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Incorporating Industry Needs into the Development of an Undergraduate Degree in Commercial Space Operations

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INCORPORATING INDUSTRY NEEDS INTO THE DEVELOPMENT OF AN UNDERGRADUATE DEGREE IN COMMERCIAL SPACE OPERATIONS

by

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This Thesis was prepared under the direction of the candidate's Thesis Committee Chair, Dr. Guy M. Smith, Associate Professor, Daytona Beach Campus, and Thesis Committee Member Dr. Lance Erickson, Professor, Daytona Beach Campus, and has been approved by the Thesis Committee. It was submitted to the Department of Applied Aviation Sciences in partial fulfillment of the requirements for the degree of Master of Science in Aeronautics

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Abstract

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The rapid expansion of the commercial space industry, not unlike the aviation industry in the early 20th century, has left the industry facing unique challenges. As companies continue to expand, the need for a well-trained workforce becomes critical. The needed workforce must be specifically educated to enter the commercial space industry at graduation. To have a successful industry, a workforce must be trained in skills that meet the industry's needs. In that regard, this study consisted of a survey of leaders in the commercial space industry to identify the different skill-sets sought by the industry. The results of the industry surveys were used in the development of an undergraduate degree in Commercial Space Operations in the College of Aviation at Embry-Riddle Aeronautical University. The findings indicated that the needs of the industry are dynamic and multi-disciplinary in nature and ranged from business planning and space policy to human factors and propulsion. The broad spectrum of needs identified indicate that the industry is fluid with evolving needs. To remain on the forefront of commercial space education, the curriculum must reflect the needs of the industry as the industry evolves. Thus, continual feedback and partnership must be pursued with the industry to ensure that future graduates of the degree possess the skills to pursue a productive career in the commercial space industry.

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Chapter I

Introduction

Since the beginning of this millennium, the commercial space industry has truly become *commercial* with the advent of companies such as SpaceX (Grantham, Perrotto, & Thomas, 2012) and Virgin Galactic (Federal Aviation Administration [FAA], 2011a) that have made space accessible to the public. Previously, space was limited to a handful of companies and space agencies. While a limited commercial space industry has existed for many years, those efforts stem directly from government assistance. For example, in Arianespace, the first satellite launch company, ownership was divided between 21 different groups with the French Space Agency (CNES) possessing the largest share at 34.7 % (Arianespace, 2011). Similarly, the Russian Federal Space Agency (Roscomos) also conducts launches for commercial satellite developers; however, the operations are government-controlled (FAA, 2012b).

In a resurgence of the commercial space industry, emerging companies such as SpaceX and The Spaceship Company are revamping the concept of a commercial space company by developing their products primarily in-house or independent of the government (The Spaceship Company, 2012). These companies define a new standard for commercial space companies to operate by, and truly define what it means to be a commercial space company.

Significance of the Study

As the commercial space industry continues to expand, the industry will need to employ individuals with the knowledge and skills necessary to contribute to the expansion within the commercial space market. The commercial space industry is currently supported by personnel with educational backgrounds in aerospace engineering and related fields. The aerospace industry and the commercial space industry are very broad and need professionals in addition to engineers for developing products. The commercial space industry requires personnel who are capable of functioning in an operational environment and capable of handling the various operational dynamics associated with launches, systems development, safety, and human factors (FAA, 2012c). Understanding and identifying the needs of the commercial space industry will be critical to the development of the undergraduate degree in Commercial Space Operations (CSO) at Embry-Riddle Aeronautical University (ERAU).

Statement of the Problem

As the commercial space industry, termed NewSpace (Foust, 2007), continues to expand, its needs will gradually become more distinct from the current aerospace industry. Determining the distinctive needs of the commercial space industry will reinforce ERAU's Applied Aviation Sciences Department's initiative to develop an undergraduate degree in Commercial Space Operations to meet the needs of the commercial space industry. Currently a degree does not exist that can produce graduates to meet many of the needs of the commercial space industry. Moreover, the exact needs of the industry remain unknown, leading to limitations in the degree development. To identify and interpret the needs of the commercial space industry is critical for the development of an undergraduate degree in commercial space operations. This study analyzed the industry needs assessment surveys and determined the skill sets desired for operations personnel within the commercial space companies.

Purpose Statement

The purpose of this study was to (a) establish a list of space-related topics relevant to the industry, (b) derive an industry survey from the list of topics, (c) deliver and collect responses from industry participants, and (d) analyze the results of the industry survey to assist in the development of the undergraduate degree in Commercial Space Operations.

Research Question

The research question addressed was: What will be the needs of the commercial space industry from future graduates of ERAU who wish to be employed in the commercial space industry?

Delimitations

Two delimitations for this study were (a) the surveys were solicited to companies and government agencies directly related to the commercial space industry, and (b) the survey was comprised of 17 topics that could be expanded into courses based on the industry responses. The topics were selected on the basis that they would provide a well-rounded education for students to be successful in the commercial space industry. The topics selected were somewhat a reflection of the skills desired by the FAA Office of Commercial Space Transportation (FAA, 2007).

Limitations and Assumptions

The data used were based on the 17 topics that were part of the industry survey developed by the principal investigator as a foundation for an undergraduate degree in commercial space operations. As such, the essential elements of the degree would be influenced by the industry response to the 17 topics in the industry survey. The survey also contained a comment section for the respondents to provide comments, concerns, and suggestions. Additionally, the survey results were complemented by direct contact with industry professionals for detailed personal feedback. However, industry professionals would be limited in their feedback due to their field of expertise, confidentiality issues, and biases due to professional affiliation.

Krejcie and Morgan's (1970) sample size determination requires that, for a population of approximately 100, the sample size should be 80. Due to the difficulty of contacting every commercial space company and having each company complete a survey, the sample was based on the industry participants who were interested in providing feedback regarding the degree program.

One challenge posed when using survey data from an unidentified respondent was that it was unclear to the researcher which company, organization, or personal interest the respondent represented. If the respondents were biased due to their affiliation with a particular company, organization, and/or agency, their responses would reflect the bias. However, not knowing the respondents' affiliation meant that the researcher could not determine if the survey responses were influenced by their involvement in the commercial space industry or by their affiliation with a particular company, organization, and/or agency.

Definitions of Terms

NewSpace	Commonly used term to refer to the commercial space industry. (Foust, 2007)
NextGen	The next generation of air traffic management system providing four dimensional real-time information (Hunter, 2010).

List of Acronyms

AABI	Aviation Accreditation Board International
AAS	Applied Aviation Sciences
AR&D	Automated Rendezvous & Docking
AST	Office of Commercial Space Transportation
C3PO	Commercial Cargo and Crew Program
CCDev	Commercial Crew Development
CCiCap	Commercial Crew integrated Capability
CNES	National Center for Space Studies (French Space Agency)
COA	College of Aviation
COTS	Commercial Orbital Transportation Service
CRS	Commercial Resupply Services
CSO	Commercial Space Operations
DOT	Department of Transportation
EDS	Emergency Detection System
ELV	Expendable Launch Vehicle
ERAU	Embry-Riddle Aeronautical University
FAA	Federal Aviation Administration
GAO	Government Accountability Office
GPS	Global Positioning System
ISS	International Space Station
LSP	Launch Service Providers
LSS	Life Support System
NAS	National Airspace System

NASA	National Aeronautics and Space Administration
NGSO	Non-Geosynchronous Orbit
NSG	NewSpace Global
ROSCOSMOS	Russian Federal Space Agency
SOST	Suborbital Space Transport
VTVL	Vertical Takeoff and Vertical Landing

Chapter II

Review of the Relevant Literature

Introduction

Prior to the development of an undergraduate degree curriculum, a philosophical framework must to be established, providing direction for the curriculum design, program outcomes, and course development (Gardiner, n.d.). The National Academy for Academic Leadership established six principles for a college curriculum design: (a) philosophy, (b) clear purposes and goals, (c) a theoretically sound process, (d) a rational sequence, (e) continuous assessment and improvement of quality, and (f) high-quality academic advising. In the curriculum design and development process, the first four principles are critical. The latter two principles are applicable after the implementation of the degree. The first principle, philosophy, states, "A curriculum should be founded on a carefully thought-out philosophy of education and should be clearly connected to an institution's mission statement" (Gardiner, n.d., para. 4). In accordance with the first principle, the mission statement of ERAU (ERAU, n.d.a) is:

> Our mission is to teach the science, practice and business of aviation and aerospace, preparing students for productive careers and leadership roles in service around the world. Our technologically enriched, student-centered environment emphasizes learning through collaboration and teamwork, concern for ethical and responsible behavior, cultivation of analytical and management abilities, and a focus on the development of the professional skills needed for participation in a global community. We believe a vibrant future for aviation and aerospace rests in the success of our students. Toward this end, Embry-Riddle is

> committed to providing a climate that facilitates the highest standards of academic achievement and knowledge discovery, in an interpersonal environment that supports the unique needs of each individual. Embry-Riddle Aeronautical University is the world's leader in aviation and aerospace education. The University is an independent, non-profit, culturally diverse institution providing quality education and research in aviation, aerospace, engineering and related fields leading to associate's, baccalaureate's, master's and doctoral degrees. (para. 1-2)

Furthermore, the philosophy of ERAU's College of Aviation (COA) (ERAU, n.d.b) is:

> The philosophy of the College is guided by concern for ethical and responsible behavior, nested in a culture of safety and professionalism. We believe a vibrant future for aviation and aerospace rests in the knowledge, skills and abilities of our graduates. (para. 2)

Lastly, the mission statement of the ERAU COA Applied Aviation Sciences Department (ERAU, n.d.c) states:

> It is the purpose of the Applied Aviation Sciences (AAS) Department to enhance the aviation and aerospace industry by providing the highest-quality academic and professional programs which prepare our graduates for productive careers.
>
> The department offers aviation-related undergraduate and graduate degree programs which prepare students for immediate productivity as well as career growth, while providing a broad-based education with emphasis on communication and analytical skills.

> AAS engages in applied research and other scholarly activities which support and enhance the intellectual and professional growth of our students, faculty and staff.
>
> The department serves the student, College, University and external community in support of the University's stated mission. (para. 1-4)

The syntheses of the three mission statements provide a philosophical framework to establish a curriculum design that provides the graduates with the knowledge, skills, and abilities to be a professional member of the aerospace industry.

The second principle, clear purposes and goals, stresses the development of curricular mission and outcomes for the students to accomplish in order to achieve a level of knowledge and attitude to be considered well-educated individuals (Gardiner, n.d.). Subsequently, the development of curriculum, based on goals and outcomes, is facilitated by a theoretically sound process, the third principle. A theoretically sound process defines a path between philosophy and curriculum outcomes, whereas educational activities, including courses, are the bricks on the path (Gardiner, n.d.). Educational activities are an element of the fourth principle, rationale sequence. It is at this point that determination is made of what courses can lead to students possessing the necessary knowledge, skills, and abilities to meet the specified outcomes (Gardiner, n.d.)

Another curriculum design, proposed by Wiggins and McTighe (1998), is the backwards design model with emphasis on outcomes. The "backward design" has three stages: (a) identify desired outcomes and results, (b) determine what constitutes acceptable evidence of competency in the outcomes and results (assessment), and (c) plan instructional strategies and learning experiences that bring students to these competency levels (Wiggins & McTighe, 1998). The first step in the backward model is to determine what the student is expected to achieve; for example, in the case of degree development, a graduate is expected to fulfill the outcomes of the degree by developing an understanding of material that is long-term, or "enduring understanding" (Wiggins & McTighe, 1998). The second step focuses on the methods of assessment that determine the fulfillment of program outcomes. Wiggins and McTighe (1998) define three assessment methods: (a) performance tasks, (b) criteria referenced assessment, and (c) unprompted assessment and self-assessment to measure outcome fulfillment. Performance task is the most critical of the three assessment types; it provides a real-world challenge for the students to counter using their knowledge, skills, and abilities. The final step is to determine how the students will be educated and equipped to demonstrate and utilize the knowledge, skills, and abilities to fulfill the outcomes (Wiggins & McTighe, 1998).

Outcome-based Learning

While both of the curriculum designs have two distinct approaches, the crux of both of the designs is outcome-based learning. As noted by Ramsay, Cutrer, and Raffel (2010) in *Development of an Outcomes-Based Undergraduate Curriculum in Homeland Security*, "such outcomes-based requirements require institutions or academic programs to demonstrate that their graduates have an appropriate set of knowledge, skills, and behaviors required by the profession when completing their course of study" (p. 4). Studies have indicated that outcome-based learning is directly related to knowledge and skills transferable to the work environment: "Transferable in this context means that knowledge, skills and abilities (KSAs) acquired while in the university are, to the largest extent practicable, directly applicable to the needs of the Homeland Security field" (Ramsay et al., 2010, p. 7). Thus, outcome-based curriculum is a profession-oriented model facilitating the transfer of knowledge acquired into the workplace. Spady (1994) purports that:

> Outcome-Based Education means clearly focusing and organising everything in an educational system around what is essential for all students to be able to do successfully at the end of their learning experiences. This means starting with a clear picture of what is important for students to be able to do, then organising the curriculum, instruction, and assessment to make sure this learning ultimately happens. (p. 1)

Thus, the purpose of outcome-based learning is to equip the students with the knowledge, skills, and abilities to enter the professional environment and apply the outcomes completed.

Industry Feedback

Butler (2004) in *Outcomes Based/ Outcomes Focused Education Overview*, identifies the need for curriculum development based on knowledge and skills; therefore, curriculum developers need to first identify the knowledge and skills the students are expected to acquire and then work backwards to develop courses based on the desired outcomes (i.e., knowledge, skills, and abilities). The ultimate goal of outcome-based learning is to prepare students with the knowledge, skills, and abilities necessary to enter the industry (Willis & Kissane, 1995). A source for establishing measurable objectives for degree programs are accreditation agencies; "in several disciplines, modern accreditation requires a program to demonstrate that they have achieved a defensible level of integrity, outcomes-based performance, and continuous quality improvement" (Ramsay et al., 2010, p. 5). In addition to serving as a standard for degree programs, accreditation also acts as template for new programs under development. The accreditation process entails developing curriculum that meets the standards of accreditation; alternatively, those same standards can act as measurable objectives for curriculum development. Furthermore, Ramsay et al. (2010) state that accreditation serves as a guide to the curriculum development "which requires programs to have a mechanism in place whereby they consistently monitor the needs of their constituents, assures degree integrity, and helps to delegitimize 'diploma mills'" (p. 6). To equip the students with the knowledge, skills, and abilities practicable in the industry, input from the industry becomes necessary. So crucial is industry input in the curriculum development process, that it is an integral part of accreditation process (Ramsay et al., 2010). The Aviation Accreditation Board International (AABI) requires baccalaureate degree programs to develop a curriculum that incorporates projects requiring students to use the knowledge and skills acquired over previous course work in preparation for careers in the aviation and aerospace industry (AABI, 2012). Specifically, the AABI (2012) *Accreditation Criteria Manual* (Criterion 3.9) states, "the aviation faculty MUST [sic.] develop and evaluate each program with advice from appropriate industry associations and/or professionals in the field" (p. 19). The ERAU CSO program curriculum was developed with the intention of seeking accreditation from AABI as a non-engineering technical degree. Thus, the degree development occurred with input from the industry. Industry input is the crux in curriculum development and has become the norm for universities (AABI, 2012; Ross, 1997; Franklin University, n.d.).

Industry Skills Demand

The expansion of the commercial space industry, both orbital and suborbital, has led the FAA to scrutinize the needs of the industry in the coming decade to highlight issues that might impede the progress of the commercial space industry. The FAA Center of Excellence for Commercial Space Transportation highlighted multiple issues that must be addressed to benefit the industry as well as the government (FAA, 2012c). The Center for Excellence has highlighted four primary areas that need to be addressed for the success of the industry:

- Space Traffic Management & Operations
- Launch Vehicle Systems, Technologies, and Operation
- Human Spaceflight
- Space Commerce (Section 3.2, p. 10)

The continually changing commercial space industry does not have one-size-fits-all requirements; rather every company or spaceport may need to be approached differently (Government Accountability Office [GAO], 2012). Similarly, safety, human spaceflight, regulation compliance, risk assessment, and insurance may be some areas that the FAA needs to address to ensure that the industry expands safely. The FAA, to better prepare its personnel to handle commercial space operations, began training its aerospace engineers in:

> ...launch and space flight operations, which include procedures for the launch and recovery of vehicles; FAA courses on avionics and aircraft operations, which are relevant because reusable launch vehicles have aircraft characteristics; and National Transportation Safety Board courses on aviation accident investigation,

> which includes procedures that would be useful in the event of a launch incident. (GAO, 2012, p. 21)

As the industry evolves, the FAA is faced with a challenge of addressing industry needs that vary greatly. For example, another GAO (2006) report states that one challenge faced by the FAA in the suborbital market is to:

> ...include obtaining the expertise and resources needed to provide safety oversight of the sector, ensuring that its various regulations are suitable for the different launches and launch sites it licenses, determining the circumstances under which it would regulate passengers and crew, and ensuring that its industry promotion responsibilities do not conflict with its safety oversight responsibilities (p. 22)

The FAA Office of Commercial Space Transportation (AST) seeks a broad set of skills from its employees that include (a) Aerospace Vehicle Systems, (b) System Safety/Quality Assurance Engineering, (c) Structural/Mechanical Engineering, (d) Software Engineering, (e) Meteorology, (f) Space Transportation Analysis, and (g) Environmental Assessment (FAA, 2007). These skills, dispersed over different disciplines, require that individuals with different skillsets work in a cohesive manner for the benefit of the industry and the government.

NASA. The National Aeronautics and Space Administration faces a similar situation to the FAA in that the current NASA workforce lacks the skillsets and the depth to address issues in the commercial space industry (Commercial Space Committee, 2012). The Commercial Space Committee (2012) recommended "that as NASA evolves its workforce skill mix and human capital planning to accommodate the Agency's future direction in the post Space Shuttle era, the unique skills needed for effectively overseeing commercialization initiatives should be considered and secured" (p. 14). Additionally, the report indicates that NASA needs expertise in "business development, business analysis, and business operations, which do not appear to be currently available in great depth in the Agency" (p. 14).

Point-to-point suborbital flight. The current suborbital market forecasts tourist flights to an altitude of 60-plus miles and back to allow the passengers to momentarily experience zero-g (The Tauri Group, 2012); however, tourist flights are limited in terms of the practical services due to the fact that flights in the near future will depart and return to the same location. However, in recent years, research has been undertaken to address the possibilities of point-to-point suborbital flights between two separate locations to transport goods and passengers. The current research addresses (a) market growth, (b) potential operational models, and (c) operational requirements. The John A. Volpe National Transportation Systems Center of the U.S. Department of Transportation's (DOT) Research and Innovative Technology Administration held a meeting in May 2010 to address the implications of point-to-point suborbital flight on the National Airspace System (NAS) (Hunter, 2010). The meeting addressed the possibility of integrating suborbital flights within the NAS and the different operational facets of such flight. According to Hunter (2010), key issues included:

- Air Traffic Management
    - National Strategy
    - International Coordination
    - Safety

- Reusable Launch Vehicles
    - Operating and Physical Environment
    - Equipment
    - Passenger and Cargo Accommodations
    - Security and Emergency Response
- Terminals
    - Logistics
    - Equipment
    - Security and Emergency Procedures
- Human Factors
    - Vehicle Crew and Ground Crew Standards and Training
    - Passenger Training and Acclimatization
    - Crew and Passenger Emergency Procedures
- Weather
- Environmental Impact (p. 8)

Air traffic management does not currently address suborbital traffic; however, as suborbital traffic increases, standardizations must be implemented to ensure that suborbital flights are part of the NAS and not exceptions. Thus, suborbital flight service providers would need to (a) operate under air traffic regulations, (b) adhere to FAA safety regulations, and (c) function in harmony with NextGen, the next generation of air traffic management system providing four-dimensional real-time information (Hunter, 2010). In terms of terminals, the challenge will be to develop spaceport infrastructure that can accommodate (a) logistics for passenger and cargo flights, (b) NextGen communication capabilities, and (c) emergency management (Hunter, 2010).

In terms of logistics, developing systems and processes that can provide faster turnaround time per flight and minimize the space plane ground and maintenance time can reduce cost (Hunter, 2010). Developing systems that are compatible with NextGen, that provide space plane crews the same degree of real-time information provided to aircraft, will be an issue that the developers and operators of the space planes will need to address. Emergency management is analogous to safety and related to FAA safety regulations. If spaceflight service providers and spaceports wish to provide point-to-point service, safety systems and processes are pivotal to realizing such operations; however, current education does not provide training specialized in logistics, airspace integration, and safety (Hunter, 2010).

Reusable launch vehicle design and development must take into consideration (a) performance and communication capabilities, (b) NextGen compatibility, and (c) emergency response capabilities. Human Factors issues include development of standards and training for flight and ground crew, as well as training regimen for passengers. Additionally, effects of flight on crew cognition and physiology are factors that need to be further studied for industry application (Hunter, 2010).

Weather factors include (a) high altitude weather, (b) near space/space weather, and (c) shielding against space hazards (Hunter, 2010). Developing accurate weather forecasts to predict high altitude winds and suborbital conditions using ground and airborne devices will be a critical need for scheduled suborbital flights. Developing shielding against radiation for crew, passengers, and onboard systems will be an area that will require further development as well (Hunter, 2010).

Environmental concerns in terminal areas include (a) noise, (b) vibration, (c) shock waves, (d) emissions and contaminants, (e) hazardous material handling, and (f) land use, the same factors that affect aircraft (Hunter, 2010). Space planes are likely to utilize chemical fuels that are combustible with detrimental impact on the environment. In the event of an inflight accident, containment of debris and fuel, which would be dispersed over a large area, requires careful analysis and planning to devise appropriate procedures. However, current education does not provide the fundamentals to address such an issue (Hunter, 2010).

Currently, the U.S. does not have a national strategy for commercial space operations, nor are there unified efforts under a single agency (Hunter, 2010). Rather, a collection of academic institutes, industry groups, and government agencies work in unison to further the commercial space industry initiatives (FAA, 2012c; Hunter, 2010). Similarly, current university-level education does not reflect the expanding needs of the commercial space industry. Current degree programs do not address these topics, especially considering that the industry needs are comprised of eclectic topics dispersed over multiple disciplines (American Military University, 2012; Naval Postgraduate School, 2012; University of Colorado, 2011; University of North Dakota, 2011).

Commercial Space Industry Growth

The resurgence of space flight with the continued progress of NASA's Commercial Crew and Cargo program is a step forward for the space program and commercial space programs in particular (Knapp, 2012). The development of new launch platforms for manned missions by Boeing, Sierra Nevada Corporation, and SpaceX is driving the industry forward with current contracts totaling $1.1 billion

(Knapp, 2012). The development of a new generation of manned space systems is paralleled by the growth in the satellite market. The FAA launch forecast from 2012 to 2014 indicates a significant growth in the satellite market with forecasted demand increasing by 67%, 63%, and 46%, respectively from 2011 satellite demand (FAA, 2012a). This equates to a total of 23, 21, and 20 satellite launches from 2012 to 2014, respectively (FAA, 2012a). The near-term forecast from 2012 to 2015 projects a far greater number of launches than from 2009 to 2011, with 50% of the forecasted launches in the heaviest mass class of 5,400kg or more. The increase in satellite size may be due to an increased demand in emerging and existing markets for more powerful telecommunication satellites (Fichtenbaum, 2009; FAA, 2012a).

Globalization, market growth, and regulatory changes have increased the demand for commercial satellites globally. Consumer demand for faster communication channels, greater availability of information systems, increased mobility, and governmental needs to supplement communication capabilities through commercial satellite deployment has led to the expansion of the communication satellite industry (FAA, 2012a). In addition to the launches of communication satellites, the next few years will also see an increase in the deployment of Global Positioning System (GPS) satellites (“Satellite Wars,” 2012). Additionally, according to the FAA launch forecasts for 2012 to 2021 for non-geosynchronous orbit launches, the average launch volume will be 233% of the 2002 to 2011 historical launch average (FAA, 2012a). The commercial telecommunication launch forecast from 2012 to 2021 is projected to be on average 75% higher than the average number of launches from 2002 to 2011. The remote sensing satellite demand will increase on average by 22% from 2012 to 2021 compared to the number of historical launches from 2002 to 2011. Science and engineering launches are expected to decline by 15% from 2012 to 2021 compared to the 2002 to 2011 average (FAA, 2012a).

The increase in satellite launches may be attributed to the increase in regional demand for GPS services and telecommunication capabilities (Fichtenbaum, 2009; “Satellite Wars,” 2012). Furthermore, along with the demand for new satellites is also the need for replacing constellations of aging communication and navigation satellites. Not only will the satellite industry see growth, but also the launch service providers (LSP) will flourish due to the increase in demand for greater number of satellites (Strickland, 2012). As the commercial launch industry continues to expand to meet the market demands for satellite placements, the launch industry also prepares to support NASA’s Commercial Cargo and Crew program (C3PO) to send personnel and supplies to the International Space Station (ISS). The FAA has projected 128 launches from 2012 until 2021, with 50% of the projected launches for Commercial Cargo and Crew Transportation Services by commercial space companies to the ISS (FAA, 2012a).

Orbital Developments

Commercial cargo and crew program. With the retirement of the Space Shuttle, NASA has had to depend on the Russian Soyuz to ferry astronauts and supplies to the ISS (Herszenhorn, 2011). In the wake of the shuttle retirement, NASA initiated the Commercial Crew Development (CCDev) project in 2010 by partnering with aerospace companies to support commercial spacecraft development (FAA, 2012a). The CCDev project was subsequently followed by the CCDev2 project in 2011, providing funding to Blue Origin, Boeing, Sierra Nevada Corporation, and SpaceX to develop new spacecraft to take crews and cargo to the ISS (FAA, 2012a). NASA awarded $296.3 million to those four companies to facilitate development of spacecraft to help expand the U.S. space transportation industry (FAA, 2012a; Mango et al., 2011).

NASA's Commercial Cargo and Crew Transportation Services program is comprised of the Commercial Orbital Transportation Services (COTS) for the Commercial Resupply Services (CRS) to the ISS. The Commercial Crew Development (CCDev) program, administered by NASA and funded by the U.S. government, is focused on stimulating the development of manned orbital spacecraft developed and operated by private companies (FAA, 2012a).

Commercial Orbital Transportation Services. The COTS program funded by NASA was initiated in 2006 to develop spacecraft to take cargo to the ISS and stimulate growth in the commercial space industry (FAA, 2012a). SpaceX and Orbital were chosen in 2008 to construct both the launch platform and the cargo delivery spacecraft to dock with the ISS (FAA, 2012a). SpaceX conducted its first mission to the ISS in May 2012 as a demonstration flight for NASA (Grantham, Perrotto, & Thomas, 2012). SpaceX has been contracted by NASA for 12 missions to the ISS between 2012 and 2016 at $1.6 billion with the option of contracting for further flights. Orbital is currently contracted for eight missions between 2012 and 2016 to the ISS with the first Antares rocket test flight scheduled for mid-to-late 2013 (NASA, 2013). Thirty-two cargo missions between 2016 and 2021 have yet to be contracted to any company; however, further contracts may be awarded to SpaceX (FAA, 2012a; SpaceX, 2013).

Cost reduction has been a major concern for both SpaceX and Orbital to proliferate launches and reduce cost per launch (Orbital Sciences, 2012; Strickland, 2012). The increase in launch demand would be paralleled by the increase in production of rockets to match the demand. The subsequent increase in production reduces the cost per rocket and thus makes space more accessible (Strickland, 2012).

Commercial Crew Development. The Commercial Crew Development (CCDev) project was initiated as part of the C3PO to develop safe and reliable transportation for manned missions. The original CCDev project, CCDev 1, began in 2010 when NASA awarded $50 million to five companies to develop technologies for manned space systems. The companies included Blue Origin, Boeing, Paragon Space Development Organization, Sierra Nevada Corporation, and United Launch Alliance (NASA, 2012a).

Blue Origin was given $3.7 million for the development of safety systems related to the Launch Escape System and the development of lightweight composites to be used in the spacecraft structure to reduce weight and increase tolerance (NASA, 2012a). Boeing was given $18 million to develop a manned spacecraft and demonstrate the "Reaction Control System, Orbital Maneuvering System, Launch Escape System, Thermal Protection System, Avionics Integration Facility, Crew Module pressure vessel fabrication, landing system, life support system, Automated Rendezvous & Docking (AR&D), and Crew Module Mockup fabrication" (NASA, 2012a, para. 4). Paragon Space Development Corporation was given $1.4 million to develop life support systems (LSS) and environmental controls (NASA, 2012a). Sierra Nevada Corporation was given the largest share at $20 million for the development of the Dream Chaser spaceplane, including the development of the critical control systems (NASA, 2012a). United Launch Alliance was awarded $6.7 million for the development of the Emergency

Detection Systems (EDS) for Delta IV and Atlas V rockets to provide the crew sufficient time to escape in the case of an impending catastrophic failure (NASA, 2012a).

In 2011, NASA initiated CCDev2 to further the projects undertaken within the CCDev (NASA, 2012a). Four companies were awarded a total of $270 million to advance projects the companies had begun under CCDev: Blue Origin, Boeing, SpaceX, and Sierra Nevada Corporation. Blue Origin was awarded $20 million for the design of a new orbital vehicle and SpaceX was given $75 million for the development of a Launch Escape System for the Dragon spacecraft. The Dragon is a reusable spacecraft designed by SpaceX to ferry cargo and crew to and from the ISS under the COTS (SpaceX, 2013). Boeing and Sierra Nevada Corporation were given $92.3 million and $80 million respectively to further their spacecraft developments (NASA, 2012a). The latest CCDev program, titled Commercial Crew Integrated Capability (CCiCap) provides Boeing, Sierra Nevada Corporation, and SpaceX with over $1.1 billion in funds to mature their spacecraft in order to meet the 2017 deadline to begin manned spaceflights to the ISS (FAA, 2012a; Perrotto & Thomas, 2012). Current FAA (2012a) projections list 10 manned flights to the ISS from 2017 to 2021 (two flights per year) (GAO, 2012). The entire CCDev initiative, spanning from 2010 to 2014, provides commercial space and aerospace companies with nearly $1.5 billion in funds to spur the growth of commercial space transportation (FAA, 2012; Perrotto & Thomas, 2012). The total cost for the Commercial Cargo and Crew Program from its inception in 2006, to 2014 is expected to be $5.5 billion. That includes 64 cargo and crew flights to the ISS between 2012 and 2021 (FAA, 2012a; Perrotto & Thomas, 2012).

Suborbital forecast. The primary customer base for the suborbital industry for the next 10 years will remain space tourism. The Tauri Group (2012) projects that 80% of suborbital customers will be space tourists with the remaining 20% being businesses, companies, and research institutes. The study done by The Tauri Group analyzed market growth in the suborbital industry based on the projected consumer demand. Considering that consumer demand is directly linked to purchasing power, the study had alternate financial projections over a 10-year period based on expected demand. The projections were based on the likelihood of individuals with net worth of $5 million or more that might consider suborbital flights. The $5 million mark was chosen since it was presumed that individuals with that net worth could afford spending $95,000 to $200,000 on a ticket. Additionally, it was projected that 76% of the total suborbital demand may be from millionaires and 4% from space enthusiasts (The Tauri Group, 2012).

Based on the current demand, the suborbital companies would have to conduct daily flights to match the market demand, yielding $600 million over a 10-year period (The Tauri Group, 2012). If the demand decreases from the current levels, flights would be reduced to few a week, thereby, reducing the market to $300 million – half of the current demand. If price elasticity leads to drastic reduction in price, or some other methods reduce the price, the 10-year growth in the market may be as high as $1.6 billion. The normal demand projects a sale of 4,000 seats over a 10-year period, the reduced demand is 2,000 seats, and the increased demand is 11,000 seats (The Tauri Group, 2012).

Suborbital developments. Growth in the suborbital industry began in 2004 with the announcement of the Ansari X PRIZE by the X PRIZE Foundation worth $10 million to further the development in the suborbital flight industry (FAA, 2011b). The prize would be awarded to anyone who could reach an altitude of 100 km or higher and conduct the flight again within two weeks. Twenty-six companies spent a total of $100 million to win the competition. However, only one company emerged as the winner from the competition: Mojave Aerospace Ventures operating Scaled Composite's SpaceShipOne (FAA, 2011b).

The subsequent development in the suborbital market is for the development of vehicles to take tourists to an altitude of 100 km or greater, with a secondary focus on small payloads delivery (FAA, 2011b). Six companies are currently developing vehicles within the suborbital spectrum for commercial flights beginning in 2013: Armadillo Aerospace, Blue Origin, Masten Space Systems, UP Aerospace, Virgin Galactic, and XCOR Aerospace; however, only four of the companies have vehicles that can support a crew: Armadillo Aerospace, Blue Origin, Virgin Galactic, and XCOR (FAA, 2011b).

Armadillo Aerospace. Armadillo Aerospace is developing a Vertical Takeoff and Vertical Landing (VTVL) suborbital vehicle for research and passengers (FAA, 2011b). The company competed in the Northrop Grumman Level 1 and Level 2 Lunar Lander X Challenge in 2008 and 2009 to win $350,000 and $500,000 respectively. The company also received funding from the NASA Flight Opportunities Program to provide Near-Space Flight Services (FAA, 2011b). The company is currently developing a two-crew Suborbital Space Transport (SOST) named Hyperion with first tests planned for 2014. In 2010, the company partnered with Space Adventures to offer suborbital flights at $102,000 per ticket. Currently, there is a waiting list comprised of 200 people.

Blue Origin. Blue Origin is developing the New Shepard rocket-propelled vehicle to take a crew of three to an altitude of 100 km to conduct microgravity research (FAA, 2011b). The New Shepard is comprised of two modules, the pressurized crew/cargo module and the propulsion module attached underneath the crew module. Blue Origin is also involved in NASA's CCDev in addition to the independent initiative to develop a suborbital vehicle. Only two tests have been conducted so far, with the last test conducted in August 2011, ending in the loss of the vehicle (Pasztor, 2011).

Virgin Galactic. Virgin Galactic remains on the forefront in the suborbital market since winning the Ansari X PRIZE in collaboration with Scaled Composites, and expects to begin suborbital flights in 2013 (FAA, 2011b). Virgin Galactic initially tested SpaceShipOne in 2004 as a technology demonstrator and prototype for the company's operational space plane, SpaceShipTwo. SpaceShipOne and SpaceShipTwo are developed and manufactured by Scaled Composites and operated by Virgin Galactic. Scaled Composites and Virgin Galactic formed The Spaceship Company in 2005 to unify their efforts in developing SpaceShipTwo. Scaled Composites is responsible for research and development. The SpaceShip Company builds the SpaceShipTwo, and Virgin Galactic provides the funding and brokers the flights. The current plan calls for the manufacturing of five SpaceShipTwo craft and securing deposits from 500 individuals prior to beginning passenger flights. Virgin Galactic plans to begin suborbital flights in 2013 at $200,000 per ticket with six passengers and a two-man crew (FAA, 2011b). Virgin Galactic has also received $10,000 from NASA's Flight Opportunities Program and the Southwest Research Institute for flying technology payloads to suborbital altitudes (FAA, 2011b).

XCOR Aerospace. XCOR is pursuing a concept similar to Virgin Galactic for using a space plane to take personnel to suborbital altitudes and back using the Lynx aircraft (FAA, 2011b). Unlike SpaceshipTwo, the Lynx is designed to reach suborbital altitudes via conventional means using its four liquid-fueled rocket engines. First flight of the Lynx was planned for either the end of 2012 or 2013, with hopes for operational flights as early as the end of 2013 or mid 2014 (Davies, 2012). The Lynx is designed to take off like a conventional aircraft, reach suborbital altitudes, and land on its own without compromising performance. The Lynx is designed to minimize maintenance cost to reduce both expenses and turnaround time. The Lynx may conduct four flights per day with a few hours between each flight. XCOR plans on wet leasing the Lynx to other companies at $95,000 per ticket (FAA, 2011b).

The company has received funding from NASA's Flight Opportunities Program, Southwest Research Institute, and Planetary Research Institute for flying technology payloads into suborbit. XCOR is negotiating for wet lease agreements with Yecheon Astro Space Center of South Korea and Space Expedition Curaçao of Netherlands Antilles (FAA, 2011b).

Spaceport Development

The growth in the orbital and suborbital development is paralleled by spaceport development to support growth in the orbital and suborbital markets. Non-Federal, or private spaceports, vary greatly in the capabilities and services offered. Some spaceports can support vertical launches whereas others support horizontal launches.

Cape Canaveral Spaceport. Cape Canaveral Spaceport, operated by Space Florida, is planning on utilizing Launch Complex 36 (LC-36) for suborbital operations

(FAA, 2011b). Space Florida and Masten Space Systems signed a $400,000 contract in May 2011 to allow Masten Space Systems to conduct VTVL tests at the facility (FAA, 2011b). Space Florida is currently building a launch pad, processing facility, and mission control center to support operations (FAA, 2011b).

Cecil Field Spaceport. Cecil Field Spaceport, formerly Naval Air Station Cecil Field, is operated by the Jacksonville Aviation Authority (FAA, 2011b). After becoming a civilian airport in 1999, the airport has supported Coast Guard and Florida Air National Guard presence. Boeing and Northrop Grumman maintain a presence at the airport to provide support services for the Department of Defense (FAA, 2011b). In January 2010, the Jacksonville Aviation Authority was issued Space Launch Site Operator's License for Cecil Field by the FAA. Later in 2010, the spaceport was given a grant of $105,000 by the FAA for development. The spaceport has four runways, including one that is 12,500 ft. (FAA, 2011b).

Mojave Air and Space Port. Mojave Air and Space Port in Mojave, California, is the most notable hub for aerospace development, and is currently home to nearly 40 aerospace companies including Masten Space Systems, National Test Pilot School, Scaled Composites, and XCOR (FAA, 2011b). The spaceport has three runways, including one that is 12,500 ft., as well as multiple rocket pads and areas for testing rocket motors. The Spaceship Company has its primary production facility at the spaceport for manufacturing SpaceShipTwo and the WhiteKnightTwo carrier aircraft. The FAA awarded the spaceport $125,000 in October 2010 for procuring emergency response vehicles and another $125,000 in August 2011 to conduct an environmental assessment (FAA, 2011b).

Spaceport America. The first spaceport built solely for space operations, Spaceport America is located in New Mexico and operated by New Mexico Spaceport Authority (FAA, 2011b). The New Mexico Spaceport Authority was granted Space Launch Site Operator's License by the FAA in December 2008. The FAA provided the Spaceport Authority with $43,000 in September 2010 and nearly $250,000 in August 2011 for implementing an automated weather broadcast system and a rollback facility for vertical launches. The spaceport is completely financed by the New Mexico taxpayers (FAA, 2011b; GAO, 2012). The spaceport is home to Virgin Galactic, which plans to operate a fleet of two WhiteKnightTwo carrier planes and five SpaceShipTwo space planes. Virgin Galactic has signed a 20-year lease agreement to operate from the spaceport (FAA, 2011b).

Summary

The increased orbital launches and the commencement of operational suborbital flights will continue to expand the commercial space industry in the coming decade. The continual expansion in the industry requires that the regulatory agencies and the companies work in collaboration to ensure that the market demand for (manned) spaceflight is adequately met with trained and qualified personnel.

A major challenge faced by the regulatory agencies and companies is cultivating the necessary skills among the workforce to counter the dynamic challenges within the industry. As these companies grow, they require personnel who can understand the technical, operational, and managerial challenges of spaceflight. The unique blend of skills necessary to address these issues are not easily found; rather, extensive training must be given to professionals to prepare them for the challenges faced by the commercial space industry.

The required training should entail the development of education that can provide the commercial space industry with skilled individuals. The education should be developed with the industry input to ensure that the future graduates of the degree possess the skills necessary to be successful in the commercial space industry. Identifying the specific skill sets desired by the industry through market growth research and industry feedback provides the framework for developing a degree that is outcome-based. Thus, the curriculum development process utilizes industry input to develop a curriculum that is practicable in the industry and meets the standards of accreditation.

Chapter III

Methodology

Research Approach

The research focused on the development and analysis of an industry survey that was designed to provide structure for the degree development. This is a descriptive study of the industry survey results to determine the essential elements of the degree. To determine the structure of the industry survey, a list of topics encompassing a wide variety of subjects relevant to the space industry were compiled through research. The research focused on identifying emerging trends in the skills sought by commercial space companies. The topics were from different disciplines related to spaceflight. Some of the topics had greater relevance to the industry in its current state or the near future. Other topics had less relevance due to the long-term implication of the topics to the industry; for example, topics such as space manufacturing or space habitat development may become more important when the industry begins to mature and possesses the capability to conduct operations requiring heavy industrial capacity. When the topics were finalized, an industry survey instrument was developed for the industry members to complete and provide feedback.

Design and procedures. Prior to developing the industry survey instrument, the degree development team (including the researcher of this study) conducted research regarding the present state of the commercial space industry through internet-based open source websites that included the websites of commercial space companies and organizations, aviation regulatory agencies, and special topics websites. Additionally, research was compiled to assess the current state of the industry and the shift in demand in the coming decades. The research focused on the broader progress of the industry as a whole as well as the particular markets within the industry that are likely to grow.

In addition, research was conducted regarding the job market in the commercial space industry and the particular skill sets that the companies and organizations seek. The synthesis of the research in industry growth, market development, and job skill requirements led to the development of the industry survey.

The list of survey topics included both the technical and non-technical subjects addressing different facets of the industry. In particular, the subjects were chosen for their relevance to the operations of the industry rather than the engineering or development. The technical topics included propulsion, orbits, spacecraft systems, and microgravity experiments. Non-technical topics included space program management, military applications in space, and commercial space programs. These topics were among many more that became part of the survey instrument administered to commercial space companies. The descriptive data obtained from the surveys determined the degree composition.

Population/Sample

A total of 24 surveys were returned by individuals from commercial space companies, organizations, and government agencies. The individuals included managers, specialists, and engineers from commercial space companies and government agencies. Of the 24 surveys received, 22 surveys were fully completed; the remaining two were partially completed. The sample of 24 surveys was part of an industry population of at least 100 companies and organizations within the industry. Companies of varying size are directly part of the commercial space industry or provide support to the industry. The respondents were from companies that varied in size ranging from only a few dozen employees to companies with thousands of employees.

The sample included private commercial space companies, support companies, and government agencies. Fifteen companies identified themselves and 14 of the 15 companies provided contact information.

Of the total 24 surveys taken, 92% were completed (n = 22) with 54% of the respondents (n = 13) providing some form of feedback in the comments section. Not every respondent provided an identity, nor did they all provide information about the company or organization they represented. Of the total 24 respondents, 66% (n = 16) identified their company or the organization. The study was intended to generalize only to the commercial space industry; as such, a purposive sample comprised of industry professionals was used. Purposive sampling has a smaller sample size that is comprised of experts providing feedback in greater depth (Remler and Van Ryzin, 2011). Therefore, it was determined that the sample size comprised of 24 surveys would be sufficient to determine the industry needs.

Sources of the Data

The data were obtained from the completed industry surveys that were used for the development of the degree. The survey was posted on SurveyMonkey.com ("Industry Survey," 2012). The industry professionals who completed the surveys were attendees of the 2012 National Space & Missile Materials Symposium and the NewSpace 2012 Space Conference.

Instrument reliability. The reliability of the survey instrument was tested through using two separate questions for each topic. The first question asked the participant to determine the suitability of different subjects within a particular topic, whereas the second question asked the participant to rate the suitability of the particular topic. Therefore, if the participant gave high ratings to the suitability of the subjects within each topic, then the participant should give a high rating to the suitability of the topic itself.

Instrument validity. The validation of the survey instrument was done through collaborative development by the Principal Investigator, Dr. Lance Erickson, Research Assistant, Rebecca Zgorski, and the researcher of this study. The survey was reviewed by the Applied Aviation Sciences Department Chair, Dr. Guy Smith, for content validity and by the Chief Executive Officer of NewSpace Global, Richard David, for relevance to the industry. Additionally, the survey was developed after research was conducted regarding the various dynamics of the commercial space industry including industry growth, market development, and job skill requirements.

Treatment of the Data

The responses are displayed herein as frequency tables to determine industry interests. For each topic, the first question asked the participant to rate the suitability of individual subjects within the topic on a scale as Required, Desirable, Optional, or Not Useful. For each topic, the second question asked the participant to rate suitability of the topic itself on a scale as Strongly Agree, Agree, Disagree, or Strongly Disagree. The survey responses were transferred to SPSS for analysis. Responses indicating Required or Strongly Agree were coded as 4, responses indicating Desirable or Agree were coded as 3, responses indicating Optional or Disagree were coded as 2, and responses indicating Not Useful or Strongly Disagree were coded as 1.

Descriptive statistics. Questions 1 – 34 on the survey used frequency distribution to determine the survey results. This enabled the researcher to place the topics in a hierarchy of suitability. Therefore, the researcher could determine the industry's interest. The survey was comprised of 17 topics focusing on technical (science-related) and non-technical facets of commercial spaceflight. Each topic was divided into two separate questions: one question validating the suitability of several different subjects within each topic, and the other question validating the suitability of the topic itself.

Besides the 34 questions that asked the participant to rate the suitability of each subject, the survey contained two opinion questions and five comment questions. Question 35 asked the participant to determine whether a potential degree graduate would be a hirable candidate for a full-time position. Question 36 asked whether a student enrolled in the degree program would be an attractive candidate for co-op or internship. For Questions 35 and 36, the options available were: Yes, No, or Maybe. Questions 37 through 41 asked the survey respondent to provide background data: (a) company name, (b) comments on the core curriculum, (c) comments on the degree program, (d) other comments, and (e) contact information. The survey is located in Appendix A.

Reliability testing. To measure the reliability of the industry survey responses, due to the ordinal nature of the data, Spearman correlations were calculated between the means of the subjects in a topic and the mean of the topic itself.

Qualitative data. The last segment of the survey (Questions 37 through 41) was comprised of a comments section. Survey participants who provided comments and/or recommendations provided greater insight into the curriculum development. Comments were incorporated into the degree development process since they provided insight and depth into industry needs. The qualitative data enabled the researcher to analyze, from a strategic perspective, what the industry is seeking. Qualitative data is compiled in Appendix B.

Chapter IV

Results

Descriptive Statistics

The 17 topics in the industry survey were comprised of 75 subjects. The descriptive statistics display the sum, the mean, and the standard deviation for each subject. Each table also includes the sum, the mean, and the standard deviation for the topic itself. The means range between 1 and 4; a mean of 1 indicates a subject or topic is not necessary, a mean of 2 indicates a subject or topic is optional, a mean of 3 indicates a subject or topic is desirable, and a mean of 4 indicates a subject or topic is required.

The sum, mean, and the standard deviation for Propulsion related subjects are displayed in Table 1. The Propulsion category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Orbit related subjects are displayed in Table 2. The Orbit category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Space History related subjects are displayed in Table 3. The Space History category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Microgravity related subjects are displayed in Table 4. The Microgravity category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Human Physiology related subjects are displayed in Table 5. The Human Physiology category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Life Support Systems related subjects are displayed in Table 6. The Life Support Systems category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Space Radiation related subjects are displayed in Table 7. The Space Radiation category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Habitation Outposts related subjects are displayed in Table 8. The Habitation Outposts category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Human Factors related subjects are displayed in Table 9. The Human Factors category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Space Manufacturing related subjects are displayed in Table 10. The Space Manufacturing category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Spacecraft Systems related subjects are displayed in Table 11. The Spacecraft Systems category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Satellite Applications related subjects are displayed in Table 12. The Satellite Applications category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Space Communications related subjects are displayed in Table 13. The Space Communications category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Space Stations related subjects are displayed in Table 14. The Space Stations category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Military Space Operations related subjects are displayed in Table 15. The Military Space Operations category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Commercial Space Programs related subjects are displayed in Table 16. The Commercial Space Programs category mean was a result of the sum of all of the subjects in each topic.

The sum, mean, and the standard deviation for Space Policy and Law related subjects are displayed in Table 17. The Space Policy and Law category mean was a result of the sum of all of the subjects in each topic.

Table 1

Propulsion Related Subjects

	N	Sum	Mean	Std. Dev.
Rocket Propulsion Basics	24	92	3.83	.381
Booster Environmental Concerns and Regulation	24	79	3.29	.624
Commercial Launchers and Boosters	24	91	3.79	.415
Propulsion Category			3.64	.539
Do you agree that Propulsion would be suitable as part of the degree program?	24	92	3.75	.532

Table 2

Orbit Related Subjects

	N	Sum	Mean	Std. Dev.
Basic Orbits and Parameters	24	93	3.88	.448
3-body Orbits	24	74	3.08	.717
Launch Windows	24	82	3.42	.654
Rendezvous and Docking Operations	24	78	3.25	.794
Flight Operations Simulations	24	87	3.63	.495
Orbit Category			3.45	.684
Do you agree that Orbits would be suitable as part of the degree program?	24	88	3.67	.482

Table 3

Space History Related Subjects

	N	Sum	Mean	Std. Dev.
Cold War and the Space Race	24	69	2.88	.680
Robotic Exploration	24	72	3.00	.933
Manned Exploration	24	72	3.00	.885
Apollo & Space Shuttle – Lessons Learned	24	83	3.46	.833
Space History Category			3.08	.854
Do you agree that Space History would be suitable as part of the degree program?	24	79	3.29	.550

Table 4

Microgravity Related Subjects

	N	Sum	Mean	Std. Dev.
Microgravity Experiments and Research	24	75	3.13	.900
Microgravity Effects on Human Physiology	24	74	3.08	.881
Microgravity Category			3.10	.881
Do you agree that Microgravity would be suitable as part of the degree program?	24	78	3.25	.608

Table 5

Human Physiology Related Subjects

	N	Sum	Mean	Std. Dev.
Basic Human Physiology	24	71	2.96	.955
Space Radiation Effects on Humans	24	75	3.13	.900
Psychological Stress in Long-Duration Space Flight	24	71	2.96	.955
Human Physiology Category			3.01	.927
Do you agree that Human Physiology would be suitable as part of the degree program?	24	74	3.08	.776

Table 6

Life Support Systems Related Subjects

	N	Sum	Mean	Std. Dev.
Basic Life Support Requirements	23	79	3.45	.728
Basic Space Life Support Systems	23	79	3.44	.662
Evolving Life Support Technology	23	72	3.13	.694
Life Support Systems Category			3.33	.700
Do you agree that Life Support Systems would be suitable as part of the degree program?	23	72	3.13	.626

Table 7

Space Radiation Related Subjects

	N	Sum	Mean	Std. Dev.
Solar Radiation Characteristics	23	75	3.26	.810
Radiological Health Hazards	23	70	3.04	.878
Space Radiation Category			3.15	.842
Do you agree that Space Radiation would be suitable as part of the degree program?	23	74	3.22	.671

Table 8

Habitation Outposts Related Subjects

	N	Sum	Mean	Std. Dev.
Lunar Outpost Concepts	23	58	2.57	.728
Mars Outpost Concepts	23	57	2.48	.846
Economics of Outpost Development	23	68	2.96	.878
Habitation Outpost Category			2.67	.834
Do you agree that Habitation Outposts would be suitable as part of the degree program?	23	68	2.96	.706

Table 9

Human Factors Related Subjects

	N	Sum	Mean	Std. Dev.
Human Performance in Extreme Environments	23	72	3.13	.869
Human Errors and Error Measurements	23	73	3.17	.834
Astronaut and Cosmonaut Training	23	66	2.87	.694
Human Factors Category			3.06	.802
Do you agree that Human Factors would be suitable as part of the degree program?	23	73	3.17	.491

Table 10

Space Manufacturing Related Subjects

	N	Sum	Mean	Std. Dev.
Space Manufacturing Concepts	23	73	3.17	.887
Lunar & Martian Surface Materials	23	60	2.61	.839
Asteroid and Comet Composition	23	59	2.57	.843
Logistics and Economics of Space Manufacturing	23	71	3.09	.900
Space Manufacturing Category			2.86	.901
Do you agree that Space Manufacturing would be suitable as part of the degree program?	23	72	3.13	.458

Table 11

Spacecraft Systems Related Subjects

	N	Sum	Mean	Std. Dev.
Basic Spacecraft Systems	23	89	3.87	.344
Space Project Management	23	80	3.48	.790
Spacecraft Systems Category			3.67	.634
Do you agree that Spacecraft Systems would be suitable as part of the degree program?	23	86	3.74	.449

Table 12

Satellite Applications Related Subjects

	N	Sum	Mean	Std. Dev.
Space Environment	23	85	3.70	.559
Earth Satellite Orbits	23	83	3.61	.656
Remote Sensing and Reconnaissance from Space	23	78	3.39	.783
Space-Based Navigation	23	80	3.48	.730
Communications Satellites	23	72	3.13	.869
Weather Satellites	23	70	3.04	.825
Exploration Satellites	23	69	3.00	.798
Satellite Applications Category			3.33	.782
Do you agree that Satellite Applications would be suitable as part of the degree program?	23	78	3.39	.583

Table 13

Space Communications Related Subjects

	N	Sum	Mean	Std. Dev.
Spacecraft Communication Basics	23	81	3.52	.790
Interplanetary Communications	23	60	2.61	.839
Space Communications Category			3.06	.929
Do you agree that Space Communications would be suitable as part of the degree program?	23	73	3.14	.576

Table 14

Space Stations Related Subjects

	N	Sum	Mean	Std. Dev.
History of Space Stations	23	51	2.22	.850
Space Station Experiments	23	63	2.74	.915
International Space Station	23	72	3.13	.757
Space Stations Category			2.70	.851
Do you agree that Space Stations would be suitable as part of the degree program?	23	72	3.17	.388

Table 15

Military Space Operations Related Subjects

	N	Sum	Mean	Std. Dev.
Military Space Programs	23	64	2.78	.850
Military Space Commands	23	58	2.52	.730
Military Space Operations Category			2.65	.805
Do you agree that Military Space Operations would be suitable as part of the degree program?	23	71	3.09	.515

Table 16

Commercial Space Programs Related Subjects

	N	Sum	Mean	Std. Dev.
Commercial Launch Vehicles	23	87	3.78	.422
Suborbital Space Flight Programs	23	76	3.30	.822
NASA Commercial Orbit Transportation System (COTS)	23	74	3.22	.850
Commercial Space Research	23	74	3.22	.736
Space Tourism Programs	23	67	2.91	.900
Basic Program Management	23	80	3.48	.846
Commercial Space Programs Category			3.32	.810
Do you agree that Commercial Space Programs would be suitable as part of the degree program?	23	80	3.48	.511

Table 17

Space Policy and Law Related Subjects

	N	Sum	Mean	Std. Dev.
Introduction to Space Policy and Law	23	83	3.61	.583
Military Influence on Space Policy and Law	23	74	3.22	.795
International Space Policy and Law	23	80	3.48	.593
Space Policy and Commercial Space Operations	23	79	3.45	.788
Space Policy and Law Category			3.45	.700
Do you agree that Space Policy and Law would be suitable as part of the degree program?	23	78	3.39	.499

The means for each topic are displayed in Table 18 ranked from the highest to the lowest score. Considering that the range of possible scores was between 1 and 4 with a value of 4 indicating Required and a value of 1 indicating Not Useful, the majority of the topics (n = 13) had a mean above 3 indicating Desirable. This indicates that the majority of the topics were deemed Desirable by the industry survey respondents.

Table 18

Category Means

Topics	Mean	SD
1. Spacecraft Systems	3.67	0.634
2. Propulsion	3.64	0.539
3. Orbits	3.45	0.684
4. Space Policy and Law	3.45	0.700
5. Satellite Applications	3.34	0.782
6. Life Support Systems	3.33	0.700
7. Commercial Space Programs	3.32	0.810
8. Space Radiation	3.15	0.842
9. Microgravity	3.10	0.881
10. Space History	3.08	0.854
11. Space Communications	3.07	0.929
12. Human Factors	3.06	0.802
13. Human Physiology	3.01	0.927
14. Space Manufacturing	2.86	0.897
15. Space Stations	2.70	0.912
16. Habitation Outposts	2.67	0.834
17. Military Space Operations	2.65	0.795

Reliability Testing

The industry survey responses were tested for reliability using a non-parametric correlation test due to the ordinal nature of the data. A Spearman's *rho* measured at $p < .05$ was used to measure any relationship between the suitability mean of each category within a topic and the suitability mean of the topic itself. Table 19 displays the correlations for each topic, ranked from the highest correlation to the lowest.

Table 19

Correlations Between Categories and Topics

Category (Average of Subjects Within a Topic)	Suitability of the Topic Itself	r_s	R^2	Sig
1. Satellite Applications	Satellite Applications	.846	.716	.000
2. Spacecraft Systems	Spacecraft Systems	.840	.706	.000
3. Microgravity Experiments	Microgravity Experiments	.810	.656	.000
4. Human Physiology	Human Physiology	.806	.650	.000
5. Space Radiation	Space Radiation	.758	.575	.000
6. Habitation Outposts	Habitation Outposts	.754	.569	.000
7. Space Communication	Space Communication	.714	.510	.000
8. Life Support Systems	Life Support Systems	.685	.469	.000
9. Human Factors	Human Factors	.675	.456	.000
10. Space Manufacturing	Space Manufacturing	.613	.376	.002
11. Space Policy and Law	Space Policy and Law	.594	.353	.003
12. Commercial Space Ops	Commercial Space Ops	.592	.351	.003
13. Orbit	Orbit	.564	.318	.004
14. Space Stations	Space Stations	.552	.305	.006
15. Military Space Ops	Military Space Ops	.427	.182	.042
16. Space History	Space History	.399	.159	.053
17. Propulsion	Propulsion	.276	.076	.192

Chapter V

Discussion, Conclusions, and Recommendations

Current and Emerging Markets

The results from the industry survey may be an indicator of the industry's current interests and what skills the industry survey participants deem necessary, based on the current market. In Table 18, the industry survey topics were listed in a ranked order from the most important to the least. There may be a direct overlap between the ranking of the survey topics and the current market demands for such skills. Figure 1 is the commercial space (or "NewSpace") market spectrum from existing to potential markets as conceived by NewSpace Global (NSG), an information service provider for the commercial space industry (NewSpace Global, 2013). The spectrum, titled the *8-Verticals of NewSpace*^{TM}, offers a spectrum of current and emerging markets beginning with current markets on the left side and progressing towards emerging and future markets on the right side. The survey results have an overlap with the progression of markets from current to future.

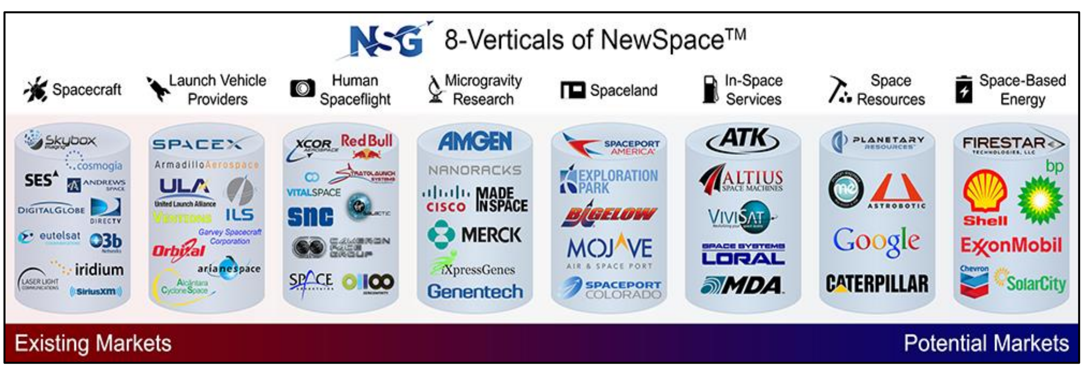

Figure 1. NewSpace Global's Current and Emerging Markets in the Commercial Space Industry.

Discussion

The first market, spacecraft, is a currently existing market associated with the development and operation of satellites. Integral to spacecraft and even launch vehicles are disciplines associated with spacecraft systems, propulsion, and orbits. The knowledge of spacecraft systems is critical in understanding the functional capabilities of a satellite or a rocket. Similarly, understanding the concepts of propulsion and orbits are critical to understand launch and orbital operations. Being critical to space operations, these three topics are the top three on the industry survey.

The topic of space policy and law, ranked fourth, provides a governing framework under which commercial spacecraft development, launch operations, satellite operations, and human spaceflight occur. Space policy at the national and international level impacts the operational facets of commercial space operations. Satellite applications, ranked fifth, is also a critical topic based on the industry response. Satellite applications in the commercial market has been the mainstay of the commercial space industry for over two decades. Functionality of satellites for commercial purposes is synonymous with the current market, spacecraft.

Progressing from the traditional commercial space markets to the emerging market of human spaceflight, a similar progression can be seen in the industry survey topics. Life support systems, ranked sixth, is critical for human spaceflight. For commercial space companies, the topic begins to take greater precedence as human spaceflight draws nearer. The topic of commercial space programs, ranked seventh, indicates that, while not a critical topic, developing an understanding of specific programs and the business potential of various markets is important to the industry and a desired topic within the curriculum.

The topic of space radiation focuses on the characteristics of solar radiation and its impact on human spaceflight operations. The topic's eight ranking may be related to the fact that human spaceflight has yet to become a primary market; thus, the topic is useful yet not critical within the curriculum. Microgravity research for commercial applications in the pharmaceutical and technology industry is not a near-term market. No commercial enterprise is currently offering a platform to conduct research in a microgravity environment. Until such a development does occur, microgravity will not be on the forefront of the commercial space market; thus as a topic, microgravity was ranked ninth due to the lack of near-term viability.

Historically, the space program has been a public endeavor undertaken with political support and a robust budget to proliferate developments in the space sector. Space history offers lessons spanning five decades for the industry to draw upon. However, unlike the public space program, the commercial space industry strives for profit and plans to undertake endeavors that will provide return on their investments. While the commercial space industry can learn from prior space programs, a strong interest did not exist, leading to the topic being ranked tenth. Space Communications as a topic ranked 11^{th}; while the basics of the topic are considered important, the topic overall was not deemed critical. Space communication is a component of any space operation; therefore, integrating the topic with the specific market services and products may be of greater interest than space communication as a stand-alone topic.

Human factors and human physiology were ranked 12^{th} and 13^{th} respectively. Both of these topics are integral to the human spaceflight market. The human spaceflight market, divided between the primarily tourism-based suborbital market and the NASA contracts orbital market, is not currently an existing market. In fact, suborbital flights, governed by the FAA, will not begin until late 2013 or early 2014. The FAA has a continually evolving set of regulations governing human spaceflight; suborbital flights have less stringent requirements than orbital flights. In the near future, orbital spaceflight in the commercial market will be limited to manned missions to and from the ISS under NASA contracts. For such flights, NASA standards for human spaceflight will act as the governing standard. Due to the multiple agency standards for human spaceflight and the lack of a mature market for human spaceflight, topics such as human factors and human physiology may not currently be of great importance to the commercial space industry.

Space manufacturing, space stations, and habitation outposts ranked 14^{th}, 15^{th}, and 16^{th} respectively. These topics are associated with the future markets of spaceland, in-space service, and space resources. In the current state of the industry, these markets do not have a near-term potential; in fact, these markets require high levels of capital and resources. As such, these topics will provide students with the knowledge of future long-term industry markets. The industry, in its current state, may not see these topics as necessary to be included in the degree curriculum, thus leading to a low ranking compared to other topics. The last topic, military space operations, is not directly related to commercial space operations. In fact, the very purposes of commercial and military space operations are unrelated; for commercial space companies, understanding military space operations does not help a student to be better equipped to enter the commercial space industry.

Reliability Analysis

The sample size for the correlations was either 23 or 24; thus, the critical values for statistical significance, measured at $p < .05$ were .415 and .406 respectively. The correlations indicated that 15 of the 17 topics were statistically significant. A strong correlation indicates that a relationship exists between the respondent ratings for each subject and the suitability of the topic itself. A negligible correlation coefficient may indicate increased variability in the scores of the individual subjects in a topic.

The interpretation of each correlation not only serves as a measure of reliability, but also as a measure of the industry's interests in the survey topics. Analysis of the correlations in relation to the topic itself and the subject means will provide further insight into the industry interests in relation to the current and developing markets in the commercial space industry.

The very strong correlations for satellite applications, spacecraft systems, microgravity experiments, and human physiology indicate that the industry interest in these topic as well as the subjects within each topic is directly related. There is a high level of consistency between the significance of the topic itself in relation to the markets and the specific subjects within each topic. The consistency in scores could either indicate that both the topic itself and the subjects within each topic are highly suitable or not suitable at all. When the correlation for each topic is compared with the market viability of a particular topic, a clearer picture emerges of the relevance of each topic.

The topics of satellite applications and spacecraft systems generated strong interest among the survey participants. Also, both of these topics are relevant to the current and near term markets. Therefore, both of the topics and the subjects within each topic are considered relevant and critical. Incorporating these topics in depth within the curriculum may be needed. Microgravity experiment and human physiology also had very strong correlations; however, the means for both of the topics ranked relatively low. The comparatively low means, the very strong correlations, and the lack of near-term market viability indicate that the industry interest in both of the topics and the subjects within each topic is limited. Incorporating general understanding of the topics within the curriculum may be sufficient.

Space radiation, habitation outposts, space communication, life support systems, human factors and space manufacturing had strong correlations. When comparing the correlations in relation to the rank of the means for each topic and comparing that to the listed markets, a clearer picture emerges. The topics of life support systems and space radiation were among the top ten means. Specifically, the industry participants considered the subjects within life support systems to be suitable in addition to considering the topic itself suitable. Similar results were observed for space radiation as well but with a slightly lower mean. However, when taking market viability into consideration, life support systems is more desirable than space radiation; therefore, greater emphasis should be placed on life support systems than space radiation in the curriculum.

Habitation outposts and space manufacturing ranked among some of the lowest means. A strong correlation for habitation outpost can be attributed to the general disinterest by the survey participants in the topic and the subjects within the topic. Considering that habitation development is a future market, it may not be of interest to the industry. Similarly, space manufacturing had a correlation that indicated industry interest in the topic as well as the subjects within the topic was somewhat low. The consistency in how the subjects and the topic itself were scored led to a strong correlation. The low mean of the topic and lack of near-term market for space manufacturing indicates that general concept of the topic may be suitable in the curriculum.

The means for space communication and human factors ranked 11th and 12th respectively and both of the topics had strong correlations as well. Compared to habitation outpost and space manufacturing, the means for space communication and human factors ranked higher. Thus, the relatively strong correlations indicate that interest was shown for both of the topics and the subjects within each topic. In the case of these two topics, incorporating the subjects within each topic into the curriculum may be more suitable.

Space policy and law had the fourth highest mean yet a moderate correlation. Considering that a strong industry interest existed in the topic, the moderate correlation may be indicative of varying interest in certain subjects. Overall, the interest in the topic itself and the subjects within the topic was high; however, one of the subjects had a lower mean compared to the other subjects, attributed to the moderate correlation. Due to the strong industry interest in most of the subjects within the topic as well as the topic itself, space policy and law should be a critical component of the curriculum.

Commercial space programs had a relatively high ranking mean but a moderate correlation. Industry participants indicated interest in the topic and many of the subjects within the topic. This fact that the means for the subjects varied from a very strong mean to a comparatively weak mean, led to the moderate correlation. However, particular subjects within the topic would be suitable in the curriculum. Thus, when incorporating this topic into the curriculum, subjects of the greatest relevance must be chosen.

Orbit had the third highest mean, indicating a strong industry interest, but it had a moderate correlation. Orbit is a fundamental part of space operations and a requirement in the curriculum. The correlation indicates that the survey participants did not consider every subject within the topic suitable, even though the topic was considered highly suitable within the curriculum. The variability in the means of the subjects compared to the mean for the suitability of the topic itself resulted in the moderate correlation. Due to the importance of the topic to the curriculum, subjects of the greatest relevance must be chosen.

Space stations had a low ranking mean and low interest in most of the subjects. Considering that space stations is a future market, the relevance of the topic within the curriculum diminishes. In fact, the subject means indicated weak industry interest. General understanding of space stations may be sufficient to be included within the curriculum. Military space operations had a weak correlation as well as the lowest mean, thus, indicating lack of interest and relevance to the curriculum. Space history had a weak correlation that was not significant. Of interest was only one subject within the topic, yet the topic itself was considered suitable. This disparity indicates that the subject of interest should be incorporated into the curriculum.

Propulsion had a weak correlation that was not significant and the second highest mean. The subjects within the topic also had very high means and the survey participants considered the topic highly suitable within the curriculum. The strong interest in all of the topics as well as a high mean for the suitability for the topic itself greatly reduced the variability and resulted in a weak correlation. In the case of propulsion, a weak correlation was due to a strong interest. As such, subjects within the topic and the general concepts of the topic need to be incorporated into the curriculum.

Conclusions

The growth of the commercial space industry will expand new markets within the industry and increase the demand for individuals who possess the knowledge and skills to address issues highlighted by the DOT, FAA, NASA, and the commercial space industry. The wide array of skills listed by the various government agencies requires individuals who can address the numerous aspects of commercial spaceflight. Addressing these issues is a challenge, since identifying what skills the commercial space industry needs is only the first step to a viable curriculum. The different skills and facets of commercial space operations identified by the DOT, FAA, NASA, and the commercial space industry indicate that an eclectic collection of skills that span different fields is needed for the industry to succeed.

Identification of the skills has not resolved how to address the needs of the commercial space industry. The commercial space industry is still in a nascent stage and is expanding in directions that one can only predict. New companies continue to emerge in the market announcing they will do something that has not been pursued before, thereby expanding the scope of the commercial space industry. What is fiction today may become a fact tomorrow.

Working with the industry to develop education that can support the commercial space industry's needs becomes critical. Developing education in the early stages of the commercial space industry enables parallel development between education and the commercial space industry. It also assures that the education developed has a high level of integrity and meets the needs of the industry.

Thus, during the development of the undergraduate degree in CSO at ERAU, an industry survey was created to gain feedback from the members of the commercial space industry. The survey had parallels, and in some cases overlap with the skills identified by the various government agencies and markets within the commercial space industry. The industry survey addressed the current issues facing the need for different skills within the commercial space industry. Furthermore, the industry survey topics addressed both near-term and long-term markets.

The industry survey addressed the needs of the commercial space industry in a holistic manner. The results of the industry survey indicate that, to develop education that can meet the needs of the commercial space industry, numerous topics must be covered to a varying degree. The results were consistent with the skills identified for current and emerging markets within the commercial space industry. What the industry survey results indicated was that developing an undergraduate degree in Commercial Space Operations will require inclusion of topics spanning many different disciplines.

Recommendations

Recognizing the need to gain industry input in the degree development process was critical to developing a curriculum that fulfills the industry's needs. However, the importance of industry input extends beyond the degree development process; to equip the future graduates of the degree with the skills that are applicable in the industry, continuous agency and industry feedback and partnership becomes crucial. The following recommendations are intended to strengthen the curriculum of the degree program.

Agency partnership. Government regulatory agencies establish the rules and procedures that regulate the commercial space industry. Moreover, regulatory agencies provide oversight and support the development of the commercial space industry. Partnership with regulatory agencies enables the curriculum to be up-to-date regarding factors that constrain the commercial space industry, including regulatory constraints. Understanding the regulatory framework within which the commercial space industry operates, enables the curriculum developers to integrate material that reflects the regulatory requirements of the commercial space industry.

Industry partnership. To develop course material that can provide the students with the knowledge and skills practicable in the industry, continuous partnership with members of the commercial space industry becomes necessary. The degree curriculum can be strengthened through collaboration with commercial space companies to develop, review, and revise course material that reflects the needs of the commercial space industry. Furthermore, developing those needs into courses can be extended further to support student development. Industry partnership also entails supporting student research and projects relevant to the commercial space industry in collaboration with the industry. Thus, both the students as well as the commercial space companies benefit. By helping students enhance their understanding of industry operations, the commercial space industry is equipping the students with the skills to support the commercial space industry. The students, on the other hand, learn how to apply academic learning to a practical industry environment.

References

Aviation Accreditation Board International. (2012). *Accreditation criteria manual*. Retrieved from http://www.aabi.aero/Forms&Pubs/AABI%20201%20Accreditation%20Criteria%20Rev.%207-20-12.pdf

American Military University. (2012). *Program description.* Retrieved from http://www.amu.apus.edu/academic/programs/degree/1264/bachelor-of-science-in-space-studies

Arianespace. (2011). *Corporate information: Shareholders*. Retrieved from http://www.arianespace.com/about-us-corporate-information/shareholders.asp

Butler, M. (2004). *Outcome based/outcome focused education*. Retrieved from http://www.docstoc.com/docs/53849063/Outcomes-Based-Education-(OBE)

Commercial Space Committee. (2012). *Report of the commercial space committee NASA advisory council.* (Issue Brief).NASA.

David, L. (2012, June 8). Virgin Galactic to launch passengers on private spaceship in 2013. *Space.com*. Retrieved from http://www.space.com/16057-virgin-galactic-spaceshiptwo-launches-2013.html

Davies, A. (2012, October 22). Here's the spaceship that will let rich people fly from NYC to Tokyo in 90 minutes. *Business Insider*. Retrieved from http://www.businessinsider.com/xcor-reveals-full-scale-model-of-lynx-2012 10?op=1

Dillingham, G. (2012). *Commercial space transportation: Industry trends, government challenges, and international competitiveness issues.* (Testimony before the Subcommittee on Science and Space, Committee on Commerce, Science, and Transportation, U.S. Senate No. GAO 12-836T). Washington, DC: Government Accountability Office.

Embry-Riddle Aeronautical University. (n.d.a). *Embry-Riddle mission and vision*. Retrieved from http://www.erau.edu/about/mission.html

Embry-Riddle Aeronautical University. (n.d.b). *Mission of the College of Aviation*. Retrieved from http://daytonabeach.erau.edu/coa/administration/about-coa/mission-statement/index.html

Embry-Riddle Aeronautical University. (n.d.c). *Mission statement*. Retrieved from http://daytonabeach.erau.edu/coa/applied-aviation-sciences/mission-statement/index.html

Federal Aviation Administration. (2002) *First quarter 2002 quarterly launch report*. Washington, DC: FAA Office of Commercial Space Transportation.

Federal Aviation Administration. (2007). *AST skill sets*. FAA Office of Commercial Space Transportation. Retrieved from http://www.faa.gov/about/office_org/ headquarters_offices/ast/careers/skillset/

Federal Aviation Administration. (2011a). *2011 U.S. commercial space transportation developments and concepts: Vehicles, technologies, and spaceports*. Washington, DC: FAA Office of Commercial Space Transportation.

Federal Aviation Administration. (2011b). *The U.S. commercial suborbital industry: A space renaissance in the making* (No. HQ-111460.INDD). Washington, DC: Author.

Federal Aviation Administration. (2012a). *2012 commercial space transportation forecasts* (No. HQ-121583.INDD). Washington, DC: FAA Office of Commercial Space Transportation.

Federal Aviation Administration. (2012b). *Commercial space transportation: 2011 year in review* (No. HQ121525.INDD). Washington, DC: FAA Office of Commercial Space Transportation.

Federal Aviation Administration. (2012c). *Overview of the Center of Excellence for commercial space transportation.* Washington, DC: FAA Office of Commercial Space Transportation Center of Excellence.

Fichtenbaum, I. (2009, January). INSIGHT: Satellites—Bigger or smaller? yes! *SatMagazine,* Retrieved from http://www.satmagazine.com/cgi-bin/display_article.cgi?number=1436181447

Foust, J. (2007, March). Current issues in NewSpace. *The Space Review*. Retrieved from http://www.thespacereview.com/article/823/1

Franklin University. (n.d.). *Ensuring academic quality*. Retrieved from http://www.franklin.edu/about-franklin/mission-philosophy/four-cornerstones-of-educational-philosophy/ensuring-academic-quality#1

Gardiner, L. (n.d.). *Designing a college curriculum*. Retrieved from the National Academy for Academic Leadership website: http://thenationalacademy.org/ readings/designing.html

Government Accountability Office. (2006). *Commercial space launches: FAA needs continued planning and monitoring to oversee the safety of the emerging space tourism industry* (Report to the Ranking Democratic Member, Committee on Transportation and Infrastructure, House of Representatives No. GAO-07-16). Washington, DC: Government Accountability Office.

Government Accountability Office. (2012). *Commercial space launches: FAA should update how it assess federal liability risk* (Report to Congressional Committees No. GAO-12-899). Washington, DC: Government Accountability Office.

Grantham, K. B., Perrotto, T. J., & Thomas, C. (2012, July 12). *NASA commercial partner Spacex completes Dragon design review* [Press Release]. Retrieved from http://www.nasa.gov/home/hqnews/2012/jul/HQ_12-233_SpaceX_CBR.txt

Herszenhorn, D. M. (2011, November 14). Russian rocket gives NASA a lift to space station. *The New York Times.* Retrieved from http://www.nytimes.com /2011/11/15/world/europe/russian-rocket-gives-nasa-a-lift-to-space-station.html?_r=0

Hunter, R.A. (2010). *Point-to-point commercial space transportation in the national aviation system*. Cambridge, MA: Department of Transportation Research and Innovative Technology Administration John A. Volpe National Transportation Systems Center.

Industry survey. (2012). Retrieved from the SurveyMonkey website: http://www.survey monkey.com

International Space University. (2011). *Space studies program.* Retrieved from http://www.isunet.edu/programs/space-studies-program

Kaliannan, M., & Suseela, D. C. (2012). Empowering students through outcome-based education (OBE). *Research in Education*, (87), 50-63. Retrieved from http://search.proquest.com. ezproxy.libproxy.db.erau.edu/docview/1030133929?accountid=27203

Krejcie, R. V. & Morgan, D. W. (1970). Determining size for research activities. *Education and Psychological Measurement, 30*, 607- 610. Retrieved from http://sunburst.usd. edu/~mbaron/edad810/Krejcie.pdf

Knapp, A. (2012, August 3). NASA awards over $1 billion in contracts to develop commercial spaceflight. *Forbes*. Retrieved from http://www.forbes.com/sites /alexknapp/2012/08/03/nasa-awards-over-1-billion-in-contracts-to-develop-commercial-spaceflight/

Mango, E., Gerace, C., Peters, J., Bayt, R., Leuders, K., & Jett, B. (2011). *Commercial crew program requirements workshop presentation*. Titusville, FL: National Aeronautics and Space Administration: Commercial Crew Program.

National Aeronautics and Space Administration. (2008). *Human-rating requirements for space system* (No. NPR 8705.2B). Titusville, FL: NASA Office of Safety and Mission Assurance.

National Aeronautics and Space Administration. (2012a). *Commercial crew program.* Retrieved from http://commercialcrew.nasa.gov/index.cfm

National Aeronautics and Space Administration. (2012b). *NASA return on investment report: June, 2012*. Author.

National Aeronautics and Space Administration. (2013*). NASA's consolidated launch schedule*. Retrieved from http://www.nasa.gov/missions/highlights/schedule.html

Naval Postgraduate School. (2012). *Master of science space systems operations (MSSSO).* Retrieved from http://www.nps.edu/Academics/DL/ DLPrograms/Programs/degProgs_MSSSO.html

NewSpace Global. (2013). *8-Verticals of NewSpace™*. Retrieved from http://www.news pacewatch.com/

Orbital Sciences. (2012). *Antares*. Retrieved from http://www.orbital.com/SpaceLaunch/ Antares/

Pasztor, A. (2011, February 9). Amazon chief's spaceship misfires. *The Wall Street Journal*. Retrieved from http://online.wsj.com/article/SB1000142405311190 4716604576546712416626614html?mod=googlenews_wsj

Perrotto, T., & Thomas, C. (2012). *NASA announces next steps in effort to launch Americans from U.S. soil.* [Press Release] Retrieved from http://www.nasa.gov /centers/ kennedy/ news/releases/2012/release-20120803.html

Ramsay, J. D., Cutrer, D. and Raffel, R. (2010, May). Development of an outcomes-based undergraduate curriculum in Homeland Security. *Homeland Security Affairs 6*, (2), 56 – 75. Retrieved from http://www.hsaj.org/?article=6.2.4

Remler, D. K., & Van Ryzin, G. G. (2011). *Research methods in practice:Strategies for description and causation*. Oakland, CA: Sage Publications. Inc

Ross, J. T. (1997). Industrial Feedback for a Microelectronics Curriculum. *Institute Electrical and Electronic Engineers*. Stockton, CA: University of the Pacific. doi: 10111299347

Satellite wars: China unveils 'cheaper' answer to GPS. (2012, December 27). *Russia Today*. Retrieved from http://rt.com/news/satellite-beidou-china-gps-944/

SpaceX. (2013). *Dragon overview*. Retrieved from http://www.spacex.com/dragon.php

Spady, W. (1994). *Outcomes based education: Critical issues and answe*rs. Arlington, VA: American Association of School Administration.

Strickland, J. K. (2012). *The SpaceX Falcon heavy booster: Why is it important?* Retrieved from http://www.nss.org/articles/falconheavy.html

The Spaceship Company. (2012). *Virgin Galactic acquires full ownership of the spaceship company* [Press Release]. Retrieved from http://www.thespaceshipcompany.com/ media/press_releases/virgin_galactic_acquires_full_ownership_of_the_spaceship_c ompany

The Tauri Group. (2012). *Suborbital reusable vehicles: A 10-year forecast of market demand*. Retrieved from http://www.taurigroup.com/files/ Suborbital_Reusable_ Vehicles_A_10_Year_ Forecast_of_Market_Demand.pdf

University of Colorado. (2011). *MESO.* Retrieved from http://www.uccs.edu/eas/meso_ proinfo.html

University of North Dakota. (2011). *Degree requirements overview.* Retrieved from http://space.edu/Academic Programs/ProgramRequirements.aspx

Wiggins, G., & McTighe, J. (1998). *Understanding by design* . Alexandria, VA: Association for Supervision and Curriculum Development.

Willis, S., & Kissane, B. (1995). *Outcome-based education: A review of the literature*. Perth, Western Australia: Department of Education.

Appendix A

Data Collection Device

Evaluate the following topics for their suitability as part of the degree program core.

1. **Propulsion, Boosters, and Launch Vehicles**

	Required	Desirable	Optional	Not Useful
Rocket Propulsion Basics	○	○	○	○
Booster Environmental Concerns and Regulation	○	○	○	○
Commercial Launchers and Boosters	○	○	○	○

2. **Do you agree that the Propulsion topics would be suitable as part of the Commercial Space Operations degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

3. **Orbits**

	Required	Desirable	Optional	Not Useful
Basic Orbits and Parameters	○	○	○	○
3-body Orbits	○	○	○	○
Launch Windows	○	○	○	○
Rendezvous and Docking Operations	○	○	○	○
Flight Operations Simulations	○	○	○	○

4. **Do you agree that the Orbits topics would be suitable as part of the degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

5. **Space History**

	Required	Desirable	Optional	Not Useful
Cold War and the Space Race	○	○	○	○
Robotic Exploration	○	○	○	○
Manned Exploration	○	○	○	○
Apollo & Space Shuttle - Lessons Learned	○	○	○	○

6. **Do you agree that the Space History topics would be suitable as part of the degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

7. **Microgravity**

	Required	Desirable	Optional	Not Useful
Microgravity Experiments and Research	○	○	○	○
Microgravity Effects on Human Physiology	○	○	○	○

8. **Do you agree that the Microgravity topics would be suitable as part of the degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

9. **Human Physiology**

	Required	Desirable	Optional	Not Useful
Basic Human Physiology	◯	◯	◯	◯
Space Radiation Effects on Humans	◯	◯	◯	◯
Psychological Stress in Long-Duration Space Flight	◯	◯	◯	◯

10. **Do you agree that the Human Physiology topics would be suitable as part of the degree program?**

◯ Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree

11. **Life Support Systems**

	Required	Desirable	Optional	Not Useful
Basic Life Support Requirements	◯	◯	◯	◯
Basic Space Life Support Systems	◯	◯	◯	◯
Evolving Life Support Technology	◯	◯	◯	◯

12. **Do you agree that the Life Support Systems topics would be suitable as part of the degree program?**

◯ Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree

13. **Space Radiation**

	Required	Desirable	Optional	Not Useful
Solar Radiation Characteristics	◯	◯	◯	◯
Radiological Health Hazards	◯	◯	◯	◯

14. **Do you agree that the Space Radiation topics would be suitable as part of the degree program?**

◯ Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree

15. **Habitation Outposts**

	Required	Desirable	Optional	Not Useful
Lunar Outpost Concepts	◯	◯	◯	◯
Mars Outpost Concepts	◯	◯	◯	◯
Economics of Outpost Development	◯	◯	◯	◯

16. **Do you agree that the Habitation Outposts topics would be suitable as part of the degree program?**

◯ Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree

17. **Human Factors**

	Required	Desirable	Optional	Not Useful
Human Performance in Extreme Environments	◯	◯	◯	◯
Human Errors and Error Measurements	◯	◯	◯	◯
Astronaut and Cosmonaut Training	◯	◯	◯	◯

18. **Do you agree that the Human Factors topics would be suitable as part of the degree program?**

◯ Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree

19. **Space Manufacturing**

	Required	Desirable	Optional	Not Useful
Space Manufacturing Concepts	◯	◯	◯	◯
Lunar & Martan Surface Materials	◯	◯	◯	◯
Asteroid and Comet Composition	◯	◯	◯	◯
Logistics and Economics of Space Manufacturing	◯	◯	◯	◯

20. **Do you agree that the Space Manufacturing topics would be suitable as part of the degree program?**

◯ Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree

21. **Spacecraft Systems**

	Required	Desirable	Optional	Not Useful
Basic Spacecraft Systems	◯	◯	◯	◯
Space Project Management	◯	◯	◯	◯

22. **Do you agree that the Spacecraft Systems topics would be suitable as part of the degree program?**

◯ Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree

23. **Satellite Applications**

	Required	Desirable	Optional	Not Useful
Space Environment	○	○	○	○
Earth Satellite Orbits	○	○	○	○
Remote Sensing and Reconnaisence from Space	○	○	○	○
Space-Based Navigation	○	○	○	○
Communications Satellites	○	○	○	○
Weather Satellites	○	○	○	○
Exploration Satellites	○	○	○	○

24. **Do you agree that the Satellite Applications topics would be suitable as part of the degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

25. **Space Communications**

	Required	Desirable	Optional	Not Useful
Spacecraft Communication Basics	○	○	○	○
Interplanetary Communications	○	○	○	○

26. **Do you agree that the Space Communications topics would be suitable as part of the degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

27. **Space Stations**

	Required	Desirable	Optional	Not Useful
History of Space Stations	○	○	○	○
Space Station Experiments	○	○	○	○
International Space Station	○	○	○	○

28. **Do you agree that the Space Stations topics would be suitable as part of the degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

29. **Military Space Operations**

	Required	Desirable	Optional	Not Useful
Military Space Programs	○	○	○	○
Military Space Commands	○	○	○	○

30. **Do you agree that the Military Space Operations topics would be suitable as part of the degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

31. **Commercial Space Programs**

	Required	Desirable	Optional	Not Useful
Commercial Launch Vehicles	○	○	○	○
Suborbital Space Flight Programs	○	○	○	○
NASA Commercial Orbit Transportation System (COTS)	○	○	○	○
Commercial Space Research	○	○	○	○
Space Tourism Programs	○	○	○	○
Basic Program Management	○	○	○	○

32. **Do you agree that the Commercial Space Programs topics would be suitable as part of the degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

33. **Space Policy and Law**

	Required	Desirable	Optional	Not Useful
Introduction to Space Policy and Law	○	○	○	○
Military Influence on Space Policy and Law	○	○	○	○
International Space Policy and Law	○	○	○	○
Space Policy and Commercial Space Operations	○	○	○	○

34. **Do you agree that the Space Policy and Law topics would be suitable as part of the degree program?**

○ Strongly Agree ○ Agree ○ Disagree ○ Strongly Disagree

35. **Would you consider a graduate of the proposed Commercial Space Operations degree program attractive as an employee of your company or agency?**

- Yes
- No
- Maybe

36. **Would your company or agency be interested in students from this program for internships or coops?**

- Yes
- No
- Maybe

37. **Your company/agency name**

38. **Comments on the core curriculum:**

39. **Comments on degree program:**

40. **Other comments:**

41. Confidential and optional (not retained after survey analysis and not distributed)

Please provide contact information if you would like to receive information on the final degree program approval and its implementation.

Appendix B

Qualitative Data

Company	Digital Solid State Propulsion
Comments on the Core Curriculum	Basic principles including propulsion, gas dynamics, structures, controls, and orbital dynamics are all needed to build a good base for an aerospace engineer. Lessons learned is vital and I've been hunting for material in that area. Though a lot of failures remain hidden in the companies in agencies, the only way to avoid repeating them is to learn about them. A class on space/missile development and its relation to politics I think would be an incredible class to have. The sad fact of the matter is that a lot of the financing/control is done, in the end, by political entities. When resources are limited, its the ones that can do the best convincing that get the funds. I would take both of those classes even though I'm a graduate.
Comments on the Degree Program	What gap does a person with this degree fill? What position can the person with this degree dominate in? They're important questions that need to be asked. Trying to train a college grad to be a chief engineer right when he graduates would seem futile as a company would want someone with experience (again, someone that has a lot of lessons learned). Also, are you training an engineer or manager or entrepeneur? Another question that needs to be evaulated as each has a different career path.
Other Comments	It will take incredible foresight to be able to predict the path of the commercial space industry in the next few decades, but as it stands right now, I wouldn't invest in classes about lunar bases or mars bases or manufacturing in space. These classes can always be added later and to be able to do bases in space or on surfaces other than earth will require some technological advances and A TON of development work. The farther you go the more invested you have to be in terms of effort, money, and time (in some cases maybe as much as multiple generations).

Company	FAA AST
Comments on the Core Curriculum	A great set of topics!
Comments on the Degree Program	It will be important to find the right balance of technical topics, operational familiarity, and policy and legal topics.
Other Comments	-

Company	FAA AST
Comments on the Core Curriculum	Pg 17 of 21 Commercial Space Programs Also Needs to Add: Commercial Crew Development (CCDev) Program. Page 18/21 Space Policy & Law also needs to ADD: FAA Commercial Space Transportation Regulations.
Comments on the Degree Program	Needs to be a B.S. Degree & possibly meet ABET Engineering requirements to fit the current Job Description Announcements by NASA, FAA and Major Contractors.
Other Comments	Definite Need.

Company	Garvey Spacecraft Corporation
Comments on the Core Curriculum	-
Comments on the Degree Program	The core should provide technical competence. Want to avoid producing leaders / managers who fail to understand between what is physically possible and what is not.
Other Comments	Avoid getting distracted by the self-promotional hype and propaganda that is rampant in the "new space" arena. Same with NASA follow-the crowd promotions and "commercial space" initiatives.

Company	Humphries & Associates
Comments on the Core Curriculum	-
Comments on the Degree Program	Make sure that it is NOT $$$ to do!
Other Comments	Make sure they do hands on. Ie get "hands dirty" not just paper work. Do do projects, not just exams

Company	Ihrenes Space Enterprises
Comments on the Core Curriculum	Interesting range of topics to choose from and they have all a relevance some been more relevant that others!
Comments on the Degree Program	This degree program looks interesting and is a great way to get in to the commercial space industry.
Other Comments	I hope this degree program is set up and works out well.

Company	International Space Consultants
Comments on the Core Curriculum	I think the basic elements required to provide a broad background in commercial space operations are all included. That you've included policy, law, economics and business management elements is key.
Comments on the Degree Program	I think in the future focused training like this will be recognized as very valuable. But in the current transition, hiring managers expect graduates to fit in established slots - like 'operations management - with a focus on space operations'. You may get resistance to defining a completely new degree, even if that pays off in the long run.
Other Comments	Well thought out survey. Make sure you give highest weight to the representatives of space vehicle operators.

Company	Jacobs Technology Inc.
Comments on the Core Curriculum	Many of the topics I have marked as "Required" could be combined into single course offerings. The program needs to not define too many required course hours relative to other majors.
Comments on the Degree Program	Based on the volume of demand for graduates from such a program (which is currently quite low), I tend to favor a Master of Science program in Commercial Space Ops instead of an undergraduate B.S. program. I think the program will struggle to place a significant volume of graduates in the field. My opionion is admittedly not based on research into the matter, but rather represents a "gut" instinct.
Other Comments	I would be pleased to explain or discuss my feedback further if needed.

Company	SpaceGroundAmalgam, LLC
Comments on the Core Curriculum	I think the basic elements required to provide a broad background in commercial space operations are all included. That you've included policy, law, economics and business management elements is key.
Comments on the Degree Program	I believe the degree program, with the curriculum elements indicated, will produce graduates that can begin work in the commercial space environment without need for a long inculcation period. It's likely to be a highly desirable degree within the commercial space community.
Other Comments	-

Company	Space Systems/Loral
Comments on the Core Curriculum	Core curriculum is broad, yet unique. I like the focus on policy and program management.
Comments on the Degree Program	This is a novel program. I'm not aware of a similar program. To benefit my employer and industry, we would want a focus on spacecraft technology, business, policy, and program management.
Other Comments	-

Company	Saber Astronautics
Comments on the Core Curriculum	good idea, needs some more emphasis on project planning and SALES/MARKETING to space companies
Comments on the Degree Program	-
Other Comments	-

Company	Virginia Commercial Space Flight Authority (VCSFA), Mid-Atlantic Regional Spaceport (MARS)
Comments on the Core Curriculum	Technical understanding of the basics is critical for effective analysis and resolution of space operations problems, including a basic understanding of orbital dynamics, space environment, space system design (launch vehicles, launch facilities, spacecraft).
Comments on the Degree Program	Emphasize applicability to solving today's problems, and a pragmatic approach to building a bridge to the future (mining the Moon, mining asteroids, Lagrange point space stations, Mars colonization, etc.), with an emphasis on rigorous commercial processes to enable the economic feasibility of space operations.
Other Comments	This has a lot of potential. Good luck, and please keep me in the loop.

Company	Xtraordinary Innovative Space Partnerships, Inc. Barnhard Associates, LLC National Space Society
Comments on the Core Curriculum	The curriculum should factor in a strong emphasis on the development of communication, presentation, and negotiation skills. Successful commercial space operations involves building and sustaining communications between diverse disciplines, the ability to establish and maintain customer relationships, as well as supply chain management.
Comments on the Degree Program	The degree program should include an experiential learning component in all elements. The students need to understand how to communicate with all levels of team.
Other Comments	-