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Space Technology Graduate Program
for
Engineers and Scientists
by
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Abstract

A Master of Science in Space Technology is offered to engineering and science graduates at the Spaceport Graduate Center which is an off-campus teaching center of the Florida Institute of Technology. Courses are offered in the evening at Kennedy Space Center and Patrick Air Force Base so that space professionals can continue their education. The goals of the program are to prepare students for broader responsibility and more rewarding careers in astronautics and space, as well as to contribute to improvement in defining and implementing national and international space goals. It has been endorsed by NASA, the USAF, and large aerospace companies.

This paper describes an education program which removes interdisciplinary barriers in accepting a spectrum of students with different engineering and scientific backgrounds. Topics addressed include course curricula, the composition of the students and faculty, program successes and challenges, as well as plans for the future. Emphasis is given to the progress that has been made since Dr. Angelo described the program to the 23rd Space Congress in 1986. Over 70 students have graduated with an MS in Space Technology and are advancing in their careers. The faculty has been expanded to include a full-time program chairman and twenty adjunct professors, seven of these holding Ph D's in physics or astronomy and eight holding Ph D's in engineering disciplines.

An important objective of this paper is to solicit inputs to make the program even more valuable. An Industry Advisory Council is being set-up for this purpose, consisting of the Chief Executive Officers of local aerospace companies and government. Future developments will include research activity in conjunction with the Space Research Institute and a Space Engineering supplement. It is fundamental that better understanding of the technical aspects of all phases of space activity will foster improved coordination among, and better decisions by, the future leaders of Space and Astronautics.

INTRODUCTION

It is the purpose of this paper to describe a program of post-graduate technical education at Kennedy Space Center/Patrick Air Force Base. The program evolved from Space Sciences in the Physics Department of Florida Institute of Technology to cover more and more graduate engineering topics in response to the needs of the professional engineers and scientists working in the Space industry - government and civilian. It is hoped that this paper will foster an interchange with employers and students that will enhance the value of the program. We strongly and emphatically solicit inputs to this end. In addition, it is expected that a clear definition and description of the program will enhance the recognition of our graduates. The types of technical activity in the area of Kennedy Space Center/Patrick Air Force Base are major factors in determining the sort of post-graduate technical education which is valuable to the engineers in the region and to the organizations for which they work. The highest visibility is for NASA at KSC and its civilian contractors; next is the U.S. Air Force as operators of the Eastern Space and Missile Center and the Air Force Technical Applications Center. Likewise, most visible are launch operations for the Shuttle (Space Transportation System) and expendable launch vehicles (Atlas, Delta and Titan). Other significant aerospace operations include payload processing, missile fabrication, data processing and robotics, and heavy emphasis on electronic systems from companies like Martin Marietta and Harris Corporation.

The following sections of this paper will describe the program and its history followed by an analysis of the students' backgrounds and the influence of their diversity on the program approach. The faculty are described and the results of a survey of alumni are presented. Their suggestions of what is good about the program and what should be improved are summarized and potential future courses of action are discussed.

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PROGRAM DESCRIPTION

It was developed by the FIT Department of Physics and Space Sciences to meet the needs of individuals pursuing careers associated with the United States space program. An objective is to provide the student with the knowledge and capability to perform in a wide variety of managerial and technical areas in industry or government agencies. It consists of nine required "Space Technology" courses, three elective Space Technology courses, two Management and two Computer Science electives. A comprehensive exam must also be completed successfully.

We have somewhat of a problem in the title of the program and of the course descriptions. Is an MS in Space Technology akin to undergraduate "technology" programs? The Accreditation Board for Engineering and Technology (ABET) has defined the following:

Engineering technology is that part of the technological field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer. The term "engineering technician" is applied to the graduates of associate degree programs. Graduates of baccalaureate programs are called "engineering technologists."

Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.

In this context a technology curriculum is less scientific, scholarly, or professional than an engineering curriculum. Undergraduate programs are so recognized. ABET Engineering Technology accreditation is divided between 2-year (leading to an "Associate" degree) and baccalaureate programs; there are no technology accreditations leading to the master's degree, nor are there any 2- or 4-year technology accreditations in the areas of space or astronautics. We conclude that our graduate program in Space Technology is not related to undergraduate "technology programs".

George A. Bunk and Stephen L. Morgan (Ref) recommended that the program name be changed to "Space Applications". They referred to course offerings in space applications at Stanford, and the Naval Postgraduate School in Monterey which offers (non-professionally accredited) Master's degrees in Space Systems Operations and Space Systems Engineering. The Air Force Institute of Technology (AFIT) offers an MS degree in "Space Operations", which has similarities to the FIT program; it has more Systems Analysis and Management courses but less Engineering depth than the AFIT (accredited) MS in Astronautical Engineering or our FIT MS in Space Technology.

In our program the nine required core courses for a total of 27 quarter hours of credit can be grouped as follows:

<u>General</u>	<u>Analytical/Engineering</u>
Intro to Space Tech I	Space Communications
Intro to Space Tech II	Rocket Propulsion
Aerospace Launch Ops	Space Power Systems
Space Applications	Orbital Mechanics
	Space Environment

The analytical courses are fully equivalent to those offered in graduate programs in Astronautics and Astronautical Engineering at other institutions in terms of depth of treatment, textbooks covered and course content. The same is true of the 14 electives, such as Space Nuclear Power, Remote Sensing, Spacecraft Guidance, Navigation and Control, and Remote Operations

Technology. Rounding out the program are the two Management electives and two Computer Science electives. These contribute to the broadening experience which makes the program valuable for progressing in management of space technical activities.

The program's most significant aspect is provision of a Space Engineering basis to graduate engineers and scientists with education in Astronautical, Mechanical, Electrical, and other Engineering fields, as well as Physics and Math majors. It provides those with a non-aerospace technical background the information and expertise to work in their area of the Space program. It is endorsed by NASA, USAF and space industry companies. Most students in the program have most or all of the program paid for by the employer. It has job benefits in the following areas:

- Application: Many times the information learned from a particular class can immediately be transferred into help on the job.
- Current Topics: Space Technology courses are taught and attended by people who have one big interest in common. Often the instructor or students will have information on the most current activities. Many of the problems discussed and worked are the same or similar to present problems facing the whole industry.
- Continue Work: Since degree work is accomplished off-duty hours, it allows progression in the job without having to leave and return. Missed opportunities are reduced.
- Convenience: Classes taught at or near the work place provide a great advantage. Hours spent commuting are often reduced. Also, with start times after work, the student can stay and attend class without having to go and return.

HISTORY

Space Technology courses were offered as far back as 1962 (Bunk and Morgan). The down scoping of the U.S. space program in the 1970's also was followed by the discontinuance of the Space Technology programs at FIT. In the late 1970's the Space Science degrees were again offered on campus under Dr. Jay Burns. He and Dr. Joseph Angelo were instrumental in setting up courses related to the space shuttle program which were begun at the Kennedy Space Center (KSC) in 1977.

The 1976-78 graduate catalog shows a Space Sciences Graduate Program which

"...stresses astrophysics, the physics of the earth and planets, astrodynamics, tracking technology and instrumentation, multispectral remote sensing, solar-terrestrial interrelations, and stellar photometry. Graduate study in Space Sciences at the Master's level prepares one for a wide range of responsibilities in industry and in the government related directly or indirectly to the space program."

"Specialized Space Sciences senior level courses commonly taken include Orbital Mechanics, Geo-physics, and Remote Multispectral Sensing, Space Technology courses such as Space Communication Systems, Space Navigation and Guidance, Theory of Space Tracking Instrumentation, and Space Vehicle Launch Operations may be elected within the 9 credit hour restriction."

Ten courses are identified as Space Technology in the 1976-78 catalog. The next milestone in recent history shows 15 courses offered in the 1982-84 graduate catalog (for courses starting in the Fall of 1980). It is not until the September 1982 addendum (Ref) that the Off-Campus program in Space Technology is identified for PAFB/KSC, with 17 courses. By September 1986, the

course offerings expanded to 23, remaining the same through Spring of 1989. Dr. Angelo wrote eloquently about the FIT program for the XXIII Space Congress, and for the 36th Congress of the International Astronautical Federation, 1985. His thoughts reflect the sort of program which has developed elsewhere as "The International Space University". The first session of the ISU was held at Massachusetts Institute of Technology (MIT) in 1988 with 104 graduate students from 21 nations. A separate paper is being presented to the 27th Space Congress on this important development.

WHO ARE THE STUDENTS?

We are starting with heterogeneous groups of people mostly with full-time jobs in Space with "Engineering" backgrounds (or sometimes with a "Science" background that has enough Math and Physics to become a part of this group). Approximately 50 percent are employed by industry, 35 percent by NASA, and 15 percent by the USAF. Table 1 shows that 79% are engineering graduates; the remaining 21% are mostly Physics graduates, including main campus students in Space Sciences who take Space Technology courses as electives.

Table 1

SPACE TECHNOLOGY STUDENT / BACKGROUNDS

<u>Bachelor of Science Degree</u>	<u>Percentage</u>
Aerospace Engineering:	28
Mechanical Engineering:	22
Electrical Engineering	20
Other Engineering (*)	9
(Engineering Combined:	79)
Physics, Math, Other	21

(*) Other degrees are Chemical, Metallurgical, Nuclear, Industrial engineering.

Admission requirements as a regular student are GPA of 3.0 or combination of GPA and GRE of 1000 or better with consideration of how the individuals may have matured since being a sub-3.0-GPA performer as an undergraduate. (We note that AFIT requires 3.0 GPA and GRE score of 1100 or better.) Let us categorize career goals of these people (who are motivated enough to want to subject themselves to the rigors of a full-time job plus three hours of class and six hours of homework per week for four years -- or double that for two years. This is roughly equivalent to a 50 hour a week job for 4 years or a 60 hour a week job for 2 years. Four potential categories come to mind as summarized in Table 2.

Table 2

CAREER GOAL CATEGORIES FOR SPACE ENGINEERS

CATEGORY	SCOPE	DEPTH	EXAMPLE	TYPE OF PROGRAM
Specialist/ Research Professor	Narrow Engrg Discipline	Extreme	Structural Analyst Depth in Finite Element Analysis, Elastic Stability, Structural Dynamics	From MS in ME to Phd in ME
Technical Direction/ Supervision of Specialists	Narrow	Extreme	Supervision of above Specialists	Same as above plus some Mgt workshop type training
Technical Direction/ Management of a Spectrum of Engineers	Broad- Technical	Moderate	Director of an Engrg Branch	MS in Space Technology with Mgt electives
Management of Operations and Engineering	Broad- Technical	Moderate	General Mgr or CEO of a Civil or Government Aerospace entity	MS in Space Technology or MS in Technology Mgt with liberal ST electives

The technical specialists in the first two categories will have a career path toward supervising other specialists and/or teaching/research in this narrow field. In important, but rare, instances such a person will go higher (and broader) in managing more than his field of expertise.

On the other hand, many individuals with good Engineering backgrounds may have little desire for extreme depth in a specialty--or for a track with teaching/research as a goal. The goal oriented ones seek advancement to higher level positions in the Space field--broader responsibility and more rewarding careers in the United States space program. They seek to contribute to improvement in defining and implementing national and international space goals. It is the latter group that are benefitted by the current program entitled "Space Technology." However, there is a growing need for an off-campus graduate-level program for the traditional advanced degrees in Astronautics and Astronautical Engineering and we are exploring the expansion of our program to that end.

FACULTY

The faculty are mostly full-time employees working in some aspect of the space program. Table 3 summarizes the backgrounds of the 20 Adjunct Professors and the program chairman. The faculty has strong backgrounds in both physics and engineering and complement their academic expertise with a great deal of space systems know-how. Examples of backgrounds are:

- 24 years in NASA Apollo and Shuttle Operations Integration
- 11 years in Launch Operations
- 15 years in Remote Sensing including software and data processing
- 36 years in Aerospace Research and Design, including aircraft, launch vehicles and Space Mission Mode Analysis

All of these, except the full-time Program Chairman and the University Professors, continue working full-time in Space Operations, Analysis, Design and other Space Engineering areas.

Table 3

SPACE TECHNOLOGY FACULTY BACKGROUNDS

ENGINEERING

Ph D in Astronautical and Mechanical	3
Ph D in other Engineering	5
MS in Electrical and other	5

PHYSICS

Ph D	7
MS	1

TOTAL FACULTY: 21

FACULTY EMPLOYMENT PATTERNS

<u>EMPLOYER</u>	<u>NO.</u>	<u>YEARS OF SPACE EXPERIENCE</u>
Space Industry	10	130
USAF	4	30
NASA	2	30
University	5	70

GRADUATES

Over 70 people have received the degree of MS in Space Technology, since August 1982. A sampling shows a breakdown of undergraduate degrees similar to that of the current students.

A questionnaire sent to these graduates in December 1989 resulted in noteworthy comments such as the following:

Perceived advantage for the program highlighted the convenience and feasibility to continue full-time employment while continuing a technical education. The fact that instructors and students are both working in the field makes the course information very current and pertinent. They liked the application orientation as opposed to only theory, and they appreciated that the program provided those with a non-aerospace technical background the information and expertise to work in their area of the Space program.

Since graduation, most (65%) continued to work for the same employer, but have achieved promotions and advancements. Others found that the program and the degree were important in opening up job opportunities with another employer. Ninety percent indicated that there was benefit then and now, and 50 percent could perceive that they were benefitted financially. Actions to improve the program are being planned, based on inputs like those from alumni and from students who are asking questions such as the following:

- (1) What value do I receive from obtaining an MS in Space Technology?
- (2) How widely is this (Space Technology) program recognized outside of the Kennedy/Cape Canaveral/PAFB area?
- (3) What is the relationship between the MS in Space Technology and the MS in an engineering discipline such as Astronautical Engineering?

- (4) What are the options for further education after the MS in Space Technology?
- (5) If I am going to take as many analytical courses in Space Technology as possible, do I need to take the two Introductory courses?

Answers have been given along the following lines:

- (1) The program has demonstrated significant value in improving the breadth of knowledge and understanding of the technical disciplines involved in the space program. Emphasis is on broadening which leads to better performance in technical management, and career progression, in contrast to a deepening and narrowing educational experience.
- (2) There is some recognition outside of the area: we have had students come here for the combined purpose of taking the course and getting a job that is space-related. We have had inquiries about helping to set up a similar program at Huntsville Alabama and at Vandenberg AFB, California.
- (3) The difference is in broadening rather than increasing depth and specialization at present.
- (4) A second (additional) master's degree may be sought at FIT, with possible application of a maximum of 24 credits from the first degree received at FIT to the second degree, subject to approval of the department head. The applicability of each course to the second program will be examined. Otherwise, at present, there is not a line of progression from Space Technology to another degree.
- (5) We will allow substitution of other courses for the Introductory courses, although this will make for some increase in difficulty in taking the more comprehensive specific courses such as Rocket Propulsion, Space Environment, Space Power, and Orbital Mechanics.

FUTURE

First and foremost we must preserve the outstanding and unique values of a program which broadens its participants by providing better understanding of the technical aspects of all phases of Space activity. We will continue to seek outstanding instructors. We will make improvements in the light of "lessons learned". We will continue to enable graduate engineers and scientists with diverse undergraduate backgrounds to achieve sufficient understanding of "Astronautics", "Astronautical Engineering", and "Space Engineering". Especially those with a non-aerospace technical background will be provided the information and expertise to work in their area of the Space program.

The diversity of backgrounds is one of the most significant challenges. We hope to expand the type of solution that has been achieved in the area of Space Communication. The same course, up to now, has been taken by Electrical and non-Electrical Engineers. Now we have an advanced course for the EE's and for others who finish the basic course in Space Communication. The latter is still a graduate-level course for non EE's. (At Air Force Institute of Technology, the accredited graduate curriculum for MS in Astronautical Engineering has a fully equivalent graduate-level course for non-Electrical Engineers, EENG 421-Space Communication Systems, which is equivalent to ours).

We hope to change the designations of Engineering courses such as this in order to avoid misunderstanding of their technical content. By calling it SPE (Space Engineering) 5009 instead of ST (Space Technology) 5009, we will convey the correct connotation as well as make it clearer that

the course should be accepted for transfer credit. Some of the other courses in which this distinction should be made are:

SPE 5012	Rocket Propulsion (now ST 5012)
SPE 5014	Space Nuclear Propulsion
SPE 5016	Space Power Systems
SPE 5031	Spacecraft Guidance, Navigation and Control
SPE 5035	Orbital Mechanics
SPE 5038	Space Materials Engineering
SPE 5041	Remote Operations Engineering
SPE 5059	Advanced Space Communications

Identification of these Space Engineering courses raises the possibility of a reasonably short step to an MS in Space Engineering. The MS in Mechanical Engineering on the campus of FIT provides the following requirement clues:

Minimum of 48 credit hours, including a 9 credit hour thesis (in some cases thesis replaced by three additional courses and a Graduate Seminar ME 5096).

Two courses in Applied Mathematics	(6 hours)
Eight courses in Mechanical/Engineering	(24 hours) (Energy or Mechanics option)
Electives (from approved list)	(9 hours)

A corresponding Space Engineering MS program might be:

Eight courses in Space Engineering	(24 hours)
Two courses in Applied Mathematics	(6 hours)
Electives (Computer Science, S.T., Mgt)	(9 hours)
Thesis or 4 other carefully selected additional courses plus a comprehensive exam	(9 hours)

Total: 48 hours (min)

In this instance, only the two mathematics courses and the thesis would have to be added to those now being offered at the Spaceport Off-Campus site.

The University of Tennessee Space Institute proposed (March 2, 1988) a "Space Engineering" concentration within the Aerospace and Mechanical Engineering Departments. It was designed for graduate level instruction in Satellite Design and Operation, Platform Design and Operation for activities such as material processing, exploration and space research and space vehicle design and operation. That MS degree requires a minimum of 24 semester hours of course work plus a minimum of 6 semester hours of credit in thesis (or a minimum of 30 semester hours of course work and a comprehensive exam).

Additional rigor should be considered for a Space Engineering program to be comparable to the ABET accredited graduate programs at Stanford and Air Force Institute of Technology. Stanford requires 45 semester hours and AFTT requires 72 quarter hours for the MS degree.

An Industry Advisory Council is being organized, with the objective of achieving maximum benefit for employees and employers. Discussions with industry and government personnel and training people have elicited enthusiastic response, and an indication that the chief executives of these entities will participate.

CONCLUSION

We have actively sought for ways to continue to make this educational program a novel, forward-looking one. We focused on the background of our engineering students to ascertain where they were employed in the space industry and why they sought enrollment. Certainly, student interaction at the graduate level is an ingredient in the recipe for learning. Similarly, we scrutinized faculty candidates in an effort to obtain the most eminently qualified to lead classes through complex subject matter. It is our pleasure to report that we have been quite successful in our efforts to recruit adjunct faculty, the majority with doctoral degrees, to instruct these evening classes. One factor contributing to our success in obtaining the desired faculty probably centers around the fact that they are, for the most part, active themselves in the space industry. Professional pride in their work shows up clearly in their classroom teaching. With space technologists and managers found both at the lectern and in student chairs, an invigorating learning environment is established that we would consider incomparable. Finally, through the good fortune of our geographic location, our FIT library resources are augmented with technical government libraries located at KSC and PAFB. Moreover, local public libraries maintain a wealth of information on the history, economics, and management of space enterprise.

In summary, we have been able to establish a very innovative and unique technology curriculum at FIT. But we must continue to care for the vitality of this program and successfully adapt to the changes that occur so rapidly in this technological field. We maintain a constant recruitment effort for both students and faculty. We campaign vigorously at our own college campus for continued support.

The challenges of space exploration bring exciting opportunities to us as engineering educators. With so many engineering jobs involved in space activities, it is important for these engineers to see the "bigger" picture of the entire industry. Our curriculum offers the working engineer an opportunity to escape from his assigned and perhaps narrowly defined job, and explore and contemplate with others what is taking place in the industry. Here is where we try and also focus on the management knowledge that is essential.

From a management perspective, we require that our graduate students study such topics as Project Management, Management Information Systems, Communication, Human Resources Management, and Finance. We look for our graduates to have several skills: knowledge of engineering sciences, an appreciation and understanding of project management; an understanding of costs and competitiveness, and a broad knowledge of how to function effectively as a mid or senior level manager.

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