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Interdisciplinary Space Systems Education
at the Florida Tech Spaceport Graduate Center

by

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Abstract

In 1959 Brevard Engineering College offered the first master of science degree program in space technology. Today that school is Florida Institute of Technology (Florida Tech), which offers master's degrees in Space Systems (MS/SPC) and Space Systems Management (MS/SSM) at its off-campus Spaceport facilities at NASA Kennedy Space Center (KSC), Patrick Air Force Base (PAFB), and Titusville, Florida.

Some sixty students, almost all full-time employees of KSC, PAFB, or their contractors, are taking one or two three-credit evening SPC courses each semester. Admission requires either a B.S. from an accredited engineering or physics curriculum with a 3.0 average, or achievement of satisfactory scores on the graduate record examination general and subject tests. Instead of a comprehensive examination, MS/SPC students take the capstone Space Applications Missions course, in which self-organized four-student teams compete to develop the best plan for a specific mission--this semester a direct broadcast satellite system. Completion of 33 credits with a 3.0 average is required for graduation. The MS/SPC draws equally from electrical/computer engineering, mechanical/aerospace engineering, and physics/space sciences. The MS/SSM adds five required management courses in place of five technical ones. Some students take the MS/SSM as a second master's degree, toward which five courses may be applied from the MS/SPC.

This program prepares its graduates to solve complex, previously unsolved problems, as members of a team, with the background needed to eventually lead the team.

Introduction

This paper describes the interdisciplinary space systems M.S. programs at Florida Tech's off-campus Spaceport Graduate Center, with emphasis on significant changes which have been made since Professor Harold Sweet presented a paper on the precursor space technology graduate program to the 27th Space Congress in 1990.

History

In 1959, two years after the Soviet Sputnik and one year after the birth of NASA, Brevard Engineering College offered the first M.S. program in space technology. Seven years later that college became Florida Tech. In 1977 courses related to the NASA space shuttle program were set up at KSC by Professor Jay Burns of the Florida Tech Department of Physics and Space Sciences and Dr. Joseph Angelo. Five years later an off-campus M.S. program in space technology, featuring 17 courses, was formally identified at KSC and PAFB. By 1990 that number had grown to 23, Florida Tech was preparing to convert from the quarter to the semester calendar, and the author succeeded Professor Sweet as Academic Program Chairman (APC).

The new APC perceived two urgent problems already known to his predecessor. One was the name, space technology, which was easily confused by the uninitiated with undergraduate technician training programs. More seriously, it brought to mind the launching of hardware into orbit as the focus of the profession when, in fact, the space segment is but one of the three components of a space system--which was the obvious source of the curriculum's new name.

The second perceived problem was the rejection of many highly motivated applicants for admission to the newly christened space systems program, because of their marginal (< 3.0) grade point average (GPA). Graduate Dean T. E. Bowman pointed out the need to ascertain a technical graduate's grasp of the basic physical and engineering principles, as well as the ability to function at a graduate student level. The Graduate Record Examination (GRE) subject test (or Professional Engineer status) now testifies to the former, while the GRE general test score assures the latter. The agreed language appears in the second half of the second paragraph of Appendix A, which has been in effect since 1991. Thus far not one of the dozens of students who have been so screened has failed to be admitted or has earned less than a 3.0 GPA as a space systems graduate student. It is believed that the maturity and motivation developed during the decade or more of on-the-job post-baccalaureate experience of many of these students are responsible for this about-face.

Conversion to a Semester Calendar

The next challenge was to maintain the breadth of the space systems program as the number of courses decreased during the conversion to semesters. Faced with a reduction from 16 to 11 three-credit courses by the change from a 48-quarter-hour to a 33-semester-hour M.S. requirement, 19 quarter courses were combined into 11 semester versions, thereby enhancing rather than diminishing the curriculum's breadth. Appendix A describes the MS/SPC program and lists all of its required and most of its

elective offerings. A thesis option is available but is expected to be used rarely, if at all.

No matter how satisfactory a major course combination and curriculum revision such as this may seem in advance, "the proof of the pudding is [still] in the eating." Early in 1992 the APC decided to offer two foundation courses, SPC 5001 and 5002, Introduction to Space Systems and Space Environment, during the 1992-93 academic year, one year in advance of the formal conversion to the semester calendar! This minor miracle was performed within the formal quarter calendar by giving credit for three core quarter courses, Introduction to Space Technology I and II, and Space Environment, in the fall, winter, and spring quarters, while actually teaching SPC 5001 for one and one-half quarters and then switching to SPC 5002 for the rest of the winter and spring quarters. The timely AIAA Education Series textbook, Space Vehicle Design, by Griffin and French, proved to be ideally suited to SPC 5001. Thus in August 1993, when the semester calendar was formally initiated, some 27 MS/SPC candidates who had the prerequisite six semester course credits (equivalent to the formal nine quarter credits) were qualified to register for any of the remaining five required SPC courses, all of which will have been offered in the fall 1993 or spring 1994 semester.

Another important matter considered by the SPC Academic Program Chairman during the semester transition was whether the final program (comprehensive) examination was the best test of a student's ability to solve complex, previously unsolved space systems problems as a member of a team. The obvious answer to this specific question is "No." It was this answer that led to the substitution of the capstone "Missions" course, which is referenced at the end of Appendix A in Note 1, for the SPC comprehensive examination. SPC 5061, Space Applications Missions, is undergoing its maiden test in the spring 1994 semester with four self-organized groups of four students each, competing to produce the best system definition (Phase B) proposal for a direct broadcast satellite (DBS) system. The APC plays the role of the source board chair and four other senior faculty members represent the disciplines of astrodynamics, communications, environment, power, and propulsion. Because each student's grade is partially determined by her team's competitive success, there is strong motivation to pull together to reach the common team goal.

One final addition to the space systems programs at the transition to the semester calendar was the space systems management curriculum. Five SPC courses, two required and three elective, were replaced by five required management courses. The intent of this added program is to extend the interdisciplinary umbrella over a broader area; but unless this MS/SSM curriculum is used as a second degree after the MS/SPC, there is the danger of allowing the technical SPC material to have insufficient depth. Appendix B gives further information concerning the MS/SSM curriculum.

Who Needs It?

Florida Tech's main campus provides M.S. and Ph.D. curricula in aerospace engineering, computer engineering, electrical engineering, mechanical engineering, physics, and space sciences, among others. Who needs an off-campus, part-time, interdisciplinary M.S. program in space systems? The answers are to be found in the phrases "off-campus," "part-time," and "interdisciplinary."

Why "off-campus" and "part-time?" Because all but one or two of the MS/SPC students work full-time at or in the vicinity of KSC or PAFB. For some students, availability of the Florida Tech Spaceport curricula was a major a priori reason for seeking employment along the Space Coast. Are these men and women motivated? Each week, for one three-hour course, they attend a three-hour lecture one evening and do another seven to ten hours of homework. If they work "only" forty hours per week at their regular jobs, this adds up to a minimum commitment of fifty hours per week for nearly four years, or sixty hours per week for nearly two years.

What about "interdisciplinary?" In round numbers, about half of these students come from aerospace/mechanical engineering curricula, another fourth from electrical/computer engineering, and the remaining fourth from physics/space sciences. For brevity, define informal contractions of these baccalaureate categories as "mechaniker," "electroniker," and "physiker." Other degrees whose holders have succeeded in space systems include chemical, general, industrial, metallurgical, and nuclear engineering; and applied mathematics. It is no accident that the course content of the MS/SPC program also draws roughly equally from the mechaniker, electroniker, and physiker categories.

To understand what is happening, consider the mission of a typical university department which offers the B.S., M.S., and Ph.D. degrees in one discipline such as physics. The B.S. candidate is taught to solve problems in physics using theory and techniques which are well understood. The Ph.D. candidate contributes new and fundamental knowledge to the discipline in a dissertation. Depending on the school, an M.S. recipient either contributes a more modest amount of new knowledge than that contained in a doctoral dissertation, or is awarded the M.S. as a "consolation prize" after substantial but ineffective pursuit of the Ph.D.

What is the role of the interdisciplinary M.S. curriculum in space systems? Griffin and French describe the shortfall of traditional single-discipline curricula very well on the first page of their introduction:

"Very few students emerge from four years of schooling in engineering or physical science feeling comfortable with the larger arena in which they will practice their

specialty. This is rarely their fault; academic work by its nature tends to concentrate on that which is known and done and to educate the student in such techniques. This it does very well, subject of course to the cooperation of the student. What is not taught is how to function in the face of the unknown, the uncertain, and the not-yet-done. This is where the practicing engineer or scientist must learn to synthesize his knowledge, to combine the specialized concepts he has learned in order to obtain a new and useful result. This does not seem to be a quality that is taught in school."

The author is convinced that a major role of technically demanding interdisciplinary curricula such as the MS/SPC is to prepare its graduates to function in the face of the unknown and the uncertain, to synthesize their knowledge, and to solve complex, previously unsolved problems, usually as members of a team. Indeed, if the graduate possesses that hard-to-define quality called leadership, this person could very well become the team leader. Such project teams are essential to the conduct of space systems development and flight programs at industrial and government facilities.

Both sides of the lectern should be interdisciplinary, particularly in the introductory SPC 5001 and capstone SPC 5061 courses. Ideally, and in practice in the MS/SPC program, mechanikers help physikers, physikers help electronikers, electronikers help mechanikers, and conversely, among the students and with the instructor. The synergism is most effective when the class (or team) is well mixed by discipline and the instructor (or leader) is comfortable in all three of the key areas. It should be evident that the capstone "missions" course can only succeed if each team includes at least one member of each of the three key disciplines.

The Future

The most important task in the next year or two is to gain experience with these new interdisciplinary space systems programs and correct problems as they reveal themselves. In a more speculative vein, a characteristic of the times is the shortening period within which the demand for trained professionals changes from one technical field to another. The task of retraining a doctorate-level professional from, say, physicist to aerospace engineer in less than five years or so is not even possible for many individuals, and is economically impractical for most. However, the success with which electronikers, mechanikers, and physikers have been broadened into interdisciplinary space systems managers in one year full-time hints that this program might provide a template for economically important conversions in other fields.

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Appendix A

MASTER OF SCIENCE IN SPACE SYSTEMS (MS/SPC)

The graduate space systems program provides its graduates with the knowledge and capability to perform in a wide variety of technical and managerial areas, in industry, academia, and government agencies involved in the space program. It is for the student who expects to plan, design, build, integrate, test, launch, operate, or manage space systems, subsystems, launch vehicles, spacecraft, payloads, or ground systems.

ADMISSION REQUIREMENTS

Admission to the Master of Science in Space Systems (MS/SPC) program requires a bachelor's degree in a recognized field of engineering or physical science from an accredited curriculum. Course work must have included mathematics through differential equations and at least one year of calculus-based physics. In the case of a marginal undergraduate record (GPA less than 3.0), letters of recommendation and results of recent GRE Tests, both General (verbal and quantitative) and Subject (engineering or physics) are required and could be deciding factors. Holders of the Professional Engineer license (or Engineering Intern status for those less than five years past the Baccalaureate) need not take the GRE Subject Test.

DEGREE REQUIREMENTS

The degree of Master of Science in Space Systems is conferred upon students who have successfully completed 33 credit hours of graduate work plus other course requirements as listed on the student's approved Graduate Program Plan. It includes 21 hours of required space systems courses, six to twelve hours of listed elective courses, and no more than six hours of additional electives.

Required Courses (7 courses)	21
SPC 5001 Introduction to Space Systems.....	3
SPC 5002 Introduction to Space Environment.....	3
SPC 5003 Astrodynamics.....	3
SPC 5004 Space Propulsion Systems.....	3
SPC 5005 Space Power Systems.....	3
SPC 5006 Space Communications and Data Systems.....	3
SPC 5007 Aerospace Remote Sensing Systems.....	3

Elective Courses (2-4 courses).....6/12

MAN 5134	Commercial Enterprise in Space.....	3
SPC 5008	Launch and Space Mission Operations.....	3
SPC 5009	Space Structures and Materials.....	3
SPC 5010	Spacecraft Guidance, Navigation, and Control.....	3
SPC 5011	Human Space Systems.....	3
SPC 5061	Space Applications Missions (Note 1).....	3
SPC 5062	Space Science Investigations and Missions (Note 1)	3
SPC 5063	Planetary and Interplanetary Missions (Note 1)....	3
SPC 5064	Space-Based Astronomy Missions (Note 1).....	3
SPC 5065	Space Systems for Remote Operations.....	3
SPC 5066	Spaceflight Human Physiology.....	3
SPC 5090	Special Topics in Space Systems.....	1, 2, or 3

Additional Electives (0-2 courses).....0/6

Total Elective Hours 12

TOTAL CREDITS REQUIRED 33

Note 1: One of these four capstone "Missions" courses must be selected as an elective. Four-person student teams compete to develop the best plan to carry out a specific mission assigned by the instructor, acting as the Source Selection Official. Each student's grade is partially determined by the team's competitive success.

Appendix B

MASTER OF SCIENCE IN SPACE SYSTEMS MANAGEMENT (MS/SSM)

This program meets the professional needs of technical graduates who are, or are looking forward to, assuming more and more managerial responsibility in some aspect of space systems and need to enhance both their managerial and technical skills.

ADMISSION REQUIREMENTS

Admission to the Master of Science in Space Systems Management program requires a bachelor's degree in a recognized field of engineering or physical science from an accredited curriculum. Course work must have included mathematics through differential equations and at least one year of calculus-based physics. Proficiency at the undergraduate level in financial accounting and statistics is also required. In the case of a marginal undergraduate record (GPA less than 3.0), letters of recommendation and results of recent GRE Tests, both General (verbal and quantitative) and Subject (engineering or physics) are required and could be deciding factors. Holders of the Professional Engineer license (or Engineering Intern status for those less than five years past the Baccalaureate) need not take the GRE Subject Test.

DEGREE REQUIREMENTS

The degree of Master of Science in Space Systems Management is conferred upon students who have successfully completed 33 credit hours of graduate work plus other course requirements as listed on the student's approved Graduate Program Plan. Students without adequate undergraduate business courses will be required to complete all or part of the program prerequisites listed below.

Program Prerequisites

BUS 5000	Financial Accounting.....	3
BUS 5006	Introductory Managerial Statistics.....	3

TOTAL PREREQUISITE CREDITS 6

The Space Systems Management (SSM) Graduate Program Plan includes 15 hours of required business courses, 15 hours of required space systems courses, and one three-hour elective course.

Required Courses (10 courses).....30

BUS 5001	Managerial Accounting.....	3
BUS 5002	Corporate Finance.....	3
BUS 5007	Intermediate Managerial Statistics.....	3
BUS 5013	Organizational Behavior.....	3
BUS 5017	Program Management.....	3
SPC 5001	Introduction to Space Systems.....	3
SPC 5002	Introduction to Space Environment.....	3
SPC 5003	Aerodynamics.....	3
SPC 5004	Space Propulsion Systems.....	3
SPC 5005	Space Power Systems.....	3

Selected Elective Courses (1 course).....3

BUS 5019	Marketing.....	3
BUS 5024	Production and Operations Management.....	3
MAN 5134	Commercial Enterprise in Space.....	3
SPC 5006	Space Communications and Data Systems.....	3
SPC 5007	Aerospace Remote Sensing Systems.....	3
SPC 5008	Launch and Space Mission Operations.....	3
SPC 5009	Space Structures and Materials.....	3
SPC 5010	Spacecraft Guidance, Navigation, and Control.....	3
SPC 5011	Human Space Systems.....	3
SPC 5065	Space Systems for Remote Operations.....	3
SPC 5066	Spaceflight Human Physiology.....	3
SPC 5090	Special Topics in Space Systems.....	1, 2, or 3

TOTAL CREDITS REQUIRED 33