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Exploring Current and Projected Skills and Knowledge Areas to Meet U.S. Commercial Space Industry Needs

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In 2007, the *Committee on Meeting the Workforce Needs for the National Vision for Space Exploration* published findings related to age and skills of the current National Aeronautics and Space Administration (NASA) workforce and projected potential expertise shortages as a result of retirement in the 2014-2015 time frame. In addition, the expanding commercial space industry in both the United States and Europe will likely create further demand for space experts in engineering and a variety of related fields. Although NASA contributes $162 million in funding for education programs annually, those programs target kindergarten through grade 12, not collegiate-level programs. Further, few aeronautical/aerospace departments focused on education related to the development of space technologies, a discipline known as astronautics, exist in the US. In 2009, Doule and Peeters, Professors at the International Space University, sought to determine the need for space-focused knowledge and skills to support the European Union (EU) space industry. The results of Doule and Peeters' 2009 survey indicate an EU desire for space-specific educational programs to meet the needs of their commercial space industry. The researchers called for additional quantitative and qualitative studies to assess the emerging EU space industry workforce requirements and how to adapt space education and training curriculum. The purpose of this study is to develop a proactive model to assist U.S. educational institutions meet the projected U.S. space industry human resource needs. Findings from the proposed mixed-methods research program are to identify current and anticipated knowledge areas and associated skill sets within the U.S. space industry, and sub-industry aspects, to guide future collegiate-level curriculum development. Results from presented findings will be used toward a partial least squares structural equation modeling (PLS-SEM) for use in informed managerial decision-making of current/forecasted U.S. space industry human resource dynamics.

Nomenclature

AFSPC = Air Force Space Command
CRV = Crew Return Vehicle
DoD = Department of Defense
EU = Europe Union
FAA = Federal Aviation Administration

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ITAR	=	International Traffic in Arms Regulations
NOAA	=	National Oceanic and Atmospheric Administration
NRO	=	National Reconnaissance Office
PLS-SEM	=	Partial least squares structural equation modeling
PMI	=	Project Management Institute

I. Introduction

THE Obama Administration has continued in the path of previous Presidential Administrations toward the commercialization of space and continued developments in space exploration[1]. One of the key goals of the *National Space Policy of the United States of America*[1] is the fostering of a globally competitive U.S. commercial space industry. A key component of the success of both public (NASA, DoD, NRO, NOAA, etc.) and private space enterprises is a highly skilled labor force to support manufacturing, operations, and innovations for continued progress.

The competitive advantage of the U.S. commercial space industry has been a topic of significant debate for the last three decades[2]. Porter's theory of firm competitive advantage (figure 1) highlights the factors relating to a firm's competitive advantage in the market. Of particular interest for this paper is the factor conditions in which Porter [3] includes the availability of skilled labor and knowledge as a condition for resource-based approach to the analysis of the competitive advantage of firms.

In an analysis of the competitive advantage of semi-conductor firms, Hatch and Dyer[4] found that human capital is a significant factor of competitive advantage and assert that "firms that are superior at acquiring, developing, and deploying human capital enjoy sustained advantages in learning and ultimately cost... and contributes to sustainable competitive advantage" (p.1156). Unfortunately, high level of education is an imperfect measure of cognitive ability and motivation for achievement[4]. However, the researchers argue that human capital as a proxy measure of firm competitive advantage is related to firm-focus of knowledge and whether it can be replicated by rival firms[4].

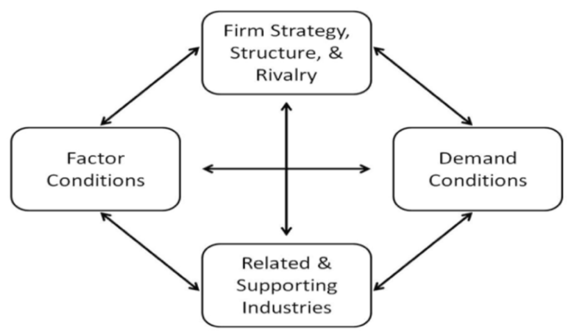

Figure 1. Porter's national competitive advantage factors. Adapted from Porter (1991, p. 111).

Using a PLS-SEM methods similar to those proposed for this study, Lejpras, Eickelpasch, and Stephan[5] assessed the competitive advantage of 2,345 (n = 2,345) East German firms using Porter's theory as the framework. The factor conditions are characterized using the following measures: supply of skilled labor, supply of additional education, and physical proximity to universities and research institutes[5]. The findings indicate that highly innovative firms are characterized by access to local skilled labor supply, proximity to research institutes and education and those firms that are cooperative in nature[5]. The researchers found highly innovative firms, as measured by patent applications and new product development, generally exhibit higher export share, profits, and market volume[5].

As the availability of skilled labor is of concern to commercial firms, attracting and retaining space expertise is a challenge for the public-sector as well. In 2006, NASA identified needs in key knowledge/skill areas (Committee on Meeting the Workforce Needs for the National Vision for Space Exploration[6]):

- Program/project management
- Systems engineering and integration engineering
- Mission operations
- Robotic spacecraft development

Over the past several decades, NASA missions have become more reliant on contractor support and university research. The Committee on Meeting the Workforce Needs for the National Vision for Space Exploration[6] acknowledges that workforce stability for university scientists supporting NASA projects is more challenging due to program cancellations and funding uncertainties.

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II. Statement of the Problem

Competitive advantage of firms or organizations is in part reliant on the availability of skilled and knowledgeable labor as well as the availability of research infrastructure[5]. Until the last decade, NASA was heavily reliant on in-house trained personnel to support projects and missions, however this pool of labor is on the decline as the workforce approaches retirement age[7]. Additionally, as the federal budget is reduced, funding for NASA missions and space research and development has declined, potentially negatively affecting the availability of skilled personnel, within NASA and under contract, to support future space initiatives. Of particular concern is the possible affects on national security and economic development due to loss of advantage in the space sector[1].

Another challenge is the process in which U.S. universities identify, approve, and develop new curriculum and degree programs to support industry. The process of new degree and education program development often takes several years from inception to degree launch, not including the time for students to complete certificate or degree programs in preparation for hiring. Industry experts and university alumni often serve as advisors to university departments regarding the content and quality of degree programs and offer input for revisions and new programs; however, the process to formalize changes involves several layers of bureacracy before such adjustments are implemented in the classroom[8]. Additional layers of degree design complexity consists of new degrees proposed by academic departments often requires scrutiny by faculty within the proposing department, comment by other university departments, review by Faculty Senate committee, and approval by the full Faculty Senate membership and university Board of Trustees[8]. The process must be completed prior to the offering of any courses within the proposed program[8]. Such processes can significantly hinder the availability of skilled labor for industry in a rapidly changing economy.

The problem affecting the current and future commercial space industry and public space sector relates to the availability of skilled labor to meet the changing demands of the global space market. Specifically, are existing university-level aerospace engineering and space-focused degree programs meeting the skilled labor needs of the emerging US commercial and public (NASA, DoD, NOAA, etc.) space industry?

III. Purpose of the Proposed Study

The purpose of the proposed study is multifold:

- Identify the knowledge areas needed to support the labor requirements of the emerging US commercial space industry and public space sector.
- Develop a predictive statistical model to facilitate informed decision making relating to academic degree and course construction.
- Determine weighted values of course component learning objectives.
- Cross-sectional design for immediate application and longitudinal repetition to achieve an industry-based dynamic informed degree/course design modification/currency.
- Ability of industry to shape near and long term specialized human resource needs.

IV. Research Questions

Questions are divided into three categories. Exploratory research questions (Q1 series) identify knowledge areas and factors of success specific to commercial and public aspects of the U.S. space industry. The second sets of questions (Q2 series) require an analysis of predictive associations between knowledge area constructs and success constructs. A third category of research questions is a comparison between public and commercial aspects.

Q1.1 What are the knowledge areas required by the U.S. commercial space workforce in order to remain competitive in the global space market?

Q1.2 What are the knowledge areas required by the U.S. public space workforce in order to meet national and state-level space objectives?

Q1.3 What are the perceived factors defining the success of U.S. commercial space firms?

Q1.4 What are the perceived factors defining the success of U.S. public space organizations?

Q2.1 To what extent, if any, does the perceived value of L_i by the U.S. commercial space industry predict industry success factors? Each latent variable (L_i), are defined as either manifest or formative variables from clustered Q1 series question(s).

Q2.2 To what extent, if any, does the perceived value of L_i by the U.S. public space industry predict industry success factors?

Q3.1 How, if at all, do public and commercial U.S. space industry perceived valuation of knowledge areas correlate?

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V. Review of Relevant Literature

A growing problem across the public sector[9] and industry is attracting and retaining qualified personnel to meet organizational needs[10]. Universities in the US are challenged to develop and maintain academic degree programs that are relevant to the needs of industry and public sector in a timely manner. As previously highlighted, new courses and degree programs often require years to identify, develop, approve, administer, and obtain accreditation status[8]. The space industry is challenged by the retirement of space experts[9] and replacement processes are further challenged by ITAR, which serves to limit the potential pool of experts to the industry[7,11]. Gruntman, Brodsky, Erwin, and Kunc[9] recommended the identification of the customers for aerospace academic programs and the development of curriculum that is more responsive to customer needs. This is the stated goal of the proposed study.

Several initiatives already address the dynamic and evolving needs of the space industry and will be reviewed in this section. The Department of Electronic Systems at Aalborg University in Denmark has devised a new approach to the development of space engineers with the skills to succeed in the demanding and dynamic commercial space industry[12]. Aalborg University's space engineering curriculum is a hybrid between traditional classroom lecture and theoretical engineering curriculum merged with a team, practical, and an industry-driven satellite or other space system development project. Students from a variety of academic disciplines team together to develop an actual space system, often a small cube satellite, from the requirements definition (as provided by industry experts) to system launch[12]. The benefits to the students include the ability to work in teams with a diverse skills and experience to meet stated goals within specified time and budget limits[12]. Further, students have earlier contact with industry professionals to form an understanding of the dynamic nature of the space industry[12]. The program enrolls up to 30 students per year and has resulted in five operational space systems[12]. The authors present a foundation for a space-focused engineering curriculum that includes industry leaders in the formulation of curriculum focus to develop an effective workforce[12]. Survey data from industry leaders, such as proposed in the current project, could be used to support such a curriculum approach at other universities.

Similar to Dalsgaard Nielsen and Bhanderi's[12] presentation, Guerra and Fowler[13] discuss how the University of Texas at Austin has expanded its aerospace engineering curriculum to incorporate systems engineering principles and approaches to meet the workforce experience needs of NASA and the growing commercial space industry. Faculty recognize the need for systems integration expertise in the design of space systems and are meeting that requirement through the implementation of NASA systems engineering training and practical projects[13]. Practical application projects involve NASA and other initiatives such that students gain actual experience in the design of systems within program constraints such as budget and time lines[13]. Currently, space flight is a specialization within the aerospace engineering program requiring 13 undergraduate credits[13]. The authors cite the National Research Council's 2007 *Building a Better NASA Workforce* as support for the need to expand space-related curriculum[13]. The focus of the evolution of curriculum is on the needs of public (e.g. government-driven) space initiatives, unfortunately little information related to the commercial space industry workforce needs is provided[13].

Doule and Peeters[14] conducted a qualitative survey of 97 ($n = 97$) respondents regarding the current and near-term educational needs of the commercial space industry workforce in Europe. The study was prompted by government studies (European Science Foundation, 2003 and National Aeronautics and Space Administration, 2009) in the US and Europe regarding concerns of an aging aerospace workforce due to retire in the 2014-2015 time frame[14]. Although the researchers acknowledge differences between the US and European space industries in terms of structure, objects, and retirement regulations; the results of the survey provide indicators of evolving needs of the industry that should be verified among US industry experts[14]. A summary of results of the European survey are as follows:

- Staffing: 45 % of respondents indicated satisfaction with the skill sets of workforce for current projects and 55 % acknowledged needs regarding new staff recruitment[14].
- Skills and education: Although engineering and science expertise is still highly sought after, there is an emerging need for expertise in business management and law and policy[14]. Employers also seek multi-disciplinary expertise between science/engineering and business management[14]. Other specific expertise includes project management; computer programming; signal processing; space sector business and marketing; systems, operations, and navigation engineers; and ground station infrastructure[14].

The results confirm the desire for space-specific educational programs to meet the emerging needs of the commercial space industry, which ISU has sought to fulfill with its Space Studies Masters Program and Executive Masters of Business Administration[14]. The researchers call for additional quantitative and qualitative studies to further assess the emerging workforce requirements of the space industry and how to alter space education and training curriculum to meet the identified needs[14].

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Gruntman[7] defined the limitations of existing aerospace engineering programs in meeting the expertise needs of the space industry and presented evidence from previous studies, to include the National Research Council, indicating shortfalls in the education of professionals in space-related fields, specifically engineering. The author presents a compelling case for aeronautical/aerospace engineering departments across the country to provide a separate degree for astronautical engineers[7]. Such programs would provide a focus on space-related engineering technologies and concepts to better train students for the growing space industry[7]. Included is an overview of the five undergraduate and graduate programs across the globe that provide engineering education programs focused toward space technologies as well as highlighting the growing nature of the commercial space industry while the current space workforce is aging[7]. Gruntman also highlights the challenges pertaining to the International Traffic in Arms Regulations (ITAR) that limits foreign engineers from working in the U.S. commercial space industry and national security-related space systems[7]. There is a growing number of foreign nationals enrolled in undergraduate and graduate space-related engineering and science degree programs across the country with fewer American students available to support the growing space industry workforce[7].

Jimenez and Mavris[15] studied the effectiveness of developing skills for effective aircraft designers in academic graduate programs. The researchers provide a historical perspective of the development of aeronautical and aerospace engineering curriculum based on the availability of analysis tools and aircraft development demands[15]. Highlighted are the differences between undergraduate and graduate programs based on homogeneity of curriculum for undergraduate degree programs and student experience whereas graduate student experience differs from the academic perspective as well as potential practical experience[15]. The researchers argue that potential industry and government employers shape graduate curriculum through research grants and joint projects with students and faculty[15]. However, undergraduate programs remain under the close purview engineering departments and remain theoretical in their approaches to training[15]. Jimenez and Marvis argue for an engineering curriculum focused on the development of critical thinking skills and an open-ended perspective for design solutions to practical problems[15]. The paper summarizes the results of a survey of graduate students as to the effectiveness of curriculum to develop such skills[15]. What is lacking is the perspective of employers of the effectiveness of graduates within their organizations. However, the researchers assert that undergraduate and graduate curriculum should be considered as separate variables when studied as the foundations and purposes are dissimilar by their nature[15].

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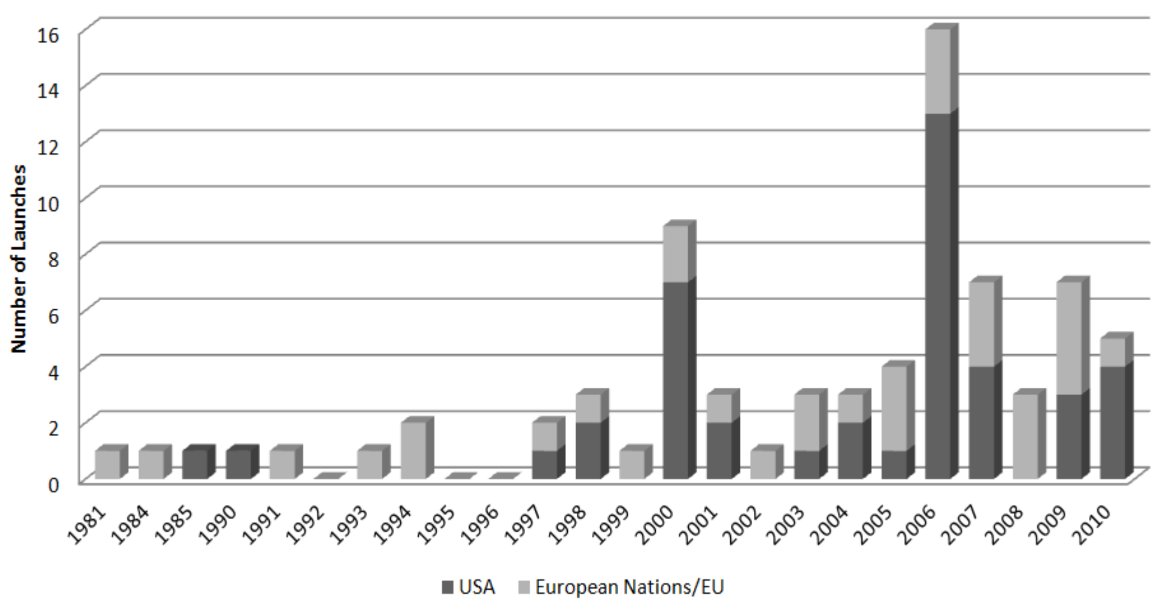

Figure 2. Comparison of U.S. student-built satellite launches to European nation student satellites by year[10].

Several of the previously reviewed studies highlight the need for proactical projects for students to develop skills to succeed in the space industry. Although U.S. universities and graduate students participated in space research in the 1970s and 1980s only 10 student-built satellites were launched from 1981 to 1994[10]. From 1995 to 1998 another 10 satellites were launched and 30 from 1999 to 2003[10]. Currently, a total of 112 amateur/student built satellites have been launched[16]. Figures 2 and 3 depict the number of US student missions as compared to other nations[10]. Purpose to train students in satellite design, integration, and spacecraft operation[10]. Jayaram and Swartwout[10] identify four student satellite programs:

- University Nanosat Program (UNP) -- funded by the Air Force Research Laboratory (AFRL) and resulted in 50 or more missions with 4000 student participants since 2000[10].
- CubeSat -- a 2-year design program with more than 40 missions through 2010[10].
- CanSat -- a 9-month competitive program for high school and university students for launch on a sounding rocket[10].
- BalloonSat -- funded by independent organizations; students design a payload carried by balloon to approximately 30 km where it is released and returned to the surface[10].

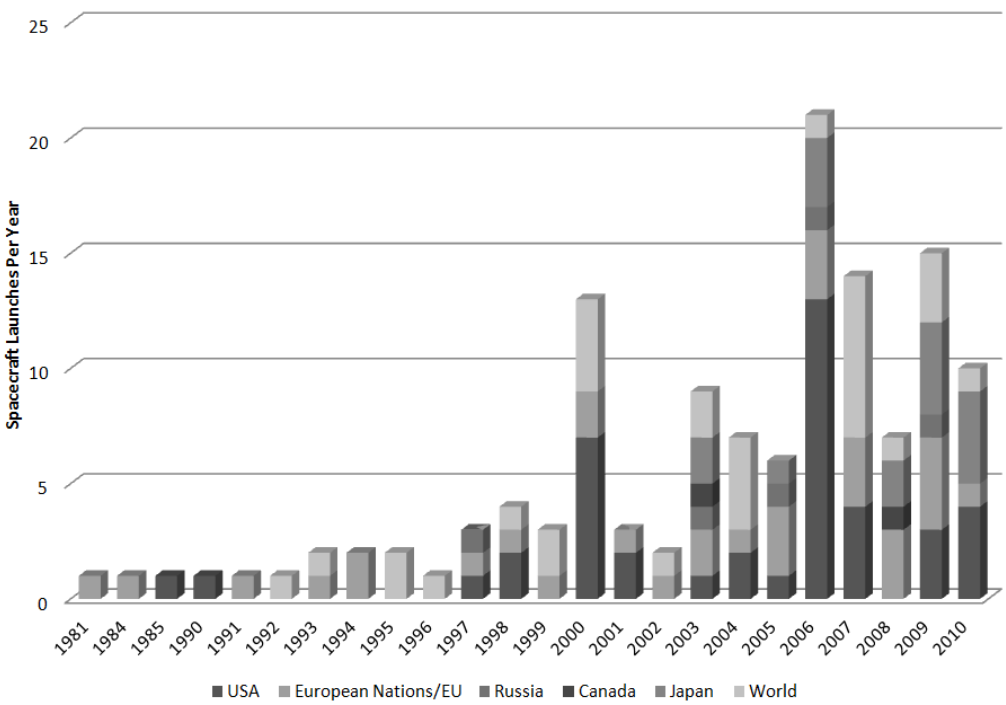

Figure 3. Comparison of U.S. student-built satellite launches to global student satellites by year[10].

Recognizing the growing commercial space industry across the globe, Fernandez-Brital and Lee[17] recommend a general curriculum for familiarization of space law. The authors highlight three core areas of focus in space law as depicted in figure 4[17]. The fundamentals principles in space law are derived from international agreements and treaties related to the use of outer space starting with the Outer Space Treaty of 1967[17]. The category of private and commercial space law reflects the current activities of most space ventures across the globe which use satellite technology but does not reflect launch operations[17]. The domestic space law category incorporates the launch operations and is recognized as the area in which many nations are experiencing growth as previously identified by Gabrynowicz[18]. A specific breakdown of the proposed curriculum topics and the general areas are shown in figure 5. Identified is the need for developing nations to focus on evolving space law as space technology emerges[17]. The emerging need for trained experts in topics related specifically to the commercial space industry is highlighted[17].

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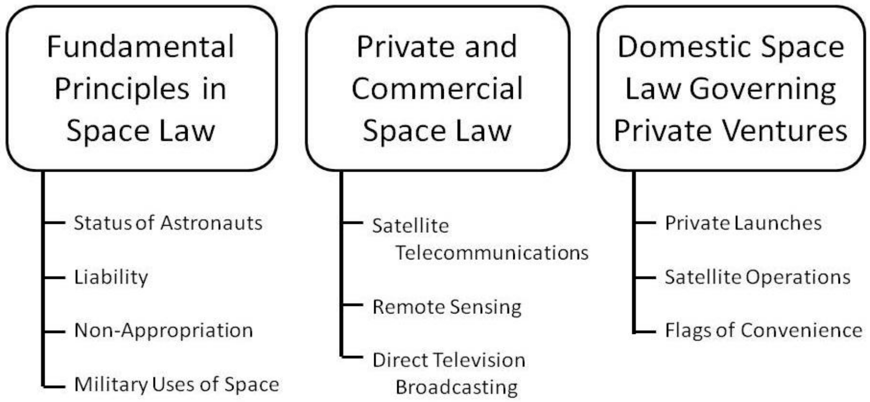

Figure 4. Core focus areas for standardized space law curriculum course[17].

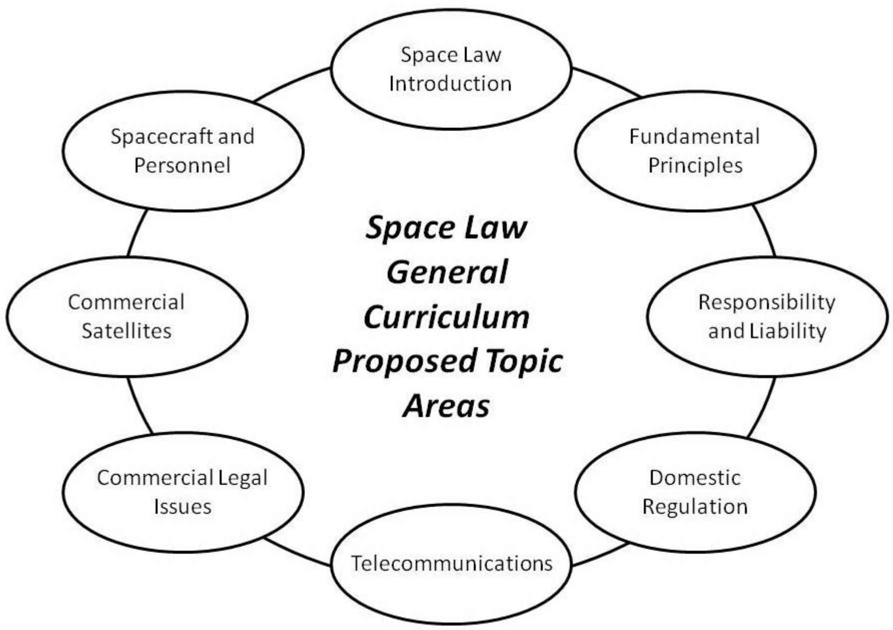

Figure 5. Proposed detailed topics for standard space law course[17].

Another concern relating to export controls is the potential effect on international collaboration on public and private projects, research, and labor force expertise[11]. International Traffic in Arms Regulations restricts foreign citizen collaboration on space development and research and resulting in a stalled joint effort toward a US-ESA Mars rover and Crew RV[11]. ITAR has presented a challenges for university research and is highlighted by a statement by Dr. Sheila Widnall, former Secretary of the U.S. Air Force and Professor at the Massachusetts Institute of Technology, argues that export control policy has impeded the peer review process, slowing innovation and scientific discovery[19]. ITAR has halted the work of foreign graduate students at U.S. universities and foreign developers of technology at U.S. facilities have been required to obtain export licenses to review their own work[11]. Given that foreign students constitute a significant proportion of the U.S. graduate school population in the sciences and engineering, with foreign students comprising 41 % of graduate engineering students in 2001 and higher in aerospace engineering, sustaining the U.S. technical labor force is a concern[11,19]. Additionally, the trend is that foreign graduate students are remaining in the United States after obtaining their degree and ITAR challenging the ability of corporations and government agencies to exploit this resource[19].

Several researchers have forged a path to address concerns relating to skilled labor needs in the public and private space sectors. As technology advances and the space industry competes with a greater number of rivals in the global market, education of the workforce becomes a growing and immediate concern. The proposed study offers the potential of an evidence-based predictive model for industry and universities to partner to meet the challenges of skilled workforce.

VI. Methodology

The proposed research program requires a sequential mixed method approach comprised of four phases (figure 6). Phase one requires concurrent qualitative studies to foundationally explore the problem and formulate theories[20]. However, the proposed research program also requires answering of research questions and testing of hypotheses, built upon phase one studies. While qualitative methods are useful to explore problems and identify variables[20], quantitative methods are needed to test formulated theories and numerically answer questions[21]. Research phase two consists of a cross-sectional correlational study built upon phase one data.

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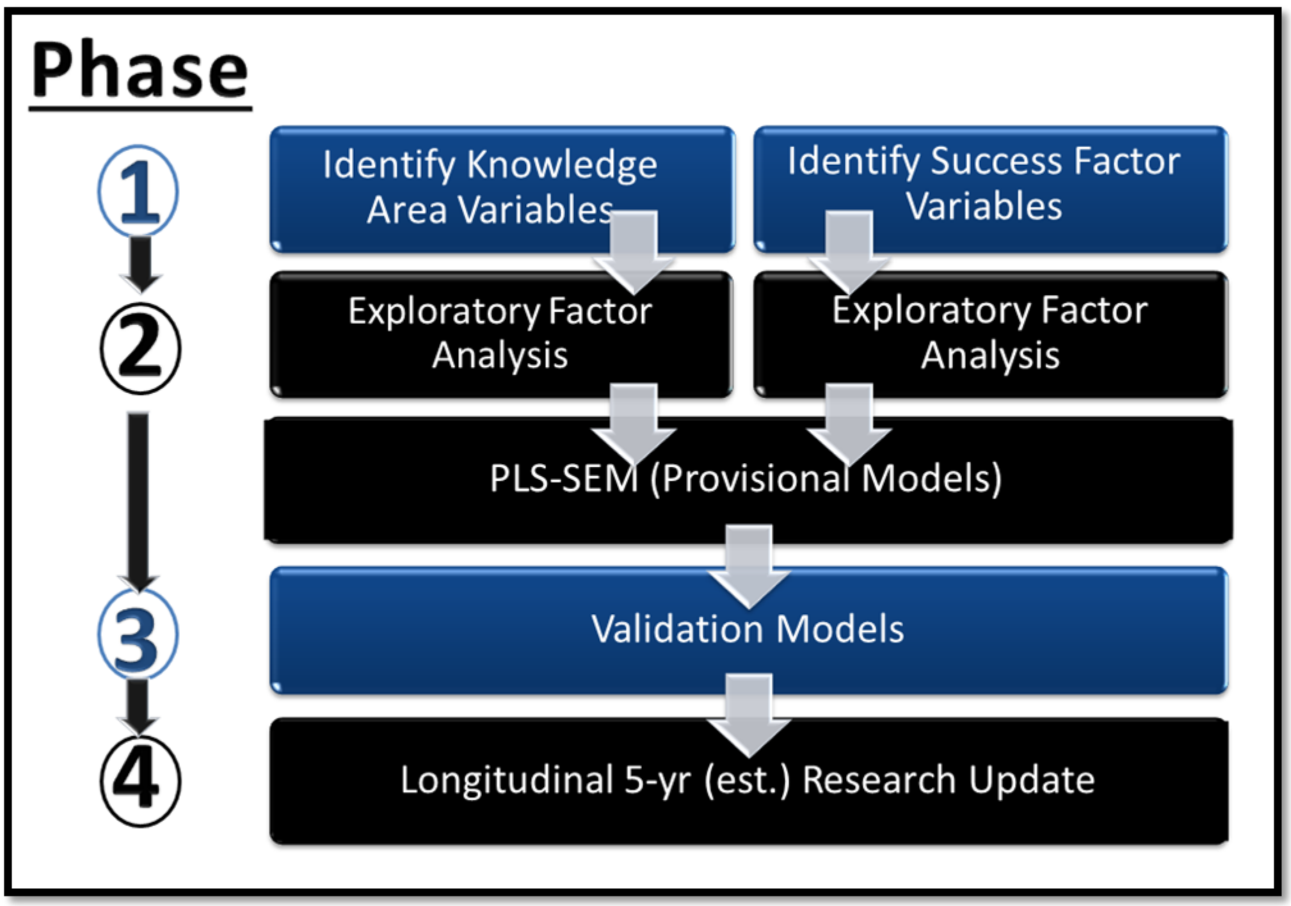

Figure 6. Research program phases.

Phase two. The phase two design is correlation to answer predictive questions from cross-sectional data[22-24]. Correlational design validity includes real-world environmental sampling[22]. A correlational design provides a description and assessment of relationships between latent variables[25]. Statistical techniques appropriate for a phase two correlational design inclusive of partial least square structural equation modeling (PLS-SEM)[26,27]. Exploratory factor analysis (EFA) may be used to cluster reflective knowledge area variables and success factor variables previously identified[21]; however, variables may be formatively aligned. For example, a course, as a construct variable, may incorporate several knowledge area variables based on university design, administration, or industry advisor considerations. Correlational research findings are limited to non-causal covariation estimates and predictions of variable associations[28].

Techniques for SEM differ from first generation validity methods due to SEM accounting for relationships among endogenous and exogenous latent variables and not just manifest variables[26]. Satisfactory convergent validity requires that indicator/manifest variables account for at-least 50% of total construct variance[26]. For example, if 49% of a construct's variance is associated with loaded manifest variables then errors account for 51% and convergent validity would then be unsatisfactory[26]. PLS-SEM type statistical models are depicted as a series of formulas as well as graphically (Figure 7). Information within the chart depicts an outer model of manifest variable regressive correlations with construct variables, and an inner model of regressive correlations among exogenous and endogenous latent variables.

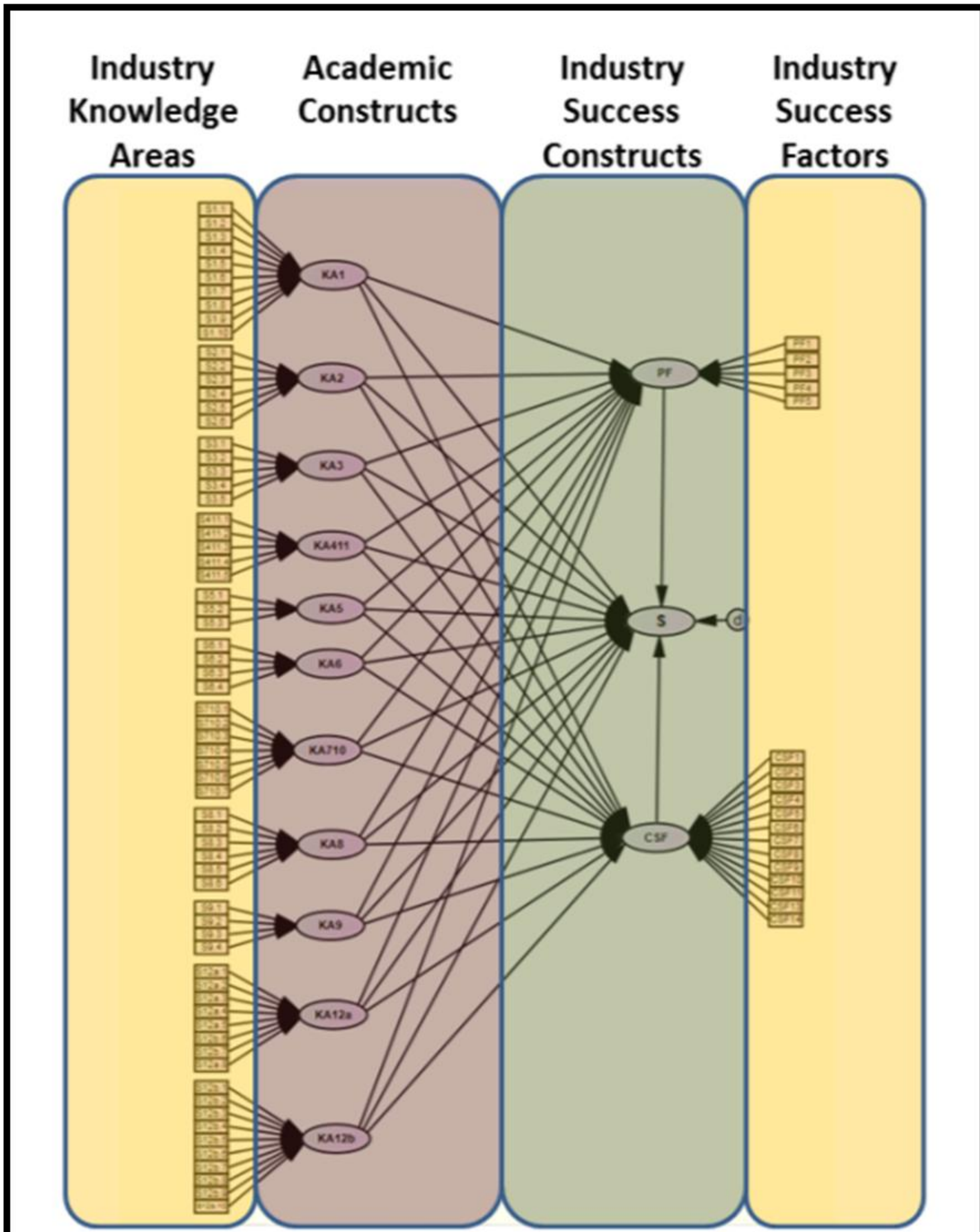

Figure 7. Example Predictive model (PLS-SEM).

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Outer model data screening. Data screening for formative indicator variables of latent constructs in the outer PLS-SEM model includes an evaluation of missing data, outliers, normality issues, linearity, homoscedasticity, and non-multicollinearity of manifest variables[21,29,30]. Missing responses for manifest variables may bias results if not addressed[3]. SPSS software, along with descriptive statistics and frequencies options, will be used to evaluate the number of missing values per manifest variable[3]; however, SurveyMonkey software includes an option to mitigate records having non-response items. Evaluation of Univariate outliers for each manifest variable, and multivariate outliers for entire records relative to the PLS-SEM model, requires the use of SPSS and AMOS software. A SPSS boxplot is used to evaluate univariate outliers and AMOS mahalonobly d-square option for multivariate outliers. Transforming the data may minimalize the outliers skewing of a distribution[21]. Outliers can cause normality and linearity issues[21].

Evaluation of each manifest variable's normality is a review of shape, skewness, and Kurtosis using SPSS software[21,30]. For instance, evaluation shape requires comparing each variable's histograms against a plotted normal. Linearity is an evaluation of constant change, or slope, between predictor and outcome variables[21,30]. For example, using ANOVA via SPSS is a check for any deviation of linearity significance values <0.05 between P^3M and SBE success manifest variables. Checking for homoscedasticity of each manifest variable is a determination of a constant variance[21,30]. Using a scatterplot via SPSS, residual error is assigned the y-axis and the variable the X-axis. A constant pattern indicates homoscedasticity. Checks form multicolinearity evaluates if predictor variables are highly correlated[21,30]; however, formative indicators can be highly correlated or not correlated because they form a construct[29].

Inner model data screening. PLS-SEM structural model data screening includes checks for multicollinearity, homogeneity, R^2, and p values. Multicollinearity of inner model latent variables, derived from formative outer model measures, is used to detect unstable weights[29]. Multicollinearity measurement requires use of the SPSS software tolerance and variance inflation factor (VIF) option[30]. Evaluation of inner model weights also requires comparative significance against a second resampling dataset[26,29]. Homogeneity evaluation of a PLS-SEM inner model requires use of Finite Mixture-PLS (FEMIX-PLS) using SmartPLS software, as recommended by Hair et al.[29]. FEMIX-PLS is an estimation of any inner model distortion due to non-observed heterogeneity[29]. The primary criteria to determine the amount of variance explained with endogenious latent variable requires running a coefficient of determination (R^2) with SPSS. The generalizable quality of the inner model requires resampling comparison of standard path coefficients (p values)[29].

Phase 3. Discriminant validity requires that the variance shared between constructs should be less than the average variance between a construct and the associated manifest variables[26]. However, convergent and discriminant validities cannot be tested with formative indicators and may overly restrict a PLS-SEM model that contains formative manifest variables[29]. Instead, validity requires the screening of the outer and inner model data, and a resampling to generate a comparative second model to cross-validate the initial provisional model[21,26,29]. The use of a second survey sample is a cross-validation technique to compare, evaluate, and generalize any provisionally accepted statistical model derived from the first sample[26]. According an assessment of PLS-SEM modeling a single SEM sample does not include goodness of fit and fit indices due to not being constrained with identification issues; however as a result, PLS-SEM is not generalizable beyond the sample[29]. Blunch[26] states that SEM models from single datasets are only provisional until accepted or reject against a new dataset before being generalizable. A second survey group provides cross-validation of the provisional accepted statistical model[26].

Phase 4. Phase one to three are designed to satisfy cross-sectional research questions; however, repeating phase one to three could be used to generate longitudinal data. For example, repeating phase one to three in five year increments would identify new industry knowledge area and success factor variables as well as changes in perceived values. New and historic PLS-SEM models would enable trend analysis within the predictive models. Updating the models over time facilitates proactive versus static design applications.

VII. The Way Ahead

The way ahead includes the development of a survey instrument in which to collect the desired data and conduct an analysis. The results of the proposed research program offer the potential to guide informed decision-making relative to curriculum focused toward the space industry. The data could be used by firms to help develop job positions that exploit the talents and knowledge of the workforce while remaining streamlined in organizational form. Universities will hopefully use the results to refine and/or develop relevant degrees that not only serve the needs of industry but students in obtaining jobs that offer growth and financial stability. Accreditation bodies should use the results to refine standards for degrees and programming across universities in support of both higher academic standards and skill relevance.

The proposed research program is designed to guide academic institutions in evolving academic programs for the changing global economy and hopefully this study will serve as a model for the analysis of other disciplines. However, the results may indicate that universities can serve some of the foundational needs for industry through undergraduate, graduate, and certificate programs but may not be able to meet rapidly changing needs due to organizational constraints. It might become necessary for firms, professional organizations, for-profit colleges/universities, or emerging entities yet defined to provide educational and training assistance outside of the traditional institutions. Such programs might be similar to certification and licensing programs as developed by the Project Management Institute, FAA continued education credits for pilots, and the software industry[8].

The advances in information technologies and communications capabilities might bring forth a yet developed framework of workforce training that involves the use of the internet for symmetric and asymmetric training and education. Some potential models to explore include SkillShare (www.skillshare.com), Open Course Consortium (http://www.ocwconsortium.org/), and Citizens Circles (http://www.citizencircles.com/).

Appendix

Table 1. Summary of existing space-related degree programs.

Institution	Degree Program Title(s)	Program Focus Areas	Residence/ Online	Level	Program Availability	Accreditation
University of North Dakota (UND)[31]	▪ Space Studies Undergrad Minor ▪ Master of Space Studies ▪ Aerospace Sciences Ph.D.	▪ Space physical sciences ▪ Space life sciences ▪ Space engineering ▪ Policy & law ▪ Business & economics ▪ History	Residence and Online options -- Master	Undergraduate Minor, Master, Ph.D.	No known restrictions	Regional - NCA-HLA
American Military (AMU)/ Public (APUS) University[32-34]	▪ Space Studies Certificate ▪ Bachelor of Sciences Space Studies Undergrad Minor ▪ Master of Science in Space Studies	▪ Space physical sciences ▪ Astronomy ▪ Space engineering ▪ Policy & history ▪ Space agencies	Online	Undergraduate, Certificate, Master	No known restrictions	Regional - NCA-HLA
University of Southern California (USC)[35]	▪ Astronautical Engineering	▪ Space mission & engineering analysis ▪ Mission & spacecraft design ▪ Propulsion ▪ Communications ▪ Remote Sensing	Residence and Distance	Undergraduate Master, Ph.D., Certificate	No known restrictions	ABET
University of Colorado, Colorado Springs (UCCS)[36]	▪ Space Operations	▪ Space mission & engineering analysis ▪ Mission & spacecraft design ▪ Communications ▪ Remote Sensing	Distance	Graduate --Master of Engineering; Certificate	No known restrictions	Regional - NCA-HLA
Capitol College[37]	▪ Space Mission & Operations Specialist ▪ Astronautical Engineering	▪ Ground system engineering ▪ Spacecraft systems ▪ Space systems engineering ▪ Orbital mechanics ▪ Propulsion ▪ Spacecraft sensors & navigation	Residence and Distance	Undergraduate, Certificate, Master	No known restrictions	Regional - Middle States & ABET

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Institution	Degree Program Title(s)	Program Focus Areas	Residence/ Online	Level	Program Availability	Accreditation
Webster University[38]	▪ Space Systems Operations Management	▪ Space environment ▪ Spacecraft systems ▪ Space systems engineering ▪ Orbital mechanics ▪ Propulsion ▪ Operations research ▪ Acquisitions & contracting	Residence (Colorado Springs, Denver, Peterson Air Force Base)	Graduate	No known restrictions	Regional - NCA-HLA
Embry- Riddle Aeronautical University (ERAU) [395]	▪ Commercial Space Operations ▪ Master of Science in Space Education ▪ Space Studies or Space Operations Management Master of Aeronautical Science Specialization	▪ Policy & history ▪ Safety & Security ▪ Spacecraft systems ▪ Launch vehicles ▪ Remote sensing ▪ Spacecraft applications ▪ Life support systems ▪ Space operations ▪ Management	Residence and Distance	Undergraduate Major; Masters and Masters Specialization	No known restrictions	Regional - SACS
California Institute of Technology[40]	▪ Space Engineering	▪ Fluid mechanics ▪ Propulsion ▪ Dynamics ▪ Control theory ▪ Remote sensing ▪ Robotics	Residence	Undergraduate Aerospace Minor; Master; Ph.D.	No known restrictions	
University of Washington[41]	▪ Aeronautical & Astronautical Engineering	▪ Fluid ▪ Propulsion ▪ Structures & composites ▪ Controls	Residence and Distance (Master)	Undergraduate, Master	No known restrictions	ABET
International Space University[42]	▪ Space Studies Program (Certificate) ▪ Space Studies ▪ Space Management	▪ Space applications ▪ Space law & policy ▪ Life sciences ▪ Management & business ▪ Physical sciences ▪ Engineering	Residence – 1-Yr	Graduate – Certificate and Master	Experienced Space Professional	
Naval Postgraduate School (NPS) [43]	▪ Space Systems Operations ▪ Space Systems Engineering ▪ Astronautical Engineering	▪ Computer sciences ▪ Info systems & management ▪ Virtual environments ▪ Orbital mechanics ▪ Propulsion ▪ Spacecraft structures ▪ Space environment ▪ Computer science ▪ Electrical engineering	Residence and Distance	Graduate – Certificate and Master	U.S. military, DoD civilians, Industry, International military officers & civilians	ABET

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Institution	Degree Program Title(s)	Program Focus Areas	Residence/ Online	Level	Program Availability	Accreditation
Air Force Institute of Technology (AFIT) [44]	▪ Astronautical Engineering ▪ Space Systems ▪ Space Systems (Certificate)	▪ Space environment ▪ Spacecraft engineering ▪ Remote sensing ▪ Dynamics & orbital mechanics ▪ Space programs	Residence and Distance (Certificate)	Certificate; Graduate – Master & Ph.D.	U.S. Citizens	Regional - NCA-HLA

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