.

Student teams often have limited laboratory space. This often leads teams to make their space as open and reconfigurable as possible. Creating an open environment further improves collaboration by creating visibility to the work being done by other subsystems and encouraging the usage of white boards. This style of close collaboration and creating an open space contrasts the cubical isolation that is sometimes used in industry.

Additionally, UNP teams often adapt more casual forms of communication. One popular form of knowledge management used on university team is wikis. Wikis allow members to freely edit content in an easily searchable form. This open style helps ensure that internal design decisions are transparent. Wikis reduce the time spent on unnecessarily formatting cumbersome, formal documentation. Although this more informal style is used for internal team communications, formal document templates are used

when interacting with the AFRL and other external stakeholders.

In addition to overseeing the project's technical work, student leaders must also work with university officials. Maintaining a team's presence on campus requires students to interact with many university organizations including department chairs, financial offices, building facilities, alumni relations, university outreach events, undergraduate leadership members, other student groups, and their program's PI. Teams must justify why their project should be given access to limited resources, such as lab space and funding. Recent economic conditions have limited the amount of money that is available to university outreach programs. The ability to demonstrate the value of these programs has become more important for student teams. Illustrating the importance of the program can make the difference between continued university support and termination.



Figure 5: Whether students are building ground stations on Kwajalein Island or testing GPS hardware in the winter; Effective communication is critical.

Students must also regularly interface with agencies outside of the team and university. In particular, student teams must interact with hardware vendors, sponsors, and the customer. Teams that secure a launch opportunity must also coordinate with the launch

provider as well as the FCC and IARU to finalize their frequency coordination. Dealing with these outside agencies requires students to demonstrate a high level of professionalism. Poor relationships with any of these agencies can cause serious problems for a program or lead to cancellation.

Besides teaching students how to interact as professionals, work with outside agencies benefits the student by expanding their professional network. Students graduating from the UNP may have a network of more than fifty aerospace professionals. Connecting with other UNP alumni gives students access to major aerospace companies and research labs including: AFRL, APL, Boeing, JPL, Lockheed Martin, NASA, Northrup Grumman, Orbital Sciences, Space Systems/Loral, SpaceX, and more. Many UNP students develop diverse professional networks that also include aerospace leaders such as: astronauts, NASA officials, vice presidents of major aerospace companies, and spacecraft hardware vendors.

Students who have worked with outside vendors understand the attention to detail that is necessary to build flight hardware. Given the small community of space hardware manufacturers, it is not surprising for UNP students to have experience working with the same suppliers used in industry, such as: Goodrich/Ithaco, Space Micro, Northrup Grumman, and Moog. Experience with flight hardware allows early career professionals to have mutually engaging conversations with senior engineers about hardware performance on their first day of work.

Since UNP satellites often provide flight heritage for

new hardware units, students are placed at the cutting edge of the market. Early career professionals with UNP experience can often suggest new hardware units that their more experienced colleagues are not aware of. This perspective, combined with their practical experiences, allows early career professions to immediately contribute to their program by championing advanced technology.

Effective communication is essential to establishing and maintaining healthy, professional relationships with teammates, university officials, and outside agencies. Understanding the basic technical challenges of building flight hardware allows early career professionals to generate creative solutions to problems and use their existing network to help implement the solutions. The ability for early career hires to effectively communicate with their team, company, and outside vendors sets former UNP participants apart and sets them on a successful career path right from the start.

Successful Transition

The UNP challenges undergraduate students to meet an aggressive two-year design cycle spanning initial mission concept through physical reality. Meeting these challenges often seems overwhelming. Having sacrificed blood, sweat, and tears to build their university satellite, students feel highly accomplished and take pride in their work. This pride is illustrated in Figure 6.

Throughout the competition, students learn the importance of developing effective relationships by



Figure 6: Students often spend 15 hours per week or more working on these projects. By the end of the two-year design cycle, students have gained a sense of accomplishment and pride in their work. These pictures illustrate this pride as Cornell's UNP-4 entry, CUSat, and UNP-6 entry, Violet (right), teams prepare for their 2007 and 2011 final competition review shipments (respectively).

engaging with other team members, university officials, and outside agencies. These experiences enable students to develop their leadership skills and communication skills, which can be weaknesses for many engineers. UNP graduates enter the industry with practical, hands-on experience; ready to implement innovation.

By working on highly technically relevant missions, undergraduate students are encouraged to explore solutions to engaging spacecraft problems. Students lack any pre-conceived notions on how the problem “should” be solved. While implementing their unique design, students are also able to learn more about how the industry works, who the key players are, and the discriminators among competitors’ technologies.

The UNP experience gives young professionals the experience to challenge the status quo by applying the lessons learned from their university experience to the industry and fundamentally challenge how things are done. Today’s demographic and budget constraints, the aerospace industry will need early career professionals to assume leadership roles and aggressively question the process of how things are done.

Since 2005, Cornell’s UNP alumni have gone on to prove this point. In the last eight years more than 300 students have “graduated” from Cornell’s CUSat and Violet programs. Many of these students have gone on to enter industry, while others have pursued graduate school at other top-ranked university research laboratories. In this short time, the CUSat and Violet alumni who have entered industry have made significant contributions to the aerospace industry. Many have gone on to work for top research labs, launch vehicle providers, and satellite manufacturers. In fact, CUSat and Violet alumni have worked on everything from overseeing Curiosity’s Mars landing, developing new launch vehicles, to designing the next generation of commercial small satellites.

Not only have CUSat and Violet alumni contributed to these projects, but several have worked as lead technical engineers or managers for these programs. Adam Maher, former CUSat mechanical systems engineer, is an outstanding example. In 2011 Maher’s work at Space Systems/Loral was recognized by the Society of Satellite Professionals International (SSPI). As an early career profession Maher has demonstrated “leadership and technical ability” allowing him to earn “a reputation for identifying issues before they became problems” and become involved in Loral’s “most complex and challenging projects.”¹⁰

Mahe’s success after graduating from the CUSat program is not unique. Many have stated that the knowledge gained while participating in the UNP gave them practical spacecraft knowledge while they were in school and was a key advantage once they entered industry. Simmie Berman and Justin Hahn, engineers at APL, commented on the professional benefits gained by participating in the UNP. Berman remarked that the long hours spent working on CUSat was an incredibly practical experience that “has had a direct impact” on her current position. She has “been able to draw from that experience” and apply it to her work on APL’s Radiation Belt Storm Probes (RBSP). Hahn, former CUSat program manager offered similar sentiments. He stated that the leadership experience he gained while working on CUSat has also been very beneficial to his career.⁸ The UNP experience often acts as a key differential factor for why these early career professionals are given the opportunity to work on high-profile and important programs.

The fact that UNP alumni have gone on to contribute immediately to industry illustrates the importance of university satellite programs. These programs, which allow students to experience an entire spacecraft lifecycle while still in college, give these students a major advantage once they enter industry. Participation in the UNP program can be used as a meaningful way to predict future success as an early career professional.

INDUSTRY PERSPECTIVE

The program manager in a major aerospace company faces several challenges. The program manager needs a workforce ready to integrate into an existing, executing team with very little time required to bring new employees into the fold. They need to retain new hires in an environment where a career in satellite design competes with gaming, visual effects, and entertainment industries. In addition, the hiring manager needs employees ready to perform complex tasks, problem solve, and generate innovative ideas. However, these skills do little to help a program if the employee is unable to plan their work, execute to a schedule, communicate effectively, and drive a project to completion.

Engineers with direct experience in the UNP have proven themselves to be ready to join the workforce the day they arrive on their first job. UNP alumni understand the complex problem of integrating a satellite system. Moreover, they are cross functionally trained and easy to fit into multiple roles. They can plan their work, effectively communicate their ideas, and collaborate to solve complex problems. Most importantly, they can translate their innovative ideas into real life applications to meet the program’s

requirements. While they have not necessarily honed all of the skills necessary to be a satellite engineer; they have a fundamental understanding of the system that facilitates faster absorption of the art that is required to design complex satellite systems.

An aging workforce nearing retirement puts the company and the industry at risk. Corporate heritage knowledge is typically retained through shared experiences, mentoring, and on the job training. However, all of these transfer methods take significant time and close collaboration between senior engineers and junior engineers. An engineering workforce that comes out of the university environment with the experiences of building satellite systems can quickly adapt to corporate processes that focus on building high-reliability satellites. Recruiting UNP graduates onto industry teams improves the company's ability to transfer experience and tradecraft knowledge from the senior technical staff, while maintaining key "lessons learned" between generations.

Retention of the new workforce is critical to the long term success of an aerospace company. Companies often spend tens of thousands of dollars hiring, relocating, and training a new hire. However retention rates are lower than in many other industries. Part of this retention challenge may have to do with the type of work new hires are given in their first year of employment. Many entry-level jobs are designed to provide on the job training while also preventing the new employee from "doing harm." This may involve removing the new engineer from jobs and tasks that directly impact the product or program. Instead typical entry-level jobs focus on non-critical roles that have little to no tie to the end products, such as document management, paper work, and simple calculations. These tasks are often de-motivating to the workforce and make many early career jobs unfulfilling and boring. Providing early career professionals with meaningful work that directly contributes to the success of the team and the program creates a more motivated workforce.

A 2006 Aberdeen Group report examined the problem of workforce retention. The study determined that 90% of employees make their decision to stay at a company within the first 6 months of employment¹¹ as shown in Figure 7.

As cited in the Aberdeen Group Report, the more exciting the first 6 months of an employee's career are, the higher the retention rate. This excitement can come in several forms, including direct access to new technologies, engaging work, and feeling like they are contributing to the success of a team. With a UNP

trained engineer, the transition to meaningful, exciting work can happen quickly, thus improving retention rates in the long term. The faster an employee is exposed to challenging, engaging work that impacts the outcome of a project; the more likely that employee will stay with a company. Hiring UNP experienced young professionals can accelerate the transition to these kinds of opportunities.

The current state of the economy coupled with the industry's market based affordability efforts have resulted in reduced training budgets and training opportunities. Due to these budgetary constraints, it is necessary to find alternative ways of bringing young professionals up to speed on their specific tradecraft.

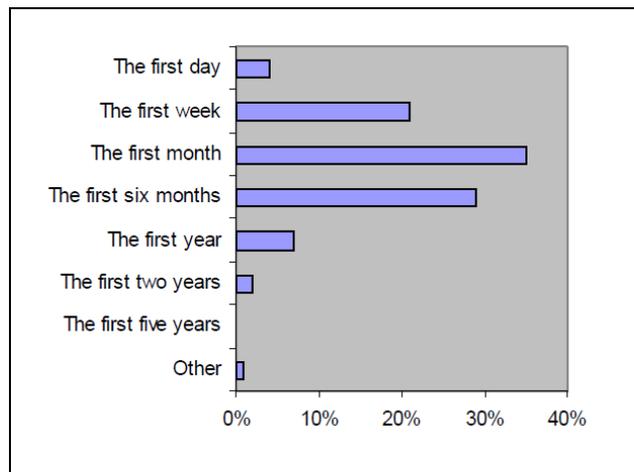


Figure 7: Timeframe an employee makes a decision to stay at a company. Source Aberdeen Group 2006.

One way of doing this is through ad-hoc mentoring and on the job training from the more-experienced workforce. The best way to create ad hoc mentoring relationships is to have junior engineers and senior engineers working shoulder-to-shoulder on a project. Figure 8 illustrates this style of close collaboration.

Newly hired engineers who can rapidly transition from the university environment to the workforce are more likely to have opportunities for this kind of collaborative work. This collaboration between junior and senior engineers is not only advantageous to the junior engineer, but it provides a great opportunity for new tools to be taught to the senior mentor as well. This cross-generational collaboration is extremely powerful when it comes to UNP experienced engineers.

The methods used to develop UNP satellites differ from traditional satellite development at a large company. The differences in process and tradecraft can often yield new innovative solutions to improving development efficiencies, reducing cost, and improving cycle times

on existing systems. The ability to adopt new development techniques like Agile software development has yielded significant improvements in process efficiencies. Many of the UNP programs have adopted Agile development, allowing small teams to complete their satellite designs within the aggressive UNP schedule. These experiences can directly translate to higher efficiencies and a large scale programs as well, improving the bottom line and successful program execution. A lot can be learned by cross-pollinating the workforce with a diversity of experiences.



Figure 8: Industry collaborative development improves program execution and breeds new ideas.

The workforce of the future will look very much like these small university teams. Aerospace companies will no longer be able to maintain massive organizations with engineers trained in one very focused area of expertise. The industry needs engineers that can work across disciplines, work effectively as small teams, and quickly adapt to a rapidly changing environment. The future environment will require collaboration among a diverse workforce. There will be geographic diversity, differences in education, backgrounds, and experiences. Innovation is born out of collaboration and diversity; while the ability to clearly communicate ideas comes from collaboration. The company of the future will need to innovate faster to keep up with the speed of technology and the speed of competition.

CONCLUSION

The AIAA and AFRL's UNP provides students with the opportunity to combine innovative spacecraft research with practical experiential learning opportunities. This experience teaches undergraduates how to plan and execute technical work, while developing the communication skills necessary to be a career professional. Successfully preparing UNP students to enter the workforce requires the Principal Investigator (PI) to hold students to the same expectations of a career professional. By setting the same high expectations of the corporate satellite development environment, UNP students experience the day-to-day life of an aerospace professional. The aggressive program schedule, coupled with the PI's high expectations, encourages students to develop collaborative environments and quality controls for their work and documentation; demonstrating the value of teamwork, communication, and leadership. Designing a flight-ready satellite system and balancing the demands of academic coursework is difficult. However, students who graduate from these programs are demonstrated professionals, ready to enter the workforce.

The cross-disciplinary exposure and understanding gained by living through a satellite development cycle gives UNP students a distinct advantage as they transition to early career professionals. These early career professionals enter their first jobs knowing how to build technologically advanced spacecraft, deliver contractual obligations, and meet the high expectations of industry customers. They possess experiences that go beyond book learning and can directly apply their newly formed skills in a real engineering environment. These early career professionals are comfortable asking hard questions, taking responsibility for their work, and engaging in mentoring. Leveraging these diverse experiences allows UNP alumni to bring a fresh perspective to their teams, work across generational gaps, and teach their co-workers new ways of doing business.

UNP alumni understand the technical, communication, and teamwork requirements that go in to building complex aerospace systems. The lessons learned from the UNP experience allow its' graduates to directly contribute to the successful implementation of their projects. Early career professionals who are able to see how their daily work directly contributes to the final product are more likely to feel satisfied at their job and stay in the aerospace industry. The decision to leave a company typically occurs within an employee's first year of employment. Highly engaged employees are more likely to stay with a company beyond five years. Program managers, who are facing the challenges

imparted by the “demographic cliff,” are able to reap the technical benefits of gaining highly skilled and experienced engineers, while also reducing their overhead expenditures due to attrition. The UNP has proven itself as an effective training method by teaching students how to overcome technical and communication challenges, and accelerating early career professionals’ growth. Its successes are measured by the immediate and continuing contributions that alumni make to the aerospace industry and the value is reflected in companies that hire UNP graduates.

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