The Search for the Commercial Space Technologist: A Comparison of Aviation and Commercial Space-related Postsecondary Programs

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Introduction

The need for technologist level support in the commercial space industry has been met over the years by either engineering scientists or traditional aerospace engineering technologists. Commercial space companies seem to operate as if they are still in their start-up phase where engineers are covering tasks in excess of their classic roles as the designers of systems. The engineers may find themselves not only designing the system, but they may also perform non-traditional tasks that include manufacturing, operations, logistics support, and post-production support of the systems. This model resembles that of the original personal computer start-up development, where systems were literally designed, built, shipped, and supported out of someone's garage. While commercial space is arguably not in the start-up phase anymore, traditional design engineers are still asked to perform tasks that are outside their training and, possibly even their interest area, just to ensure the job gets done.

As commercial space organizations have grown, aviation trained technicians have been hired for detailed component manufacturing and assembly tasks. This transition to a skilled workforce, with typically less formal training than an engineer, is a logical progression. However, the training and skills of a technician are not sufficient to analyze and manage logistics support matters. These tasks in the aviation industry are filled by engineering technologists who fill the space between technicians and engineers. Due to the similarities between the aviation and commercial space industry, design and support activities could logically evolve to mirror the structure of the legacy aviation industry. There are four roles in the manufacturing, design, and logistics support functions with three unique responsibilities in the industry. System design functions are the responsibility of the engineer. The responsibility of schedule and cost are the responsibility of the manager. The hands-on manufacturing tasks are completed by the technician. Engineering technologists perform the logistics support functions that exists in the area between the engineer and the technician.

Definitions

Engineering is defined as "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" [1].

Technician, as defined by Webster, is a specialist in the technical details of a subject or occupation such as a computer technician; one who has acquired the technique of an art or other area of specialization [2]. The English Oxford online dictionary defines a technician as a person employed to look after technical equipment or do practical work in a laboratory; an expert in the practical application of a science; a person skilled in the technique of an art or craft [3]. For this study technician is defined as a person with the direct, applied, hands-on skills, and knowledge at a highly "vocational" or "craftsman" level. The technician may have vocational certifications and possibly a two-year college degree.

Engineering technologist per the American Heritage Dictionary is “a person who uses scientific knowledge to solve practical problems [4]. According to ABET “... engineering technology programs stress current industrial design practices that allow students to start developing practical workplace skills [5].” For this study the technologist is defined as a person with some education or training in technician activities, but also who has training and education in topics related to engineering activities, project/program management, systems integration, and manufacturing processes. The Technologist or Engineering Technologist typically has a four-year college degree.

Engineering technology is defined as “part of the technology logical field which requires the application of scientific and engineering knowledge and methods combined with technical skills to support engineering activities,” [1].

Logistics support, or engineering design support, is defined as the processes of Integrated Logistics Support (ILS), also known as the “-illities”: manufacturability, maintainability, and supportability. These processes include, but are not limited to failure rate projections, cost projections, spare parts forecasting, spare parts provisioning, process planning, quality assurance, document control, support equipment procurement and maintenance, facilities planning, vendor management, personnel training, contract compliance, development of work instructions from engineering specifications, regulatory compliance, manufacturing scheduling, tooling design and manufacturing, systems integration, shipping, consumable materials planning [6], [7].

Managers/operators are defined by their ability to use of a “collection of tools and techniques... to direct the use of diverse resources toward the accomplishment of a unique, complex, one-time task within time, cost and quality constraints… to fit the task environment and life cycle (from conception to completion) of the task” [8].

The state of the commercial space industry

In 2017, there were 469 civil, military, non-profit, and commercial spacecraft launches. Of these, 268 were from the United States, 91 from Europe, 26 from China, and the remaining were from 12 other countries [9]. Within the United States, the majority of these orbital launches were from United Launch Alliance (ULA) or Space Exploration Technologies (SpaceX). Both of these companies developed their own orbital launch systems through years of extensive testing. As part of this testing, prototypes were designed, build, and evaluated. Teams of engineers and technicians were required to work together to complete these tasks. Once the design was finalized, the rockets were launched and additional teams supported the launch. Ground equipment was used to support the launches. This equipment included fuel, launch pad infrastructure, ground testing, and launch control.

In 2016, $2.8 billion was invested in approximately 100 space-related startup companies [9]. By 2018, the commercial space industry was valued at approximately $350 billion and was forecast to grow to $1 trillion within 20 years [9], [10]. Satellite services refer to communications or observations relayed or received from satellites. In 2018, approximately $98 billion in revenue was attributed to satellite television [11]. This amount represented the largest amount of revenues in the entire industry and was typically generated by selling bandwidth on satellites in geostationary orbit.

Due to the high cost of building and launching these satellites, satellites are built with a 10 to 15-year service life and take two to four years to build. Even though satellites are sophisticated and expensive pieces of equipment, satellites are built from traditional aluminum frames that are welded or riveted together. An essential part of the construction of a satellite is the system integration of various components. Having a technologist who understands how the systems work together is a critical part of manufacturing and testing since there is usually no repair or modification capability after launch.

Commercial space skills and competencies

One of the challenges facing the commercial space industry is the lack of skilled workers to fill open positions [10]. However, it is not only the private sector finding it difficult to find and retain skilled workers but the public sector as well [9], [10]. The reasons for the challenges are many and varied, but one reason is the aging of the aerospace workforce in general. The average age of aerospace workers is increasing, and more are retiring [12], [13], [14]. Since the U.S. Federal budgets are decreasing, including the budget at NASA, retirees, including those at NASA, are not being replaced with younger workers in the space industry [10]. So the pipeline of commercial space workers who have been coming from government funded space programs are decreasing. As a result, younger workers, who had potential to be involved in the space industry are, presumably, finding employment in other tech companies such as Google or Amazon, and not in the space industry [15]. Or they may not be finding high tech jobs at all. This increases the need for anyone employed at a space company to have the necessary skills to build and support spacecraft. Determining the specific skills is difficult though there have been several attempts to identify them.

In 2007, the Committee on Meeting the Workforce Needs for the National Vision for Space Exploration found NASA lacked a workforce that was skilled in program management, systems and integration engineering, and development of large human spaceflight systems [13]. The skills cited highlighted only a few of the 110 existing skills found at NASA. The four critical skills included hard skills, such as the development of large human spaceflight systems and systems and integration engineering. While program management included hard skills, much of what made a good program manager is the mastery of soft skills.

Doule and Peters [14], in their examination of skills needed in the European space industry, found a combination of hard and soft skills were needed. They found in the hard skill category the focus was in two areas technical and non-technical disciplines. In the technical discipline, they found the need for explicit knowledge and rational processes. In the non-technical discipline, they found the need for business management, policy, and law. Analytical/conceptual thinking, communication, creativity, motivation, and teamwork were most critical in soft skills.

Research completed at Purdue University surveyed alumni and students from an aeronautical engineering technology program. Their results found a broad range of hard skills needed for a commercial space workforce [16]. The top-rated hard skills found were safety procedures, space industry terminology, and clean rooms. A full accounting of the skills and their rankings were summarized in Figure 1.

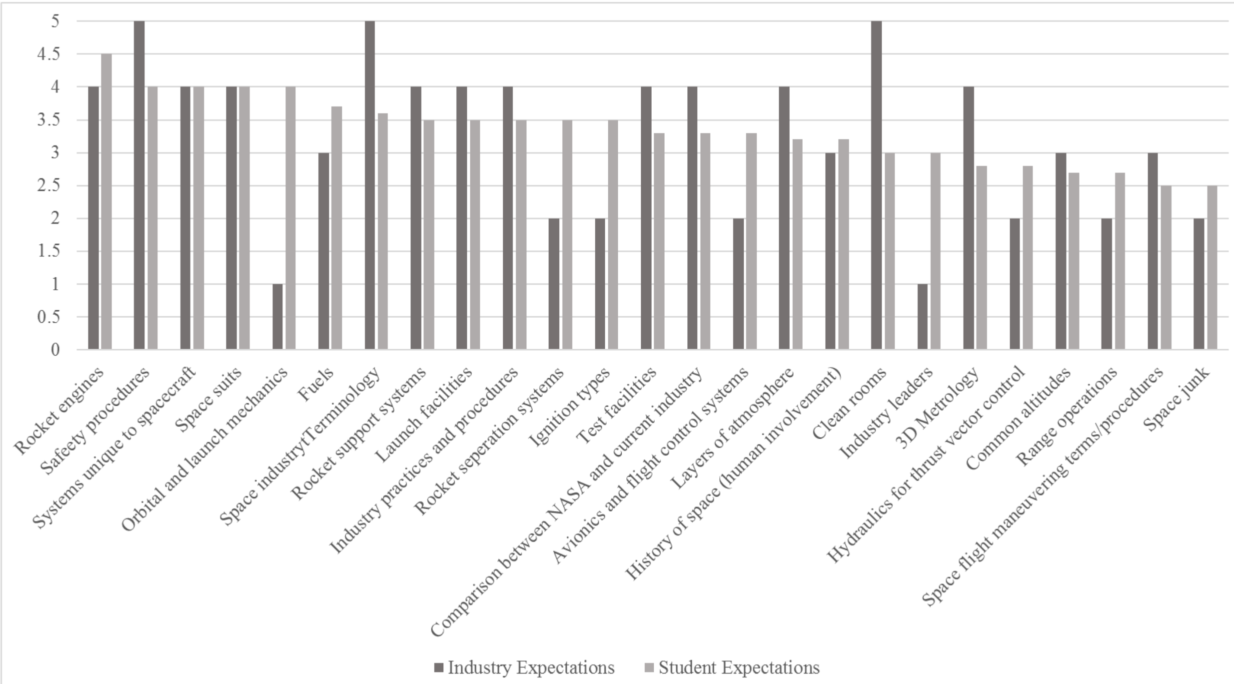

Fig. 1. Comparison of topic ratings between commercial space industry professionals and aeronautical engineering technology students.

Additional research, done at Embry Riddle Aeronautical University was completed by Mehta [17]. This research was focused on participants working in commercial space only, no students. The researcher asked the participants to rate 17 major areas, with three to five topics under each major area. For instance, one major area was propulsion and the topics under propulsion was rocket propulsion basics, booster environmental concerns and regulation, and commercial launchers and boosters. The participants were asked to rate the importance subtopics as well as propulsion overall. The seventeen major areas were spacecraft systems, propulsion, orbits, space policy and law, satellite applications, life support systems, commercial space programs, space radiation, microgravity, space history, space communications, human factors, human physiology, space manufacturing, space stations, habitation outposts, and military space operations. Respondents were asked to respond using a Likert scale with responses of “strongly agree”, “agree”, “disagree”, and “strongly disagree”. The results were all items had a mean between 2.65 to 3.67 on a 4.0 scale. Meaning all items were at least somewhat important.

The previous research was incomplete in that it did was not specific to a particular job function, but instead apparently all job functions. Did every employee in the commercial space industry need all those skills? If not, which ones did they need and at what time did they need them? Was every skill expected on the first day of work, or was it learned immediately after hire, after five years of employment, or after ten years?

Taken together, the research painted a picture of what skills are needed in the commercial space manufacturing industry, but it is still incomplete. The skills needed to work in the commercial space industry needed an additional review to identify skills needed by different types of positions. Were the skills needed by an engineer the same as the ones needed for the technologist? Was the skill set different for a manager? Since there was limited information in the body of literature, a review of the programs offered by academia should offer additional information and focus on the different skill sets.

The purpose of this study is to categorize and compare the content of traditional aviation programs and commercial space programs for differences in characteristics, traits, and paths of program focus. Areas of concentration were engineering, engineering technology, i.e. engineering technologists, and management/operations programs. This study was just the first step in evaluating workforce implications primarily related to issues and gaps in skills and competencies associated with adequate training that is grounded in the specific industry of work.

The perspective of the authors undoubtedly influenced this work. In this study, two of the authors had extensive experience in aviation manufacturing and fleet use of aircraft. One author had as experience working in the contemporary space industry, and another author had extensive knowledge of the spacecraft industry and operations. This extensive background of the authors provided a rich history and expertise to draw from to understand the nature of the logistics and engineering support activities.

The process for this study was to evaluate published plans of study for commercial space and aviation programs. Programs were then compared to identify similarities and differences. A goal of this evaluation was to understand the differences in how academia prepared engineering technologists in the aviation industry versus those in the commercial space industry.

For this paper, the programs below were separated and discussed in three distinct groups: managers/operators, engineering technologists, and engineers. While overlap did exist between the groups, in general, each category of graduate had its own characteristics and traits. These groups of graduates were also divided into aviation and commercial space divisions in order to gain a clearer view of the curriculum being taught to each discipline, see Figure 2.

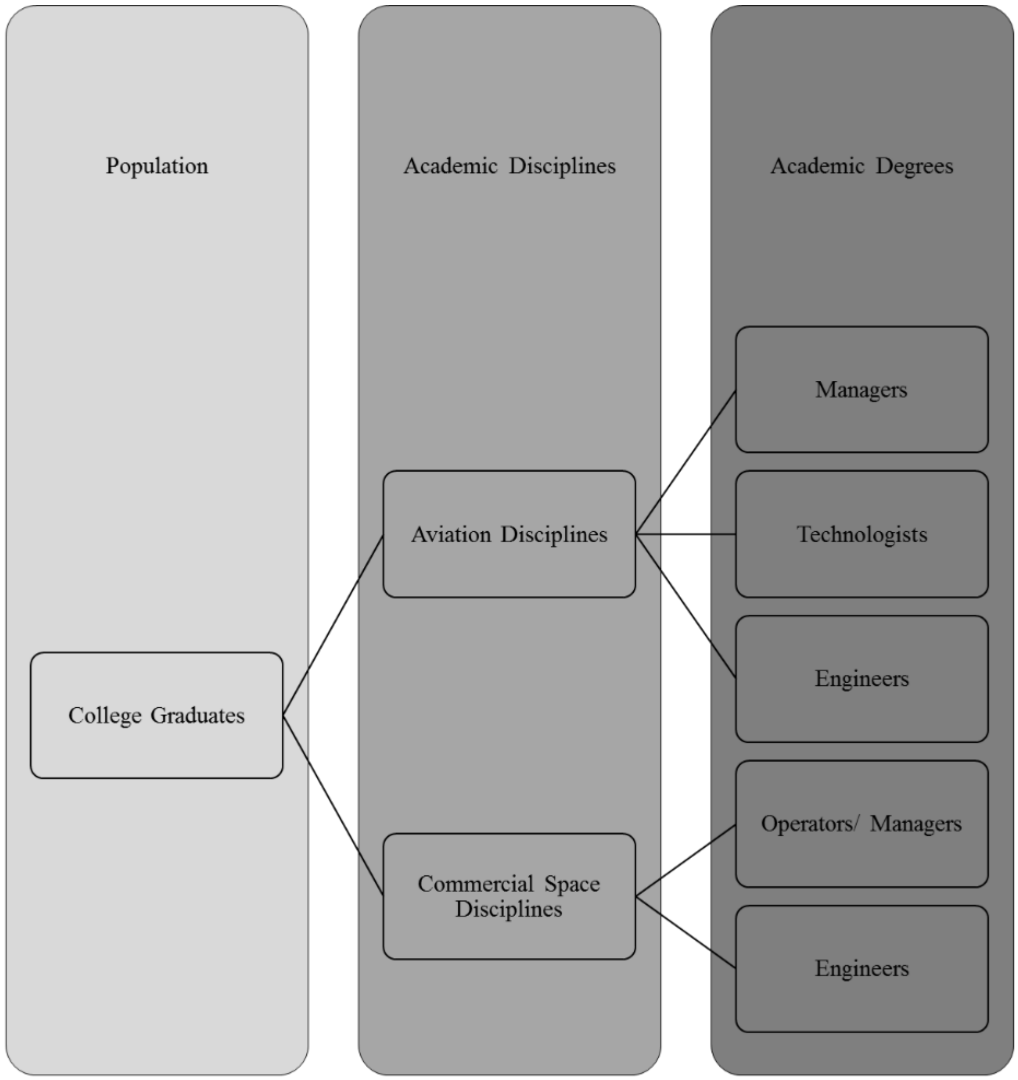

Fig. 2. Breakdown of Possible Graduate Degree Paths

Aviation Programs

Within the aviation programs, the three groups were generally segregated without too much overlap between them. Each degree path had its own strengths and weaknesses, and each had its own specific role within the aviation industry. Detailed breakdowns of aviation managers, aeronautical engineering technologists, and aeronautical engineers were given below.

In the aviation industry, the driving force behind projects, perhaps primarily in airport operations, was the aviation manager. Regardless of whether these graduates worked as Air Traffic Control (ATC), airport or airline managers, or aircraft insurance consultants, etc., all had a proficiency for business logistics, project and team management, and at least a partial understanding of efficient business practices in the aviation sector. As the need for project managers and administrative positions increased, the colleges and universities across the U.S. rose to meet these needs, and programs expanded.

Over fifty-three schools, according to the College Board Organization [18], offered a four-year bachelor's program in aviation management, or other closely related fields of study. Perhaps some of the best-known universities to offer degrees in this field were Purdue University, the University of North Dakota, Embry Riddle Aeronautical University, and The Ohio State University. While each university offered its own spin to the field, consistent themes emerged. Instilling sound and healthy business practices, promoting safety in the industry, and cultivating logistically aware minds were some of the common practices found within these programs.

While the programs strove to instill similar traits in their graduates, each had its own unique traits within their plans of study that differentiated it from other programs. Purdue University offered students both a bachelor and a master's in aviation management [19]. The University of North Dakota also offered advanced, master and doctoral degrees along with a four-year bachelor's, but required that all students, regardless of degree path, take mandatory flight courses [20]. The Ohio State University offered the same basic class courses as both Purdue University and University of North Dakota; however, The Ohio State University undergrads choose between a BS in aviation, a BS in business administration in aviation management, or a BA in social sciences in air transportation [21].

The next group of graduates were perhaps the least understood group of the three; engineering technologists, sometimes referred to as a technical engineer. They fell "in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer," according to Don Mennie in his journal entry to IEEE in 1974 [1]. While the entry was older, the definition of technologist has not changed in this study. Engineering technologists acted as the liaison between the technicians and the design engineers, and they were able to work any job position between those two points. Common jobs for graduates ranged from manufacturing and reliability engineering positions at major defense contractors to production line managers at Part 147 approved repair stations and maintenance, repair, and operations (MRO). These graduates focused on applied or hands-on engineering aspects including running modeling programs or test cells.

While there were approximately 25 schools in the nation that offered engineering technology degrees in the field of either aeronautics or astronautics [22], only three had their ABET-ETAC accreditation [23]: Kent State University, Purdue University, and the Vaughn College of Aeronautics and Technology. Each university attempted to mold their engineering technologists in that school's own unique way; however, major recurring themes were detected in each program. While some of the programs were not as heavy on mathematics or physics as a traditional engineering degree program, an understanding of calculus, physics, and aircraft sciences was common. The primary difference between programs was that the graduates did not have schooling in the mathematical science constructs that traditional aeronautical engineering students had, instead engineering technologists had an advanced understanding of system logistics, modeling, and applied electrical engineering in addition to their traditional aeronautics' background.

Much like the previously mentioned aviation management programs, each school that offered an aeronautical engineering technology degree offered its graduates a unique specialty. Kent State offered its graduates an in-depth look at avionics and mechatronics. Six out of the eight semesters that a graduate of Kent's program have at least one course that focused on electronics, motors, controllers, logic controllers, or mechatronics specifically [24]. Vaughn offered its graduates an associate degree in the field of aeronautical engineering technology, with a heavy focus on computer-aided design, primarily involving CATIA design software. Graduates of Vaughn were also offered the chance to take traditional engineering courses as part of their plan of study, including thermodynamics and fluid mechanics [25]. Purdue University offered its graduates the opportunity to take the FAA Airframe and Powerplant Certification exam at the end of its four-year degree plan. Purdue was one of two schools to be both Part 147 certified as well as ABET-ETAC accredited, Vaughn College of Aeronautics and technology is the other, and as such, offered its graduates courses covering advanced composite structure assembly and repair as well as requiring a two-semester capstone project as part of its graduation criteria [25], [26].

The final and most known group were the classical aeronautical engineers. The category was included here for completeness of discussion, despite the arguably obviousness of the discipline. These graduates were abundant in the aviation industry and held positions ranging from aerodynamicists to computational modeler, to proposal design and safety evaluator. A thorough understanding of advanced mathematics and calculus was common among these graduates, as was an education in fluid dynamics, thermodynamics, and aero-mechanical control systems. These graduates had in-depth analytical skills and were adept at coding and computer modeling.

There were over one hundred universities in the United States offering a bachelor's degree in aeronautical engineering: Massachusetts Institute of Technology [27], Georgia Tech University [28], and Purdue University [29] were used for baseline comparison. Each of these universities focuses on ensuring that their graduates met the basic requirements of the ABET certification program as well as various other engineering certifications. Course catalogs for each of these universities included aerodynamics, aircraft structure design, statics, dynamics, and their own personal degree specializations which allowed graduates to individualize themselves among other graduates of similar programs.

Commercial Space Programs

Twelve schools were identified that offered a degree in the commercial space field, as identified by Sonya McMullen and her team in their paper to the AIAA [30]. These programs ranged across both the engineering and management/operations programs. Of the twelve, the front runners in the management/operations programs were Embry-Riddle Aeronautical University [31], the University of North Dakota [32], and the American Military University [33]. Each of these universities offered students the opportunity to enroll and receive a Bachelors in Space Management and/or Space Operations degree. This not only prepared the graduates for the analytical aspects of the aerospace industry but also cultivated the humanitarian and soft skill aspects of their graduates by incorporating space policy, advanced communication, and technical writing in their plans of study.

For classical aeronautical engineers, that is engineers primarily learning and engaging with air breathing vehicles, training and lessons learned in the first two years of the traditional four-year bachelor's degree shows almost no difference than that of a classical astronautical engineer looking to make a living working on non-air breathing vehicle. This commonality is due to what these graduates do, where they go to school, and what they learn at these schools is the same as in the previously mentioned area of engineering. The only difference is that in most programs, graduates were given the choice in their last two years to specialize in the field of astronautics, allowing them to take classes focusing on spacecraft design and orbital dynamics, which better helped them prepare for the field they wished to enter.

Discussion

A review of the programs revealed a gap that might not be clear at first look. Specifically, there appeared to be a lack of commercial space programs related to the skill set of the technologist, see figure 4. Aviation programs included all three categories to support the different functions in industry. In most cases there are multiple options for focus as well for the student to pursue. Management programs could take more of a tradition approach to management or include more aviation focused pursuits such as flight. Technologist also had choices. They could pursue programs that are ABET-ETAC or FAA certified. If they wanted both they still had a choice between a two-year program at Vaughn College or a four-year program at Purdue University. The options for an engineering program are too numerous to devolve too deeply in this paper, but there are multiple avenues and specializations for the engineer to pursue.

In contrast, there were far fewer programs available to the student wishing to pursue a career in commercial space. First, one avenue was completely missing, the technologist. The commercial space focused programs provided educational opportunities for only the engineer and the management/operations, see Figure 3. Should someone wish to pursue the technologist role in commercial space the only option that existed was the traditional aviation path and gain specialized education on the job. This was concerning due to the ever-increasing need for a workforce that understands the system related requirements, both in the manufacturing and operational support of the vehicle, for working in space [34]. This lack of options could be driving students from commercial space careers because they did not see an educational path available to them. In an industry where there was a shortage in all job functions, the loss of a possible workforce creates significant problems.

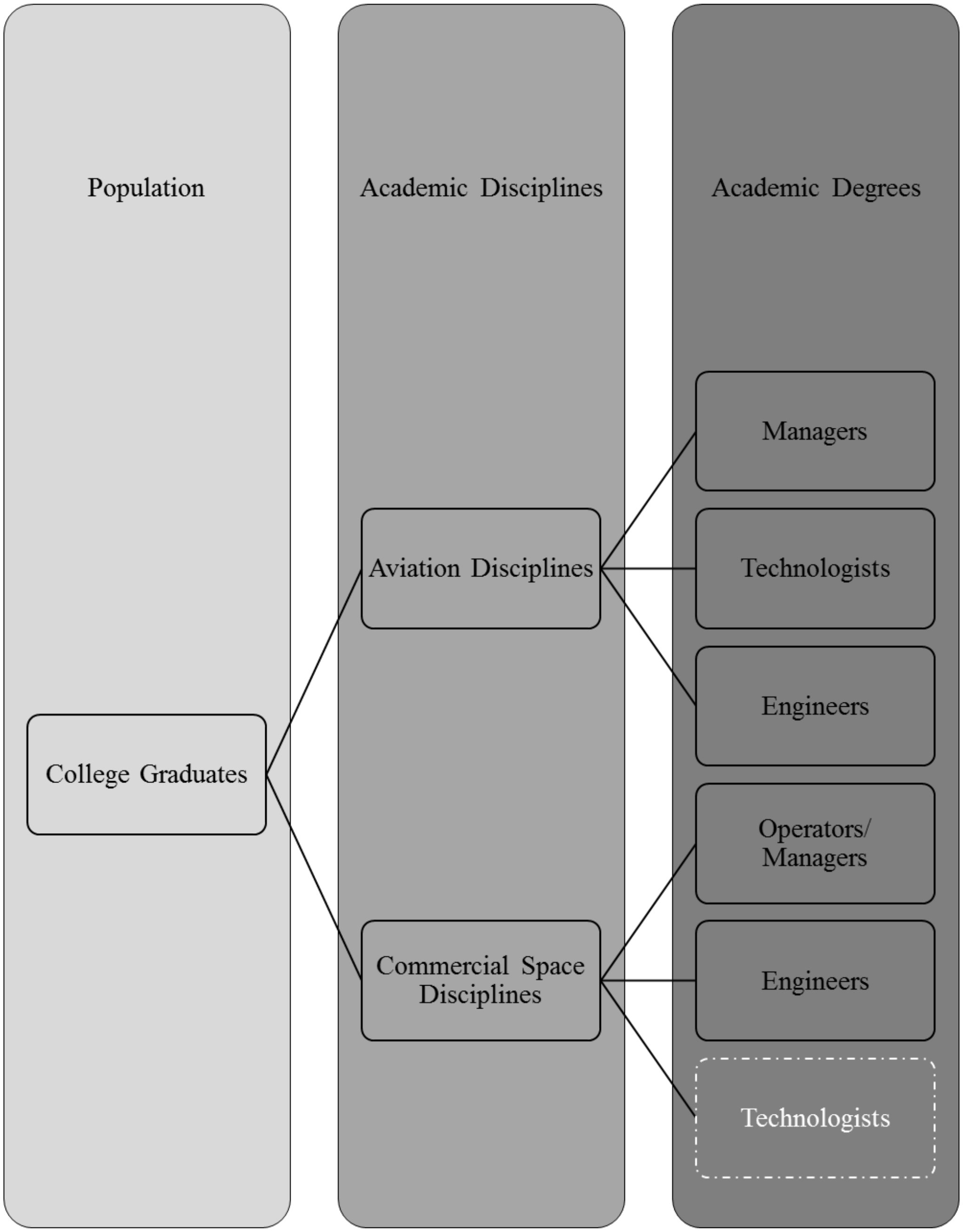

Fig. 3. Breakdown of Analyzed Gap in Graduate Degree Paths

The aviation industry built an industry model that was successful for decades with a technologist filling the gap between the technician and the engineer. These engineering technologists were typically trained at four-year universities to obtain the proper technical and problem-solving skills required to perform logistics support functions. The function the technologist was being inefficiently met using a combination of the functions engineer, technician, and operations/management personnel. Engineers were splitting their time between design engineering and hands-on detailed technical planning or other functions where, they generally have not previously received training. This split focus meant fewer hours devoted to tasks that were aligned with their background and training.

Conclusions

The gap created by the missing technologist specializing in the commercial space industry is a significant issue that must be addressed for the industry to grow. The paradigm created by the aviation industry is established and successfully working. Arguably the easiest path for the commercial space industry to follow is that of the aviation industry and establish the model of three positions performing unique and separate functions. However, to follow that path certain changes must be made in order to support the shift in paradigm.

There are multiple avenues to resolve the missing technologist dilemma. One possible, and easily implemented, resolution is to use aviation trained engineering technologists. Any specific or unique requirements that exist in the commercial space industry are learned on the job. This option is simple for academia to implement as there is nothing, in fact, to implement. However, it puts the onus for training on industry who may be resource-limited and may still require better-trained engineering technologists.

Another option is academia modifies existing technologist programs to change their focus from aviation to the commercial space industry. This option requires more work from academia since they will need to develop a new curriculum and resources to support a commercial space program focus. Additionally, there is a lack of study on the specific skills and competencies that are required for the commercial space technologist. Research must be completed first, or any modified program runs the risk of not meeting the needs of the industry.

A third option is to simply acquire individuals with technologist skills from military space or legacy aviation/aerospace. This is probably happening already. However, this option comes at a cost. Legacy military space and legacy aviation/aerospace is suffering a shortage of the technologist for its own ongoing programs. And there is a risk of acquiring "bad habits" and a way of thinking from legacy programs that do not fit the commercial space paradigm.

The options for going forward are straightforward but few, as seen above. If we choose to educate engineering technologists in the discipline of commercial space, there needs to be more definition of what the content of such a program, or programs, might be. From the review conducted for this study, it is likely that there is going to be more than one educational path for the engineering technologist in commercial space. In the end, the program structure might mirror its aviation counterpart and be different focuses or specialties at different schools. Add to that the fact that professionally educated space engineering technologists can still have skills that allow them to flow across most of aviation, aerospace, or other high technology disciplines. This allows the commercial space technologist a diverse choice of career options.

Future Work

The implications on workforce development and on academic programs are substantial and deserving of future study. Many questions are currently left unanswered. For example, this paper did not spend much time examining the impact and interplay of the technician with the other three functions. This paper simply frames the overall issue with the technologist, engineer, and manager. The future intent is to find solutions for the some of the remaining questions. Some of these questions are:

- What are the skills and competencies required for a commercial space technologist?
- Do technology programs need to completely re-tool and create new programs to support commercial space?
- Are entirely new programs needed to supply the people required?
- What is the loss of a possible workforce due to the gap that a lack of a commercial space trained technologist creates?
- Can commercial space technology-based programs co-exist with legacy aviation/aeronautics programs?
- Given the current massive global demand for technicians and engineering technologists needed to support existing legacy programs, what is the implication of adding the pressure on existing education systems for engineering technologists to the global demand for people?
- What government or industry support is going to be needed to keep existing technology education programs viable, and to increase the number of education programs to meet global demands.
- What must be done to make engineering technology programs be perceived as relevant enough to survive as colleges and universities struggle with enrollments and direction in the 21st century?

It is within this larger framework of questions, that the authors here have begun to define the gaps and opportunities for engineering technologists in commercial space.

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