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Workforce Development for the Space Industry

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ABSTRACT

The Astronautics and Space Technology Program (http://astronautics.usc.edu) of the University of Southern California (USC) offers a full set of undergraduate and graduate degree programs in Aerospace Engineering with emphasis in Astronautics. The program focuses on the needs of the space industry and government research and development centers. The program classes cover practically all main areas of spacecraft technology and many graduate classes are taught by adjunct faculty who are leading specialists working in the space industry. The Master of Science degree is available through the USC Distance Education Network (DEN), reaching students anywhere in the world through webcasting. The majority of our graduate students work full time as engineers in the space industry and government research and development centers. We describe in detail the program's academic focus, student reach, enrollment dynamics, and structure of program components. The achievements, difficulties, and lessons learned are discussed. The development of the future workforce requires a concerted effort by all stakeholders, including the space industry and government. We outline the areas where such cooperation can make a difference in improving quality of space education.

AEROSPACE WORKFORCE

More than thirty years has passed since the great advances in space technology of the 1960s. Much of the expertise in the space industry and government research and development centers is held today by engineers nearing or past retirement age. One survey pointed out that one-third of the technical workforce of the space industry will reach retirement eligibility within the next few years. The need to improve space-related education has become acute and emerges as a major challenge for the American space enterprise.

NASA's Associate Administrator for Education described the current situation as a national crisis:[1] "this year [2003], [NASA] potentially may have 200 to 300 engineers and scientists exit the workforce because they will be retirement-eligible. Also, in the next three to five years, roughly 25 to 30% of that skill set also will be retiring, and that's a national crisis."

A magazine of the space industry sounded an alarm[2] already in the mid-1990s: "There is a growing shortage of engineers available to space-oriented businesses in the U.S. and Canada. The shortage, because of industry predictions of rapid and sustained growth in commercial space activities and low student enrollment rates at engineering schools, is likely to adversely affect the industry for a decade or more." A recent editorial[3] in *Aerospace America* chillingly noted that in one survey of aerospace workers "80% said that they would not recommend aerospace careers for their own children."

The workforce problem has been exacerbated by a steady decline in enrollment in nation's engineering schools. In addition, many undergraduate and graduate students are foreign nationals. It was recently reported that 37% of Bachelor of Science technical graduates are non-U.S. citizens, which makes them largely ineligible for defense contractors and the military. According to the American Institute of Physics (AIP), foreign students (52%) outnumbered U.S. students among those beginning graduate studies in physics and astronomy in 1999. The largest single international component is Chinese students (25%) closely followed by Eastern Europeans (22%).

The report (issued in November 2002) of the Commission on the Future of the U.S. Aerospace Industry, chaired by former congressman Robert S. Walker, called to arms[4] by recommending to "reverse immediately the decline in the scientifically and technologically trained U.S. aerospace workforce and promote its future growth." Whether this alarming assessment of the state of the American space enterprise collects dust on library shelves or translates into changes depends on a concerted effort by all stakeholders, including the space industry, government, academia, and professional societies, especially AIAA.

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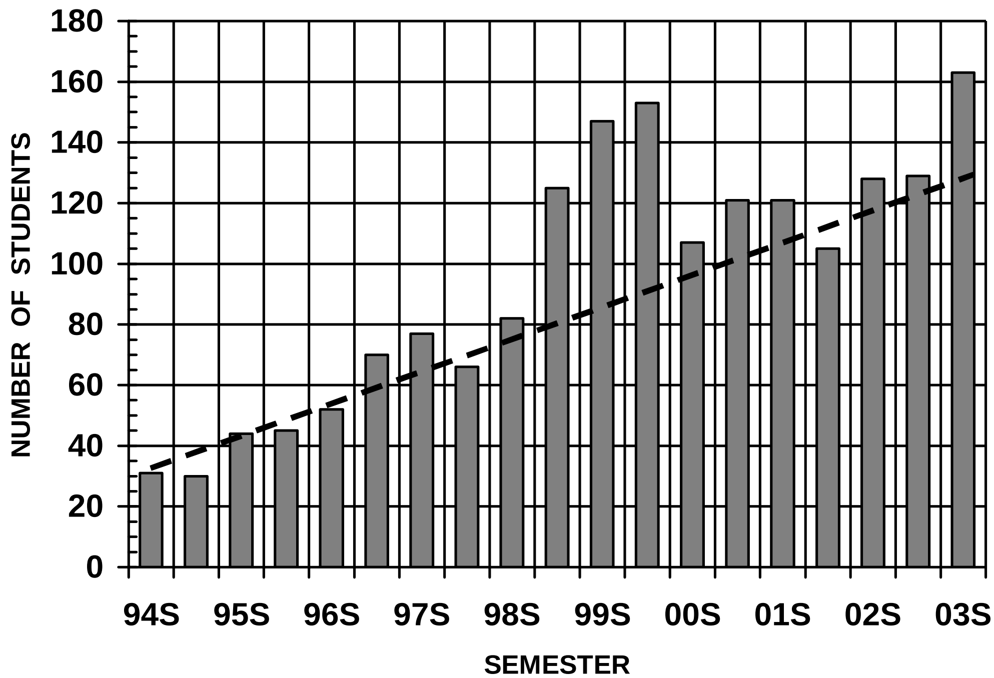

Figure 1. Number of USC graduate students enrolled in astronautics classes each semester since 1994; F - fall semester; S - spring semester. An enrollment spike in 1999 was caused by significant expansion of a major space company in Southern California. The dashed line shows the enrollment trend and does not exhibit saturation yet.

The universities can contribute to correcting the current situation and reversing the trend by identifying the customer for their programs, developing educational products responsive to customer needs, soliciting and listening to feedback, and, importantly, by determined and focused actions. We report here how our efforts have made a difference in one particular university (University of Southern California – USC) and in one particular geographical region – Southern California.

Our response to the doom-and-gloom atmosphere of the mid-1990s was to found the Astronautics and Space Technology Program (Astronautics Program) focused on providing engineering degrees in the area of spacecraft technology for the space industry and government research and development centers. The program has become a success: the specialized Bachelor of Science and Master of Science degrees and the Graduate Certificate have been established; the number of graduate students taking astronautics-related classes has quintupled (fig.1); and the recently launched and rapidly growing undergraduate Astronautics-degree program boasts a 92% fraction of the U.S. citizens among its students.

Today we have a comprehensive educational program in space technology with both undergraduate and graduate components. The future looks promising and we are posed to significantly expand our graduate program nationwide through distance learning. We have learned what works and what does not, we know where the limitations are, and what specific actions by government and industry could bring most significant improvements in workforce development.

USC ASTRONAUTICS PROGRAM

In the early 1980s, a large majority of the undergraduate and graduate students in the Aerospace Engineering program at the University of Southern California were employed after graduation by aerospace companies doing government and military business. The end of the Cold War deeply affected the aerospace industry and our undergraduate student population dropped by a factor of 5 from its peak. (Total aerospace-related employment in the United States was 1,280,000 and 700,000 workers in 1987 and 2002, respectively.[3])

At major research universities, the faculty members largely determine the areas of their concentration and change in the areas of faculty interests does not come easily. Edward Teller once noted[6] "that the substance with the greatest inertia known to man is the human brain, and that the only substance more inert is the collection of human brains found in a large organization such as military service or the faculty of a university." Most of the USC Aerospace Engineering faculty have been traditionally focused on incompressible fluid dynamics research since the Department's founding in the 1960s. Only a very few courses in space technology were offered in 1980s to graduate students by adjunct faculty, including by one of the authors (RFB) of this paper. More recently, however, several tenure-track faculty were added in modern areas of research such as hypersonic flight, physical kinetics, and space science. This group formed the nucleus of the Astronautics Program.

In the mid-1990s, the space side of the aerospace sector of the economy began to grow again. The commercial space business expanded, while the national security programs stabilized. By 1999, commercial satellites and satellite services accounted for twice as much revenue as the military and government space share of the market.[7] The number of commercial launches from Cape Canaveral Air Force Station outnumbered military and civilian government launches in 2000.[8]

USC, the oldest and largest private university on the West Coast, is strategically positioned in the heart of the American space industry in Southern California. (California accounts for roughly one half of the revenues of the U.S. space enterprise and California dominates (~80%) the satellite segment of the market.[5]) The university is located in Los Angeles and USC's nationally-ranked School of Engineering has broad expertise and long tradition of working with the aerospace industry. As part of a private research university, the School is dynamic, innovative, and entrepreneurial.

In the mid-1990s, the astronautics faculty of the Aerospace Engineering Department began introducing coursework designed to support the space industry and government research and development centers in Southern California. We started with only a few selected space-related courses and steadily expanded the curriculum.[9] The Master's degree program with emphasis in astronautics was introduced first as a specialization in 1997 and was formally approved as a separate degree program by the university in 1998. The approval of the Graduate Certificate and the Bachelor of Science degree in Aerospace Engineering (Astronautics) followed. Our first steps in program development were reported in 2000;[10] a detailed program description including the program's history and focus can be found in Gruntman et al., 2002.[9]

We began with the Master's degree program, building on the reach of USC's Distance Education Network (DEN), which broadcasts graduate classes to working engineers at their company sites and homes. Webcasting has now replaced television broadcasts and DEN reaches any place in the United States, or in the world for that matter, with a standard high-speed internet connection. More than 800 students were enrolled in USC's DEN-webcast classes during the spring, 2003, semester, including students pursuing advanced degrees in astronautics.[9,11]

It was also practical to begin with the Master's degree because of seemingly unending resistance in academia to separate undergraduate programs in astronautics. The need for distinctive accredited undergraduate programs in space engineering reflects the needs of the space industry and has been advocated in academia since the early 1980s,[12] with the first such degree introduced by the Air Force Academy. A number of universities have experimented since then in various mixes of programs in aeronautics and astronautics.[13] The resistance to separate degrees is gradually subsiding, forced largely by market demands and generational transformation of aerospace faculty. Establishment of separate degrees obviously brings new challenges of going through the time-consuming process and wrenching experience of a separate ABET (Accreditation Board for Engineering and Technology; http://www.abet.org) accreditation.

Today, the USC Astronautics Program offers Bachelor's degree, Master's degree, and Graduate Certificate programs in Aerospace Engineering with emphasis in Astronautics. All undergraduate and a number of graduate students study full-time on campus. In addition to the required mathematics classes, six graduate astronautics classes are offered to students every semester throughout the country through DEN. Graduate degrees in the Astronautics Program, whether obtained through on-campus study or remotely through the distance education program, are bona fide university degrees. By contrast, programs of professional study such as UCLA's Extension Program (http://www.uclaextension.org) and the short course programs offered by AIAA (http://www.aiaa.org/professional), LaunchSpace (http://www.LaunchSpace.com), or Applied Technology Institute (http://www.aticourses.com), do not grant degrees.

A degree program emphasizes fundamentals and basic science and engineering and their role and applications in specialized topics, whereas a typical short course emphasizes specific applications. The semester-long courses taken towards advanced degrees last three-four months and provide much deeper penetration into the topic through extensive homework, term papers, and other course-related projects. In addition, the feedback and corrections through graded course assignments and continuous contact – live and/or electronic – with the instructors and teaching assistants offer much more than can be usually obtained in even the best-taught short course.

Table 1. Core, core elective, recommended elective, and applied mathematics courses for the degree of Master of Science in Aerospace Engineering (Astronautics). All courses are 3 units. A student must take two required core courses, two required engineering mathematics courses, one course from the list of core electives, and four technical electives (most graduate level science and engineering courses are approved as technical electives). Usually, students choose technical electives from the list of core electives that covers most areas of spacecraft technology.

<u>Core Courses (Required):</u>

- * Spacecraft System Design
- * Space Environment & Spacecraft Interaction

<u>Core Elective Courses:</u>

- * Spacecraft Propulsion
- * Systems for Remote Sensing from Space
- * Design of Low Cost Space Missions
- * Spacecraft Power Systems
- * Orbital Mechanics I
- Orbital Mechanics II
- * Spacecraft Attitude Control
- * Spacecraft Attitude Dynamics
- * Spacecraft Thermal Control
- * Space Navigation: Principles and Practice
- * Advanced Spacecraft Propulsion
- * Spacecraft Structural Dynamics

<u>Recommended Technical Elective Courses:</u>

- Compressible Gas Dynamics
- Physical Gas Dynamics I
- Physical Gas Dynamics II
- * Systems Architecting I
- Systems Architecting II
- Space Studio Architecting
- Computational Techniques in Rarefied Gas Dynamics
- Partially Ionized Plasmas
- Gas-Surface Interactions
- Engineering Vibrations II

<u>Engineering Mathematics Courses (Required):</u>

- * Engineering Analysis I
- * Engineering Analysis II

* - Courses marked with * are available (webcast) through the USC Distance Education Network (DEN)

paper, a spacecraft to meet selected mission goals, which includes sizing up the spacecraft and working out mass, power and communication link budgets, as well as performing mission and lifetime analyses. Many students gain valuable practical experience of working in a team by joining the student microsatellite project. This is an interdisciplinary collaboration of students, primarily undergraduates, with the goal of designing, building, and launching a small student satellite.

MASTER OF SCIENCE IN AEROSPACE ENGINEERING (ASTRONAUTICS)

Our Master of Science (M.S.) program focuses on students who work full-time while earning their degrees. Most of the students are employed by the space industry and government research and development centers and take their classes through DEN. The required coursework for the Master's degree consists of nine courses (27 units), with all regular graduate classes being 3 units. A full-time graduate student not engaged in research could thus complete the degree in one year of two semesters. In practice, full-time graduate students are also engaged in research towards more advanced (Engineer's or Ph.D.) degrees and complete the degree requirements in three or more semesters.

To earn the Master's degree, students must take two required core courses (6 units); two courses (6 units) in engineering mathematics; one core elective (3 units) chosen from a list of core elective classes; and four technical electives (12 units). The program courses (Table 1) cover a wide range of topics in astronautics and space technology. Most of graduate non-aerospace science and engineering courses can be approved as technical electives. Many students, however, find the diverse offering of core electives (Table 1) so attractive that they choose all their technical electives from this list.

We anticipate that several new courses, in addition to those shown in Table 1, will be offered in the future. Among the considered additions are courses in manned spaceflight, constellation design, space communications, space sensors, and space science. Introduction of new courses depends on the availability of high-quality experienced instructors, industrial interest, and other programmatic factors.

Astronautics program advisors help the students to select sets of courses that best fit their educational goals. Usually students desire to get in-depth knowledge in the technical area of their present job. There is another category of students, however, that concentrates on the areas of technology where they would like to transfer to in their companies. Specializing in the desired areas often facilitates such internal moves.

The two required classes, *Spacecraft Design* and *Space Environment and Spacecraft Interactions*, are broad survey-type courses. The *Spacecraft Design* course also serves as an entrance gateway both for students with non-aerospace engineering undergraduate majors and for those who have been some years out of school. Students of the latter category have often been promoted into management of technical projects and for them this course program is a return to direct involvement with technical study.

GRADUATE CERTIFICATE IN AEROSPACE ENGINEERING (ASTRONAUTICS)

The Graduate Certificate program focuses on practicing engineers and scientists who enter space-related fields and who wish to obtain training in specific space-related areas. Certificate students enroll at USC as limited-status students, and are required to take 12 units (four classes) chosen from the core and core elective courses of the Astronautics Master of Science degree program (Table 1). After completion of the 12 units, a special Graduate Certificate is awarded.

Some students would like to undergo training or retraining, but they do not wish to commit to the more serious amount of work needed for the Master of Science degree. There are also students who have been out of school for 10-15 years or even more and who lack confidence to embark on an engineering, non-management-oriented degree. The Certificate offers such students an opportunity to study advanced technical topics without a major commitment. Our experience shows, however, that many students, upon completing the Certificate, find that their interest and ability has increased to the level where they do want to continue their studies pursuing the Master of Science degree in Astronautics. The coursework for the Certificate is fully applicable towards the MS degree should the student choose to continue.

ENGINEER AND PH.D. PROGRAMS IN AEROSPACE ENGINEERING

USC is a major research university and our faculty conduct research programs in science and engineering, primarily supported by NASA, the Department of Defense, and the National Science Foundation. The students involved in this research are typically full-time Ph.D. candidates. Doctoral work is performed on topics of fundamental engineering science and there is no need for a separate (from aerospace engineering) astronautics-oriented Ph.D. program. We do not plan at this time to convert the existing PhD degree program into a degree in astronautics.

The situation is different with another advanced degree, the Engineer in Aerospace Engineering. The Engineer degree requires the same coursework, 60 units or 20 3-unit courses, as the doctoral program but no advanced research work that dominates the PhD degree. There appears to be a desire both among some students and from the industry for a more advanced degree than the Master of Science, but providing greater breadth than is obtained in Ph.D. work. We are currently revising the existing Engineer degree program towards an astronautics-specific degree. With the great choice of astronautics courses offered through DEN, we anticipate a significant interest in the new Engineer degree in the future. The breadth of the available courses focused on spacecraft subsystems will appeal to the students with the desire to concentrate on complex space systems.

ENROLLMENT TRENDS

The Astronautics Program has grown steadily since its inception in the mid-1990s, and now accounts for half of all students, undergraduate and graduate, taking classes in the Aerospace and Mechanical Engineering Department. The enrollment in the graduate program is closely linked with the advancement in distance education.[9,11]

Several decades ago, USC initiated a pioneering effort in distance education called the Instructional Television Network (ITV). Remote classrooms were set up at local aerospace companies such as Hughes, McDonnell Douglas, Rockwell, TRW, and the Aerospace Corporation. ITV was an extensive interactive one-way video, two-way audio broadcast system.[11]

The ITV system had limitations, was costly, and covered only the Los Angeles and Orange counties through eight F.C.C.-licensed digital television channels. A USC courier daily collected homework and delivered to the remote sites graded homework, new assignments, and course handouts. Examinations were held on campus and required student presence at USC. Many students actually welcomed this opportunity to visit campus, with its atmosphere reminding them of their undergraduate years.

The ITV expanded in the 1990s reaching more distant locations throughout the United States by compressed video links via ISDN and by geostationary satellite links. In addition, selected USC engineering courses were and are delivered by the National Technological University (NTU) as part of NTU's degree programs.

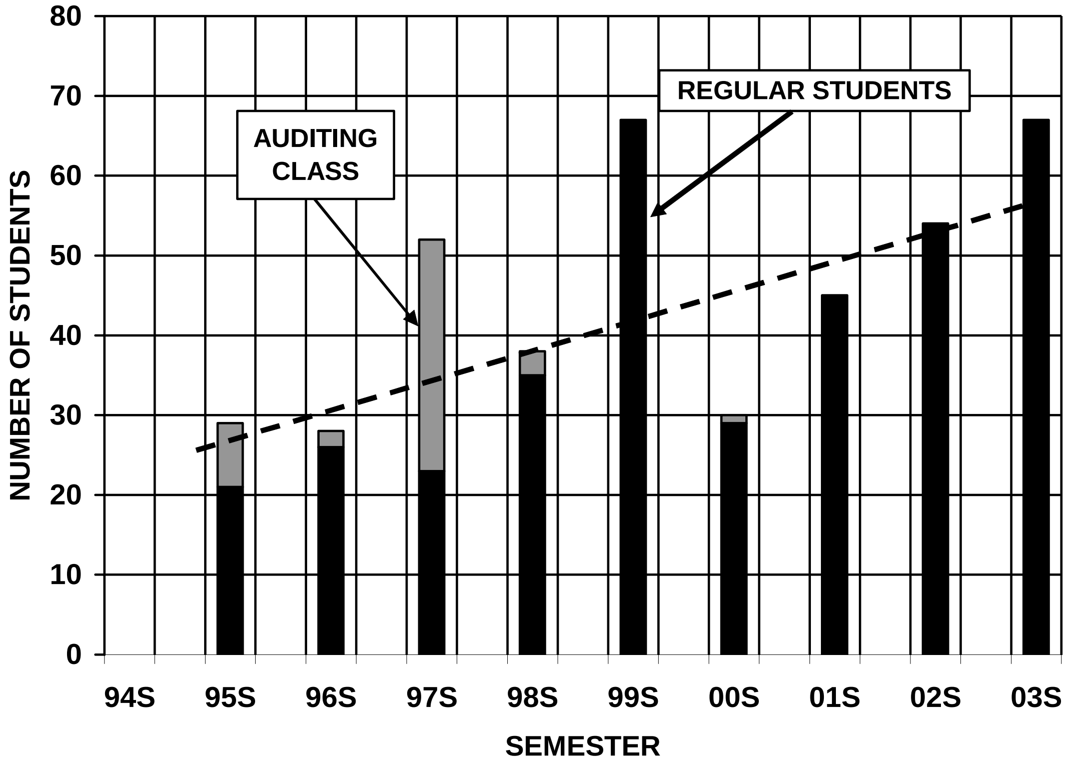

Figure 2. Graduate student enrollment in the required course *Spacecraft Design* since 1995; F - fall semester; S - spring semester. Many students would continue study by taking specialized astronautics courses. An enrollment spike in 1999 was caused by a significant expansion of a major space company in Southern California. This class enrollment is a reliable indicator of the total student enrollment in astronautics courses during the two years in the future. The trend (dashed line) does not show saturation yet.

A few years ago ITV was reorganized into the USC Distance Education Network (DEN), with the courses broadcast over the Internet, or "webcast," using streaming compressed video and audio over the web. The new arrangements allowed a wide range of companies to participate in the distance education programs, regardless of their location. Standard broadband Internet access already provides quality webcasting, the technology is continuously and rapidly evolving, and the quality of the class delivery will only get better with time. Today, the lectures are viewed, asynchronously, at any time during or after the actual lectures. The password-protected class lectures are available for students for the entire semester on USC servers and students can log in and watch classes at their convenience. USC makes no distinction between its on-campus and distance students. Although distance students can watch their lectures from the comfort of their home or office, they are held to the same high standards as all full-time students and are expected to show the same dedication toward their education.[11]

The change to webcasting made it possible for students anywhere in the United States to enroll in our program. The webcasting has opened a way for small companies and even individuals to join our DEN programs. The homework assignments and handouts are transmitted to students electronically. Exams are taken on campus by students in the greater Los Angeles area. At truly distant sites such as Alabama, Connecticut, Florida, Iowa, Kwajalein Island, Texas, and Virginia, the exams are proctored typically at local community colleges. Consequently, we anticipate rapid expansion of the Astronautics Program, reaching students all over the United States.

The graduate program in astronautics is tied closely to the dynamics of the space industry as demonstrated (Fig.1) by a spike in the enrollment in 1999 which was caused by developments in a major company in the Los Angeles area. The overall enrollment trend clearly shows that we have not reached saturation yet in the number of students. In fact we anticipate that the student enrollment will likely double within the next few years or perhaps even faster because of the nationwide expansion through distance learning.

Another indicator of future enrollment is the number of students in the required *Spacecraft Design* class (Fig.2).

This class is taken by all Astronautics students as well as by many engineering students with other specialties who work or plan to work in the space industry. Those Astronautics students who take the *Spacecraft Design* class will continue their studies in our program and take a number of specialized courses in space technology. Therefore, the enrollment in the *Spacecraft Design* class, which also does not exhibit signs of saturation, serves as a reliable indicator of the program state during the next two years.

Most of the specialized elective astronautics courses are now offered every other year. This arrangement allowed us to roughly double the choice of the available courses while preserving acceptable levels of enrollment in individual classes and utilizing the same number of slots allocated to astronautics distance classes by DEN. Financial soundness of the program, particularly in a private university without generous state subsidies, is an important element that, together with academic excellence, made the Astronautics Program a success. With the growing number of students, we anticipate to gradually transform to the system when most classes are offered every year.

The first freshmen were directly admitted to the Bachelor's degree program in Astronautics in the fall of 1999, although a number of aerospace students enthusiastically converted their major to Astronautics when it became available. Our highly visible and expanding graduate program played an important role in attracting attention to the new undergraduate component. After only 4 years of program existence, Astronautics students constitute approximately one third of the undergraduate student population in the Aerospace and Mechanical Engineering Department. With the Master of Science program well established and steadily expanding, the undergraduate program receives more attention from the astronautics faculty. The leadership of the School of Engineering is committed to the program's growth, and we anticipate significant increase in enrollment of students pursuing the Bachelor's degree in Astronautics in the years ahead.

LESSONS LEARNED

There are several lessons that we learned during the program buildup. First, the program should be on a financially sound basis. Although this requirement is beyond the usual academic figures of merit, anyone with real-world experience will immediately recognize the importance of this factor.

Our typical graduate student works full-time and typically takes one or two courses every semester. A Master's degree requires 9 courses and it correspondingly takes from two and a half to four years for such a student to complete the studies. Therefore, it was practical to offer only core courses every year, while offering many technical electives every other year. Under such arrangements, a student would have an opportunity to take all courses of interest. At the same time, demand accumulates for elective classes during the off semesters, so the enrollment in the classes is typically sufficient for the program to be financially sound. Consequently, we could gradually build the program up experimenting with new courses. With the student enrollment rapidly growing, however, we may switch back to offering elective courses each year.

Second, offering classes every other year requires that classes be scheduled several years in advance, so that students can plan accordingly. We now publish a schedule covering four years, from the current year through three years in the future. It is understood that the schedule is tentative and the student has always to discuss his or her plans with program graduate faculty advisors and the staff student coordinator.

Third, our adjunct faculty are an exceptionally important asset and the importance of selecting the right instructors cannot be overestimated. The real-world experience, brought by the experts from the space industry and government research and development centers, is a vital component of a high-quality program.

Fourth, providing a high quality degree program through distance education calls for elimination of any distinction between the requirements for full-time on-campus and distance students. This approach is critical for maintaining the high academic standard of the program.

Fifth, the feedback from our customers, the space industry and government research and development centers, should not only be sought but acted upon. Our program's success is to a large degree due to the attention that we paid – and are paying – to the opinion of leading experts in the industry. Our adjunct faculty is an outstanding source of such feedback, well thought out and insightful. Some our graduate students are mature individuals, with many years of working experience. They are "in the trenches" and they can sometimes provide insight as valuable as occupants of corner offices. Very often, these students make excellent observations regarding the trends and the needs of the industry. In short, on-campus faculty of the program must listen to the customer and learn what the needs of the real world are. Complacency and arrogance would lead to stagnation and pose a major threat to the quality of the program.

The last, but not the least important lesson, is relative administrative independence of the program. Space technology is a dynamic area and a successful Astronautics Program must provide strong science and engineering fundamentals and be, at the same time, flexible and follow the developments in the industry and government programs. This unusually dynamic environment calls for relative independence of the program within the traditional administrative structures of academic units.

CHALLENGES AND THE FUTURE

There are several areas where a successful academic program reaches limitations and can advance further only with the help of and in collaboration with the industry and government.

One such area, student microsatellite projects, has emerged as critically important for quality undergraduate programs in space technology. Finding a solution to this formidable problem requires a concerted effort of academia, government, and industry.

Satellite projects attract students and offer a highly valuable experience of working in teams and participating in design of real systems. The problem is that no funding structure exists in the nation that would provide support for such programs on a sustainable basis. NASA-funded flight programs are usually science-driven and student teams do not stand a chance of winning on science merit in a severe competition. A student-built satellite may offer a significant cost benefit, but such an arrangement would be considered, justifiably, as unacceptable financial and management risk and would doom the proposal. In short, student satellites cannot survive a competition on a science and technological basis.

Treating student satellite projects as purely educational also does not solve the problem. In that case, a student satellite would remain a "student project." As a result, top-notch university faculty would be reluctant to get involved because of the lack of advanced science and engineering and tremendous demands on their time and effort working with and training a large (and changing) group of inexperienced students. In addition, a typical research university does not place much merit on such activities of the faculty.

Practical training in spacecraft engineering could become possible, financially sound, and educationally rewarding if students work with and under supervision of professional engineers and scientists. Generally, the universities are poorly equipped to engage in the programs with flight hardware deliverables on a scale of a satellite. On the other hand, the industry with its tight schedules and deadlines is also poorly compatible with student participation. A possible solution could be a not-for-profit university-linked or university-affiliated research center, a Federally Funded Research and Development Center type (FFRDC-type) establishment, partially supported by the government and engaged in competitively-obtained contracts.

In graduate education, the greater availability of fellowships will make a difference for the space industry. Regular university teaching (TA) and research assistantship (RA) positions are justifiably and unavoidably filled by the students pursuing PhD degrees. Therefore, a student with the desire to obtain a Master's degree studying full-time has poor chances of finding support. Availability of the government-funded fellowships supporting best students – American citizens – pursuing (full-time) M.S. degrees in astronautics and space technology would enhance the quality of education of our future engineers and directly benefit our space industry. While industrial companies support their engineers pursuing Master's degrees, no support is available for students who are not employed by industry and who would like to obtain the Master's degree studying full time. Full-time on-campus study has advantages of greater exposure to top-notch faculty and access to advanced courses unavailable through distance learning.

Funding a number of fellowships for U.S. citizens pursuing full-time MS degrees in space technology will make a difference. Such fellowships may also require the students to devote some time, say 25%, working as teaching assistants in astronautics classes. Not only assistants usually learn a great deal when do teaching and supporting courses, but they will also directly help to improve quality of instruction. Such structured graduate fellowships will help to correct the serious problem of diverging technical expertise of many teaching assistants pursuing PhD degrees in purely academic areas (such as fluid mechanics) and the required support of courses focused on the applied areas of space technology.

Another area ripe for advancement in quality space education is establishing a space operations and control center on campus. Such a center would be staffed by a core of engineers and by properly supervised undergraduate and graduate students. The center would offer an unmatched hands-on training and will help attract the best and brightest to the astronautics program. Finding the right business model and funding sources to achieve a self-sustainable space operations center has been and still is a formidable challenge.

AD ASTRA

The workforce development for the space industry is an acute national problem. The situation is not hopeless, however. We, at USC, have worked to change the situation in one university and one geographical area. We have built up a comprehensive Astronautics and Space Technology Program focused on the needs of the space-

spacecraft industry. Our student enrollment is rapidly growing and we are energetically expanding nationwide through distance learning. We have learned many lessons. We know what works and what does not, and we know where the limitations are. We are confident that the universities, working together with the industry and the government, can bring most significant improvements in the workforce development for the American space enterprise.

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