USC Astronautics and Space Technology Program: From Humble Beginning to New Academic Unit

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Abstract

The Astronautics and Space Technology Division (http://astronautics.usc.edu) of the University of Southern California (USC) offers today a full set of undergraduate and graduate degree programs in astronautical engineering. The program focuses on the needs of the space industry and government research and development centers and covers main areas of spacecraft technology. Many graduate courses are taught by adjunct faculty who are top experts working in the space industry. The Master of Science degree and Graduate Certificate are available through the USC Distance Education Network (DEN), reaching students anywhere in the world through webcasting. We describe the origin and academic focus of the program that was recently reorganized as an independent academic unit in the USC Viterbi School of Engineering.

Aerospace Workforce

The acute need to improve space-related education has emerged as a major challenge for the American space enterprise.[1] One-third of the technical workforce of the space industry and government research and development centers will reach retirement eligibility within the next several years. NASA's Associate Administrator for Education described the current situation as a national crisis.[2] The report of the Commission on the Future of the U.S. Aerospace Industry, chaired by former congressman Robert S. Walker, urged in November 2002 to "reverse immediately the decline in the scientifically and technologically trained U.S. aerospace workforce and promote its future growth."[3] In another chilling observation, an editorial in AIAA's Aerospace America noted that "80% [of aerospace workers] said that they would not recommend aerospace careers for their own children." In addition, enrollment in nation's engineering schools steadily declines, while many undergraduate and graduate students are foreign nationals, which makes them largely ineligible for defense contractors and the military.

At the same time, the importance of space continues to grow for national security and economy. The United States depends on space assets more than any other nation on earth and this country leads the world in exploration and utilization of space. Most of the nations are simply not committed to space to the same degree. Only France (and the old Soviet Union of the past) approaches the U.S. space expenditures in terms of fraction of the gross domestic product (GDP). Most other industrialized countries spend in space, as fraction of GDP, four to six times less than the United States.[4]

Whether the alarming government, Congressional, and industrial findings and reports on the state of the American space workforce collect dust on library shelves or translate into changes depend on a concerted effort by all stakeholders, including the space industry, government, academia, and professional societies.

The Air Force's Space Command recently made a major step to addressing flaws in space education. Space Command stood up a space education and training organization by activating on 18 October 2004 the National Security Space Institute (NSSI) as the Department of Defense's single focal point for space education and training, complementing existing space education programs at Air University, the Naval Postgraduate School, and the Air Force Institute of Technology. Some space fans may call NSSI the beginning of the "Starfleet Academy." Whether NASA, industry, and academia match this bold initiative in national security space remain to be seen.

The universities can and should contribute to correcting the current situation and reversing the trend in the nation's space workforce by determined and focused actions. We report here how our efforts have made a difference in one particular university, the University of Southern California (USC). Some earlier history of the program was described elsewhere.[1]

Astronautics at USC

The USC aerospace engineering program was rather typical for American universities.[1,5] After program rapid growth in 1980s, the undergraduate student population dropped following the end of the Cold War 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.[6])

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[7] "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.[8] The attitude of the USC Aerospace Engineering Department toward space technology was not much different from other engineering schools in the country. The history of the department penned by the former department chair only casually mentions the astronautics program,[8] though already at that time the courses offered by this space-focused program accounted for 70-80% of graduate students taking aerospace courses and the recently established undergraduate component was rapidly growing and approaching half of the aerospace students, capped by the school's enrollment regulations.

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.[1] The program has become a success: the Bachelor of Science and Master of Science degrees and the Graduate Certificate in aerospace engineering with specialization in astronautics have been established; the number of graduate students taking astronautics-related

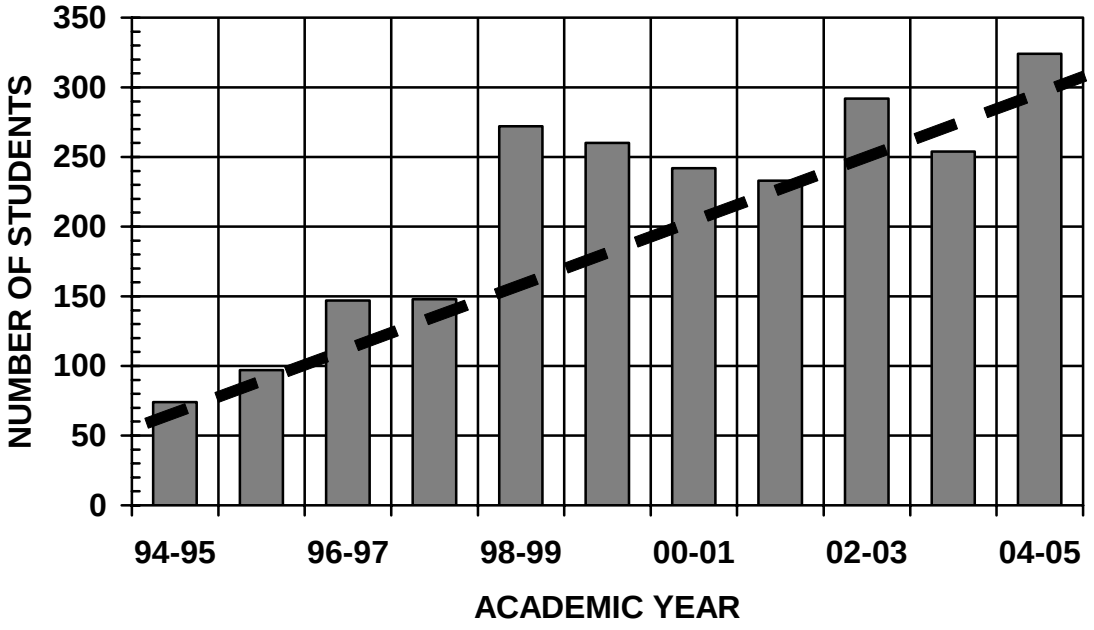

Figure 1. Graduate student enrollment in astronautics classes since 1994. The dashed line shows the enrollment trend and does not exhibit saturation yet. An enrollment spike in the 1998-1999 academic year reflects developments in a major California space company.

classes has more than quadrupled; and the recently launched and rapidly growing undergraduate Astronautics-degree program boasts an overwhelming fraction of the U.S. citizens among its students.

Only a very few courses in space technology were offered in 1980s to graduate students by adjunct faculty. 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 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.[1]

Our initial effort focused on the Master's degree program by identifying the customer for the program, developing educational products responsive to customer needs, and soliciting and listening to feedback.[1,9] We built 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.

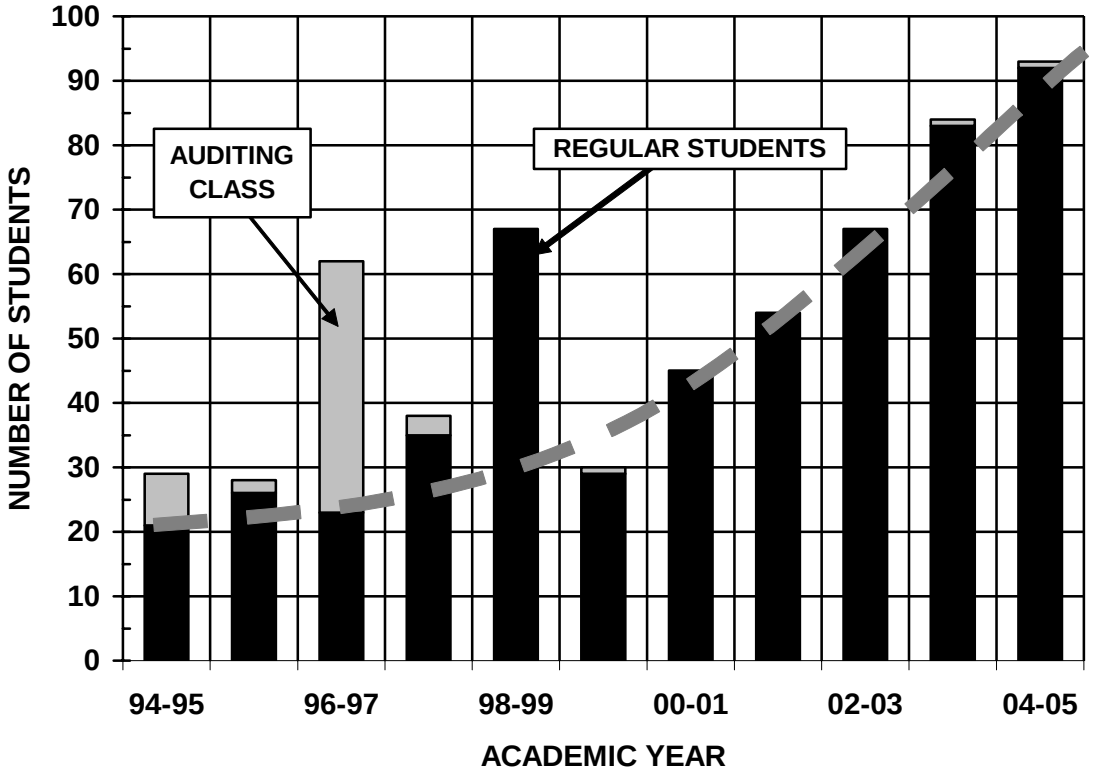

Figure 2. Graduate student enrollment in the required course *Spacecraft Design* since 1995; the course is offered every spring semester. Many students enrolled in this class will continue their studies by taking specialized astronautics courses. Therefore, this class enrollment is a reliable indicator of the total student enrollment trend in astronautics courses during the two years in the future. The trend (dashed line) does not show saturation yet. An enrollment spike in the 1998-1999 academic year reflects developments in a major California space company.

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 by some in academia since the early 1980s,[10] 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.[11] The resistance to separate degrees is gradually subsiding, forced largely by market demands and generational transformation of aerospace faculty. Establishment of separate degrees would obviously bring new challenges of going through the time-consuming process and wrenching experience of a separate ABET accreditation.

The University of Southern California was a natural home for such an initiative in space technology. 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 the satellite segment of the market.[12]) The university is located in Los Angeles and USC Viterbi School

of Engineering has broad expertise and long tradition of working with the aerospace and defense industries. As part of a private research university, the Viterbi School is dynamic, innovative, and entrepreneurial.

Astronautics Degree Programs

Today, the USC Astronautics Program offers Bachelor's degree, Master's degree, and Graduate Certificate programs in Aerospace Engineering with emphasis in Astronautics.

The typical undergraduate student takes classes full-time and completes the degree work in four years or eight semesters, taking four to six courses per semester. In addition to the courses required of all undergraduate engineering students (mathematics, physics, chemistry, and humanities), specialized undergraduate courses cover the following astronautics areas: orbital mechanics; space environment; rarefied and molecular gas dynamics; spacecraft attitude dynamics; rocket propulsion; and spacecraft design.

The underlying basic science and engineering courses, along with engineering design and laboratories, are for the most part the same as taken by aerospace and mechanical engineering undergraduates. A notable exception and significant difference are in the thermo-fluids course sequence that emphasizes modern statistical concepts, compressible gasdynamics, and rarefied gases and plasmas. Space communications is another important technical area which is outside of the scope of a traditional aerospace curriculum but required for program ABET accreditation. Astronautics students are exposed to various aspects of space communications in several courses: orbital mechanics classes address orbital features and ground coverage; space environment lectures deal with wave propagation in the ionosphere; and the spacecraft design course covers communications link budgets, communications subsystems, and constraints and effects on other spacecraft subsystems.

Our Master of Science program focuses on students who work full-time while earning their degrees. About 20% of students are full-time on-campus students. Most of the students are employed by the space industry and government research and development centers and take their classes 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.

The required coursework for the Master’s degree consists of nine courses, with all regular graduate classes being 3 units. In addition to the required mathematics classes, five-six graduate astronautics classes are offered to students every semester. Many specialized courses are taught by our adjunct faculty who are leading specialists working in the space industry and government centers. Adjunct faculty brings the real-world experience, a vital component of a high-quality program.

To earn the Master’s degree, students must take two required core overview courses in spacecraft design and space environment and interactions; two required courses in engineering mathematics; one core elective course chosen from a list of core elective classes; and four technical electives. While most of graduate non-astronautics science and engineering courses can be approved

as technical electives, many students, however, find the diverse offering of core electives so attractive that they choose all their technical electives from this list.

The program courses cover a wide range of topics in astronautics and space technology and include

- Spacecraft System Design
- Space Environment & Spacecraft Interaction
- Spacecraft Propulsion
- Advanced Spacecraft Propulsion
- Orbital Mechanics I
- Orbital Mechanics II
- Space Navigation: Principles and Practice
- Spacecraft Attitude Control
- Spacecraft Attitude Dynamics
- Systems for Remote Sensing from Space
- Design of Low Cost Space Missions
- Spacecraft Power Systems
- Spacecraft Thermal Control
- Spacecraft Structural Dynamics
- Compressible Gas Dynamics
- Physical Gas Dynamics I
- Physical Gas Dynamics II
- Space Studio Architecting

New academic unit

Following the initial success of the USC Astronautics Program, the University has taken a major step for the further program development. In order to position the USC Viterbi School of Engineering to take full advantage of rapidly growing opportunities in space, Dean of Engineering Prof. Max Nikias announced in August 2004 the creation of a new Astronautics and Space Technology Division (ASTD). ASTD, the reorganized Astronautics program, is an independent academic unit within the Viterbi School of Engineering and functions in a manner similar to an academic department.

ASTD assumed immediate charge of all degree programs in aerospace engineering (astronautics) and astronautics courses. The Division is responsible for programs in astronautics and space technology. All astronautics degree programs are currently being revised and it is anticipated that a new comprehensive academic program in astronautical engineering will be approved in 2005. The new programs will include Bachelor of Science, Master of Science, Engineer, and Ph.D. degrees and Graduate Certificate.

The USC Viterbi School of Engineering has created a foundation for an independent program in space technology to meet the educational and research needs of interest to the space and defense industries, academia, and government research and development centers.

1. M. Gruntman, R.F. Brodsky, D.A. Erwin, and J.A. Kunc, Workforce development for the space industry, AIAA-2003-6309, Space-2003, AIAA. 2003.
2. A.W. Loston, interview with, NASA Tech Briefs, 27(6), 14-16, June 2003.
3. F. Sietzen, Call to arms for an ailing industry, Aerospace America, 41(3), 30-34, March 2003.
4. M. Gruntman, *Blazing the Trail: The Early History of Spacecraft and Rocketry*, p. 462, AIAA, Reston, Va., 2004.
5. B. McCormick, C. Newberry, and E. Jumper, eds., *Aerospace Engineering Education During the First Century of Flight*, AIAA, Reston, Va., 2004.
6. C. Durocher, C., Our future, our hands, Aerospace America, 41(2), 3, February 2003.
7. E. Teller with J.L. Shoolery, *Memoirs: A Twentieth Century Journey in Science and Politics*, Perseus Publ., 2001.
8. R.E. Kaplan, Aerospace Engineering at the University of Southern California, in *Aerospace Engineering Education During the First Century of Flight*, eds. B. McCormick, C. Newberry, and E. Jumper, AIAA, Reston, Va., 2004.
9. M. Gruntman, R.F. Brodsky, D.A. Erwin, and J.A. Kunc, Astronautics degrees for the space industry, Adv. Space Res., 34, 2159-2166, 2004.
10. R.F. Brodsky, The time has come for the B.S. in astronautical engineering, *Engineering Education*, 149-152, December 1985.
11. J.M. Hunter and D.D. Desautel, Undergraduate astronautics initiatives at San Jose State University, *J. Engineering Education*, 51-58, January 1993.
12. Spacebound!, Vol.13, California Space Authority, Summer 2003.

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