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## Model Curricula: Embry-Riddle Aeronautical University

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## A Taxonomy for Space Curricula

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### Abstract

Many universities have added courses and curricula related to satellites and space. A search of the Internet reveals that few of these are designated degree programs in space studies degree, rather they are traditional programs offering courses and concentrations which involve study of space and space applications from several perspectives. The Internet search also reveals a large variation in both the titles and the curricula for these programs. The author has sought to standardize definitions, identify workable program names and suggest core courses. Five programs and their core courses are outlined for consideration.

### INTRODUCTION

Curricula for such technical disciplines as mechanical engineering are quite standardized. These programs of study have settled on core courses like differential equations, which appear in the engineering requirements of almost all schools.

The study of space from the perspective of astronomy is quite old, whereas exploration of space is a relatively new discipline. One can argue that 4 October 1957, the launching of Sputnik 1, marks the beginning of the exploration of space. One can also argue that Robert Goddard's flight of a liquid fueled rocket in 1926 was the beginning. Whether the starting date was 1957 or 1926, the majority of colleges and universities have only just begun to offer, or have just begun their planning for, degree programs centered on space studies. Since these programs of study and degree offerings differ not only in their titles but also in their course requirements, there is a need for some standardization with common names.

At the top of the hierarchy, one can place the curriculum name "Space Studies." This designates a general degree, which includes some aspects of each of the four disciplines beneath it: Space Sciences, Space Engineering, Space Technology and Space Operations. Each of these disciplines is more narrowly defined than Space Studies; the sum of these is a superset of Space Studies. The order of the disciplines is purposeful: science, engineering, technology, operations. When one moves from science to operations, one is moving from the abstract to the practical. Figure 1 shows this hierarchy.

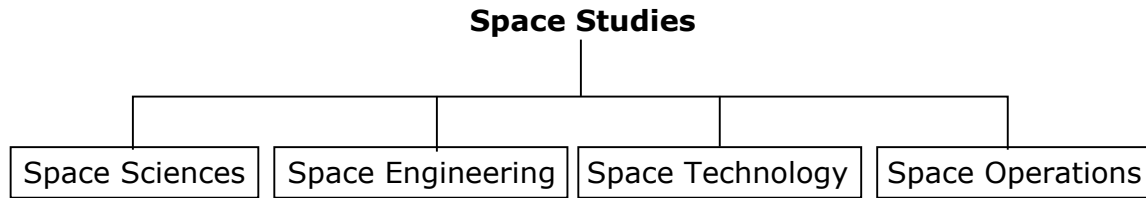


Figure 1

## THE DEFINITIONS

For human communication to be productive, participants must speak the same language and be in agreement on common meanings for terms used. To avoid the confusion of differing meanings for such terms as science, engineering, technology and operations, the following definitions are offered.

Science: The study of the basic laws of nature.

Engineering: The design of devices that implement the basic laws of nature.

Technology: The fabrication, installation and maintenance of devices.

Operations: Scheduling and tracking the use and maintenance of devices; training and scheduling the human operators of devices.

There is a distinct difference between science and engineering. In science, there is usually one correct answer to a given problem. In engineering, there are usually several answers to a problem. The devices being designed and the innovations under development often have several parameters used to measure their success, and there are usually trade-offs between these. Analyzing such trade-offs is the process of design, a major component of engineering.

In physics, for example, one might observe the spinning motion of a body and be interested in the angular acceleration produced by a given torque. For a given torque, there is only one angular acceleration. An aeronautical engineer who is designing the ailerons on an aircraft knows from the laws of physics that the torque about the longitudinal axis produced by a certain aileron deflection will result in a certain angular acceleration (In pilot terminology, this is an increase in the rate of roll). However, the engineer has to consider the purpose of the aircraft. Some aircraft require a small amount of stability about the longitudinal axis, giving a quick response to aileron deflection. Such an aircraft is highly maneuverable and requires the pilot to be more attentive to the rate of roll. Other aircraft require a high degree of stability about the longitudinal axis, giving a slower, smoother,

steadier response to aileron deflection. Such an aircraft is not highly maneuverable and places less demand on the pilot to be attentive to rate of roll, thus giving the pilot more time to monitor other aspects of flying. There is, therefore, no one correct aileron design.

In present day discussion, technology is an overused term with a broad definition. The definition used here relates specifically to the design of curricula. A Space Studies degree with a Technology specification will represent a totally new program in which graduates will possess the skills for fabricating, installing, or maintaining launch vehicles and other devices used in space.

Space Studies degrees emphasizing science and engineering are likely to be offered at the baccalaureate, Masters and Ph.D. levels. Space Studies degrees with a Technology specification may lead to either a two-year or four-year undergraduate degree or a master's degree.

A Space Studies degree with a concentration in Operations would be similar to a management degree or a business degree, but, in the context of space, would require higher levels of math and science. New fields under consideration in Space Studies are the Politics of Space Exploration and International Law in Space Operations. These will require courses in political science and law. Another new area of study at the university level is human physiology in space environments.

## THE PROGRAM NAMES

The appendix contains a list of programs at various schools. This list is limited to those that represent space-specific programs. While many universities have departments of astronomy offering a concentration in astrophysics or cosmology, a specific degree entitled "Astrophysics" or "Cosmology" was not found among those examined. Astronomy programs are numerous and similar, thus have not been included in those selected for the appendix. Many schools also have departments entitled Aerospace Engineering, some offering an engineering degree with a concentration in space. These also have not been included.

Selected university institutes and laboratories that conduct research programs in some aspect of space have been included in the appendix. Although these institutes and labs do not award degrees, students pursuing a degree in the associated college would have access to these facilities.

Typical program names that one finds under the category of space sciences are "Astrobiology," "Astronomy," "Planetary Geology" and "Space Physics." Programs of "Space Physics" will include "Astrophysics," the study of

star systems and galaxies, and "Cosmology," study of the entire universe. Historically, astrophysics programs have grown out of astronomy departments, but this discipline could be placed under space physics because it is not concerned with observational techniques and with the positions and velocities of objects, but with the structure of the objects and with the processes occurring within the objects. Astrobiology and planetary geology are specialized versions of biology and geology.

"Aeronautical Engineering" is the most common name for engineering emphasizing space. "Space Engineering" or "Astroengineering" are suggested titles.

Programs exist with the name "Aeronautical Technology." There is such a program at Arizona State University, for example. The name "Space Technology" did not appear in the Internet search.

There are some programs with the name "Space Operations," for example the program at the Air Force Institute of Technology.

## THE CURRICULA

Rather than attempt to redefine standard curricula, this paper seeks to create categories and suggest program names for the future curriculum of space and to assign content to its programs.

**Space Studies.** Students who pursue a Space Studies degree program will expect to take some courses drawn from the arts and humanities and social sciences as well as natural science and mathematics. The number of courses and the level of rigor pursued in mathematics and basic sciences, for example, will depend on the student's major area of study, e.g., Space Sciences, Space Engineering, Space Technology, and Space Operations.

**Space Sciences.** Math, physics and chemistry will be included in all of the sciences, and in astronomy, planetary geology, and space physics, the physics and chemistry courses should be calculus based. Space physics will not differ from a standard physics curriculum in topics but will differ in the depth of coverage of certain topics.

Astrobiology can be derived from a standard biology curriculum with an emphasis on certain aspects of life. For example: life in accelerations other than 9.8 meters/second squared; life in distorted solar radiation and other than 24 hour diurnal periods of light and dark; life in artificial light with non

standard spectra; and life in non standard atmospheres. Also, astrobiology attempts to ascertain the origin of life in the universe.

Planetary geology can be derived from a standard earth geology curriculum with the following considerations of the characteristics of other planets: size; composition; atmosphere; incident radiation; and meteorite impacts.

Space physics will cover everything from the earth's upper atmosphere to the entire universe. The curriculum will be similar to a standard physics curriculum with emphasis on electromagnetic radiation, nuclear radiation, high-energy physics, gravitation, relativity, and orbital mechanics.

Astrophysics and cosmology will fall under space physics. Astrophysics is a study of the structure and processes of stars, star systems, and galaxies. Processes include activities such as evolution, sources and production of energy, motion, and radiation. Cosmology is a study, similar to astrophysics, of the structure and processes of the entire universe. At the undergraduate level, there can be concentrations in astrophysics or cosmology as a student option. At the graduate level there can be degrees offered in either field.

**Space Engineering.** In many schools, Space Engineering is included in the Aeronautical/Astronautical/Aerospace Engineering departments. However, Space Engineering is more general than Aeronautical Engineering.

Space Engineering cannot be restricted to space outside the earth's atmosphere. It should cover the launch of a spacecraft, so it must include studies of atmospheric flight as well as space flight. It must also cover typical space topics such as radiation, telecommunications, remote sensing, spacecraft propulsion, spacecraft attitude control, gravity, and orbital mechanics, which are not in the core of most aeronautical curricula.

The Aeronautical curricula cover topics such as turbojet engines and the dynamics of complicated aircraft maneuvers. Such topics are not necessary to the study of rocket launches. Therefore, there are trade-offs. Space Engineering curriculum, which evolves from an Aeronautical Engineering curriculum, can accommodate the broader range of topics by eliminating topics that are specific to atmospheric flight.

In many schools, a degree in Aerospace Engineering offers a choice of concentrations in either Aeronautics or Space. There should instead be a separate degree entitled "Space Engineering."

**Space Technology.** This degree would include studies from Aeronautical, Electrical/Electronic, and Mechanical Technology programs. New topics must be added to these that are specific to space technology such as rocketry, radiation shielding, and assembly in zero gravity.

Many aviation-oriented schools offer a two-year program in aviation technology for which the graduate receives an FAA certification to practice aircraft maintenance. There is no such certificate for practicing spacecraft maintenance, but it is not too early to plan space technology programs. There are many companies entering the business of launching spacecraft. There is a need for technicians who can assemble and repair spacecraft and launch vehicles both terrestrially and in space. Currently, trained astronauts perform these technical duties in space. In the future, space technicians (not trained as astronauts) will fly to orbiting objects to accomplish assembly and repair.

**Space Operations.** Space operations specialists manage devices and people. Typical tasks would include maintenance of a database for scheduling, tracking and training. A study of international politics and law would be important because space operations specialists must be aware of the orbits of spacecraft and the nations that own or control those spacecraft.

## THE COURSES

Suggested courses are listed for each discipline. The number of required courses and their sequence, as well as general studies and electives will be chosen according to university requirements.

### **Space Studies**

Mathematics	Rocketry	Planetary Atmospheres
Physics	Orbital Mechanics	International Politics
Chemistry	Space Medicine	Space Law
Biology	Space Environment	Space Policy
Physiology	Planetary Geology	Sociology

### **Space Sciences**

#### Astrobiology

A standard biology curriculum in addition to newly created courses to cover these topics:

- life in accelerations other than 9.8 meters per second squared.
- life in nonstandard light conditions (spectra and diurnal period).
- life in nonstandard atmospheres.

- the origin of life in the universe.

### Planetary Geology

A standard earth geology curriculum, with newly created or augmented courses to cover these characteristics of other planets:

- size
- composition
- atmosphere
- incident radiation
- meteorite impacts

### Space Physics

A standard physics curriculum, including courses that extend the coverage of the following topics:

- electromagnetic radiation
- nuclear radiation
- high energy physics
- space environment
- gravitation
- relativity
- orbital mechanics

### **Space Engineering**

This sequence will adopt standard core courses from Aeronautical, Electrical, or Mechanical Engineering. Existing courses will be extended and new courses created to include the following topics:

- spacecraft structures (materials)
- radiation shielding
- high energy physics
- space environment
- rocketry
- aerodynamics (launch to orbit)
- spacecraft attitude control
- orbital mechanics
- remote sensing
- telecommunications
- space environment

### **Space Technology**

This sequence will adopt standard core courses from Aeronautical, Electrical, or Mechanical Technology programs. Existing courses will be extended and new courses created to include the following topics:

- spacecraft structures (materials)
- radiation shielding
- rocketry
- spacecraft propulsion
- assembly in zero gravity
- remote sensing
- telecommunications

### **Space Operations**

This sequence will adopt standard business and management core courses. Additional courses will be added to include the following topics:

- space law
- physics and chemistry (non-calculus)



- space politics
- space policy
- space medicine
- computer science to include programming, data bases, spread sheets, and web pages.
- upper atmosphere characteristics
- introduction to orbital mechanics

## GRADUATE VS. UNDERGRADUATE DEGREES

Just as one can earn a BS, MS, or PhD degree in science, engineering, or business programs at increasingly advanced levels, one should also be able to earn the BS, MS, or PhD in space related programs. As in other programs, the BS covers a broad range of topics at a level that is not too rigorous. The MS and PhD programs focus more narrowly on specific topics at a much deeper level of rigor and should also include original research.

## THE LIBERAL ARTS

This paper is limited to curricula in space related programs. As space exploration grows, philosophers, economists, lawyers, and artists will become interested in and, indeed will become necessary to, the space development. It is not too early for liberal arts programs to plan to include space studies topics in their curricula. There should be serious consideration of new liberal arts curricula for space related disciplines.

## SUMMARY

Five academic space program names have been presented: Space Studies, Space Sciences, Space Engineering, Space Technology and Space Operations. These names were chosen after a search of the Internet for space-related academic programs of study. There is little standardization in the names and curricula of the various programs currently being taught. The five programs were defined and topics were suggested. Academic deans, department chairs, and faculty should take these into consideration when creating new programs directed towards the exploration and development of space.

## APPENDIX

Air Force Institute of Technology  
MS Engineering Physics (Space Environment Specialization)  
<http://en.afit.edu/enp>

Air Force Institute of Technology  
MS Astronautical Engineering  
<http://en.afit.edu/eny/astroeng.htm>

Air Force Institute of Technology

MS Space Operations  
<http://en.afit.edu/eny/GradAerospace&InformationOperations.htm>

George Washington University  
Institute for Applied Space Research  
<http://www.seas.gwu.edu/~iasr>

George Washington University  
Space Policy Institute  
<http://www.gwu.edu/~elliott/researchcenters/spi.html>

Harvard-Smithsonian Center for Astrophysics  
<http://cfa-www.harvard.edu>

International Space University  
MS Space Studies  
[http://www.isunet.edu/academic\\_programs/mss.htm](http://www.isunet.edu/academic_programs/mss.htm)

NASA National Space Grant College & Fellowship Program  
<http://www.dfrc.nasa.gov/trc/Undergrad/nsgc.html>

NASA NASA Astrobiology Institute  
<http://nai.arc.nasa.gov>

North Dakota, University of  
MS Space Studies  
<http://www.space.edu>

Oklahoma State University  
NASA Aerospace Education Services Program  
<http://www.okstate.edu/aesp/AESP.html>

Stanford University  
BS, MS, PhD in Astronautics  
<http://www.stanford.edu/dept/registrar/bulletin/pdf/AeroandAstro.pdf>

Texas, University of  
Center for Space Research  
<http://www.csr.utexas.edu>

Umea University, Sweden  
BS, MS Space Engineering  
<http://www.irf.se>

University of Southern California  
Space Sciences Center  
[http://www.usc.edu/dept/space\\_science/aboutus.htm](http://www.usc.edu/dept/space_science/aboutus.htm)

USAF Academy  
BS Astronautical Engineering, Space Operations

<http://www.usafa.af.mil/dfas/Majors/majors.html>

Washington University in St Louis  
Astrophysics and Space Science  
<http://wuphys.wustl.edu>

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