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COLLEGIATE AVIATION REVIEW

Richard O. Fanjoy, Ph.D., Editor
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Cover Image: Two cumulus clouds, one each side of the centerline, are drawn into the vortex created by this 747 over London, England. Reprinted with permission of Steve Morris © Steve Morris 2007.

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No juried publication can excel, unless experts in the field serve as anonymous reviewers. Indeed, the ultimate guarantors of quality and appropriateness of scholarly materials for a professional journal are the knowledge, integrity, and thoroughness of those who serve in this capacity. The thoughtful, careful, and timely work of the Editorial Board and each of the following professionals added substantively to the quality of the journal, and made the editor's task much easier. Thanks are extended to each reviewer for performing this critically important work.

In addition to the members of the UAA Publications Committee, the reviewers include:

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In addition, the editors express thanks to Ms. Sheron Griggs, Purdue University, for her tireless and very effective efforts in assembling and formatting the manuscript.

STATEMENT OF OBJECTIVES

The *Collegiate Aviation Review* is published semi-annually by the University Aviation Association. Papers published in this volume were selected from submissions that were subjected to a blind peer review process, for presentation at the 2007 Fall Education Conference of the Association.

The University Aviation Association is the only professional organization representing all levels of the non-engineering/technology element in collegiate aviation education. Working through its officers, trustees, committees and professional staff, the University Aviation Association plays a vital role in collegiate aviation and in the aviation industry.

The University Aviation Association accomplishes its goals through a number of objectives:

> To encourage and promote the attainment of the highest standards in aviation education at the college level.
>
> To provide a means of developing a cadre of aviation experts who make themselves available for such activities as consultation, aviation program evaluation, speaking assignments, and other professional contributions that stimulate and develop aviation education.
>
> To furnish a national vehicle for the dissemination of knowledge relative to aviation among institutions of higher education and governmental and industrial organizations in the aviation/aerospace field.
>
> To foster the interchange of information among institutions that offer non-engineering oriented aviation programs including business technology, transportation, and education.
>
> To actively support aviation/aerospace-oriented teacher education with particular emphasis on the presentation of educational workshops and the development of educational materials in the aviation and aerospace fields.

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Both qualitative and quantitative research manuscripts are acceptable. All submissions must be accompanied by a statement that the manuscript has not been previously published and is not under consideration for publication elsewhere.

All authors will be required to sign a "Transfer of Copyright and Agreement to Present" statement in which (1) the copyright to any submitted paper which is subsequently published in the ***CAR*** will be assigned to the University Aviation Association (UAA) and in which (2) the authors agree to present any accepted paper at a UAA conference to be selected by the UAA, if requested.

Authors should email an electronic version of their manuscript to the editor, conforming to the guidelines contained in the *Publication Manual of the American Psychological Association,* 5th Ed. (APA). The UAA review process incorporates editorial input and recommendations from "blind" peer reviewers. A list of all reviewers is available from the ***CAR*** editor and is published annually in the ***CAR.*** If the manuscript is accepted for the publication, the author(s) will be required to submit a final version of the manuscript via e-mail, in "camera-ready" Microsoft Word format, by the prescribed deadline. *Authors should use the previous year's CAR for guidance in format and page layout.*

All manuscripts must be emailed no later than December 1 (Spring Issue) or June 1 (Fall Issue), and should be sent to the editor, at CARjournal@purdue.edu.

Questions regarding the submission or publication process may be directed to the editor at (765) 494-5782, or may be sent by email to: CARjournal@purdue.edu.

Students are encouraged to submit manuscripts to the ***CAR***. A travel stipend up to $500 is available for successful student submissions. Please contact the editor or UAA for additional information.

TABLE OF CONTENTS

Factors Influencing a Decision to Pursue a Degree in Aerospace Technology

R. Troy Allen. and Harry E. Minniear
Indiana State University

ABSTRACT

This research was completed in order to identify factors that influence a student's decision-making process when deciding to enroll in the Aerospace Program at Indiana State University. Many research studies have identified factors that influence a student's decision process when choosing between universities. However, very little research dealt with the factors that influence the decision- making process of a student when selecting a collegiate aviation program. A convenience sampling was taken of 133 students who were completing a degree in aerospace administration or professional piloting. Nineteen different factors were ranked in descending order of mean value. Additionally an independent sample one-way analysis of variance was completed to identify any statistically significant differences between the two aerospace majors.

INTRODUCTION

Many state universities face a new financial reality where more is expected while less money is given. This pressure is being felt at the departmental level. With the ever-mounting pressure on faculty to maintain enrollment numbers, identifying ways in which educators could increase or at least maintain high enrollment numbers has become imperative. As found by Bowen, Carstenson and Hansen (1999), "Aviation faculties must be proactive and must maximize efforts to use all available tools to recruit aviation students" (p. 15).

Fund-raising efforts are but one measure used to stem the loss of capital. In addition, enrollment numbers are linked directly to revenue and are used to gauge the health of a program. Bowen, Carstenson and Hansen (1999), found that "For an academic program to successfully compete for resources today, it must keep its enrollments up by actively marketing its courses" (p. 18). Therefore, a program could be in danger of elimination for chronic low enrollment. For these reasons, there must be an awareness of the factors which influence a student's decision. There is a direct relationship between these factors and student enrollment.

There has been very little research completed identifying factors that influence a student's decision when selecting a collegiate aviation program. However, there has been considerable research performed that identified the factors that influenced a student's decision when choosing which university to attend. These factors have relevance to this study since some are synonymous with the ones that influence a student when determining what collegiate aviation program to attend. Therefore, it is relevant to include the university factors as they are closely interrelated and, in some cases, inseparable. They also provide additional justification for the need to complete this study.

Identifying these factors is important not only to an aviation department but also to the university since the success of a department is, in fact, the success of the university. Therefore, knowing what factors play a key role in a student's decision can be of great value to the aviation department.

RESEARCH QUESTIONS

1. Is there a significant difference between aviation students and the magnitude of influence the factors have on their decision to attend Indiana State University and pursue a degree in aerospace?
2. What factors are the most influential on a student's decision when deciding to enroll at Indiana State University and pursue a degree in aerospace?

LITERATURE REVIEW

Many factors influence a student's decision when deciding what university to attend. A study completed by Michael Paulsen (1990) found that, "Understanding these student choice behaviors are important so that institutions can enhance their enrollment planning activities and student marketing and recruitment activities" (p. 1). Factors such as cost, academic reputation and teacher attributes (Canale. and Dunlap, 1996); high school counselor and friends (Johnson and Stewart, 1991); and family (Naylor, M., 1986) all have been identified as factors that influence a student's choice in selecting a university. This study found that many of these same factors play a role in the decision-making process a student uses to determine the collegiate aviation program in which to enroll.

A study by Johnson and Stewart (1991) found that a "particular academic program of interest to the student" is a major factor that influences a student in selecting one university over another (p. 84). The same was found to be true in research completed (Canale and Dunlap, 1996) which found "areas of study" offered ranked among the top factors in influencing a student to attend a university.

Research completed by Barnhart and Allen (2006), identified factors that influence a student to pursue an aviation career. The top three influential factors were flight in an aircraft, visit to an airport and watching an aviation movie. However, as the study did not investigate why a student choose a particular aviation program.

Therefore, the value of this research has been established in the literature. Although there is some commonality with university factors, this study has identified additional unique factors that influence a student's decision when considering a collegiate aviation program.

LIMITATIONS

- This study is limited to a sample of just under one-third of the student population in ISU's Aerospace Technology Program.
- This survey assumed that the students were honest when completing the survey document.
- The survey is not reflective of any distance education students.
- This study only surveyed students who choose ISU's aerospace program and did not survey those who reviewed the program and elected not to enroll.
- This survey assumed that each of the suggested factors influenced the students to some degree.

INDIANA STATE UNIVERSITY

Indiana State University (ISU) is located in the city of Terre Haute (pop. 57,000), approximately 70 miles west of Indianapolis. The university maintains a full time enrollment of approximately 11,000 students. The aerospace degree program at ISU is well established and has been in existence for over 40 years. During the last ten years, the Aerospace Technology program has averaged a total enrollment of between 250 to 300 students.

Aerospace Faculty

During the 2005-2006 academic school year the aerospace faculty consisted of two full-time associate professors, six full time assistant professors, three adjunct professors, and two graduate assistants. One of the full-time associate professors also served as chairperson of the department. The student to full-time faculty member ratio would be approximately 35 to 1. Class sizes generally hover around 17-20 students with only one class exceeding 60 students.

The three adjunct professors and graduate assistants each taught one class, with the eight full time faculty members teaching the remainder of the classes. All full-time faculty members have varying degrees of general aviation flying experience. Three faculty members have military backgrounds and one has major airline experience. The approved terminal degree in the Aerospace Department at ISU is a master's degree in an aviation-related field of study. With respect to the eight full-time faculty, two have earned doctorial degrees, two are pursuing a doctorial degree, three have masters degrees, and one is pursuing a masters degree. In addition to standard university duties for faculty members, great emphasis is also placed upon research and scholarship activities.

Admission Requirements

Prospective students must have received a high school diploma. In addition, a ranking in the upper 40% of their high school graduation class is highly desired. Minimum SAT scores for admission are 900-1000. Previous flight time and college transfer credit hours can be applied towards degree completion requirements.

Graduation Requirements

Graduates of the ISU professional pilot program must complete 124 semester credit hours and obtain a Certified Flight Instructor Instrument certificate along with an aerobatic endorsement, tail wheel endorsement, and multi engine rating. Degree completion requirements for the aerospace administration degree require 124 semester credit hours.

Facilities

ISU has provided the Aerospace Department with state of the art facilities. All aviation classes are held in the twenty-four million dollar Myers Technology Center located on campus. The Technology Center is 9 years old and houses spacious classrooms with modern audiovisual equipment. The department has a weather laboratory that accommodates 30 students with separate desktop computers. The simulator lab has Frasca 141 and 142 simulators for basic training as well as two B-200 King Air simulators.

Competition

The nearest universities offering similar degree programs include Vincennes University (58 miles), Purdue University (90 miles), the University of Illinois (100 miles), and Southern Illinois University (170 miles).

Cost

Presently, the annual cost for tuition, room, board, books and incidental fees runs about $12,000 per year for an in-state student. The flight fees for completion of all required certificates are estimated at $38,000 over a four-year period. The fees are based on a student's flying the most expensive aircraft in a category. This training results in a student obtaining a Certified Flight Instructor Instrument certificate with additional endorsements. Flight training is provided by two independent contractors. On average, students will graduate with approximately 350 hours of flight time.

RESEARCH METHODOLOGY

Research Model

The purpose of this study was to determine what factors influenced prospective students when choosing an aviation program. It utilized a survey instrument given to students currently enrolled in the undergraduate aerospace administration and flight degree program.

According to Leedy and Ormrod (2005), "Any single researcher is apt to have certain perspectives, assumptions, and theoretical biases-not to mention holes in his or her knowledge about the subject matter-that will limit how he or she approaches a research project" (p.34). For this reason, the research was completed by two researchers to take full advantage of collective expertise and create a more sound comprehensive study.

A convenience sample was obtained by surveying 133 students who are currently pursuing a degree in Aerospace Technology at Indiana State University. The survey was created to answer the question of what factors influence students when they are determining what collegiate aviation program in which to enroll.

In order to capture a sample that represented the entire population of students, the survey instrument was distributed to regularly scheduled aviation classes. A minimum of 100 surveys were desired for the research. In total 133 students completed surveys. The surveys were distributed and collected under strict adherence to all federal regulations and in compliance with the ISU Institutional Review Board.

Survey Population

All student participants in the survey were currently enrolled in one of the aviation degree majors at the university. Data was gathered by asking students to participate in the survey. Students ranged in age from 19 to 36 with the vast majority being recent high school graduates.

Sources of Data

Preliminary and background information for this project was found through traditional research methods. Data was collected with the aid of a survey and through a literature search that utilized the Internet and other library resources.

Survey instrument

The survey instrument, attached as Appendix A, was jointly created by the researchers. Student demographics were collected on aviation major, gender, class standing, and city of home residence. Nineteen factors were listed, and the students were asked to identify how influential each factor was in their decision to pursue an aviation degree at Indiana State University. The respondents were directed to rate on a scale of 1-7 how much a suggested factor influenced their decision. A "7" indicated that they immensely agreed while a "1" indicated that the factor played a less influential role in their decision making process.

Instrument Validity and Reliability

According to Gay and Airasian (2000) "Content validity is determined by expert judgment" (p. 164). The data collection device obtained content validity through review by aviation professors who had years of experience in collegiate teaching and research. The professors who reviewed the document were not part of the research team and had extensive experience meeting with students who were considering the ISU Aerospace Department program. The comments provided by the reviewers were incorporated into the survey instrument.

Reliability is the ability of a testing instrument to obtain the same results when it is administered multiple times. This survey instrument was only administered once to the subjects. Therefore, verifying reliability through multiple testing was not possible. McMillian and Schumacher (1997) state "The Cronbach Alpha is generally the most appropriate type of reliability for survey research and other questionnaires in which there is a range of possible answers for each item" (p. 242). In order to obtain reliability of the survey instrument, a Cronbach Alpha was completed which obtained an inter- rater reliability (r_s = .83). This indicates that 83% of variation is due to true variation. According to Fraenkel and Wallen (2006), this falls within acceptable limits for research purposes.

Treatment of the Data

The data was gathered by a survey instrument that was used to answer the research questions. The surveys were managed under the institutional review board standards required by federal mandate.

RESULTS

This study was conducted to determine what factors influence a student's decision-making process when considering what collegiate aviation program to attend. SPSS was utilized to turn the survey data into meaningful statistical results.

In order to interpret the data, the mean values were rank ordered for professional pilot majors in Table 1 and for aviation administration majors in Table 2. Additionally, the standard deviation was listed to describe, "how spread out the scores are in the distribution" (Gravetter and Wallnau, 2007, p.123). In Table 3, the mean values and standard deviations for both majors have been combined.

An independent sample one-way analysis of variance (ANOVA) was completed with the alpha level set at .05 to determine which of the factors were significantly different between the two groups. The results of this statistical analysis are in Table 4 and were used to answer research question number one.

DISCUSSION, ANALYSIS, AND RECOMMENDATIONS

This study sought to find factors that influenced a student's decision to pursue a degree in aerospace at Indiana State University. A total of 133 students completed the survey consisting of aerospace administration majors (*n* = 26) and professional pilot majors (*n* = 107).

In order to determine which of the factors play a significant role in a student's decision-making process, the factors were rank ordered. The results of the mean rankings are found in tables 1 through 6. In an effort to interpret the data derived from this research, the factors were grouped under four major headings.

Table 1. *Professional Pilot Rank Ordering of the Mean*

Factors	Mean	Std. Deviation
Speed to attain Flight Certificates	5.0748	1.91174
Tuition	5.0187	1.69339
Quality of Facilities	4.9533	1.58640
Personal Attention	4.8505	1.85210
Faculty to Student Ratio	4.7290	1.78870
Flight Simulators	4.5794	1.66562
Time to Completion of Degree	4.4766	1.70098
Flight Fees	4.4393	1.70558
Department Representative	4.4393	1.68331
ROI	4.2430	1.85737
Faculty Qualifications	4.2336	1.76218
Admittance Requirements	4.1308	1.85352
University Representative	3.9533	1.58044
Location of College	3.8598	1.77747
Financial Aid	3.7570	1.94665
Accept Previous Flight Time	3.6822	2.48997
Graduate Recommendation	3.2897	2.05127
Accept Previous College Credit	3.1869	2.31537
Parent	2.9533	1.62749

Table 2. *Aerospace Administration Rank Ordering of the Mean*

Factors	Mean	Std. Deviation
Quality of the Facilities	5.0226	1.59291
Tuition	4.9248	1.77791
Personal Attention	4.9098	1.78571
Faculty to Student Ratio	4.8271	1.76460
Speed Flight Certificates	4.6090	2.18061
Department Representative	4.3684	1.70771
Time to Completion of Degree	4.3383	1.74029
Flight Simulators	4.3233	1.86088
Flight Fees	4.2256	1.85708
ROI	4.1729	1.86885
Faculty Qualifications	4.1504	1.79434
Admittance Requirements	4.0226	1.87272
University Representative	3.8797	1.56688
Location of College	3.8421	1.84162
Financial Aid	3.7143	1.98697
Accept Previous Flight Time	3.3609	2.46902
Accept Previous College Credit	3.2406	2.31317
Graduate Recommendation	3.1955	2.08697
Parent	2.9398	1.70009

Table 3. *Combined Mean Ranking*

Factors	Mean	Std. Deviation
Quality of Facilities	5.0226	1.59291
Tuition	4.9248	1.77791
Personal Attention	4.9098	1.78571
Faculty to Student Ratio	4.8271	1.76460
Speed to Attain Flight Certificates	4.6090	2.18061
Department Representative	4.3684	1.70771
Time to Completion of Degree	4.3383	1.74029
Flight Simulators	4.3233	1.86088
Flight Fees	4.2256	1.85708
ROI	4.1729	1.86885
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Financial Aid	3.7143	1.98697
Accept Previous Flight Time	3.3609	2.46902
Accept Previous College Credit	3.2406	2.31317
Graduate Recommendation	3.1955	2.08697
Parent	2.9398	1.70009

Table 4. *ANOVA Statistically Significant Factors*

Factors		Sum of Squares	Mean Square	F	Sig.
Flight Fees	Between Groups	24.993	24.993	7.610	.007
	Within Groups	430.240	3.284		
	Total	455.233			
Flight Simulators	Between Groups	35.908	35.908	11.168	.001
	Within Groups	421.190	3.215		
	Total	457.098			
Speed to Obtain Flight Certificates	Between Groups	118.729	118.729	30.561	.000
	Within Groups	508.940	3.885		
	Total	627.669			
Acceptance of Previous Flight Time	Between Groups	56.519	56.519	9.896	.002
	Within Groups	748.158	5.711		
	Total	804.677			

Table 5. *Mean Ranking of Groupings*

Grouping	Mean
Shared Department/University Factors	4.36
Flight Related Factors	4.13
Program Attribute Factors	3.91
Social Interaction Factors	3.86

Social Interaction Factors

Factors such as Personal Attention (M = 4.91, S.D. = 1.79), Department Representative (M = 4.37, S.D = 2.18), University Representative (M = 3.88, S.D. = 1.57), Graduate Recommendation (M = 3.20, S.D. = 2.09), and Parent (M = 2.94, S.D. = 1.70), all deal with the exchange of information through social interaction. A significant attribute of this group is that efforts can be made in this area without significant capital investments. Cost is always a consideration, and therefore, if changes could be made to a program that would have a positive impact on enrollments with no monetary commitment they should be given serious consideration. These factors should be reviewed to assure that best practices are being used. For those social interactions that are within the control of departmental faculty the factors listed in "program attributes" should be highlighted during the interaction.

Obviously, these factors illustrate that the perception by others is paramount to a healthy aviation program. Proper interpersonal skills are a necessity when interacting with parents and alumni. Additionally, today's students become tomorrow's alumni and should be treated with respect while in a program so that a cordial relationship will be established.

Flight Related Factors

Understandably, some of the factors listed could be influential with one of the aerospace majors while having less significance on the other. An independent sample one-way analysis of variance was completed using Statistical Package for the Social Sciences (SPSS). This statistical procedure has the ability to determine differences in the means that are not a result of chance but are true differences (Gravetter & Wallnau, 2007).

The ANOVA found statistical significance exists between the mean values reported on professional pilots and aerospace administration majors in the following factors: Flight Fees $F(1, 19) = 7.61$, $p = .007$, Flight Simulators $F(1,19) = 11.17$, $p = .001$, Speed to Obtain Flight Certificates $F(1,19) = 30.56$, $p = .000$ and Acceptance of Previous Flight Time $F(1,19) = 9.89$, $p = .002$. Thus noted, all of these factors can be grouped under flying, and as expected, the professional pilot majors reported these as more influential than the aerospace majors.

Interestingly, the aerospace majors indicated that these factors were influential to any degree. However, a portion of the aerospace administration majors were initially professional pilot majors who decided to change majors for a variety of reasons. Thus, when they recall what influenced them initially to pursue a degree at ISU, these factors were influential. Many of these factors ranked very high on mean values. They should be covered in detail in any attempts to sell the program one-on-one or when utilizing mass marketing methods.

Shared Department/University Factors

When referencing Table 5 it can be seen that this grouping has the highest combined mean value of all of the groups. Factors in rank order under this heading were Quality of Facilities (M = 5.02, S.D. = 1.59), Tuition (M= 4.93, S.D. = 1.78), Faculty to Student Ratio (M = 4.82, S.D. 1.76), Time to Completion of Degree (M = 4.34, S.D. = 1.74), Faculty Qualifications (M = 4.15, S.D. = 1.79), Admittance Requirements (M = 4.02, S.D. 1.87 and Acceptance of Previous College Credit (M = 3.24, S.D. = 2.31).

These factors require a combined effort by the university and department in order to affect change. Nonetheless, attempts should be made to increase their positive influence on students. These attributes could be highlighted during any social interaction with outside groups in order to make a positive impact on enrollments. Potential students and parents should be informed of these program aspects.

Program Attributes Factors

Other factors on which data were collected included Return on Investment (M = 4.17, S.D. = 1.87), Location of College (M = 3.84, S.D. = 1.84) and Financial Aid (M = 3.71, S.D. 1.99). These factors are very difficult for a department to change. For example, college location is something over which departments have no control. However, highlighting the positive attributes of living in a certain community could influence a student's decision in a positive manner when considering the program. Additionally, explaining their return on investment and potential financial aid could impart a positive contribution to enrollments. Educating students on these factors would have very little associated cost, and they should be included in any program overview given to a potential student or in departmental literature.

Additional Factors Listed by Respondents

Question number 20 on the survey instrument asked the respondents to list any additional factors that played a significant role in their decision. The only comment that was voiced by multiple respondents was that the program offered them the ability to pick between two flight contractors in order to obtain their flight certificates and ratings. This was seen as a positive attribute.

CONCLUSIONS

This research was born out of a need to determine why a student decided to attend the Indiana State University Aviation Program. Recently, there has been a decline in enrollments in the ISU aerospace program. However, this does not mean that steps cannot be taken to reverse the trend. The authors sought to identify and quantify those factors that were influential in the decision-making process. That objective has been accomplished.

With respect to research question one:

> Is there a significant difference between aviation students and the magnitude of influence the factors have on their decision to attend Indiana State University and pursue a degree in aerospace?

An independent sample one-way ANOVA was completed at the .05 level to answer this question. Statistical significance was found to exist. Those factors that were significant are all listed in Table 4.

With respect to research question two:

> What factors are the most influential on a student's decision when deciding to enroll at Indiana State University and pursue a degree in aerospace?

In order to answer this question the mean value of the entire sample was calculated on each factor. The factors were then rank ordered on a mean value. It was determined that some factors are more influential in the students' decision-making process. This ranking is listed in Table 5

It should be noted that this study found how these 19 factors influenced a student's decision. It did not explore the 19 factors full ability to influence a student's decision. Consider that parents ranked as the least influential out of all of the factors. Should one assume that parents do not have the ability to influence a student? It could be that the Aerospace Department has not fully utilized a factor to influence enrollments in a positive manner. Therefore, it needs to be stressed that this study did not determine the potential of a factor to influence a student's decision.

The information contained in this study may be beneficial in affecting enrollments in a positive manner. A follow-up study could be completed to determine how to use the results of this research to accomplish that goal.

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Appendix A

Factors Influencing a Decision to Pursue a Degree in Aerospace Technology at Indiana State University

The items below list factors that may have influenced your decision to pursue a degree in aerospace technology at Indiana State University. Please read each item and indicate the degree to which you believe the stated factor influenced your decision to pursue a degree in aerospace at Indiana State University. If the factor listed influenced you immensely, circle "7."If the factor listed did not influence you at all, circle "1." If the degree to which you believe the factor listed falls somewhere between "7" and "1" for you, circle the number that best represents the degree to which that factor assisted you in making your decision to pursue an aviation technology degree.

My decision to pursue an Aerospace Technology degree at Indiana State University was influenced by …

	IMMENSELY						NOT AT ALL
1. Cost of tuition	7	6	5	4	3	2	1
2. Location of home residence to the college	7	6	5	4	3	2	1
3. Parental influence	7	6	5	4	3	2	1
4. Cost of flight fees	7	6	5	4	3	2	1
5. Reputation of University	7	6	5	4	3	2	1
6. Reputation of Aerospace Department	7	6	5	4	3	2	1
7. Faculty to student ratio in the classroom	7	6	5	4	3	2	1
8. Personal attention by faculty member	7	6	5	4	3	2	1
9. Recommendations by graduates	7	6	5	4	3	2	1
10. Quality of facilities	7	6	5	4	3	2	1
11. Flight simulators	7	6	5	4	3	2	1
12. University admittance requirements	7	6	5	4	3	2	1
13. Return on the investment	7	6	5	4	3	2	1
14. Availability of financial aid	7	6	5	4	3	2	1
15. Time to completion of degree	7	6	5	4	3	2	1
16. Time to obtain flight certificates	7	6	5	4	3	2	1
17. Acceptance of previous flight time	7	6	5	4	3	2	1
18. Acceptance of previous credits	7	6	5	4	3	2	1
19. Faculty qualifications	7	6	5	4	3	2	1
20. Other ______________________________							

Using Rubrics for Assessing Student Projects in FAR Part 147 Programs

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ABSTRACT

Most educators in Aviation Maintenance Technology (AMT) programs will agree that the assessment and grading of practical projects in the lab portion of their AMT courses should be as objective as possible. The U.S. Department of Transportation (USDOT) and the Federal Aviation Administration (FAA) have published Advisory Circular (AC) 147-3A, to provide guidance to aviation maintenance technician schools operating under Part 147 of Title 14 of the Code of Federal Regulations (14 CFR), commonly known as the Federal Aviation Regulations (FAR). According to AC 147-3A, in the development of practical projects, *objective* grading criteria *must* be used. The challenge for the instructor is to develop practical solutions for the objective grading of projects, and the purpose of this paper is to suggest one such practical solution – the development and use of *rubrics*.

INTRODUCTION

The activity of completing projects in a Part 147 (Aircraft Maintenance Schools) program is a requirement of the FAA. It is also a requirement that those projects be graded *objectively*. This can easily become a very subjective task for the instructor. Instructors who have been teaching for a number of years, and also have field experience in the industry, pride themselves in being able to look at a project, determine that the work has been satisfactorily completed in terms of airworthiness, then issue a grade for the project. Has the student really learned, however, how to evaluate his or her own work, or the work of someone else, to determine what makes the project component an airworthy item?

One of the most effective methods of measuring abilities *objectively* is the use of a well designed rubric. What is a *rubric*? A rubric may be thought of as a *qualitative* check list that allows for a precise determination of quality and objective guidelines for assigning a score to a project (UNC/CTL, 2005). Stevens and Levi define a rubric as "a scoring tool that lays out the specific expectations for an assignment," (2005, p. 3). Rubrics have been around for a long time but not all educators have been exposed to the rubric-method of assessment. Rubrics have usually been used to evaluate lab projects, particularly in secondary education settings. Projects, however, are often considered to be nontraditional learning activities by the post secondary academia (UNC/CTL, 2005). Nevertheless, according to Karen Owens, "Rubrics have emerged as evaluation tools that higher education constituents are increasingly exploring" (2006, p. 72).

BACKGROUND

Meeting the Requirements

It is interesting to see that higher education academia is recognizing the value in students producing creative and innovative projects in which they are able to put into practice the concepts they have learned in any given course rather than rely only on term papers and written examinations. The staff of the Center for Teaching and Learning at the University of North Carolina (UNC/CTL) has written, "When students are required to exercise judgment and create something new, they must operate on the highest cognitive levels (which, incidentally, are the same levels at which we operate in our professional lives). Often, term papers and similar exercises only approximate some of the important intellectual skills that we expect our students to demonstrate. Of course, paper assignments and tests are usually easier to design, evaluate, and administer than special projects and performance exercises. The assignment of nontraditional projects also requires clearly-defined criteria for evaluation, otherwise grading becomes unacceptably subjective," (UNC/CTL, 2005).

In the world of academia, high school and post-secondary educators are realizing more the importance of applying theory and head-knowledge to real-life situations through the use of projects – a basic understanding that has always been a "given" among the trades educators, "shop" teachers, and industrial technology education instructors. The learning activity of doing hands-on projects lends itself to the broadened pedagogical needs of the student – more specifically, his or her learning style (Bloom, Engelhart, Furst, Hill, & Krathwohl 1956). The teaching and assessment methods for meeting those needs, however, have to be continually evaluated for reliability and validity (Keiser, Lawrenz, & Appleton, 2004). It matters not what you know if you cannot transfer the knowledge into a functional, reliable activity.

This concept is not new to the FAA. For decades the FAA has administered testing not only in written form, but also in oral and practical examinations, as directed in section 65.79 of Part 65 of Title 14 of the Code of Federal Regulations (14 CFR): "Each applicant for a mechanic certificate or rating must pass an oral and a practical test on the rating he/she seeks. The tests cover the applicant's basic skill in performing practical projects on the subjects covered by the written test for that rating" (USDOT, FAA, 2007). The student has to be able to answer questions and express himself or herself verbally, and perform project requirements satisfactorily to demonstrate an ability to perform an activity as he or she would while working in the industry – generally that of returning a product to *airworthy* condition.

What does *airworthy* condition mean? Although you will not find the term "airworthy" or "airworthiness" in Part 1 (Definitions & Abbreviations) of 14 CFR, "airworthy" is defined in the *Airworthiness Inspector's Handbook*, technically known as Order 8300.10, as having two conditions: 1) It must conform to its type design or type certificate, meaning the aircraft, engine, propeller, appliance, or parts thereof, must meet the specifications under which it was designed according to 14 CFR §21.31, and 2) that it is in a condition for safe flight (USDOT, FAA, 2006). The same terminology is used in 14 CFR §21.183(a), for issuing standard *airworthiness* certificates for aircraft. (USDOT, FAA, 2007).

The required projects assigned to the student during the FAA practical examination are typical of those that the student has to produce during the regular course laboratory periods, which are in conjunction with the course lecture periods. Course curriculum requirements for an approved aircraft maintenance technology school are listed in 14 CFR, Part 147, Appendix B. The FAA also requires a specific "teaching level" for each curriculum requirement listed in Appendix B to Part 147. Those teaching levels listed below are from Appendix A to Part 147 (USDOT, FAA, 2007):

1. Level 1 requires:
   a. Knowledge of general principles, but *no practical application*.
   b. *No development of manipulative skill*.
   c. Instruction by lecture, demonstration, and discussion.
2. Level 2 requires:
   a. Knowledge of general principles, and *limited practical application*.
   b. Development of *sufficient manipulative skill to perform basic operations*.
   c. Instruction by lecture, demonstration, discussion, and *limited practical application*.
3. Level 3 requires:
   a. Knowledge of general principles, and *performance of a high degree of practical application*.
   b. Development of *sufficient manipulative skills to simulate return to service*.
   c. Instruction by lecture, demonstration, discussion, and a *high degree of practical application*. [italics added] (USDOT, FAA, 2007, Part 147, Appendix A)

The outline clearly shows that "practical application" progresses from *none* at level one to *a high degree* at level three, and "development of manipulative skill" progresses from *none* at level one to *sufficient manipulative skills to simulate return to service* at level three [italics added] (USDOT, FAA, 2007, Part 147, Appendix A). Clearly, level 1 instruction can be accomplished through lecture and reading assignments, without the completion of lab projects by the students. However, instruction at levels 2 and 3 (especially level 3) would not be practically achievable if it were not for the production and completion of projects in the lab segments of the airframe and powerplant curriculum.

Objectivity in Grading

Exams covering the lecture material and general knowledge are, for the most part, objective, particularly if they consist of multiple choice, or true/false questions. Not only are these types of exams the most objective, but they are easiest on the instructor for grading, thanks to Scantron technology. There is generally little discussion about the scoring, except in the case of a poorly worded question. The grading of lab projects, on the other hand, inherently invites subjective evaluation. When the students do lab projects and work with their hands, performing their personal *manipulative skills*, the grading of the projects becomes an opportunity for debates over how *perfect* the project should be and what the grades should be. Students are sometimes offended by the assigned grade and become defensive of their work and skill. "That's good enough!" and "That will work just fine!" or "I did exactly what you told me to do!" are the phrases the instructor hears while trying to critically evaluate a project for airworthiness *and* a grade. The expectations of the student are frequently not in line with the expectations of the instructor.

In the final analysis of a project, the instructor has to determine, "Is the product airworthy or un-airworthy?" Is it a "go" or "no-go" item? And if the product is airworthy, how does the instructor assign a grade to the student's work? In real life, *airworthiness* is generally what it comes down to. There may be other considerations such as how much time is left on a life-limited part, and if it is airworthy now will it continue to be airworthy until the time of the next inspection? However, in this discussion let us stay with simply determining whether or not a part, such as an example of a rigid fluid line, which has been manufactured by a student, meets the criteria of *airworthiness* as published by accepted or approved aircraft maintenance standards. Is the part worthy of being placed in an aircraft which is going to be flown for an undetermined number of hours? And if so, does the student deserve an "A" simply because the product meets the minimum requirements to be airworthy? As instructors in schools certified by the FAA under 14 CFR Part 147, we usually need to determine a grade other than just pass or fail, particularly if the course is part of a bachelor degree program.

With more AMT programs moving from trade-school status to bachelor degree programs, students are more focused on their individual grade point averages (GPA). Therefore, it is not enough anymore to know how to properly clean a spark plug so it will function as per design, but "how to accomplish the job to receive an 'A'" becomes the primary concern. In fact, in some instances the student is perfectly satisfied knowing that he or she received an "A" on the project, without regard for whether or not the spark plug even works in a live running engine. That is extreme; however, from the student's reference point it is very frustrating to receive an assignment or project without knowing how the instructor is going to grade the final product (Loveland, 2005). From the instructor's reference point, it becomes very difficult to grade the thirtieth project with the same enthusiasm and critical eye as the first project; even worse if the project grading is carried over to the next lab period, which is likely to be a week later. Consistency, fairness, and objectivity make for a big challenge in grading projects and that's where a careful objective plan needs to be implemented.

FAA Mandates Objective Assessment

Regarding Part 147 programs, the FAA also has concerns about the subjectivity and objectivity of the assessment of practical projects. From an authoritative standpoint, the FAA requires that the aircraft mechanic or technician applicant meets a level of "basic skill in performing practical projects on the subjects covered by the written test for that rating" (USDOT, FAA, 2005, Section 65.79). How does the instructor know if the student has reached a responsible level of performing a skill? This is often a very *subjective* task for the instructor, whereas, according to the FAA, it *must* be an *objective* assessment. Concerning requirements in curriculum development of a Part 147 program, Advisory Circular (AC) 147-3A states that the AMT course curriculum developer (in most cases that means the course instructor) "*must* develop practical projects and *objective* project grading criteria" [italics added] (USDOT, FAA, 2005, January 18, p. 2). The FAA *Airworthiness Inspector's Handbook* states that the "curriculum shall include enough detail to evaluate the practical projects for correct teaching level . . . and for performance standards and *objective* grading criteria" [italics added] (USDOT, FAA, 2006, Vol. 2, p. 187-2).

Consider the example of bending and flaring rigid fluid tubing. 14 CFR Part 147, Appendix B (D) (13), states that the student will "fabricate and install rigid and flexible fluid lines and fittings" to the proficiency of level 3 requirements (USDOT, FAA, 2007). Again, level 3 means that the student must demonstrate knowledge of the general principles of the activity, perform to a high degree the application of that knowledge in a practical way, and develop the manipulative skills that are necessary for simulating a return to service of the product (USDOT, FAA, 2007).

The student needs clear guidelines as to *how to achieve* the skilled level of proficiency of manufacturing an airworthy fluid line, how to recognize and avoid the pitfalls of producing an inferior product, and *how to recognize* an airworthy final product before turning it in for a grade. This will help the student to determine what to look for and learn how to evaluate his or her own project and see the progress he or she has made (Loveland, 2005). This cannot be achieved simply by reading charts and viewing figures in manuals and textbooks. Having a "level 3" working knowledge coupled with critical-thinking skills are especially important for the student who is going to be an aircraft technician, as he or she makes decisions daily based upon the judgment of a product as to whether or not it is qualified to be returned to service.

Using *Rubrics* in AMT Programs

As already stated, one of the most effective methods of measuring abilities *objectively* is the use of a well designed rubric. "Rubrics divide an assignment into its component parts and provide a detailed description of what constitutes acceptable or unacceptable levels of performance for each of those parts" (Stevens & Levi, 2005, p. 3).

So far, in my limited search, I have found no rubrics that adequately represent what we do with aviation maintenance projects. If we choose to use rubrics for assessing student projects we will have to design our own using the criteria that are laid out for us already in the FAA approved and acceptable publications and guidelines, which we use in the industry.

THE ANATOMY AND USE OF A RUBRIC

An example of a rubric titled "Bending, Flaring, & Installation of Rigid Aluminum Fluid Lines" has been provided in the appendix. *Introduction to Rubrics*, by Stevens and Levi, is an excellent source for learning to design specific rubrics. In designing rubrics, Excel by Microsoft is an excellent construction tool, but it can also be done with a simple Microsoft Word or WordPerfect table. The initial attempt to design a rubric for a specific project will require some extra preparation time. However, if the instructor knows the material and possesses the empirical knowledge (i.e., practical experience in the fabrication and flaring of tubing), this should not be a monumental challenge.

Title and Task

At the top of the example rubric in the appendix, and the partial view in Table 1, you will find the title, "Bending, Flaring, & Installation of Rigid Aluminum Fluid Lines." Next, the *Task Description* may be placed under the title of the rubric, which briefly describes what the assignment is about. The purpose of the rubric is not to provide step-by-step instructions to the student. It is to serve the instructor as a qualitative checklist for inspecting the project and determining a grade; however, it does also provide guideline criteria and feedback for the student. The actual instructions are provided separately in the class lecture, in the textbooks, and by the instructor's demonstrations.

Table 1. *Partial view of Rubric in Appendix - Criteria, Scale, and Score*

Bending, Flaring, & Installation of Rigid Aluminum Fluid Lines (Rubric)

Task Description: Each student will fabricate an airworthy aluminum fluid line with flared ends and AN fittings in accordance with Advisory Circular 43.13-1B, the specifications below, and the instructions from class lectures.

	Criteria Bends:1-4 Flares: 5-11	Not a pretty picture: Zero Points	Novice: 75% of Total Points	Proficient: 90% of Total Points	Exemplary: 100% of Total Points	Enter Score
1	**Flattened O.D. of bend must be at least 75% of original O.D. (5 points total)**	Flattened O.D. is less than 75% of the original diameter of the tubing.	Not Applicable. Pass or fail.	Not Applicable. Pass or fail.	Flattened O.D. is still at least 75% of the original diameter of the tubing.	
2	**All bend radii within limits. (5 pts.)**	Does not meet minimum bend radii.	Not Applicable. Pass or fail.	Not Applicable. Pass or fail.	Meets minimum bend radii.	
3	**Dents must be less than 20% of O.D. of tubing and not in heel of bend. (5 pts)**	Dent is 20% or more of outside diameter of tube or in the heel of the bend.	Dents less than 20% of the outside diameter and not removed.	Dents less than 20% of the outside diameter but removed with a "bullet."	No dents.	
4	**Tubing free of tool marks and damage. (10 pts.)**	Nicks or scratches in heel of bend. Twisting, wrinkling, or buckling.	Scratches/nicks no deeper than 10% of wall thickness.	Scratches/nicks no deeper than 10% of wall thickness but repaired.	No scratches, nicks, twisting, wrinkling, buckling or tool marks.	
5	**#1 Flare width. (10 pts.)**	Too wide or too narrow.	Minimum width as per information provided.	Between minimum and recommended width.	Recommended width.	
6	**#2 Flare width. (10 pts.)**	Too wide or too narrow.	Minimum width as per information provided.	Between minimum and recommended width.	Recommended width.	

The Criteria

The column of cells down the left side of the rubric (Table 1) lists the *criteria* being evaluated on the project. The example rubric in the appendix has a longer list of criteria than what is recommended. Stevens and Levi suggest that one should begin with three to five criteria (2005). Shorter versions of the example could be created by dividing the project into three separate rubrics, one for each part of the assignment.

Included with each criterion are assigned points. The assignment of point value to each criterion, which of course is somewhat subjective, is left to the experience of the instructor, both as an instructor and as a competent aviation maintenance technician in the industry. However, there will be consistency in the grading of individual projects. For the sake of consistency, assign equal value points to each criterion of relative significance, depending upon the required skill level, and have the maximum possible points of each criterion add up to 100%. In the example rubric, 10 points total are awarded for the higher-skill criteria and 5 points each for the lower-skill criteria.

The Scale

Horizontally across the top row of the rubric table (Table 1) is the *scale*, in percentage of total points, indicating the range of quality to which each criterion of the project might be performed. The range goes from zero percentage of the points allowed (an un-airworthy condition, which is "Not a pretty picture") to 100% of the points, which indicates that the work done on the tubing is "Exemplary" and has been fabricated according to the best practices of AC 43.13-1B, which is the publication of the U.S. Department of Transportation (USDOT) and FAA for acceptable methods, techniques, and practices used in aircraft inspections and repairs (USDOT, FAA, 1998). The percentage of the maximum points for each criterion, as indicated in each criterion cell in the left column, is determined by the quality of the work done by the student in relation to the limitations outlined by the appropriate maintenance manual or FAA guideline – in this case, AC 43.13-1B – and other training aids and manufacturers' instructions.

Work that meets minimum requirements for airworthiness would be considered "Novice," earning 75% of the total possible points of a criterion (70% is passing), and "middle-of-the-road" work, earning 90% of the points, would be "Proficient." The rows under the top row scale uses inspection criteria primarily from the guidelines in FAA Advisory Circular (AC) 43.13-1B, chapter 9, section 2, for describing the quality of work for each criterion and aligning appropriately under the scale (USDOT, FAA, 1998).

Levels of Quality

As stated above, each criterion has an unacceptable limit that causes the project to be totally rejected. The old cliché, "a chain is only as strong as its weakest link," certainly applies here. One un-airworthy criterion renders the product un-airworthy – end of story! If a student has a fluid line with perfect flares but a dent in the heel of a bend, the greatest flares in the world will not make it an airworthy product. The student's next try may have less-than-perfect flares but in every respect be of airworthy quality. Knowing this from the start will help motivate the student to do each step of the assignment with care. Final products seldom result in something better than what was sought after. A clearly defined rubric will help motivate and encourage a student to aim for as perfect a product as he or she is capable of producing.

Interestingly, regarding "perfect flares," information about the quality of the tubing flare itself is very limited in AC 43.13-1B. Also, the most popular text books that deal with the subject differ from each other somewhat in how detailed the criteria should be for an airworthy flare, however they do not contradict each other. Each text contributes a little different light on the subject. The old advisory circular AC 65-9A, *Airframe & Powerplant Mechanics General Handbook*, is still a reliable basic text of standard practices from which the newer text books derive much of their information (USDOT, FAA, 1976).

The Final Step

The final step in using the rubric would be, of course, tallying the score. The column to the right (Table 1), under "Enter Score," is where the instructor enters the individual scores for each criterion, which is the result of the assessed percentage of the total points assigned to that criterion. In this rubric the score for each criterion would be a zero, or 75%, 90%, or 100% of the number of points assigned to that criterion, that being either five or ten points. For example, criterion 4, *Tubing free of tool marks and damage*, yields a total of 10 possible points. If the student's tubing has a nick less than 10% of the wall thickness, but it has been properly repaired, the student would receive 90% of the 10 possible points, which equals 9 points. A "9" is entered in the cell where criterion 4 *row* and "Enter Score" *column* intersect.

When all the criteria on the rubric are completed, the total points under "Enter Score" will be added for a total score of 100% or less in the bottom right corner of the rubric (Table 2). If any criterion falls under the "Not a pretty picture" column, the task has to be done again until the student produces an airworthy product. If laid out correctly, 100% of each criterion would total 100, 90% of each criterion will total 90, and so forth.

Two criteria near the bottom of the rubric (Table 2) are not assigned points but are only an "Accept or Reject" of the project. The tube must be clean of debris and it must past the 2000-psi leak test. No matter how good the line appears, a failure in either of those last two criteria renders the fluid line *un-airworthy*, therefore results in zero points and a rework of the project.

Notice the last line of the rubric (Table 2) gives the instructions to "total points" and also provides for indicating which "attempt" the student has made on the project. The cell states, "Failure in any criteria requires a rework. A maximum of two reworks is allowed for this project. Each rework will result in a 5-point reduction of the numerical grade of the best attempt. The project grade will be the best of the attempts." The instructor may select to deduct a certain number of points from the final total for each time the project has to be reworked.

Table 2. *Partial View of Rubric in Appendix - "Accept or Reject" and Total Points*

10	**Uniformity of each flare contact surface. (10 pts.)**	Distortion of the flare mating surface.	Slight difference in uniformity but good contact surface.	Very slight difference in uniformity.	Visually uniform around inside of flare.	
11	**Bends follow lines on training board. Fittings properly torqued. (10 pts.)**	Line does not follow indicated path. Fittings were not properly torqued.	Tubing veers outside of the path but follows pattern.	Tubing veers off center but aligns with path.	Tubing follows on center of the indicated path. Fittings properly torqued.	
12	**Flared ends not under stress when installed on training board. (5 pts.)**	With one nut tight, other flare does not align with fitting.	With one nut tight, other flare needs tweaking to align.	With one nut tight, other flare aligns & B-nut goes on easily.	With one nut tight, other flare rests on & inline with fitting.	
	Tube and fittings must be clean, free of foreign material (No points - Accept or Reject).					**(A) (R)**
	Leak test one minute, 2000 psi. No seeping/leaking permitted (No points - Accept or Reject).					**(A) (R)**
	Total points of criteria 1 through 12 for total point grade of project. Attempt # (1) (2) (3) Failure in any criteria requires a rework. A maximum of two reworks is allowed for this project. Each rework will result in a 5-point reduction of the numerical grade of the best attempt. Project grade will be the best of the attempts.					

These instructions are at the discretion of the instructor, but there should be an incentive for the student to do as well as possible on the project the first time.

Practicing flares on scrap material before actually beginning the project is certainly reasonable. Any good mechanic in the field, who does not fabricate flared lines on a regular basis, will practice on scrap material before beginning the product that will be installed in an aircraft.

In the same token, when developing a new rubric, it is wise for the instructor to first try it on her or himself, and then try it on a student who has already passed the class. To facilitate the measurement of flare diameters, “go” and “no-go” gauges can be fabricated and used for grading the projects quickly. This too takes some of the student questioning out of the exercise. However, where scratches, gouges, or dents are a concern, a suitable micrometer may have to be used.

Criteria for Bending and Flaring Aluminum Tubing

The criteria used in the rubric for a lab project needs to align with the standards of the industry and the workplace. The student then has the opportunity to apply the knowledge gained in lecture and use the tools and technology to perform quality maintenance on a particular product (Keiser, Lawrenz, & Appleton, 2004). Instructors in an aircraft maintenance program do not share the same freedom that educators from other disciplines have in developing performance criteria. The standards for determining what is acceptable and what is not acceptable in the example of a rigid fluid line has been established by the FAA, and in some cases by the aircraft manufacturer. However, if the aircraft manufacturer doesn’t provide the criteria needed, the technician and the instructor must turn to AC 43.13-1B.

Regarding the fabrication and inspection of aviation fluid lines, the FAA has some definite guidelines in chapter 9, section 2 of AC 43.13-1B (USDOT, FAA, 1998):

1. A small amount of flattening in a bend is acceptable as long as the narrowest outside diameter is not less than 75% of the original outside diameter.
2. Bend radius for the tubing being used must not be less than the minimum radius as per Table 9-2 of AC 43-13-1B.
3. A dent less than 20% of the tube diameter is permissible as long as it is not in the heel of the bend.
4. Scratches or nicks cannot be deeper than 10% of the wall thickness. These are repairable as long as they are not in the heel of the bend.
5. No twisting, wrinkling, or buckling is allowed in the tubing.

6. Flares are to be made using a 37-degree aviation flare forming tool of the correct size for the tubing being flared.
7. Severe die marks, seams, or splits in the tube are not acceptable.
8. The flare is to be smooth, free of burrs and sharp edges.
9. Any crack or deformity in a flare is not acceptable.
10. All foreign material must be removed from the tubing before installation.
11. The torque used when tightening the fittings when connecting to the pressure test stand must be in accordance with Table 9-2 of AC 43.13-1B.
12. When doing a leak check, no leakage is permitted.

As illustrated in the appendix, most of the above criteria are listed down the left side of the rubric table.

ARE RUBRICS WORTH THE TROUBLE?

Rubrics are Good for Student Motivation

Rubrics "provide timely, meaningful feedback for students, and have the potential to become an effective part of the teaching and learning process," helping the students become motivated and independent learners (Steven & Levi, 2005, p. 17). Rubrics establish consistency in assessing student projects and let the students know "right up front" what is expected in their practical project assignments. Many students enter an aviation maintenance technology program with little or no experience in being a mechanic, much less having a familiarity with airplanes and related technologies. Their introduction to the projects that are required, and which have to be completed to an acceptable level of competency in an AMT program, can sometimes be very overwhelming for the first semester student. However, if a student is given a detailed list of clear expectations for a project while going from point A to point B, that attitude is more likely to become an I-can-do-that attitude rather than one of overwhelming frustration of not knowing what is good enough for the instructor. Owens writes, "Best practices have surmised that student expectations play an important role in student success" (2006, p. 73).

The rubric encourages the student to examine his or her work critically (Steven & Levi, 2005). The student doesn't have to hand in a project to the instructor blindly, having no idea how she or he has done until the grade is placed on the lab project assignment. The student can make a self evaluation of the project, using the parameters of the rubric, and asking the appropriate questions: "Does this flare meet the requirements my instructor is looking for?" – or more importantly, "the requirements of the industry?" "Is this bend too flat?" "Is this nick too deep?" Corrections can be made based upon the *student's* decision that the work is not airworthy, rather than upon that of the instructor. Critical thinking in *examining* a rigid fluid line is as important as constructing an airworthy fluid line. More than likely an aircraft maintenance technician in the field will be inspecting fluid lines for airworthiness more often than he or she will be fabricating one, therefore developing a critical eye and mind for the project assignment should be considered a major part of the student's training and education.

Rubrics are Time-Saving for the Instructor

There are professors and instructors who have been teaching aircraft maintenance *forever* and "don't need a so-called rubric." They know what they are looking for in a project and their *rubric* is in their head. They know how to grade fairly and the students all get an even break. That may or may not be true. Instructors need tools to assess student projects fairly, to encourage students in critical thinking while providing them with useful and constructive feedback, to provide the students with the expectations for an airworthy product. Instructors will also be providing themselves with better teaching methods and techniques (Owens, 2006; Stevens & Levi, 2005). By using a rubric as a guide in lectures, the instructor can demonstrate to the students what causes the discrepancies in a less-than-perfect flare, and how to avoid them. By directing the students' attention, for example, to criteria 7 and 8 (Table 3), the instructor can demonstrate what causes die marks or slippage marks in the flare or tubing, and how to avoid the pitfalls that result

Table 3. *Partial View of Rubric in Appendix - Die Marks and Tool Damage*

7	**#1 flare O.D. free from die marks, splits, or damage. (10 pts.)**	Severe die mark, split, or seam from over-tightening or slip marks from under-tightening.	Very slight die mark from flaring tool and slight indication of slipping in tool.	Very slight die mark from flaring tool but no indication of slipping in tool.	No die mark or split in flare, and no damage or slippage marks whatsoever.	
8	**#2 flare O.D. free from die marks, splits, or damage. (10 pts.)**	Severe die mark, split, or seam from over-tightening or slip marks from under-tightening.	Very slight die mark from flaring tool and slight indication of slipping in tool.	Very slight die mark from flaring tool but no indication of slipping in tool.	No die mark or split in flare, and no damage or slippage marks whatsoever.	
9	**Each flare contact surface and lip edge for smoothness. (10 pts. total)**	Imbedded particles in the inside contact surface or flare lip has rough or sharp edge.	Inside contact surface has appearance of "wiping" from the flaring cone.	Some very minute lines around the mating surface. No significant rough/sharp lip.	Smooth, polished mating surface. Flare lip edge is smooth with no rough/sharp edges.	
10	**Uniformity of each flare contact surface. (10 pts.)**	Distortion of the flare mating surface.	Slight difference in uniformity but good contact surface.	Very slight difference in uniformity.	Visually uniform around inside of flare.	
11	**Bends follow lines on training board. Fittings properly torqued. (10 pts.)**	Line does not follow indicated path. Fittings were not properly torqued.	Tubing veers out-side of the path but follows pattern.	Tubing veers off center but aligns with path.	Tubing follows on center of the indicated path. Fittings properly torqued.	
12	**Flared ends not under stress when installed on training board. (5 pts.)**	With one nut tight, other flare does not align with fitting.	With one nut tight, other flare needs tweaking to align.	With one nut tight, other flare aligns & B-nut goes on easily.	With one nut tight, other flare rests on & inline with fitting.	
	Tube and fittings must be clean, free of foreign material (No points - Accept or Reject).					**(A) (R)**
	Leak test one minute, 2000 psi. No seeping/leaking permitted (No points - Accept or Reject).					**(A) (R)**
	Total points of criteria 1 through 12 for total point grade of project. Attempt # (1) (2) (3) Failure in any criteria requires a rework. A maximum of two reworks is allowed for this project. Each rework will result in a 5-point reduction of the numerical grade of the best attempt. Project grade will be the best of the attempts.					

in a lower grade.

Rubrics are Good for the Program

The rubric offers the objectivity in grading projects that meets the criteria of DOT/FAA Advisory Circular 147-3A: It is worth repeating that the curriculum developer "must also develop practical projects and *objective* project grading criteria" [italics added] (USDOT, FAA, 2005, January 18, p. 2). In the words of Keiser, Lawrenz, and Appleton of the University of Minnesota, rubrics "assess workplace competencies, technical accuracy, and pedagogical soundness of technical education curricula" (2004, p. 182). It is absolutely necessary, especially in a Part 147 AMT program, that projects and rubrics be "consistent from both industrial and pedagogical perspectives" (Keiser, Lawrenz, & Appleton, 2004, p. 190). In what other program can you find criteria such as these more important than where men and women are training to perform maintenance on aircraft – vehicles in which thousands of people entrust their lives daily to the integrity and technical competency of aircraft maintenance technicians? The "success of technical education curricula is not only measured by students' achievement in school, but also through the results of that achievement in the world of work" (Keiser, Lawrenz, & Appleton, 2004, p. 183).

CONCLUSION AND RECOMMENDATIONS

Rubrics are good for the student, good for the teacher, and good for the program. "Rubrics save time, provide timely, meaningful feedback for students, and have the potential to become an effective part of the teaching and learning process" (Stevens & Levi, 2005, p. 17). It would be in the best interest of instructors and students if rubrics and other methods for objective assessment were implemented more frequently in the aviation maintenance technology curricula. Designing rubrics would require critical thought and extra time initially, but in the long run rubrics do *save* time, and relieve the instructor and the student of unnecessary anxiety and debate. As instructors in aircraft maintenance, we should possess curricular goals that are measurable and assessment tools that are objective; "the more explicit the outcomes, the easier it is to determine if students achieve them" (Keiser, Lawrenz, & Appleton, 2004, p. 184; Finch & Crunkilton, 1999). As instructors in aircraft maintenance, we *must* use objective and measurable criteria in the assessment of practical projects in which the student will be expected to be competent in performing in the aviation industry. The design and use of rubrics is just one way that objective can be realized.

APPENDIX: RUBRIC

Bending, Flaring, & Installation of Rigid Aluminum Fluid Lines (Rubric)

Task Description: Each student will fabricate an airworthy aluminum fluid line with flared ends and AN fittings in accordance with Advisory Circular 43.13-1B, the specifications below, and the instructions from class lectures.

	Criteria Bends: 1-4 Flares: 5-11	Not a pretty picture: Zero Points	Novice: 75% of Total Points	Proficient: 90% of Total Points	Exemplary: 100% of Total Points	Enter Score
1	**Flattened O.D. of bend must be at least 75% of original O.D. (5 points total)**	Flattened O.D. is less than 75% of the original diameter of the tubing.	Not Applicable. Pass or fail.	Not Applicable. Pass or fail.	Flattened O.D. is still at least 75% of the original diameter of the tubing.	
2	**All bend radii within limits. (5 pts.)**	Does not meet minimum bend radii.	Not Applicable. Pass or fail.	Not Applicable. Pass or fail.	Meets minimum bend radii.	
3	**Dents must be less than 20% of O.D. of tubing and not in heel of bend. (5 pts)**	Dent is 20% or more of outside diameter of tube or in the heel of the bend.	Dents less than 20% of the outside diameter and not removed.	Dents less than 20% of the outside diameter but removed with a "bullet."	No dents.	
4	**Tubing free of tool marks and damage. (10 pts.)**	Nicks or scratches in heel of bend. Twisting, wrinkling, or buckling.	Scratches/nicks no deeper than 10% of wall thickness.	Scratches/nicks no deeper than 10% of wall thickness but repaired.	No scratches, nicks, twisting, wrinkling, buckling or tool marks.	
5	**#1 Flare width. (10 pts.)**	Too wide or too narrow.	Minimum width as per information provided.	Between minimum and recommended width.	Recommended width.	
6	**#2 Flare width. (10 pts.)**	Too wide or too narrow.	Minimum width as per information provided.	Between minimum and recommended width.	Recommended width.	
7	**#1 flare O.D. free from die marks, splits, or damage. (10 pts.)**	Severe die mark, split, or seam from over-tightening or slip marks from under-tightening.	Very slight die mark from flaring tool and slight indication of slipping in tool.	Very slight die mark from flaring tool but no indication of slipping in tool.	No die mark or split in flare, and no damage or slippage marks whatsoever.	
8	**#2 flare O.D. free from die marks, splits, or damage. (10 pts.)**	Severe die mark, split, or seam from over-tightening or slip marks from under-tightening.	Very slight die mark from flaring tool and slight indication of slipping in tool.	Very slight die mark from flaring tool but no indication of slipping in tool.	No die mark or split in flare, and no damage or slippage marks whatsoever.	
9	**Each flare contact surface and lip edge for smoothness. (10 pts. total)**	Imbedded particles in the inside contact surface or flare lip has rough or sharp edge.	Inside contact surface has appearance of "wiping" from the flaring cone.	Some very minute lines around the mating surface. No significant rough/sharp lip.	Smooth, polished mating surface. Flare lip edge is smooth with no rough/sharp edges.	
10	**Uniformity of each flare contact surface. (10 pts.)**	Distortion of the flare mating surface.	Slight difference in uniformity but good contact surface.	Very slight difference in uniformity.	Visually uniform around inside of flare.	
11	**Bends follow lines on training board. Fittings properly torqued. (10 pts.)**	Line does not follow indicated path. Fittings were not properly torqued.	Tubing veers out-side of the path but follows pattern.	Tubing veers off center but aligns with path.	Tubing follows on center of the indicated path. Fittings properly torqued.	
12	**Flared ends not under stress when installed on training board. (5 pts.)**	With one nut tight, other flare does not align with fitting.	With one nut tight, other flare needs tweaking to align.	With one nut tight, other flare aligns & B-nut goes on easily.	With one nut tight, other flare rests on & inline with fitting.	
	Tube and fittings must be clean, free of foreign material (No points - Accept or Reject).					**(A) (R)**
	Leak test one minute, 2000 psi. No seeping/leaking permitted (No points - Accept or Reject).					**(A) (R)**
	Total points of criteria 1 through 12 for total point grade of project. Attempt # (1) (2) (3) Failure in any criteria requires a rework. A maximum of two reworks is allowed for this project. Each rework will result in a 5-point reduction of the numerical grade of the best attempt. Project grade will be the best of the attempts.					

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Evaluating Voice and Data Link Air Traffic Control Communications for General Aviation

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ABSTRACT

This study examined the effects of data link and voice air traffic control commands on pilot recall and execution. Instrument-rated pilots (*N* = 26) were tested on both a series of data link command tasks and a series of voice command tasks. The researchers predicted that participants would have a significant difference in overall errors in pilot recall and execution in the data link ATC command condition as compared to the voice ATC command condition. Also predicted was that there would be a greater gap in errors in pilot recall and execution at the ATC command blocks that contained higher parameters of ATC instructions. Our results indicate that pilots had significantly fewer errors in recall and execution in the data link condition compared to the voice condition at the moderate and high load ATC command levels. There was little or no difference in errors in pilot recall and execution in the data link condition compared to the voice condition at the low load ATC command levels.

INTRODUCTION

The world-wide aviation community is interested in implementing options to the traditional interaction via voice exchanges between air traffic controllers and pilots. One of these options is Controller to Pilot Data Link Communication (CPDLC). CPDLC uses a Very High Frequency (VHF) or satcom link to route text messages that are displayed on Flight Management System (FMS) or Aircraft Communication Addressing and Reporting System (ACARS) screens in the cockpit (Ambrose, 2004). According to Kerns (1991), the perceived benefits of data link include an improved clarity and efficiency of communication, reduced number of misunderstood communications, expanded airspace capacity, freeing up of frequencies used in voice communications, and reduced pilot and controller workload.

Today, the bulk of exchange between controllers and pilots is carried out by means of voice communication. Flight operations in the National Airspace System (NAS) depend on the timely and accurate exchange of information between Air Traffic Control (ATC) and pilots in the cockpit (McGann, Morrow, Rodvold, & Mackintosh, 1998). According to Helleberg and Wickens (2003), "…data link is one of the new technologies designed to replace or alter more traditional information exchanges between the pilot and ATC" (p. 1). Wickens, Mavor, Parasuraman, and Mcgee (1998) reported on the challenges facing the NAS and determined the need to upgrade the system within the context of the next generation air traffic control system (NGATS). NGATS and *free flight* will primarily use orbiting satellites, on board automation, and data link communications.

LITERATURE REVIEW

In a study by Olson (1996) to determine the services that general aviation pilots desired via data link, he found a high preference for data link use in Pilot Reports (PIREPS), Notice(s) to Airmen (NOTAMS), Automated Terminal Information Service (ATIS), and instrument flight rules (IFR) operations. In a NASA study (Lee et al., 2003) that focused on ATC controllers' views of data link, researchers found that "controllers had a high preference for transfer of communication through data link as a workload saving mechanism" (p. 1). Despite these early studies that highlighted both controller and pilot preference for text-based technologies, current use of data link in the NAS is limited to pre-departure clearances and oceanic clearances between ATC and airline crews via a third party delivery system (Ambrose, 2004).

According to Ambrose, the FAA began direct data link trials in a Miami Center test program in 2003, with a complete rollout for all national high-altitude control centers planned for 2006. Due to lack of funding, however, this program was put on hold in late 2003. Despite the setback in the U.S. CPDLC project, the Europeans are continuing with their rollout of the system. Currently, data link is being used at the Europe's Maastricht Upper Area Control Center, which handled over 4,000 CPDLC flights in a recent 12 month period (Hughes, 2005). The Maastricht project includes support and participation from U.S. airlines and U.S. avionics companies. Hughes summarizes that the complete ATC deployment, as well as the mandate of data link avionics in aircraft, is planned for the entire European continent by 2009.

According to Kerns (1991), past experience with the advent of innovative automation applications to the flight deck have indicated that changes in technology and machine responsibility will alter workload demands on pilots, and that additional research will be needed to determine human performance, technology design, human-computer interaction, and future training requirements. Wickens et al. (1998) furthers this notion that while these innovative technologies may improve efficiency, they create additional concerns about human performance integration with automation systems design. Wickens et al. conclude that the choice of what to automate should be guided by research in human-centered automation that focuses on the need to compensate for human vulnerabilities.

According to earlier research, most of the results of previous data link studies focused on airline crews and airline operations (Billings & Cheaney, 1981; Lee, 1989; McGann, Morrow, Rodvold, & Mackintosh, 1998). With the advent of very light jets (VLJs) and the use of multi-function displays with data link capabilities in current light piston Technically Advanced Aircraft (TAA), general aviation now has the ability to use data link in their operations. Few studies have compared the two delivery methods of voice and text in today's general aviation system.

One study (Risser, Scerbo, Baldwin, & McNamara, 2006) used non-pilot graduate students to manipulate a panel using a computer screen and mouse controls in response to simulated speech and text ATC commands while measuring response time and accuracy. Another study (Helleberg, Wickens, & Goh, 2003) used fifteen instrument rated pilots in a simulator with a visual display focusing on heads-down time results while scanning for traffic using three different data link display conditions. A third study (Wickens, Goh, Helleberg, Horrey, & Talleur, 2003) used twelve instrument rated pilots in a flight simulator that incorporated data link and cockpit display of traffic information while primarily reporting results on visual scanning.

PURPOSE

Few studies have compared the two methods of ATC command delivery (voice vs. data link) in a modern general aviation cockpit environment. Empirical studies of general aviation pilot performance with data link are limited, especially with respect to future requirements. Therefore, the purpose of this research study was to evaluate and measure accuracy of pilot recall and execution regarding use of text (data link) or voice as an ATC communications interaction in general aviation.

The researchers first predicted that there would be no main effect or interaction effect for order of trial (voice first or data link first). Then we predicted that participants in this study would have a significant difference in overall errors in pilot recall and execution in the data link ATC command condition compared to the voice ATC command condition. Finally we predicted that there would be a greater gap in errors at the ATC command blocks that contained a higher number of parameters of ATC instructions.

METHOD

Participants

Participants included 26 instrument-rated pilot volunteers from Indiana State University who all held a current FAA medical. Those who volunteered, and did not hold at least a current third class FAA medical were excluded, as were potential participants that were not instrument-rated. One condition of this experiment's design was that participants have no auditory, visual, or other impairments that may affect the results of this study. This condition was controlled for by requiring all participants to hold at least a current third class FAA medical. The pilots' total flight hours ranged from 160 to 1,220 hours (M = 350.0, SD = 244.8).

Measures

The Frasca 142 flight training device (FTD) located in the Indiana State University Flight Simulator Lab was used to conduct these trials. The FTD was preset to conform to the flight characteristics of a Cessna 172 Skyhawk RG. The FTD consisted of a primary flight instrument panel arranged in the standard 'T' configuration. The radio control panel included two communication radio controls, two navigation radio controls, and a transponder control head. The pilots flew the FTD manually (no autopilot) using traditional aircraft controls (control yoke, rudder pedals, and a single throttle control). A Dell 15-inch color monitor set at a screen resolution of 1024 X 768 was mounted in the FTD in the pilot's normal field of vision. The monitor displayed a data link control panel measuring approximately 4 inches by 5 inches. An aural ACARS tone was used to alert participants of an incoming text message.

Procedures

At an initial briefing, participants gave informed consent for this Institutional Review Board (IRB) approved study. Each participant flew two cross-country flights (each approximately 15 minutes long) under instrument flight rules (IFR) in simulated instrument meteorological conditions (IMC). Each trial consisted of two flights: a flight under the ATC voice command condition; and another flight under the ATC text (data link) command condition. A counter-balancing technique was used to control for the carry over effects of practice effect or positive carry over treatment effect. In this study, half the participants were given the voice command task flight first and the text (data link) command task flight second. The other half of the participants were given the text (data link) task flight first and the voice command task flight second.

The pilots began each simulated flight at a preset altitude, airspeed, and heading. The scenario began as a flight that was airborne after having departed a local non-tower airport and requesting an IFR clearance in the air. Once the participant was comfortably established in stable cruise flight, the FTD operator initiated ATC commands regarding initial clearances (heading, altitude, airspeed, IFR clearance, squawk, and altimeter setting). In the text condition, ATC commands were always preceded by an aural alerting tone as an indicator of an incoming data link message. In the voice condition, pilots were briefed to either verbally read back or acknowledge all ATC commands. In the text condition, pilots were required to press an acknowledge button near the data link display to confirm receipt of a message and willingness to comply with ATC commands. In the voice condition, the FTD operator acted as a pseudo-controller and read the ATC scripted commands to the pilot. The participants were briefed that they could ask to have controller commands repeated to them. The FTD operator, acting as the pseudo-controller, would also correct participant's errors during acknowledgements and read backs.

Each flight included nine ATC command blocks. Three ATC command blocks had a load of four parameters or more in length and were considered high workload (e.g., Frasca 142 is cleared to the STL airport except fly heading 280 to intercept the VLA 250 radial via the VLA 4 arrival, climb and maintain 5,000 ft., squawk code 2312). Another three ATC command blocks had a load of three parameters in length and were considered moderate workload (e.g., Frasca 142 turn right heading 360 descend and maintain 4,500 ft., and maintain 110 knots.). The other three ATC command blocks had a load of one or two parameters in length and were considered low workload (e.g., Frasca 142 contact St. Louis Approach on 126.5).

The main factors of interest in this study were the number of errors made in pilot recall and execution across the ATC command condition (voice or text) given the level of command workload (high, moderate, or low) and order of flight presentation (voice or text first). An observer counted the number of errors made by each pilot in ATC command recall and execution. For example, if the pilot was given a command to descend to an altitude and the pilot either did not initiate the descent or set the wrong altitude (misread, misheard or did not execute properly) the observer recorded an error.

The characteristics of this research study are consistent with a within-subjects design where each of the participants provided data from two trials (flights), each under a different condition (voice or text ATC commands). The order of trials was altered using a counterbalancing technique which also provided a between-subjects factor. All data for this study was entered into SPSS 14.0 for analysis. A *3* (levels of ATC commands) X *2* (conditions of voice or text) X 2 (order of trials) mixed model Analysis of Variance (ANOVA) design technique was used to provide the initial analysis for this study. The dependent variable was the number of errors in pilot recall and execution as recorded by the observer. The independent variables were condition of ATC commands (voice or text), loads in parameters of commands (high, moderate, or low), and a between-subjects factor of order of trial (voice first or data link first).

The Type I error for this investigation was set at .05 (α = .05). Minium, Clarke, and Coladarci (1999) suggest that the Type I error of .05 is the most commonly used for this type of research. While this alpha gives a higher probability of Type I error than an alpha of .01, the results of this data link study are informational only. In this case, the risk involved in a Type I error is small and reducing the Type I error to .01 was not necessary.

RESULTS

A *3* X *2* X 2 mixed design ANOVA was used to first determine the between-subjects effects of the order of trial (voice first or data link first) on errors in pilot recall across the within-subjects effects of ATC command condition (text or voice) and ATC command load (high, moderate, or low). No significant main effects or interactions for order were found. The ATC Command condition X Order interaction (F (1, 24) = .937, p > .05) and the ATC Command condition X Load X Order interaction (F (2, 48) = .385, p > .05) were all not significant. The analysis fails to reject the first null hypothesis. Data link and voice command condition errors in pilot recall and execution were not significantly influenced by order of trial.

A *3* X *2* X 2 ANOVA was then used to determine the effect of the ATC command load (high, moderate, or low) and command condition (voice or text) on errors in pilot recall and execution. The descriptive statistics for the means of each condition are consistent with the researcher's prediction that participant errors in recall and execution at the high load ATC command blocks that contained four or more parameters of instructions would be less in the text (data link) condition than in the voice condition. The average overall number of errors made in pilot recall and execution while flying the flight training device under the data link command condition (M = 4.2) were less than the average number of errors while flying under the voice command condition (M = 6.8). There is little or no difference in errors in pilot recall and execution across voice or text at the lower parameters of commands (see Table 1).

The errors in pilot recall and execution were then analyzed within the *3* X *2* X 2 ANOVA across the command conditions of voice and text. A significant effect was found (F (1, 24) = 15.4, p < .05). The second null hypothesis was rejected. Overall number of errors in pilot recall and execution in the text (data link) condition are significantly less than in the voice ATC command condition. Further analysis then compared the pilot recall and execution errors in the conditions of voice and text to include the load levels of ATC commands (high, moderate, or low).

Table 1. *Descriptive Statistics for Mean Errors in Pilot Recall and Execution*

ATC Command Condition	Overall Errors	High Load Errors	Mod Load Errors	Low Load Errors
Voice (n = 26)	6.8	3.8	2.0	0.9
Data link (n = 26)	4.2	2.2	1.1	0.8

A significant effect was found (F (2, 50) = 9.1, p < .05). The third null hypothesis was also rejected. There is a significant difference in number of errors in pilot recall and execution with regard to load of ATC command parameters (high, moderate, or low) in either the text or voice condition (see Table 2).

Table 2. *ANOVA Table of Within-Subjects Effects*

Source	SS	DF	MS	F	p-value
Command	30.519	1	30.519	15.433	.001
Command X Order	1.853	1	1.853	.937	.343
Error (command)	47.462	24	1.978		
Load	126.27	1.7	73.307	32.213	.000
Load X Order	7.321	2	3.660	1.868	.166
Error (Load)	94.077	48	1.960		
Command X Load	15.500	2	7.750	5.890	.005
Com X Load X Order	1.013	2	.506	.385	.683

Upon examination of the data, it appeared that the high load ATC commands had fewer errors in pilot recall and execution in the data link condition. This effect appears to diminish at the low loads of ATC commands (see Figure 1).

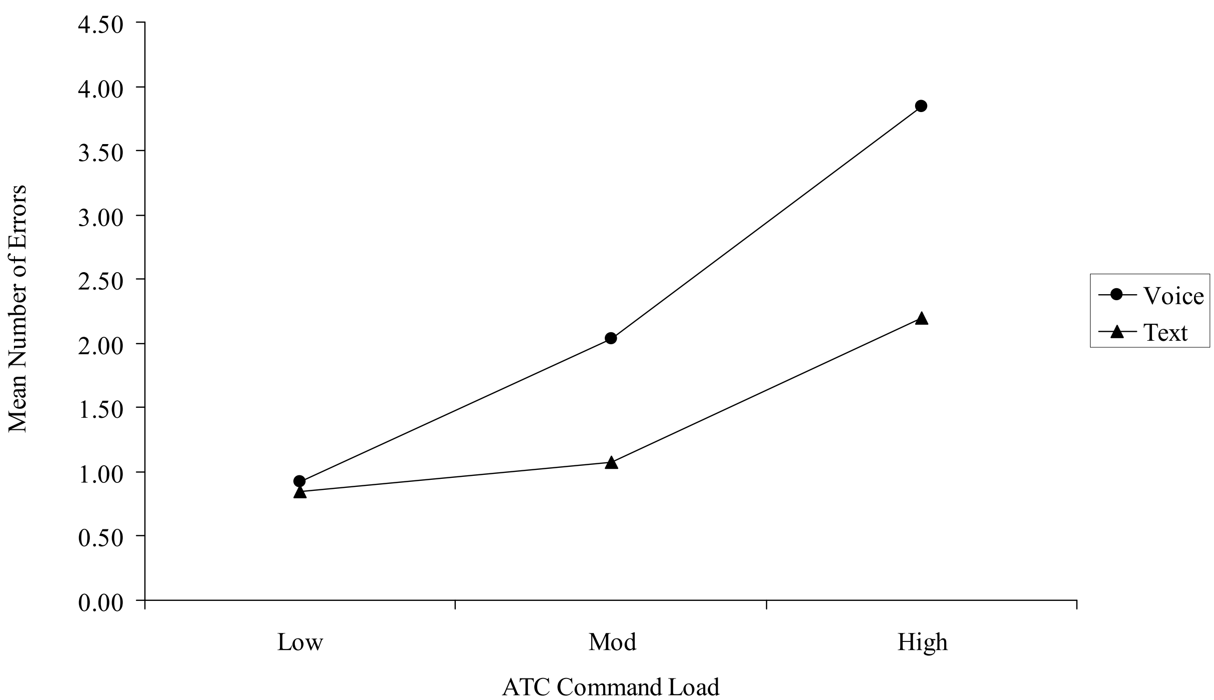

Figure 1. Errors in Pilot Recall and Execution across ATC Command Loads in Voice versus Text

As a follow-up, three protected dependent *t* tests were conducted to test that the mean errors in pilot recall and execution increased significantly with ATC command load intensity. This procedure was recommended by Cronk (2006) to substitute as a post-hoc analysis for this type of situation in repeated measures ANOVA. Because this analysis included three tests, and therefore inflated the Type I error rate, we used a significance level of .017 (.05/3) instead of .05. The follow-up protected *t* tests were calculated to compare the mean text (data link) errors to the mean voice errors in the high, medium, and low load parameter ATC command levels (see Table 3). The mean difference between high load voice commands and high load text (data link) was 1.62 (*SD* = 2.53) errors. A significant decrease in errors from voice to text at the high load ATC command level was found (t (25) = 3.26, p < .017). The mean difference between moderate load voice commands and moderate load text (data link) was .96 (*SD* = 1.08) errors. A significant decrease in errors from voice to text at the moderate load ATC command level was found (t (25) = 4.56, p < .017). Finally, the mean difference between low load voice commands and low load text (data link) commands was .08 (*SD* = 1.23) errors. No significant difference from voice to text at the low load ATC command level was found (t (25) = .32, p > .017).

Table 3. *Paired Samples t Tests*

Source	M	SD	t	DF	Sig.
Voice High – Data High	1.62	2.53	3.25	25	.003
Voice Mod – Data Mod	.96	1.08	4.56	25	.000
Voice Low – Data Low	.08	1.23	.319	25	.753

In summary, a pair wise comparison of the three protected dependent *t* tests, with an adjusted alpha level of .017, revealed a statistically significant decrease in errors from voice to text at the high and moderate load ATC command level. However, no significant difference from voice to text at the low load ATC command level was found.

DISCUSSION

The primary purpose of this study was to investigate how different levels of datalink and voice commands affect errors in pilot recall and execution. Specifically, this study addressed the human reliability analysis of the data link automation issue in the general aviation environment. The researchers predicted that participants would have a significant difference in overall errors in pilot recall and execution in the data link ATC command condition as compared to the voice ATC command condition. Also, we predicted that there would be a greater gap in errors in pilot recall and execution at the ATC command blocks that contained higher parameters of ATC instructions. In this study the pilots had significantly fewer errors in pilot recall and execution in the data link condition compared to the voice condition at the moderate and high load ATC command levels. However, there is little or no difference in errors in pilot recall and execution in the data link condition compared to the voice condition at the low load ATC command levels.

The findings of this study are consistent with those of Risser et al. (2006), where results demonstrated an advantage in text commands with longer messages. Taken together, these findings suggest that data link may provide an increase in pilot performance with regard to high parameter communications from ATC such as: ATIS information; NOTAMS; PIREPS; initial IFR clearances; detailed route changes; and oceanic clearances. However, the evidence from this study and previous research in the field generally endorses the role of the dual modalities of voice and text over a preemption of one modality of communication.

Appropriate or likely uses of this research include assistance in the development of flight performance objectives for future general aviation aircraft systems. Other uses include direction in the incorporation of data link technologies in general aviation and Air Traffic Control. While this study focused on comparing a pure voice to a pure data link medium of communication, future research could examine the dual use of voice and data link for general aviation. Another limitation of this study was a focus on one aspect of data link with regard to errors in pilot recall and execution. Further research would be necessary to determine other implications of a change from voice to text displays with regards to heads-down time and the possible negative implications of this technology for the high-priority visual tasks regarding single-pilot operations that are predominant in general aviation.

In conclusion, accurate pilot recall and execution is likely to remain one of the critical aspects in general aviation that will be challenged by new technologies. As a consequence, it is important to gather empirical evidence that will drive future cockpit technologies and pilot training programs to improve safety in general aviation. Wickens et al. (1998) summarize that these new tools should continue to be evaluated with human-centered simulation and careful experimental design. The introduction of the new data link technology into the general aviation cockpit should proceed gradually, with a high degree of attention to training, differences and pilot requirements.

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The Impacts of VLJs on Tennessee Airports: A Case Study

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ABSTRACT

In an effort to determine the level of preparedness among Tennessee general aviation (GA) airports for accommodating and servicing Very Light Jets (VLJs), a survey was conducted to determine if managers of Tennessee's GA airports feel their operations are adequately prepared to support the anticipated increase in aircraft movements and on-demand services related to the introduction of this new class of aircraft. The study investigated the perceptions of airport executives concerning the emerging VLJ market, and efforts undertaken to both prepare and promote general aviation airports in Tennessee as viable destinations for the VLJ operator. The paper highlights the VLJ movement (including the background of VLJ development), discusses the projected benefits of VLJs to local Tennessee communities not serviced by commercial air carrier service, and presents results of the survey. The study concludes by presenting several practical recommendations that governmental leaders and airport managers may use to justify improvements and expansion projects aimed at marketing general aviation airports across the state of Tennessee as important destinations for VLJs.

INTRODUCTION

Long before it became an economically viable product, the airplane was envisioned by aviation pioneers as the one machine that would shrink the world and bring the human race closer through the friendly exchange of cultures. This evolution continues today with the introduction of a new category of turbine powered aircraft: Very Light Jet (VLJ). As a class, VLJs incorporate significant advances in airframe design, powerplants, computerized avionics, materials and manufacturing techniques. These advances result in VLJs being less expensive to obtain and operate, certificated to be operated by a single pilot, and capable of operating into GA airports in smaller communities that previously were not able to safely accommodate larger corporate class jet aircraft.

The Federal Aviation Administration predicts that perhaps as many as 5,000 VLJs will be flying by the year 2016 (Sabatini, 2006). To put the potential impact of VLJs into perspective, in its annual industry delivery and shipment report, the General Aviation Manufacturers Association (GAMA) estimates there are only about 15,000 business jets of various weight and performance classes operating worldwide (GAMA, 2006). Even if considered as a conservative estimate of a few thousand aircraft, the manufacturing and support of VLJs represent a significant growth factor in the aerospace industry.

VLJ manufacturers agree with Federal Aviation Administration forecasts, expressing a shared optimism that an expanding world economy will produce an increasing number of wealthy individuals and business entrepreneurs who will demand utility, comfort and flexible aviation options (Polek, 2006). General aviation organizations such as the National Business Aviation Association (NBAA) anticipate a dynamic shift in corporate aviation with the introduction of VLJS. In a press release, Ed Bolen, President of the NBAA recently stated:

> The development of VLJ aircraft is good news on many levels. Their introduction produces high-skill manufacturing jobs. They will help make many small and midsized companies more competitive, and they will strengthen aviation services for many small communities. Those benefits should be the focus of discussion about VLJs (Bolen, 2006, para 5).

Leading aviation conglomerates such as Honeywell Aerospace and Rolls-Royce predict a strong business jet market for at least the next decade during which general aviation manufacturers will distribute 12,000 airplanes worth an estimated $195 billion. Rolls-Royce, a leading turbine engine supplier, anticipates that the VLJ niche will be responsible for a third of these new aircraft delivered. A major supplier of avionics and system components, Honeywell Aerospace calculates that VLJ assembly lines will produce about 250 airframes annually (Polek, 2006).

VLJs DEFINED

While the VLJ idiom may be new to many, the private jet concept certainly is not. The first personnel size business jet was envisioned in the early 1960s by the renowned innovator Bill Lear. Introduced in 1964, the Lear 23 was the first successful small jet aircraft when it entered mass production. The original Model 23 was a seven-passenger, pressurized jet that flew at a top speed of 564 miles per hour with a range of 1,875 miles. The Lear 23 was a commercial success and led to the development of a number of new models with increased size, range and speed (Boyne, 1987).

Although small jet aircraft are not new to the world of aviation, the VLJ is considered innovative in many ways. Specifically, VLJs are turbine powered aircraft with a take-off weight of 10,000 pounds or less and certificated for single pilot operations (NBAA, 2005). VLJs will offer four to nine passenger seats, cruise speeds around 400 miles per hour and an operating range between 1,100 to 2,300 miles (George, 2005). Along with modern turbine engine technologies, these next generation light jet aircraft incorporate highly integrated avionics, along with advanced cockpit automation, refined passenger amenities and simplified aircraft systems designed to reduce pilot workloads.

The emerging VLJ market represents a new breed of general aviation aircraft and the beginning of a new niche of personnel air transportation and private jet charter. The operating parameters of most VLJ models afford little difference between a 10,000 pound maximum takeoff weight (MTOW) VLJ, a popular cabin-class turboprop aircraft such as a Raytheon King Air model, or heavier corporate aircraft. However, VLJs will afford slower approach speeds than most turboprops and several models will be capable of operating at the higher extremes of controlled airspace. Reduced weight resulting in slower approach speeds allows operations at more than 5,000 general aviation airports around the U.S. with paved runways 3,000 to 5,000 feet in length (NBAA, 2005).

The VLJ era is being ushered in by numerous aircraft manufacturers in various stages of development and competition. These varied manufacturing and design activities around the globe fuel an exciting period in the general aviation industry. This growth is spurred by a sustained demand for corporate class aircraft that allows determined travelers to avoid congested airport terminals and lengthy security screening queues, while realizing low operating costs and timely point-to-point service. As a consequence of a generally strong economy and favorable tax incentives, potential aircraft owners are seriously considering VLJs. The price of this new class of aircraft ranges from $1.0 million to $3.5 million, placing them well within the reach of many small, but emerging businesses, jet charter operators and moderately wealthy individuals (Phillips, 2006).

At the time of this research, there were no less than eight companies manufacturing VLJs. The following is a brief summary of VLJs that have either recently entered service or are expected to do so in the near future (specifications summarized in Table 1).

Eclipse 500

The Eclipse 500 was the first VLJ to receive provisional FAA type certification (Phillips, 2006). With an advertised range of nearly 1,400 miles, it can seat six passengers. The Eclipse VLJ is powered by two Pratt and Whitney PW610F medium-bypass turbofans that produce 900 pounds of thrust each. The Eclipse is able to operate from 3,400 foot long runways and cruise at 370 knots at a maximum service ceiling of 41,000 feet. Eclipse Aviation delivered its first customer aircraft on December 31, 2006, at its headquarters in Albuquerque, New Mexico. According to company officials, the manufacturing and support facilities at Eclipse Aviation are designed to produce 1,000 aircraft annually, and the company has an order backlog for more than

2,500 aircraft costing about 1.5 million dollars each (Trautvetter, 2006).

Cessna Mustang

The Cessna Mustang is credited with many "firsts." Specifically, the Mustang was not only the first of the VLJ class to receive full type certification, but also the first to receive certification for flight into known-icing conditions, and the first VLJ to be delivered to a customer. The Cessna Aircraft Company said it expects to deliver about 40 Mustangs in 2007 with a price of about 2.4 million dollars per airframe. The Mustang is powered by two Pratt & Whitney Canada PW600 turbofans producing 1,460 pounds of thrust each. It is configured for six seats and has a balanced field length of only 3,110 feet (George, 2006).

HondaJet

After nearly 15 years in development, Honda announced at AirVenture 2006 in Oshkosh that it would produce the Hondajet commercially. It plans to produce 70 aircraft per year at its new 250,000 square foot facility and hangar at Piedmont Triad International Airport in Greensboro, North Carolina, and has begun accepting orders for its VLJ entry through Piper aircraft dealers. An all-composite fuselage, the Hondajet is powered by two General Electric Honda HF120 turbofan engines, each rated at 1,880 pounds take-off thrust. Priced at 3.6 million dollars, the Hondajet is easily recognized by its unique over-the-wing engine mount configuration. According to Honda, this design eliminates the fuselage structure necessary to support engines, resulting in significantly reduced cabin noise and vibration, a larger cabin size and lower risk of engine damage resulting from the ingestion of foreign objects from tarmacs and runways. Takeoff distance for the HondaJet is estimated to be 3,120 feet over a 35-foot obstacle (Thruber, 2006).

Adams Aircraft A700

The A700 is the turbine-powered derivative of the piston engine A500. The new AdamJet will use the same wing, boom, tail, nose gear, instrument panel and comparable interior level and cabin seats as the A500. Unlike the Cessna Mustang and Eclipse 500, the AdamJet will be powered by Williams FJ-33 engines that produce 1,200 pounds of thrust each. Beginning in the summer of 2006, the A700 VLJ was in the midst of flight tests and development, and the company expected its VLJ to enter the marketplace sometime in 2008, costing about $2.25 million each. It has also been reported that the company has more than 85 confirmed orders for the A700. The A700 will be powered by the Williams FJ33 turbine that was certified in 2004 and is a slightly less powerful version of the company's FJ44 engine that currently powers the Cessna Citation CJ1 and Raytheon Premier (Trautvetter, 2006).

Embraer Phenom 100

Developed by the Brazilian aircraft manufacturer Embraer, the Phenom cabin is designed for 4 passengers with a flying range of 1,160 nautical miles. Its price is estimated at $2.85 million. The Phenom is expected to make its first flight mid-2008 with first deliveries beginning in 2010. It has been reported that the Phenom 100 will the most expensive VLJ on the market; nevertheless, Embraer is convinced that, in addition to the aircraft's performance, the elevated cabin amenities and passenger comfort features will serve as a distinction for this aircraft and be a significant selling point. The interior of the aircraft is being designed by BMW, and the Phenom 100 is the car manufacturer's first venture into the aircraft industry. The Phenom 100 will be powered by Pratt & Whitney Canada PW617F engines, with 1,615 pounds of thrust each and expected to achieve a maximum operating speed of Mach 0.7 at 41,000 feet (Trautvetter, 2006).

GENERAL AVIATION AIRPORTS: THE FRONT DOOR OF COMMUNITIES

The most amazing aspect of air transportation is that it has become so important to our economy, defense, and social wellbeing in such a short time. Today, in cities and towns across the country, the local airport has developed into one of a community's greatest assets for economic and community development. Regardless of its size or number of flight operations, an airport directly impacts the local economy and overall strengths in the community it serves. Airports are major economic factors locally, not just by providing a variety of direct employment opportunities, but also through the creation of opportunities through the aircraft service sector. Local airports are excellent representatives of their community and often provide the first and perhaps only impression of the community to air travelers (Tennessee, 2005).

Table 1. *VLJ Specifications*

VLJ Specifications					
	MTOW	Landing Distance	Range	Max Cruise	Cost
Eclipse 500	5,920	2,250 ft.	1,125 nm	370 kts	$1.52M
Cessna Mustang	8,645	2,380 ft.	1,150 nm	340 kts	$2.39M
Adam A700	8,500	2,520 ft.	1,200 nm	340 kts	$2.25M
Honda Jet	9,200	2,500 ft.	1,180 nm	420 kts	$3.65M
Embraer Phenom 100	TBD	3,000 ft.	1,160 nm	380 kts	$2.85M

Notes: MTOW refers to maximum takeoff weight in pounds. Data based on NBAA IFR reserves (35 min) with 100 nm alternate; 4 occupants @ 200lb. Adapted from "Your Window on the Emerging World of VLJs," (2007); "Eclipse 500 Compared to Other Aircraft," (2007).

Tennessee is fortunate to have a well-developed air transportation system consisting of six commercial service airports offering scheduled airline passenger service, 14 regional airports specifically designed to support high performance general and corporate class aircraft, and 55 smaller general aviation airports designed to meet the general aviation wants of local aviation enthusiasts (Tennessee, 2005). This current status evolves from efforts in the early 1920s by the Tennessee legislature enacting the first of a series of aviation acts promoting aviation, airways and airport development (Fulbright, 1996). These efforts continue today, through the Aeronautics Division of the Tennessee Department of Transportation which provides engineering and construction support, grant procurement and educational assistance to communities across the state (Fulbright, 1996, p.146).

Beech River Regional Airport in Darden, Tennessee is the newest regional general aviation facility built in Tennessee in over 20 years. Opened on May 25, 2006, Beech River replaced two smaller local airports deemed obsolete and too expensive to enhance to meet current and future demands. Beech River was intentionally designed and built to attract business and industrial prospects. With a concrete-paved 6,000 foot long runway and 100 foot wide full length concrete-paved parallel taxiway, Beech River Regional Airport is ideally suited for VLJ operations and heavier corporate aircraft such as the Gulfstream V (Decatur County, 2006). Tennessee is also the corporate home of Federal Express Corporation (FedEx), the world's largest express freight transportation company. FedEx operates its principal overnight package sorting facility at the Memphis International Airport and has consistently been the international leader for total air cargo handled since 1992 (Airports Council International, 2006).

METHODOLOGY

Purpose

In designing this research effort, the authors desired to determine both the current status of the VLJ industry and the degree to which Tennessee airports were prepared to meet the needs of this new class of jet aircraft. In essence, as the VLJ will likely introduce jet operations to airports which previously had no or very few jet operations, our goal was to determine if these airports were prepared for

VLJs, and if not, what plans had been adopted to become better prepared. To conduct this study, two methods were selected. First, a review of literature on this topic was conducted to gain insight into the VLJ market, the VLJ manufacturers, and potential demand. Second, to determine the level of preparedness of Tennessee general aviation airports in accommodating VLJs, a survey research effort was undertaken.

The results of this study should prove important for Tennessee airport managers, Tennessee communities, VLJ manufacturers, potential VLJ customers, and the State of Tennessee Division of Aeronautics. In essence, by providing insight into the level of preparedness of general aviation airports throughout the state of Tennessee and the manner in which these airports are better preparing to meet the needs of VLJs, the study results will allow these stakeholders to better anticipate and plan for the introduction of VLJs into the Tennessee aviation system, and make adjustments to marketing plans, airport master plans, and other airport-specific programs and objectives.

Participants

The focus of this research effort was airports throughout the state of Tennessee. This population was selected as a matter of convenience, as both authors currently reside in this state and are more familiar with the airports and airport managers located throughout this state. According to the most recent *Tennessee Airport Directory* (Tennessee Department of Aeronautics, 2003), the State of Tennessee currently has 81 public-use airports. Six of these airports are commercial-service airports and were excluded from this study (Chattanooga, Jackson, Knoxville, Memphis, Nashville, and Tri-Cities). The remaining 75 airports were included in this study.

Utilizing the State of Tennessee Division of Aeronautics *Tennessee Airport Directory*, supplemented with phone calls as necessary to confirm e-mail addresses, the entire population of 75 public-use general aviation airports throughout the state of Tennessee was selected for this study. As all contact with participants was planned via email, the email addresses for airport managers at each of these airports was entered into a database.

Survey Instrument

The authors designed an original questionnaire for this study (Appendix A). Utilizing Survey Monkey, an on-line survey website, a nine-item questionnaire was designed. The questionnaire focused not only on the current facilities and services available at these airports, but also the anticipated impact of VLJs, and the level to which each airport was currently prepared to accommodate VLJs. If an airport indicated they were either currently "unprepared" or "very unprepared" to meet the needs of VLJs, they were directed to two additional questions (using SurveyMonkey's question logic) that asked how well prepared they would be within the next three years, and what plans they had to become better prepared. Lastly, the questionnaire asked respondents to explain what potential problems would be experienced with the introduction of VLJs into the Tennessee airport system and to recommend ways in which to address these problems.

Procedure

This study, which was conducted from November 2006 to January 2007, began with an email invitation to the entire population of 75 airport managers on November 13, 2006. Included in the email was an electronic link to the on-line survey. The email introduced the survey and explained the importance of the research effort. Per SurveyMonkey policy, a link was also included to allow individuals the opportunity to decline participation in the survey and discourage future follow-up by the researcher.

In determining the completed sample size necessary for valid results, Dillman (2000) was consulted. Utilizing his formula, and allowing for +/- 10% sampling error with an estimated 80/20 split answer variability at the 95 percent confidence level, the completed sample size needed for this desired level of precision was 34.

A total of nine emails were returned as undeliverable, which required additional phone calls to determine correct email addresses. With correct email addresses, these airport managers were then sent the email containing the survey link. As of November 21, a total of 20 survey responses had been received. A reminder email was sent to all non-respondents on November 21. By year-end, a total 35 responses had been received, which equated to a 46.6 percent response rate and satisfied the desired completed sample size previously determined.

Limitations

Due to the inclusion of only airports throughout the state of Tennessee, this study is limited in that conclusions drawn from the results can only be attributed to airports in this state. However, the authors plan to conduct future research on this topic to include airports nationwide.

RESULTS

Runway lengths

One benefit of VLJs is the short runway length required for takeoff, compared to many other turbine-powered aircraft. In fact, all of the VLJs previously discussed are able to take off (at sea level) in distances between 2,297 and 3,400 feet. Thus, if an airport does not have runways of this minimum length, it becomes apparent that such an airport is not currently prepared to accommodate these jets. Item one asked participants, "What is the length of your airport's longest paved runway?" All respondents indicated their longest paved runway was at least 3,000 feet, with 31 respondents (88.6) percent indicating a runway of at least 3,500 feet. Thus, it appears from those responding airports that lack of runway length will not prevent the accommodation of at least some types of VLJs.

Airport services

Airport managers were also asked about the services currently provided either by their airport or an FBO located on their airport. See Figure 1 for an indication of their responses. Of particular interest to VLJ operators, although 80 percent of responding airports have at least one hangar and over 90 percent have ramp parking and tie-downs, approximately 90 percent do not have de-icing capability, 30 percent do not have an instrument approach, 30 percent do not sell Jet A fuel, 25 percent do not have an on-field FBO, 55 percent do not have a power cart, 35 percent do not have security (in the form of Airport Watch, security guard, or Security Plan), 70 percent do not have a turbine-aircraft maintenance run-up area, and 70 percent do not have turbine maintenance and/or repair services. Thus, while each of these services is offered in some form at some of the responding airports, it appears that airports wishing to attract VLJs in the future and offer a high level of customer service, will need to invest in these additional services (such as Jet A fuel and turbine maintenance services).

Anticipated demand

Although industry is predicting a great influx of VLJs into the aviation system in the near future, the researchers of this study felt it important to ask airport managers how they felt about this anticipated demand. Respondents were asked "How likely do you feel it is that at least one VLJ will begin utilizing your airport on a regular basis within the following time periods?" (See Table 2.) Clearly, over half of respondents are fairly confident that at least one VLJ will begin utilizing their airport within one year. Seventy-five percent are confident that they will begin seeing a VLJ on a regular basis 1 to 2 years from today. Almost 85 percent of respondents expect to see regular VLJ operations at their airport more than two years from today.

Level of preparedness

When asked how prepared their airport is currently to meet the needs of VLJs, 34 percent indicated they were very prepared, 37 percent indicated they were prepared, 23 percent indicated they were unprepared, and 6 percent indicated they were very unprepared. Thus, although it is positive to see that over 70 percent feel prepared to some degree, almost 30 percent of responding airport managers feel their airport is not prepared to meet the needs of VLJs.

As a follow-up question to those airports not prepared to accommodate VLJs, airports were asked how well prepared they would be within the next three years to meet the needs of VLJs.

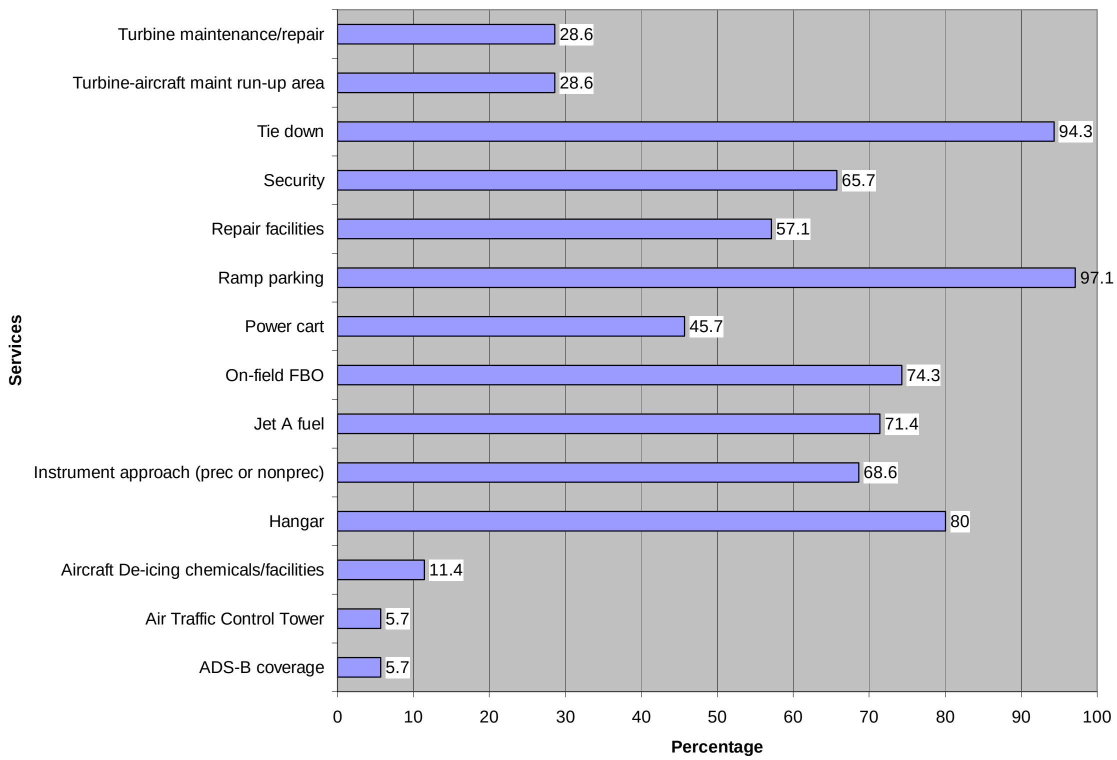

Figure 1. "Which of the following services are available at your airport?"

Table 2. *"How likely do you feel it is that at least one VLJ will begin utilizing your airport on a regular basis within the following time periods?"*

	Very Likely	Likely	Unlikely	Very Unlikely
Less than 1 year from today	35% (9)	19% (5)	19% (5)	27% (7)
1-2 years from today	32% (9)	43% (12)	18% (5)	7% (2)
More than 2 years from today	33% (7)	52% (11)	5% (1)	10% (2)

Note: Number of responses in parentheses.

Although 40 percent indicated they would be prepared, 60 percent indicated they would still be unprepared to meet the needs of VLJs within the next three years. This finding should be of concern to VLJ manufacturers, as well as potential VLJ operators. In essence, with a number of Tennessee airports unprepared to handle VLJs, these airports should not be considered as viable destinations for VLJ operators. Clearly, this should be of concern to these airports, as well as the entire Tennessee airport system.

Future plans

To determine what "unprepared" airports are doing to become prepared, the questionnaire asked airport managers to detail their airport's future plans to become better prepared to meet the needs of VLJs. Nine airport managers responded to this question by offering the comments detailed in Table 3.

It is indeed interesting to see what future plans these airports have to better meet the needs of VLJs. Although two airports have no plans for improvements, the majority are moving in the right direction to become well prepared to meet the needs of VLJs.

Potential problems

Lastly, survey participants were also asked if they could foresee any potential problems associated with the introduction of VLJs into the

Table 3. *For those airports currently unprepared to meet the needs of VLJs, "What are your airport's future plans to become better prepared to meet the needs of VLJs?"*

Runway will be 5,004 feet and will have jet fuel.
Would like to have GPS approach, runway lighting and extending runway from 4,700 to 6,000 feet
Only if it is certain that a VLJ will be visiting regularly will we take steps to provide Jet A or other basic jet services.
No plans for improvements. I am operating a Metroliner with max gross weight of 12,500 lbs and pushing the limits on a 3,500 ft runway. The powers that be cannot see the advantages of a longer runway and [are] really not pro-aviation.
Extension of the runway, secure area, add on-site fuel with credit card payment.
None at this time.
Hope to extend runway to 5,000 ft. Long range plans include preparing for VLJs.
Installation of new fuel barn to include sales of Jet-A fuel and erection of new hangars to offer accommodations for aircraft based at airport.
Runway extension [and] Jet A

Tennessee airport system. The vast majority, 97 percent, could see no problems. However, one airport manager expressed concerns similar to those voiced by the National Air Traffic Controllers Association. This respondent predicted "airspace saturation due to low performance capabilities of these jets (VLJs) versus airliner type aircraft." This individual further explained that "at [the] present time, the regional jets (such as CRJ's and EMB's) 'clog' the jet airways with their slow airspeed and impede [larger air carrier] aircraft from achieving optimal cruise flight speeds." To counteract this tendency of becoming "an obstruction to orderly traffic flow," this respondent suggests that the FAA mandate "that ATC controllers restrict their altitude or require that they fly off jet airways while above FL240 if traffic demands deem appropriate."

Although these VLJs are generally able to fly at maximum cruise speeds of 315 to 380 knots, there are predictions that they will "clog" the airways and interfere with commercial jet traffic. However, the FAA has attempted to quiet these fears by assuring the aviation community that measures are in place to prevent VLJs from becoming a burden on the national air transportation system. In fact, Nicholas Sabatini, FAA associate administrator for aviation safety, assured the Senate Commerce Committee in September 2006 that, "The system is in place today to accommodate the entry of new aircraft into the National Airspace System…this is nothing new for the FAA. It is our day-to-day business" (AAAE, 2006, para. 5). Whether this is true remains to be seen.

DISCUSSION AND RECOMMENDATIONS

As can be seen, this study of Tennessee airport managers resulted in a great deal of insight into the study's goal of determining if Tennessee airports are adequately prepared to accommodate VLJ aircraft at their facility. First, lack of available runway length will not, in general, prevent a VLJ from utilizing a particular airport. All survey participants reported runway lengths of at least 3,000 feet. This is sufficient to handle many of the VLJs highlighted in this paper, which typically require 2,300 to 3,400 feet for takeoff at sea level.

Second, although many responding airports do have the basic services necessary to service a VLJ, approximately 1/3 of responding airports do not have an instrument approach, Jet A fuel, an on-fuel FBO, or security (in the form of Airport Watch, security guard, or security plan). Plus, less than 30 percent of responding airports have a turbine aircraft maintenance run-up area or turbine maintenance and/or repair services. Does this mean that these airports will not be able to accommodate a VLJ? No, it does not. However, it does mean that the airport will not be able to offer a level of service that VLJ operators will expect. In essence, at 1/3 of these airports, a VLJ can fly in and land. But, they cannot land in instrument weather conditions, purchase fuel, be assured of security while their multi-million dollar aircraft is at the airport, or receive turbine maintenance and/or repair services. This simply means that approximately 1/3 of Tennessee general aviation airports (if survey results are representative of the population), may be viewed as unable to serve VLJs, due these lack of services. This will negatively impact the communities that hope to attract new aircraft operations by these new generation jets, in terms of lost revenue, and lost aircraft operations.

Third, it is interesting to note that approximately 1/3 of responding airports feel unprepared to meet the needs of VLJs. This confirms the study findings discussed in the previous paragraph. Interestingly, there is also a group of airports ranging from between 46 percent to 15 percent that feel it is unlikely that at least one VLJ will begin utilizing their airport in either less than one year, 1 to 2 years, or more than 2 years from today. It seems plausible, therefore, that the group of airports both lacking jet services and feeling unprepared to handle VLJs, is a group of airports that also feel it is unlikely their airport will even see a VLJ on a regular basis in the near future. Although it is not possible to determine if the same airports responded in the same way to these questions, it is possible that these unprepared airports are unprepared because they see no need to become prepared; in essence, considering it unlikely that at least one VLJ will begin utilizing their airport in the near future. If this finding proves true, it should be of little concern to Tennessee airports. However, the researchers conducting this study are both familiar with Tennessee airports and the requirements of VLJs. It would seem that all general aviation Tennessee airports should be prepared to accommodate VLJs, or else the fact some are unprepared would become a self-fulfilling prophecy in which VLJs do not serve those airports because they are not adequately prepared.

As such, the researchers believe it is prudent for all Tennessee general aviation airports to develop plans to accommodate VLJs in the near future. At a minimum, these plans should include improvements to security and safety operations that will appease the discriminating owner of this new class of corporate aircraft. To accommodate increased aircraft operations and the more sophisticated needs of turbine powered aircraft, airport managers and governing authorities should give serious consideration to adding new runways or extending existing runways and incorporating high speed taxiways to safely and expeditiously handle VLJs. Tennessee airports that currently do not offer jet fuel, heated hangers or maintenance services should begin the process to secure these conveniences as quickly as possible to maximize their marketability as the VLJ fleet grows. Upgrading physical facilities such as terminal buildings, flight planning rooms, restrooms and lounges will also be an important tool for attracting and retaining significant VLJ operations.

CONCLUSION

The Beech River Regional Airport, like many other general aviation airports in Tennessee, serves as an important link for businesses operating in the state and as a reliever airport for the larger commercial airports. These general aviation airports are a key component of the state's transportation system and must be kept up to date, not only to support the airport's continued growth, but the economic viability of the local community as well.

If predictions prove correct, the VLJ niche will be a strong market with lasting appeal. If these numerous forecasts are only partially correct, the nation's air transportation system could see the addition of thousands of new aircraft entering service in a very short time span. It is certain that a significant number of these airplanes will operate from general aviation airports and will require the services of Tennessee airports. While many airports in Tennessee indicate they are capable of handling VLJ aircraft and welcome the VLJ class as a unique marketing opportunity, a significant number are not prepared for a variety or reasons. Consequently, unless these under-prepared airports increase their level of services soon and engage in a plan of action designed to attract new aircraft such as the VLJ, it is predictable that these communities will languish while others enjoy a significant level of growth, influence and prosperity.

APPENDIX A

Survey of Tennessee Airports on VLJ Preparedness

Consent

The Airport Managers of all non-commercial service, General Aviation Airports throughout the state of Tennessee are invited to participate in this study to determine the level of preparedness among Tennessee Airports to accommodate VLJs. There are no known risks if you choose to participate, nor will you be penalized if you decide not to participate. There are no rewards (monetary or otherwise) available to those who choose to participate. By completing this on-line survey, you are voluntarily agreeing to participate. Your responses will remain confidential; neither you nor the Airport you represent will be identified in the study results. The questionnaire should take approximately 5 minutes to complete.

IRB # 07-092

If you have any questions concerning your rights as a research subject, please contact:

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Thank you for your time!

For the purpose of this study, VLJ refers to Very Light Jets. VLJs are generally defined as technologically advanced, high-performance turbine-engine-powered aircraft weighing 10,000 pounds or less (maximum certificated takeoff weight) and certificated for single pilot operations. Examples of VLJs include the Eclipse 500, Cessna Mustang, Adam 700, Embraer VLJ, Epic LT, HondaJet, and D-Jet.

1. What is the length of your airport's longest paved runway?

☐	Less than 2,400 feet
☐	At least 2,400 feet, but no more than 3,000 feet
☐	At least 3,000 feet, but no more than 3,500 feet
☐	At least 3,500 feet

2. Which of the following services are available at your airport?

☐	ADS-B coverage
☐	Air Traffic Control Tower
☐	Aircraft De-icing chemicals and/or facilities
☐	Hangar
☐	Instrument approach (precision or non-precision)
☐	Jet A fuel
☐	On-field FBO
☐	Power cart
☐	Ramp parking
☐	Repair facilities
☐	Security (Airport Watch, security guard, or Security Plan)
☐	Tie-down
☐	Turbine-aircraft maintenance run-up area
☐	Turbine maintenance and/or repair services

3. How likely do you feel it is that at least one VLJ will begin utilizing your airport on a regular basis within the following time periods?

	Very Likely	Likely	Unlikely	Very Unlikely
Less than 1 year from today	☐	☐	☐	☐
1-2 years from today	☐	☐	☐	☐
More than 2 years from today	☐	☐	☐	☐

4. Overall, how well prepared is your airport to meet the needs of VLJs?

Very Prepared	Prepared	Unprepared	Very Unprepared
☐	☐	☐	☐

**If answering "Unprepared" or "Very Unprepared" to Item 4, respondents were directed to items 5 and 6. If answering "Very Prepared" or "Prepared" to Item 4, respondents were directed to item 7.*

5. How well prepared will your airport be within the next three years to meet the needs of VLJs?

Very Prepared	Prepared	Unprepared	Very Unprepared
☐	☐	☐	☐

6. What are your airport's future plans to become better prepared to meet the needs of VLJs?

7. Based on your professional expertise and experience, do you foresee any potential problems with the introduction of VLJs to the Tennessee airport system?

☐	Yes
☐	No

Note: **If answering "Yes" to item 7, respondents were directed to items 8 and 9. If answering "No" to item 7, respondents were directed to end of questionnaire*

8. Specifically, please explain what potential problems you foresee with the introduction of VLJs to the Tennessee airport system.

9. How would you recommend these potential problems be addressed?

Thank you very much for your time and effort in completing this questionnaire!

Please contact either of us with any comments.

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A Comparison of In-flight Refueling Methods for Fighter Aircraft: Boom-receptacle vs. Probe-and-drogue

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ABSTRACT

Aerial refueling dates back to the very beginnings of flight and has developed into two very different and incompatible methods. While the U.S. Air Force primarily uses a boom-receptacle method, the U.S. Navy uses a probe-and-drogue method. Cross-service commonality of aerial refueling methods is a concept that has the potential to save money and increase the tactical abilities of the armed services. This paper serves to examine the feasibility of using a common method of aerial refueling for fighter/attack aircraft (collectively referred to as fighter aircraft). Safety, reliability, weight and refuel rates have been examined for each method. Currently there can be no set standard for fighter aircraft. The requirements for the U.S. Navy are such that they would not be able to utilize boom-receptacle refueling adequately, and similarly the requirements for the U.S. Air Force are such that probe-and-drogue refueling would not be feasible. There are many variables to consider with each aircraft and its intended use that affect which method is best incorporated.

INTRODUCTION

Currently, there are two different and incompatible methods for aerial refueling. The first method is a probe-and-drogue method used by the United States Navy, Marine Corps, and limited United States Air Force aircraft. The aircraft requiring fuel is equipped with a probe that extends forward from the aircraft. The pilot must maneuver to insert the probe into a basket or drogue that trails from the tanker aircraft to obtain fuel and then must disconnect when the operation is complete (Smith, 1998). The second method is a boom-receptacle method used by the United States Air Force. The aircraft requiring fuel is equipped with a receptacle while the tanker has a boom with control surfaces, better known as a flying boom. The aircraft requiring fuel is directed into place by the boom operator using director lights that are either manually or automatically activated. Once the aircraft is stable in the correct position, the boom operator inserts the boom into the receptacle and refuels the aircraft. Once refueling is complete, the boom operator withdraws the boom (Holder & Wallace, 2000). Tankers with only a flying boom, like many KC-135s, can use a boom-drogue adapter (BDA) kit that attaches to the boom as shown in Figure 1. Probe equipped aircraft can then refuel from the boom through the adapter. The limitation is that once the adapter is attached, the tanker can only refuel probe-equipped aircraft (Byrd, 1994). The BDA kit also has a greater tendency to snap off at the probe (Gebicke, 1993a). The Navy requires two drogues in the air for redundancy and that translates to two KC-135s with adapter kits for Navy operations (Gebicke, 1993a). The KC-10 has both a centerline drogue and a flying boom and therefore does not need an adapter kit. Still, without wingtip drogue pods for multiport refueling, there must be two KC-10s in the air for Navy operations.

HISTORY

Aerial refueling dates back to World War I, when the need to extend aircraft range was realized. Frequent stops to refuel fighter aircraft are costly in terms of time and range and may not be feasible due to the weather. Alexander Seversky was a WWI pilot for the Imperial Russian Navy who immigrated to the United States and was the first person to apply for a patent on an aerial refueling system in 1921 (Byrd, 1994). The first refueling operation took place on November 12, 1921, when Wesley May climbed from a JN4 with a five gallon gas can strapped to his back (Holder & Wallace, 2000). The first method that resembles aerial refueling of today was performed by dropping a fuel hose from one plane, while the pilot of the second

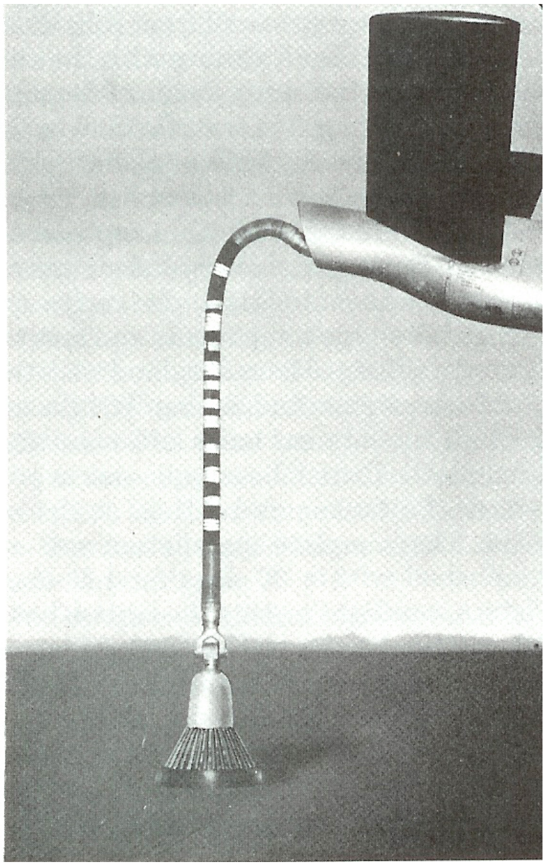

Figure 1. Boom-drogue adapter (BDA). *Note*. From Byrd, 1994 (p. 128).

plane reached out, grabbed the hose and refueled his plane in flight (Holder & Wallace). This method proved quite dangerous and interest faded until 1942 when Col. Jimmy Doolittle wrote a letter to Major General Hap Arnold describing an aerial refueling concept (Holder & Wallace). The Air Force Material Command (AMC) requested that Boeing conduct a study of air-to-air refueling. "Four months later, Boeing presented the results of its studies, outlining the possibilities of installing "hose-type" refueling equipment in both B-29 and B-50 bombers" (Holder & Wallace, 2000, p. 13). Further research by Boeing brought about the flying boom (Byrd, 1994) while Britain's Flight Refueling Ltd. (FRL) developed the probe-and-drogue system (Byrd, 1994). During the Vietnam War, Air Force fighter airplanes such as the F-100 Super Saber were equipped with fixed refueling probes (Davis, 1986) and others, such as the F-105 Thunderchief, were equipped with both a retractable probe and a slipway (Drendel, 1986). Aircraft today are equipped with one or the other system, depending on the branch of service the aircraft is designed for. For example, the F-35 has an Air Force variant equipped with a slipway, while the Navy variant is equipped with a probe

STATEMENT OF THE PROBLEM

The problem is that U.S. Air Force (USAF) fighter aircraft and U.S. Navy (USN) fighter aircraft use two different and incompatible refueling methods. This study sought to find what the fuel transfer rates to fighter aircraft were for each method of aerial refueling, what the weight and volume impact on fighter aircraft was for aerial refueling equipment, and if there were safety or reliability concerns with either aerial refueling method.

There are very few fighter pilots who have had experience with both methods of aerial refueling, though their insights would prove most valuable. USAF boom operators have had experience with both methods, while USN aerial refueling crews have only had experience with the probe-and-drogue method. Much of the information regarding aerial refueling is considered sensitive since it details the capability and specifications of aircraft and their mission.

This study was limited to USAF tanker aircraft since they supply fuel for both USAF and USN fighter aircraft flown by the United States. Most other countries use the probe-and-drogue method exclusively and their input would add no additional insight to that of the USN. Examples may be used from other countries to make a point about tanker capability. Manufacturers of aerial refueling equipment were limited to those that have refueling equipment on USAF or USN fighter aircraft.

REVIEW OF RELEVANT LITERATURE

Two reports written by Mark E. Gebicke for the United States General Accounting Office (GAO) titled Aerial Refueling Initiative: Cross-Service Analysis Needed to Determine Best Approach (Gebicke, 1993a) and Operation Desert Storm: An Assessment of Aerial Refueling Operational Efficiency (Gebicke, 1993b) stress the importance of multipoint refueling and suggest that Air Force fighter aircraft be equipped with probes and tankers be equipped with drogue baskets. Both reports were in response to a "request for an assessment of the performance of the air refueling tanker force during Operation Desert Storm" (Gebicke, 1993a, p. 1). The assessment was directed to analyze: (a) "the relevance, in light of that wartime experience, of a 1990 initiative to enhance tanker efficiency, effectiveness, and interoperability," and (b) "the adequacy of the Department of Defense assessment of the initiative" (Gebicke, 1993a, p. 1). "Essentially, the initiative called for standardizing Air Force refueling equipment for tankers and fighters on the probe/drogue refueling system" (Gebicke, 1993a, p. 1). Gebicke (1993b) actually states that the second point is to standardize the refueling systems of U.S. fighter aircraft.

One point made in Gebicke (1993a) is that "reasonable solutions to equipping F-16s and F-22s with [probes] may exist" (p. 1). One option for mounting a probe on aircraft that were not produced with a refueling probe is the Aerial Refueling Tank System (ART/S) pod. The system is produced by Sargent Fletcher (a company under Flight Refueling Limited). The ART/S pod is basically a drop tank with a retractable probe ("Sargent Fletcher", 2001). Gebicke (1993a) recognizes that at one time the Air Force used external probes where "the probe is bolted to the outside and covered with a second skin to smooth over the protrusion" (p. 6).

Gebicke (1993a) also states that "if the Air Force does not increase its participation in the initiative by adding probes to its fighters, it may not be cost-effective to add multipoint to both KC-10s and KC-135s for naval support" (p. 2). As shown in Figure 2 and Figure 3, operational multipoint systems have already been added to both the KC-10 and the KC-135 tankers. Other countries have been able to refuel two probe aircraft and one slipway aircraft at the same time as shown in Figure 4.

As part of the background, Gebicke (1993b) states that "both the Marine Corps and the Navy must rely on the Air Force if extensive tanker support is required" (p. 2). The Navy has used the KA-6 Intruder as a tanker which has a maximum of 2,300 gallons of transferable fuel (Jenkins, 2002). The USAF and USMC KC-130 has 33,000 lbs (5,076 gallons) of transferable fuel (Reed, 1999) while the USAF KC-135 has 200,000 lbs (30,770 gallons) of transferable fuel

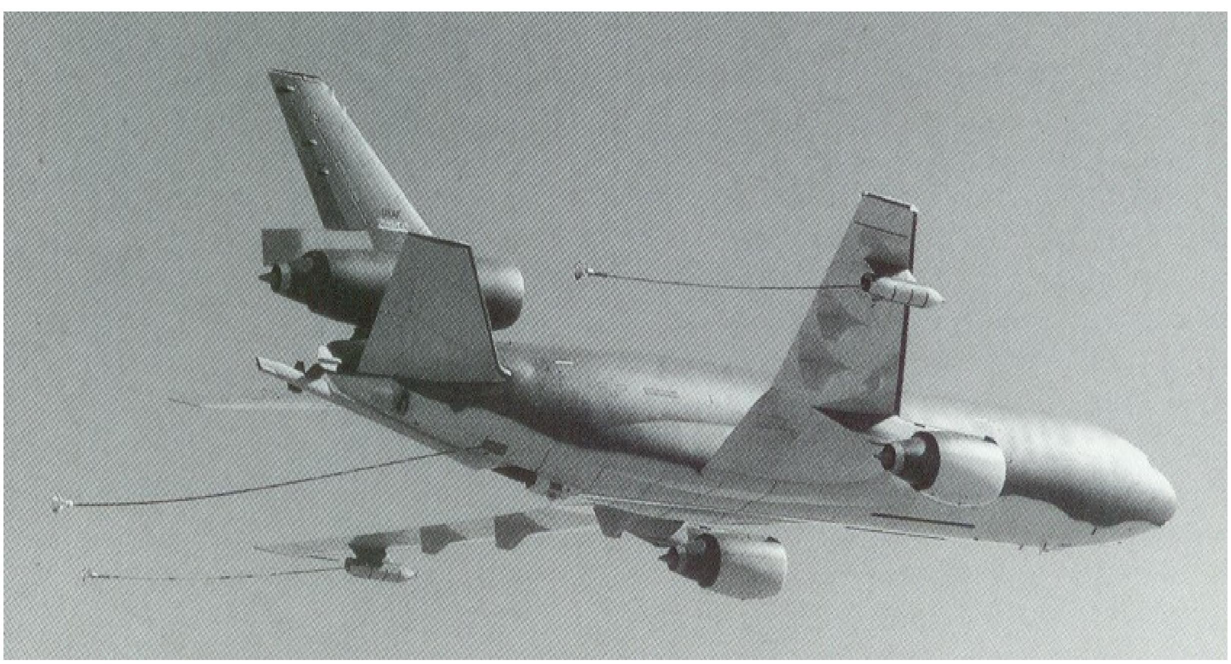

Figure 2. KC-10 multipoint. *Note*. From Steffen, 1998 (p. 112).

Figure 3. KC-135 multipoint. *Note*. From Holder & Wallace, 2000 (p. 135).

Figure 4. IAF multipoint. *Note*. From Holder & Wallace, 2000 (p. 72).

("U.S. Air Force Fact Sheet: KC-135 Stratotanker," 2004) and the KC-10 has 356,000 lbs (54,770 gallons) of transferable fuel (Steffen, 1998). There was an attempt in 1963 to use the KC-130 on a carrier but the KC-130 "was far too large for hangar stowage, and would have proved too difficult to integrate into normal operations with a full air wing embarked" (Reed, 1999). The F/A-18 Super Hornet has also been used as a Navy tanker but this would be a great misuse of an aircraft that was intended as an attack-fighter (Bolkcom & Klaus, 2005).

Throughout both reports, Gebicke (1993a, 1993b) writes about the benefits of multipoint. "Since a multipoint tanker can transfer fuel more quickly, the tanker itself consumes less of its available fuel, leaving more fuel available for fighters" (Gebicke, 1993a, p. 7). "Since multipoint tankers have two off-load points, in these circumstances they would have been able to meet the tighter time constraints dictated by conventional operations with fewer tankers" (Gebicke, 1993b, p. 10).

Gebecke (1993a) recommends that "the Secretary of Defense reassess the aerial refueling initiative from a cross-service perspective with the primary goal of determining if probes should be added to Air Force fighters and how many multipoint tankers would be required to support Air Force and Naval operations" (Gebicke, 1993a, p. 17-18).

A similar report to Congress was written more recently by Bolkcom and Klaus (2005). In the introduction, it states that "a single hose-and-drogue can transfer between 1,500 and 2,000 lbs of fuel per minute," "today's fighter aircraft can accept fuel at 1,000 to 3,000 lbs per minute," and "the flying boom's primary advantage over the hose-and-drogue system is lost when refueling fighter aircraft" (Bolkcom & Klaus, p. 2). Bolkcom and Klaus also state that "because KC-135 aircraft employ a single hose, Navy fighters must cycle six to eight aircraft through the refueling queue. By the time the last aircraft has refueled, the first one requires more gas" (p. 3). F/A-18 Super Hornets have been used as tankers, but Bolkcom and Klaus state that "using these assets for aerial refueling rather than combat is seen as a sub-optimization of a scarce and valuable resource" (p. 4). Bolkcom and Klaus state that "seventy four percent of the [Air Force] fleet could potentially refuel with the [probe]-and-drogue with no reduction in fuel transfer rates" (p. 4). Bolkcom and Klaus described how the JSF and the F-22 Raptor with a refueling probe could replace the current inventory of Air Force fighter aircraft that have slipways. Bolkcom and Klaus discussed equipping tanker aircraft with booms versus equipping them with drogues. It is stated that the cost and complexity of the boom is greater than the drogue and the modifications are more significant. Bolkcom and Klaus state that "legacy USAF fighter aircraft would need to be retrofitted, and new aircraft would need to be manufactured with refueling probes if they were to exploit multipoint [probe]-and-drogue refueling" (p. 6).

There is a wing mounted probe that has been tested but is not operational. Figure 5 shows a drawing by Dexter Kalt (advisor to the board of directors of ARSAG) depicting the Universal Aerial Refueling Store.

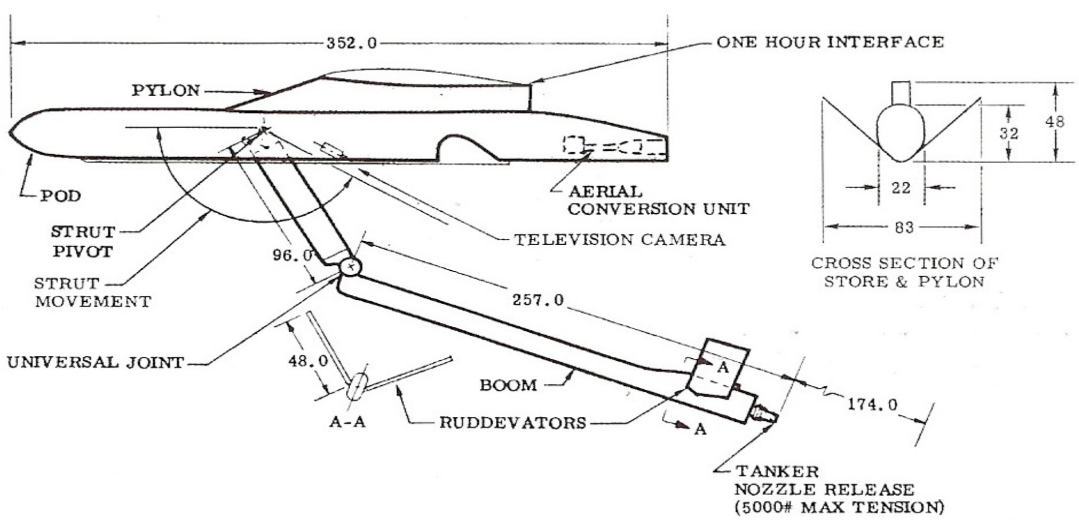

Figure 5. Universal aerial refueling store. *Note*. From Holder & Wallace, 2000 (p. 37).

"This technique was tested on a KC-135, and it performed well. Receiver aircraft noted the lack of turbulence since there was less turbulence around the wings than the fuselage. The system was operated remotely" (Holder & Wallace, 2000, p. 37). Bolkcom and Klaus (2005) cite five studies and state that "all found that tankers equipped with multipoint hose-and-drogue refueling would refuel combat aircraft more effectively than boom equipped aircraft" (p. 7). One of the reports cited by Bolkcom and Klaus is the Aerial Refueling Initiative (Gebecke, 1993a).

Bolkcom and Klaus (2005) argue in support of flying booms. "A tanker with a flying boom can be converted in the field to accommodate probe-equipped aircraft, if necessary. [Probe]-and-drogue tankers cannot be converted to accommodate aircraft with boom receptacles. To accommodate fighter aircraft, tankers with flying booms can reduce the speed at which they dispense fuel. Tankers with [probe]-and-drogue refueling cannot increase the speed at which they dispense fuel to accommodate bombers and other large aircraft" (Bolkcom & Klaus, p. 8).

Smith (1998) provides an historical account of aerial refueling. One section of the piece is titled Boom Versus Probe-and-Drogue Refueling. This section explains the influence of the Strategic Air Commander, General Curtis E. LeMay, who did not approve of the probe-and-drogue method. "Probe-and-drogue involved a lot of rubber, a material that could become unreliable in the -60°F temperatures above 30,000 feet" (p. 41). "During February 4-7, 1951, a fly-off between the probe-and-drogue and the Boeing boom conducted at Offutt AFB, Nebraska, produced predictable results. Pilots of small maneuverable airplanes liked probe-and-drogue; those who flew big airplanes preferred the boom" (p. 41-43). "Headquarters United States Air Force finally settled this issue on July 14, 1958, when it announced that boom refueling would be the standard for its airplanes" (p. 43).

Killingsworth (1996) reviewed five past studies to determine whether any general conclusions could be drawn. "Advocates of a transition to multipoint aerial refueling describe multipoint benefits as follows: greater flexibility and interoperability of U.S. forces, and the possibility of budgetary savings resulting from the smaller tanker inventory that could be required" (p. vii). Killingsworth is published by the RAND Corporation, a nonprofit institution that helps improve policy and decision making through research and analysis ("RAND Mission", 2005). Killingsworth reviewed a RAND study from 1990. "The study helped to focus on probe/drogue technology as an alternative with potential to enhance tanker force effectiveness" (p. vii). "As recommended by the RAND work, the Air Force in 1991 and 1992 conducted its own studies of the cost effectiveness of multipoint. Some of the assumptions made by the Air Force Studies and Analyses Agency (AFSAA) in these studies were less favorable to multipoint than those used by RAND. In particular, AFSAA used higher overall fuel transfer rates, as well as relatively higher rates for transfers using the boom/receptacle than using the probe/drogue transfers" (Killingsworth, p. vii-viii). "In 1993, the Air Mobility Command (AMC) conducted a study of the numbers of multipoint-equipped tankers needed to support Navy carrier-based operations during a contingency." "The AMC study showed little advantage to having multipoint-equipped tankers" (Killingsworth, p. viii). Killingsworth conducted a contingency analysis for the Gulf War focusing on the 32nd day after the start of the war because he was looking for a boom-limited situation or a situation in which multipoint would have made possible the use of fewer tankers or the refueling of more fighters. "Of 214 tanker sorties flown on that day, only 21 could have been deleted by combining fighter packages behind fewer tankers. Further analysis indicates that only one of these combinations would actually have required multipoint capability" (Killingsworth, p. x). Killingsworth continues with observations on fighter retrofits, "a program to retrofit large numbers of current U.S. fighters with probes is probably inadvisable, but the apparent advantages of multipoint aerial refueling indicate that the installation of probes on follow-on fighter aircraft should be considered" (pp. x-xi).

RESEARCH QUESTIONS

Based on the review of literature, the following six research questions were proposed for this study.

1. What is the fuel transfer rate of the boom-receptacle method of aerial refueling?
2. What is the fuel transfer rate of the probe-and-drogue method of aerial refueling?
3. What is the weight and volume impact of a refueling receptacle on fighter aircraft?
4. What is the weight and volume impact of a refueling probe on fighter aircraft?
5. Are there safety or reliability concerns with a boom-receptacle method of aerial refueling?
6. Are there safety or reliability concerns with a probe-and-drogue method of aerial refueling?

METHODOLOGY

This research was a descriptive study, focused on historical data. Data was requested from aerial refueling wings, USAF and USN fighter pilots, and manufacturers of aerial refueling equipment. Information from aerial refueling wings was requested to answer questions about refuel rates and equipment reliability concerns. Fighter pilots were asked to supply information about refuel rates and equipment reliability concerns. Manufacturers of aerial refueling equipment were asked to supply information about equipment weight and volume and refueling flow rates.

The survey population for aerial refueling wings or groups is listed in Appendix A. There were 15 aerial refueling units. The survey population of fighter pilots was all active and retired fighter pilots that have performed aerial refueling. The first method of sampling fighter pilots was to ask current and former pilots whom I was in contact with to fill out the survey and pass it along to others. The second method was to send the form to USAF and USN fighter squadrons and request that pilots fill out the form. The sample size is all surveys that were returned. The only known manufacturers of aerial refueling equipment were Sargent Fletcher and Parker Hannifin Corporation.

For the Aerial Refueling Wing Survey, aerial refueling wings were asked to supply information about fuel transfer rates and safety or reliability concerns for their operations since 1998. For the Fighter Pilot Survey, fighter pilots were asked to supply information about fuel transfer rates and safety or reliability concerns during their aerial refueling experiences. Manufacturers of aerial refueling equipment were asked to supply information about fuel transfer rates and weight and volume impacts of their products.

The first 10 questions on the Aerial Refueling Wing Survey addressed the transfer rates of fuel to fighter aircraft. This included the amount of time it takes to connect and to disconnect. Questions 11 and 12 addressed the reliability and safety of each refueling system. Questions 13 through 15 were general questions that augmented the research questions. Question 16 was related to the research question of refueling rates. Questions 17 and 18 related to aerial refueling safety and reliability.

Questions 1 and 2 of the Fighter Pilot Survey were demographic questions regarding the background of the fighter pilots. Questions 3 and 4 addressed the safety and reliability research questions. Question 5 addressed research questions on refuel rates. Questions 6 and 7 concerned factors that might influence refuel rates. Question 8 addressed preference for a particular refueling method. Question 9 was a qualitative question asking for amplifying research information.

The Aerial Refueling Wing Survey was valid, since the information came from the people who operate the tanker refueling equipment. Information from aerial refueling equipment manufacturers was valid because the companies design and create the equipment for a specific range of fuel flow rates and to fit in a specific volume with a specific weight.

Consistent results depended on similarity among the items that make up the two independent constructs of the surveys, safety or reliability concerns and the fuel transfer rate. Two questions in the fighter pilot survey were developed to evaluate safety and reliability concerns and three questions were developed to evaluate fuel transfer rates. Eleven questions in the refueling wing survey were developed to evaluate fuel transfer rates, and correlation coefficients among each of these questions were calculated to assess the internal consistency of each construct in the survey.

Descriptive statistics were used to describe each of the variables collected in the surveys. Data from the first two questions in the fighter pilot survey, type of aircraft flown, flight hours and aerial refueling method (Question 1) and number of aerial refuelings (Question 2), were described by tables depicting the number of responses and totals for each question. Responses to number of refueling incidents (Question 4), time required to refuel four aircraft (Question 5), and which system is preferred (Question 8) in the fighter pilot survey were described by tables depicting totals and percentages for each question.

Data from the first five questions in the aerial refueling wing survey, time considerations for refueling operations, were described by a table depicting the averages for each question and the total for the five questions. Responses to the number of aircraft refueled (Question 6), the mission time (Question 7), missions per flight (Question 8), flow rate (Question 9), and fuel amount transferred (Question 10) in the aerial refueling wing survey were described by a table depicting the averages for each question. Responses to the question regarding the receiver or tanker being fouled (Question 11), mechanical failures (Question 12), other aircraft being refueled on the same mission (Question 13 and Question 14) and multi-port (Question 15) were described by a table depicting percentages for each question. Responses to the questions regarding which method the respondent thought was faster (Question 16), which was safer (Question 17) and which was more reliable (Question 18) were described by a table depicting the fractional preference for each method.

Data from manufacturers and additional sources were described by tables depicting the information collected.

The qualitative responses were evaluated and themes created to identify any noted barriers that could be resolved to facilitate acceptance of one aerial refueling method. Selected qualitative responses were used to clarify and enrich the discussion and conclusions of the study.

RESULTS

Fighter Pilot Survey Results

Thirty-one fighter pilots responded to the fighter pilot survey (Appendix B). Each pilot was given a number from 1 to 31 in no specific order. Table 1 shows the responses from Question 1, the method of aerial refueling the respondents have used.

Table 1. *Fighter Pilot Refueling Methods*

Respondent's aerial refueling method	Number of respondents	Percentage of respondents
Probe-and-drogue only	6	19%
Boom-receptacle only	18	58%
Both	7	23%
Total	31	100%

Table 2 shows the total hours the pilots have flown with respect to the method of aerial refueling the aircraft is capable of (also from Question 1). Two fighter pilots did not state how many hours they had flown and one pilot did not specify which method was used in an aircraft that could have refueled either way.

Table 2. *Fighter Pilot Flight Hours*

Respondent's aerial refueling method	Flight hours in type	Percentage of total respondents
Probe-and-drogue	19,870	26%
Boom-receptacle	54,690	72%
Not specified	1,500	2%
Total	76,060	100%

Table 3 shows responses from Question 2 regarding how many aerial refueling operations the respondents have performed during training, deployments and combat as well as totals for each method and situation.

Table 3. *Number of Aerial Refueling Operations*

	Training	Deployment	Combat	Total
Probe-and-	2,410	1,106	285	3,801
Boom-	5,874	1,771	1,332	8,977
Either	50	100	10	160
Total	8,334	2,977	1,627	12,938

Table 4. *Probe-and-drogue Aerial Refueling Incidents*

KC-130 low altitude tanking turbulence damaged FA-18 probe tip.

KC-135 hose whip from BDA damaged FA-18 probe tip.

Near mid-air due to other fighter flying with night vision lights on.

Hydraulic failure in drogue hose causing probe and/or drogue damage.

Fuel leaking from probe/drogue connection.

Drogue failed to extend.

Drogue failed to pump fuel.

Basket slaps (drogue slaps receiver aircraft).

KC-130 reel response failure.

F-100 probe snapped off.

Table 5. *Boom-receptacle Aerial Refueling Incidents*

FOD from tanker (KC-135 lights falling, KC-135 antenna wire).

Near mid-air (2 tankers plus one receiver / 2 formations plus one tanker).

Failure of boom latches in the receptacle to grasp boom tip and hold under pressure.

Pump malfunctions - reduced flow rate or no flow.

Spatial disorientation.

Tanker autopilot turning off while on boom.

Brute force disconnects.

Table 4 contains answers to Question 3 detailing some incidents that occurred during probe-and-drogue aerial refueling, while Table 5 contains answers detailing incidents that occurred during boom-receptacle aerial refueling.

Table 6 shows responses to Question 4, how many times there was a mission change due to an aerial refueling incident, coupled with responses to Question 2, the number of aerial refueling operations.

Table 6. *Aerial Refueling Incidents*

Method	Mission change incidents (Q4)	Total refueling operations (Q2)	Percentage of incidents
Probe-and-drogue	49	2,925	1.7%
Boom-receptacle	195	6,003	3.2%
Either	15	4,010	0.4%
Total	259	12,938	2.0%

Table 7 shows the responses to Question 5 about the fuel transfer rate for four aircraft. Also in Table 7 are answers to Question 6, 7 and 8, about multi-port, quick flow and buddy store. Where "N/A" is listed, the operation is not currently applicable to that method of aerial refueling.

Table 7. *Fuel Transfer Rate*

Method	4-Ship transfer time (minutes) (Q5)	Multi-port (Q6)	Buddy store (Q7)	Quick flow (Q8)
Probe-and-drogue	20.9	24%	18%	N/A
Boom-receptacle	19.6	N/A	N/A	10%

Table 8 shows responses to Question 9, which aerial refueling method is preferred. Pilots who have had experience with both methods of aerial refueling have been listed as "Dual Method Pilots."

Aerial Refueling Wing Survey Results

Of the 15 surveys that were sent to each aerial refueling wing (Appendix C), four replied. Table 9 shows responses that were supplied by the four refueling wings for the first 5 questions which concerned the amount of time it takes to refuel an aircraft.

Table 8. *Fighter Pilot Preferred Method*

Group	Preference?	Preference	Number	Percentage
All Respondents	Yes	Boom-Receptacle	13	41.9%
		Probe-and-Drogue	5	16.1%
	No		13	41.9%
Dual Method Pilots	Yes	Boom-Receptacle	5	71.4%
		Probe-and-Drogue	1	14.3%
	No		1	14.3%

Table 9. *Time to Refuel Aircraft*

	Probe-and-drogue	Boom-receptacle
Line up (seconds)	90.0	90.0
Hook up (seconds)	85.0	40.8
Transfer fuel (seconds)	420.0	300.0
Disconnect (seconds)	3.8	2.3
Clear (seconds)	8.3	8.3
Total (seconds)	607.2	441.5
Total (1 ship)	10 minutes 7 seconds	7 minutes 21 seconds

Table 10 shows responses from the four aerial refueling wings on Questions 6 through 10 on factors that affect or are affected by the amount of time it takes to refuel fighter aircraft.

Table 10. *Aerial Refueling Factors Affecting Time*

	Probe-and-drogue	Boom-receptacle
Number of AC refueled	2	2
Mission time (minutes)	13.0	11.7
Missions per flight	1	1
Flow rate (lbs/min)	791.8	1,291.9
Fuel amount (lbs)	13,833.3	13,833.3

Table 11 summarizes the responses given to Questions 11 through 15 which address safety, reliability, and factors that affect aerial refueling operations.

Table 11. *Safety, Reliability, and Operational Refueling Factors*

	Probe-and-drogue	Boom-receptacle
Receiver or tanker fouled	7.2%	2.0%
Mechanical failure	3.3%	2.0%
Fighter + helicopter	0.0%	0.0%
Fighter + cargo	0.3%	0.3%
Multi-port	3.3%	0.0%

Table 12 shows responses to Questions 16 through 18, which method of aerial refueling is preferred by the respondents.

Table 12. *ARW Preferred Method*

	Probe-and-drogue	Boom-receptacle
16. Which is faster?	0	4
17. Which is safer?	0	4
18. Which is more reliable?	0	4

Aerial Refueling Wing Activity

The fifteen aerial refueling wings were asked to supply information regarding aerial refueling operations under the Freedom of Information Act (FOIA). Five aerial refueling wings replied to the request. Each refueling wing was given a number 1 through 5 in no specific order. There were no responses to the request for fuel transfer rates because fuel transfer rates (pounds/minute) and the time it takes to transfer fuel (minutes) are not tracked by the aerial refueling wings. Aerial refueling wings do track the type of aircraft refueled and the amount of fuel transferred. From the type of aircraft refueled, it can be discerned what aerial refueling method was used. Table 13 shows a summary of the responses. ARW number 1 supplied a conversion for fuel at 1 gallon = 6.8 lbs.

Table 13. *Aircraft Refueled by USAF Aerial Refueling Wings*

	Probe-and-drogue	Boom-receptacle
Total aircraft	103	1,595
Percentage of aircraft	6.1%	93.9%
Total offload	695,200 lbs	11,678,820 lbs
Percentage of offload	5.6%	94.4%
Average offload	6,750 lbs (993 Gal)	7,322 lbs (1,077 Gal)

In response to the request for whether any incidents occurred to damage equipment or interrupt the refueling mission, one aerial refueling wing stated that no incidents damaged any aircraft or interrupted any missions. Two aerial refueling wings supplied maintenance records, but it could not be discerned whether any maintenance was required due to an aerial refueling incident or if any aerial refueling mission was altered due to equipment malfunction.

Manufacturer Aerial Refueling Information

Table 14 ("Sargent Fletcher," 2005) shows fuel flow rates for some of the Sargent Fletcher products. These are all tanker delivery systems and weights of the products do not affect the fighter receiver.

Table 14. *Fuel Flow Rates For Sargent Fletcher Products*

System	Part No. (Model)	Fuel Flow (GPM)
Buddy-Store	28-300-48116	200
	31-300-48310	200
	31-301-48310	220
Hose-Reel	149R1001(FR300 B, D, E, F)	150-330
	149R1051 (FR300 C)	150-330
	230-101 (FR300 K)	150-330
	149R1001-118 (FR	150-330
	208-1001 (FR400)	400
	233-1001 (FR480)	450
	227-1004 (FR500)	500
	224-1070 (FR600)	600
Wing-Mounted Pod	34-000-48317	400
	48-000-4862	150-330

Note. From www.sargentfletcher.com/ars_charact.htm

Parker Aerospace, a division of Parker Hannifin Corporation produces probe equipment as well as receptacle equipment. The probe tip (nozzle) model MA-2 supplied by Parker aerospace weighs a maximum of 18.0 pounds ("Parker Aerospace," 2004). No other data was supplied by the Parker Hannifin Corporation including weight, volume and flow rate data for receptacles.

Additional Sources

The USN trains fighter pilots in the use of many different tanker platforms. One manual used to brief pilots on aerial refueling is the Naval Air Training and Operating Procedures Standardization Program (NATOPS) Air Refueling Manual. Table 15 shows flow rates that are to be expected from various platforms (Naval Air Training, 1985).

Table 15. *NATOPS Probe-and-drogue Aerial Refueling Rates*

Platform	Comments and/or Conditions	Max Flow Rate	Typical Flow Rate
D-704 (Buddy-Store)	Used on F-4, A-4, A-6, and A-7 aircraft.	180 GPM	
KC-130	With 2 removable 3,600 gal tanks and both	600 GPM	
	With one pump used	300 GPM	
	Only wing store fuel available	150 GPM	
KA-3B		420 GPM	
KA-6		350 GPM	
KC-10	Depending on the specific receiver and the number of pumps operating	600 GPM	100-500 GPM
KC-135	CAUTION: There is no hose response with this system.	Governed by the fuel-flow capacity of the receiver air refueling system.	

One U.S. Government document that is used in the design of aerial refueling systems is the Joint Service Specification Guide (Department of Defense, 1998). Paragraph F.3.4.6.2.1.2 addresses receiver aerial refueling rates. Table 16 is a reduced table from the guidelines to show fighter aircraft only.

Table 16. *Fighter Receiver Aerial Refueling Rates*

Total Air Vehicle Fuel Weight (lb)	Flow Rate – Referenced	Time (Minutes) 90% Load
10,000-25,000	400	4-9
UP TO-10,000	300	≤ 5

DISCUSSION

Some of the fighter pilot surveys were completed with answers that need some clarification or correction. One pilot did not specify the method of aerial refueling but had 1,500 hours in an aircraft that could have refueled either way (the A-7 Corsair). This resulted in the "Not Specified" row in Table 2. Of the 54,690 hours of experience in receptacle equipped aircraft, 26,130 hours (48%) are in the F-16. The pilot with the most flight hours had 5,600 hours with 1,000 hours in the A-7, 1,600 hours in the F-4 and 3,000 hours in the F-16, all of which refueled with the boom-receptacle method. Of the aircraft flown by the fighter pilots, there were nine different probe equipped aircraft, eight different receptacle aircraft and one aircraft where it was not specified which of the two possible methods was used. The F-105 also has both a probe and a receptacle but fighter pilot 17 specified that he refueled via the probe only in that aircraft. Fighter pilot 29 stated that he refueled via the probe on an A-10 aircraft, but the A-10 uses only a receptacle and has no provisions for a probe. The data for fighter pilot

29 has been corrected in the results. Fighter pilot 13 flew the OA-37 which is an observation and attack aircraft that refuels with a probe and fighter pilot 5 flew the SR-71 which is a reconnaissance aircraft that refuels with a receptacle. Although not a fighter aircraft, the SR-71 was included to show other jet aircraft that the fighter pilots have flown that perform aerial refueling. One fighter pilot has flown the H-3, a helicopter, and one pilot has flown the S-2 Tracker, a propeller driven submarine hunter, but neither aircraft is included in the results because they are too dissimilar from fighter aircraft.

There is a difference between Table 3 and Table 6 in the total number of refueling operations for each method of aerial refueling. This is because many of the pilots that have had experience with both methods of aerial refueling did not state how many incidents they experienced with each method of aerial refueling.

Most of the fighter pilots noted their estimate for the amount of time it took to refuel a flight of four aircraft. Thirteen pilots specified the receiver aircraft, one specified the tanker aircraft, fifteen did not specify either but gave an estimate and two pilots did not answer the question.

The top two reasons given to Question 9 of the fighter pilot survey for a preference in the probe-and-drogue method of aerial refueling were: (a) the fighter pilot is in control, and (b) tactical aircraft can be used as tankers (buddy store). As stated by Bolkcom and Klaus (2005), this would be a great misuse of an aircraft that was intended as an attack-fighter. The top two reasons given for a preference in the boom-receptacle method of aerial refueling were: (a) it is easier to fly, and (b) faster flow rate.

From Table 10, the only differences between probe-and-drogue and boom-receptacle aerial refueling were mission time and flow rate. The number of aircraft refueled, missions per flight and fuel amount transferred were the same for both types of aerial refueling.

Question 11 of the aerial refueling wing survey was a safety concern question that asked what percentage of refueling operations fouled the tanker or receiver system. The percentages of safety concern were 5.2% higher for the probe-and-drogue method than for the boom-receptacle method of aerial refueling. Question 12 was a reliability question that asked what percentage of refueling operations had a mechanical failure. The percentages of reliability concern were 1.3% higher for the probe-and-drogue method than for the boom-receptacle method of aerial refueling. Multi-port operation percentages were also higher for probe-and-drogue. Question 13 asked what percentage of missions refueled helicopters before or after fighter aircraft and one aerial refueling wing answered that 1% of boom-receptacle missions did. This is impossible because helicopters require the probe-and-drogue method. The data has been adjusted to zero for that response. Question 15 asked what percentage of refueling missions were multi-port, and one aerial refueling wing answered that 8% of boom-receptacle missions were. Multi-port is an option currently not available to the boom-receptacle method of aerial refueling. The data for this answer was also adjusted to zero.

CONCLUSIONS

The first two questions proposed for this study concern fuel transfer rates for each method of aerial refueling. From Table 7, the 4-ship transfer time for boom-receptacle aerial refueling is 19.6 minutes, or 4.9 minutes per ship. From Table 13, the average offload per boom-receptacle aircraft is 7,322 lbs. Dividing the offload per ship by the time per ship, gives 1,494.3 lbs/min (219.8 GPM) for boom-receptacle aerial refueling experienced by fighter pilots. From Table 7, the 4-ship transfer time for probe-and-drogue aerial refueling is 20.9 minutes, and multi-port was performed 24% of the time. If 24% of the time there were two aircraft refueling at the same time, it would be incorrect to assume that the time per ship is 5.2 minutes. Instead, Equation 1 shows how multi-port affects the transfer time:

$$20.9\,\text{min} = \frac{(X \cdot 76\%) + (\frac{1}{2} X \cdot 24\%)}{100\%}$$
$$\therefore X = 23.75\,\text{min} \qquad (1)$$

Now the per ship transfer time becomes 5.9 minutes for probe-and-drogue aerial refueling. From Table 13, the average offload per probe-and-drogue aircraft is 6,750 lbs. Dividing the offload per ship by the time per ship, gives 1,144.1 lbs/min (168.3 GPM) for probe-and-drogue aerial refueling experienced by fighter pilots.

From Table 9, the aerial refueling wing transfer time for probe-and-drogue aerial refueling is 420 seconds (7 minutes). From Table 11, 3.3% of probe-and-drogue refueling operations are multi-port. The formula in Equation 2 shows how multi-port affects the transfer time:

$$7\min = \frac{(X \cdot 96.7\%) + (\frac{1}{2}X \cdot 3.3\%)}{100\%}$$
$$\therefore X = 7.12\min \quad (2)$$

The per ship transfer time is now 7.12 minutes. Dividing the offload per ship from Table 13 (6,750 lbs) by the transfer time for probe-and-drogue aerial refueling, gives a refuel rate of 948.0 lbs/min (139.4 GPM). The aerial refueling wing transfer time for boom-receptacle aerial refueling is 300 seconds (5 minutes). Dividing the offload per ship from Table 13 (7,322 lbs) by the transfer time for boom-receptacle aerial refueling, gives a refuel rate of 1,464.4 lbs/min (215.4 GPM). The aerial refueling wings also supplied their estimates of the flow rates in Table 10. For probe-and-drogue the estimated flow rate is 791.8 lbs/min (116 GPM), and for boom-receptacle the estimated flow rate is 1,291.9 lbs/min (190 GPM).

The above figures that were experienced by fighter pilots and aerial refueling wings are low compared to what Sargent Fletcher advertises, as seen in Table 14 and what NATOPS expects, as seen in Table 15. For hose-reel systems, Sargent Fletcher advertises flow rates from 150 GPM (1020 lbs/min) on the low side to 600 GPM (4080 lbs/min) on the high side. Similarly, NATOPS expects a typical flow rate from a KC-10 to be between 100 GPM (680 lbs/min) and 500 GPM (3400 lbs/min). Table 17 summarizes the findings for flow rates.

Table 17. *Summary of Flow Rates*

	Probe-and-drogue		Boom-receptacle	
	(lb/min)	(GPM)	(lb/min)	(GPM)
Fighter pilots	1,144.1	168.3	1,494.3	219.8
Aerial refueling wings				
(Table 9 & Table 13)	948.0	139.4	1,464.4	215.4
(Table 10, Question 9)	791.8	116.4	1,291.9	190.0
Sargent Fletcher				
High	4080.0	600		
Low	1020.0	150		
NATOPS				
High	3,400.0	500		
Low	680.0	100		

Table 18 shows the experienced flow rates as a percentile of Sargent Fletcher's advertised flow rates and the NATOPS expected flow rates. A negative number means that the experienced flow rate is lower than the lowest expected flow rate. This applies only to probe-and-drogue aerial refueling because there were no advertised or expected values associated with boom-receptacle aerial refueling exclusively.

Table 18. *Experienced Flow Rates*

	Percentile of Sargent Fletcher	Percentile of NATOPS
Fighter pilots	15	30
Aerial refueling wings		
(Table 9 & Table 13)	-2	10
(Table 10, Question 9)	-7	4

Table 16 can be applied to either method of aerial refueling, and it is noted that the experienced flow rates of either probe-and-drogue or boom-receptacle aerial refueling under perform the expected flow rates. Fighter pilots refueling with a probe-and-drogue system experienced flow rates 44% to 58% slower than the referenced flow rates. Fighter pilots refueling with boom-receptacle systems experienced flow rates 27% to 45% slower than the referenced flow rates. The aerial refueling wing rates are even further off of the referenced flow rates.

It is also noticed that boom-receptacle method of aerial refueling is faster than the probe-and-drogue method of aerial refueling per ship. The fighter pilots who performed boom-receptacle aerial refueling experienced flow rates 31% faster than pilots who performed probe-and-drogue aerial refueling. Similarly, aerial refueling wings experienced flow rates 54% to 63% faster with the boom-receptacle method.

The second two questions (Question 3 and Question 4) proposed for this study concern the weight and volume impact for each method of aerial refueling. No hard evidence was gathered to show what the weight and volume impact is, largely because the information is company proprietary and each system varies greatly. Probes have many options for incorporation into aircraft from stationary probes like those attached to the A-4 Skyhawk to retractable probes like those attached to the F-18 Hornet to articulating probes like those on the S-3 Viking. Slipways also have varied placements from the nose of the aircraft like on the A-10 Thunderbolt to the shoulder as on the F-15 Eagle to the back as on the F-16 Fighting Falcon. The varied placement of the slipways is accompanied with varying amounts of plumbing required to reach a tank, wherever the tank may be placed in the aircraft. Another question that needs to be addressed in consideration of an aerial refueling system is what the system would displace. In some cases electronics could be placed where the refueling system is located while in other cases fuel may be displaced for the refueling system. There is no one answer for either of the questions concerning the weight and volume impact to an aircraft.

The last two questions (Question 5 and Question 6) proposed for this study concern safety and reliability for each method of aerial refueling. As seen in Table 4 and Table 5, some problems are common among both types of aerial refueling. For example; the performance of the tanker pumps, the connection between tanker and receiver, and FOD. There are some problems unique to probe-and-drogue refueling. Some of these unique problems include having a probe or probe tip snap off, and reel response (a BDA has no reel response).

From Table 6, the fighter pilots estimate that 1.7% of probe-and-drogue refueling operations have a refueling incident that causes a mission change. Fighter pilots, who flew boom-receptacle refueling, estimate that 3.2% of the refueling operations have an incident that causes a mission change. From the fighter pilot's point of view, boom-receptacle aerial refueling operations are almost twice as likely to have some refueling incident happen that would cause a mission change. From Table 8, 5 of 7 pilots that have flown both methods of aerial refueling prefer the boom-receptacle method of aerial refueling.

From Table 11, the aerial refueling wings estimate that 2% of boom-receptacle operations foul the receiver or tanker and more than three times that number (7.2%) of probe-and-drogue operations do. The aerial refueling wings estimate that 2% of boom-receptacle operations have a mechanical failure and slightly more (3.3%) of probe-and-drogue operations do. When asked for a preference, all aerial refueling wings preferred the boom-receptacle method for safety and reliability.

Fighter pilots estimate that probe-and-drogue aerial refueling is safer and/or more reliable but they prefer the boom-receptacle method of aerial refueling. Aerial refueling wings estimate that the boom-receptacle method is safer and more reliable and they prefer the boom-receptacle method. While no definite conclusion can be formed from the above information, the issue of safety and reliability is a definite concern to both fighter pilots and aerial refueling wings.

With the coming age of unmanned combat aerial vehicles (UCAV), a consideration of which method of aerial refueling is best for the aircraft must be made. Can a UCAV refuel with either method? Would the UCAV fly as part of a fighter unit? Would the UCAV serve both the USAF and the USN? All are questions that affect how fighter aircraft refuel in the future.

RECOMMENDATIONS

It first needs to be stated that neither the boom-receptacle nor the probe-and-drogue methods of aerial refueling will ever be eliminated altogether. Probe-and-drogue aerial refueling will always be required to refuel helicopters and other aircraft on which a receptacle would not be feasible. The rotors on the helicopter would not allow a path for a boom to reach a receptacle, therefore there must be a probe extended beyond the rotors in order to refuel. Boom-receptacle aerial refueling will always be required to refuel large cargo aircraft and other large body aircraft on which a probe would not be feasible. These aircraft are too large to be able to maneuver a probe into a drogue, the aircraft would not be able to utilize multi-port due to their large wingspan, and the flow rates would not be sufficient.

It is recommended that a requirement of any new tanker design incorporate multi-port boom-receptacle aerial refueling. There is a benefit to multi-port and with the higher flow rates of boom-receptacle aerial refueling, formations of fighter aircraft would be able to refuel much faster with less turbulence. Drogues should also be incorporated in the designs of a new tanker since there are many probe equipped aircraft that will always require drogues.

The Air Force should increase its support of Navy aircraft with multi-port capability in order to reduce or eliminate the need for buddy-store and reduce or eliminate the need for multiple tankers while supporting U.S. Navy operations. Without this support, the USN will always require buddy-store and the function of Navy tactical aircraft will be reduced. This would also increase the interoperability of tanker aircraft.

There should be a considerable effort to eliminate BDAs and replace them with wing mounted pods. The BDA is the most dangerous prospect for probe-and-drogue aerial refueling since it has no reel response and it negates the tanker's ability to utilize boom-receptacle refueling until the BDA is removed.

Aerial refueling wings should monitor refueling rates and insure that aircraft are being refueled in a timely manner. From the results, aircraft are being refueled at rates much lower than expected or at rates lower than the equipment can optimally deliver.

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APPENDIX A - List Of Aerial Refueling Wings And Groups

Address	Phone	FAX / Email
107th ARW Niagara Falls International Airport Niagara Falls, NY 14304	(716) 236-2458	
108CF/SCBI(FOIA) 3324 Charles Blvd McGuire AFB, NJ 08641	(609) 754-5806	(609) 754-6158
121st ARW/PA 7370 Minuteman Way Columbus, OH 43217-5875	(614) 492-4357	(614) 492-4215 help@ohcolu.ang.af.mil
128th Air Refueling Wing Attn: FOIA Office 1835 East Grange Avenue Milwaukee, WI 53207-6142	(414) 944-8782	foia@wimilw.ang.af.mil
141st Air Refueling Wing 1403 W. Wainwright Blvd. Fairchild AFB, WA 99011-99410	(509) 247-7042	
186th ARW/SCIM (FOIA) 6225 M Street, Bldg 603 Meridian, MS 39307-7112	(601) 484-9266	(601) 484-9219
19th ARG 225 Beale Dr. Robbins AFB, GA 31098-2700	(478) 327-2958	
22 CS/SCXIR 53298 Kansas St, Ste 5 McConnell AFB, KS 67221-7701	(316) 759-3141	christelle.meyer@mcconnell.af.mil
319th Air Refueling Wing 375 Steen Blvd., Rm 102 Grand Forks AFB, ND 58205-6015	(701) 747-5023	publicaffairs@grandforks.af.mil
434 CS/SCBK Freedom of Information Act Office Bldg 100 Grissom ARB, IN 46971	(765) 688-2362	(765) 688-2362 434arw.pa@grissom.af.mil
459th ARW 3755 Patrick Avenue Andrews AFB MD 20672	(240) 857-6873	
916th ARW 1195 Blakeslee Ave. Seymour Johnson AFB, NC 27531-2203	(919) 722-2230	(919) 722-2239
92nd Air Refueling Wing 1 E. Bong St. Suite 117A Fairchild AFB, WA 99011-9588	(509)247-2312	92arw.pa@fairchild.af.mil
927 ARW 43087 Lake St. Sang, MI 48045	(586) 307-5575	927arw.pa@selfridge.af.mil
940 CF/SCB 19395 Edison Avenue Bldg. 11606 Beale AFB, CA 95903-1215	(530) 634-1838	(530) 634-1864 940arw.pa@beale.af.mil

APPENDIX B

Fighter Pilot Survey

1. What type of aircraft have you flown, how many hours per aircraft and what method of aerial refueling was performed in each aircraft?
2. Approximate number of aerial refuelings in each aircraft.Training | Deployments | Combat
3. Describe any incidents that occurred during aerial refueling.
4. Approximate number of times there was a mission change due to an aerial refueling incidence.
5. Estimate the average time required for 4 ships to receive a normal off load for each aircraft type flown.
6. Approximate percentage of refueling operations that were multi-port.
7. Were you trained in the use of "quick flow"? How many times have you used this?
8. How many times have you refueled from the probe & drogue "buddy store" system?
9. Which method of aerial refueling do you prefer (probe & drogue or boom-receptacle) and why?
10. Any additional comments about aerial refueling that may aid in my research?

APPENDIX C

Aerial Refueling Wing Survey

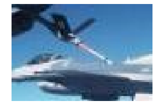
This questionnaire is concerned with **fighter receiver** aircraft only unless otherwise noted.

P-D = Probe and Drogue refueling system
B-R = Boom Receptacle refueling system

	P-D	**B-R**
Refueling Averages		
1. Average time for an aircraft to line up (seconds):	_____	_____
2. Average time to hook up (seconds):	_____	_____
3. Average time to transfer fuel (seconds):	_____	_____
4. Average time to disconnect (seconds):	_____	_____
5. Average time to clear (seconds):	_____	_____
6. Average number of aircraft refueled:	_____	_____
7. Average time for refueling mission (minutes):	_____	_____
8. Average number of missions per flight:	_____	_____
9. Average fuel flow rate (lbs/min):	_____	_____
10. Average amount of fuel transferred (lbs):	_____	_____
Reliability & Safety		
11. Percentage of refuelings that foul tanker or receiver system:	_____	_____
12. Percentage of refuelings that have a mechanical failure:	_____	_____

Aerial Refueling Wing Survey (Continued)

P-D = Probe and Drogue refueling system
B-R = Boom Receptacle refueling system

	P-D	B-R
		
Other		
13. What percentage of missions refuel helicopters (or other probe mandatory aircraft) before or after fighters?	_____	_____
14. What percentage of missions refuel cargo (or other receptacle mandatory aircraft) before or after fighters?	_____	_____
15. What percentage of missions are multi-port?	_____	_____
Preferred System		
16. Which system is faster?	☐	☐
17. Which system is safer?	☐	☐
18. Which system is more reliable?	☐	☐

Safety or Reliability Concerns

19. What are your safety or reliability concerns with the boom-receptacle method of aerial refueling?
20. What are your safety or reliability concerns with the probe-and-drogue method of aerial refueling?

The Role and Function of Work-based Learning in Aviation Management Programs

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ABSTRACT

Work-based learning (WBL) encompasses various and diverse components of experiential learning. Cooperative education and internship comprise two elements of experiential learning constituting WBL in this study. The importance of WBL is amplified by an aviation industry that identifies "job skill and knowledge" as "highly regarded" characteristics of new hires (Phillips, Ruiz, & Mehta, 2006, p. 126). The study sets out to define the roles and functions of WBL and determine their overall importance from the perspective of those that are engaged in administrating and managing WBL activities in Aviation Management (AVM) programs.

INTRODUCTION

An Aviation Management (AVM) program should, among other things, prepare graduates for a wide array of management positions within the aviation industry. The purpose of Work-based learning (WBL) is to complement AVM programs and take advantage of the college and university system by developing additional resources and improving the quality of entry-level employees (Spencer, 1988).

WBL typically "bridges the gap" between the classroom and the world of work. WBL has become increasingly valuable to students and participating institutions and industries (Phillips, 1996). WBL activities have expanded from student participation in various and sundry administrative tasks to becoming familiar with flight crew training, customer relations, maintenance operations, and dispatch. WBL is commonly conducted by the airlines, more recently however, aerospace manufacturers, airport authorities, education/training facilities, and fixed base operators have gotten involved (Schukert, 1993). A coincidental benefit from WBL is the opportunity for the work-site partner and the student to concurrently review the promise of each other for future employment opportunities.

Students regularly take advantage of WBL opportunities that include, but are not limited to:

1. Aerospace manufacturing companies
2. Aircraft maintenance companies
3. Airport administrators
4. Aviation consultants
5. Federal Aviation Administration
6. General aviation companies
7. State Department's of Transportation
8. National Transportation Safety Board
9. Professional aviation organizations

The purpose of this study was to describe and analyze the perceptions of the roles and functions of WBL in post-secondary AVM programs by those actively engaged in the management and administration thereof. It was determined that the University Aviation Association (UAA) member organizations represent a wide and diverse population from which assumptions can be readily generalized to the larger aviation academe. Therefore, the study was delimited to: community colleges, colleges, and universities affiliated with the UAA that are actively engaged in WBL activities. In the context of this paper roles and functions of WBL are the deliberate use of the work-place as a site for student learning; formal, structured, and strategically organized by instructional staff and employers.

REVIEW OF LITERATURE

Evolution of WBL in AVM programs

Many U.S. organizations allocate substantial financial resources and jeopardize workplace productivity to provide employees management training in a variety of classroom settings. Much of this knowledge is on a broad range of conceptual knowledge and skill as they pertain to the discipline of management. Beyond the classroom, the predominant mode of developing managers and administrators is through experience (Raelin, 1997). According to Raelin, "…mastery of an interdisciplinary, inter-functional field like management is best achieved by exposure to diverse challenges in corporate life normally through the judicious mapping of assignments. As we have seen, WBL deliberately merges theory with practice and acknowledges the intersection of explicit and tacit forms of knowing" (p. 574). Academic institutions, however, cannot provide the projected need for these qualified aviation professionals without the assistance of the industry that it supports. Mitchell (n.d.) recommended that the aviation industry "…provide sufficient support to grow a long-term manpower base using a variety of cooperative agreement tools such as scholarship, internships, fellowships and just plain regular and ongoing communication" (p. 2). Work-based learning partnerships between industry and academic institutions can help provide the training and experience needed by the civil aviation industry. According to Phillips et al. (2006), "…externships, internships, cooperatives, play a significant role in bridging the 'real world' experience gap" (p. 126). Aviation-related WBL activities evolved from business and education maintenance apprenticeships. Gradually, they evolved to include WBL activities in flight and management.

In 1971, LaGuardia Community College established the first mandatory WBL requirement in aviation at a community college in the US. Enrollment in 1971 was 500 students. By 1998, it was recognized as a leader in WBL with one of the largest programs in the country (Bailey, Hughes, & Barr, 1998).

Soon after becoming a university in 1971, Embry-Riddle Aeronautical University developed a WBL program. The purpose, according to Howell and Scott (2001), was to develop students' professional and personal aspirations and to guide their life in the direction of a sound career. Here again it is recognized that participation in WBL provides opportunity to bridge the gap between the classroom and work environment; to earn credit hours toward an undergraduate/graduate degree.

The Northrop/California State University, Fullerton Invitational Program in Operations Management was established in 1983. This program allowed students to work within Northrop's Operations Department in a variety of areas during the summer. Northrop also maintained an active WBL program with other universities allowing students to alternate between work and study (McCarthy, 1984).

Southern Illinois University Carbondale's Department of Aviation Management and Flight recognized the significance of WBL opportunities and administered its first airline flight operations internship in 1987. That single WBL opportunity has grown into numerous agreements with major and regional carriers that allow the student to apply in the workplace the knowledge they have gained in the classroom (Ruiz, 2004).

The applied research partnership program developed at Purdue University exemplifies the role WBL plays in an AVM program. The program was initiated in 1996 in response to industry representatives who complained of a significant adjustment period for graduates entering aviation careers (Morton, Eiff, & Lopp, 2001).

While aviation industry employers generally agree that aviation education programs are providing excellent foundational technical and managerial knowledge and skills, they continue to report that students lack confidence in applying their education during the initial phases of their aviation careers. Additionally, industry feedback often indicates that students lack comprehensive knowledge of aviation industry settings and processes. Graduates are generally reported to understand the concepts of problem solving, project management, team building and work analysis but demonstrate a weakness in applying those concepts within the context of their aviation work settings.

Roles and Functions of WBL in AVM Programs

Schukert (1993) found that 71.9% of employer participants in WBL were from the public sector: federal government agencies (59.6%), airport authorities (8.8%), and state government agencies (3.5%). The remaining 28.1% of participants were from the private sector: airlines (10.5%), fixed base operations

(7.0%), and various other aviation enterprises (10.6%). Schukert provided five examples of the degree to which WBL has been institutionalized among participants: (a) administrating legal/formal agreements among sponsors, (b) designating a course title and number, (c) granting academic credit and issuing a grade, (d) specifying student participation requirements, and (e) sponsoring industry advisory committees.

Owens (1995) reported on an evaluation of The Boeing Company's WBL program. The purpose of the evaluation was to: (a) describe the operations and outcomes of WBL, (b) provide information for continuous quality improvement of WBL, (c) document the impact of WBL on students and others, and (d) identify promising practices related to WBL that could be adapted by others in business and industry. The evaluation methodology included: (a) a review of documents describing WBL structure, student selection process, and curriculum; (b) a survey of students participants before and after the WBL activity; and (c) a follow-up study of work and educational experiences since high school graduation.

Findings of the study revealed that: (a) 22 participants (91.7%) reported increasing their understanding of manufacturing, (b) 2 participants (8.3%) were influenced to stay in school, (c) 20 participants (83.3%) reported that the experience had enhanced or confirmed their career plans, (d) 24 participants (100%) were motivated to go on to postsecondary education following high school, and (e) 16 participants (66.7%) reported that the experience had improved their workplace and employability skills (Owens, 1995).

Luedtke and Papazafiropoulos (1996) studied retention issues as related to academic programs and the field of aviation in general. Pattie et al. (as cited in Luedtke & Papazafiropoulos, 1996) identified WBL as a key component of student retention.

Fuller and Truitt (1997) in a study of airport consultants revealed that WBL industry sponsors had a very positive attitude toward their participation in, and benefits from WBL activities. "We feel very strongly that the internship component is one of the strengths of our program. One can not be effective without real world experience" (p. 68).

Respondents to a survey by Mitchell (2000) reported the following strengths, weaknesses, and opportunities in WBL activities. Strengths: (a) provides a foot in the door, (b) students and schools keep abreast of the industry, and (c) provides invaluable experience for the intern. Weaknesses: (a) participation is low, (b) most are not paid, and (c) programs are too easy. Opportunities: (a) institutions need to promote them better, (b) institutions need to work out the problems associated with remuneration, (c) more opportunities need to be established, (d) meaningful work experiences are essential, and (e) coordination and implementation of a feedback system, from past participants to future participants, will improve the program.

The preceding studies indicate that WBL activities have become essential components of AVM programs. They have been shown to be an asset to students, industry, and institutional partners as they help to synthesize the concepts revealed in the classroom and how they are practiced in the workplace. Work-based learning activities play a key role in bridging the gap between school and the work-place, in aviation education, and in the students' pursuit of their career goals.

METHODOLOGY

A descriptive research method that employed a self-report research instrument was used to collect data for the current study. According to Best and Kahn (2006):

> A descriptive study describes and interprets what is. It is concerned with conditions or relationships that exist, opinions that are held, processes that are going on, effects that are evident, or trends that are developing. It is primarily concerned with the present, although it often considers past events and influences as they relate to current conditions. (p. 118)

More specifically, survey research was used to identify and describe the perceptions of aviation management program representatives regarding the role and function of WBL in AVM programs.

SUBJECTS

The population for the study was drawn from the 114 institutional members of the UAA as listed in the *Collegiate Aviation Guide* (Williamson, 2003). The *Guide* contains an "Alphabetical Listing with Options and Degrees" offered by various colleges and universities that was analyzed to identify programs having an "Aviation Management/Airway Science Management" curriculum. Seventy-eight institutional members met the following definition of aviation management according to the U.S. Department of Education's (2000) *Classification of Instructional Programs* and also participate in WBL:

> A program that prepares individuals to apply technical knowledge and skills to the management of aviation industry operations and services. Includes instruction in airport operations, ground traffic direction, ground support and flight line operations, passenger and cargo operations, flight safety and security operations, aviation industry regulation, and related business aspects of managing aviation enterprises. (para. 6, 49.0104)

The 78 UAA programs meeting selection criteria were designated as the target population. Ten roles and functions of WBL were derived from the review of literature. By the beginning of January 2005, information had been received from all 78 institutions. Four institutions were eliminated because they did not have an AVM program as previously defined. Four others were eliminated because they did not, in fact, have a functioning WBL program. As a result, the accessible population was reduced to 70 institutions having AVM programs which offer WBL.

INSTRUMENTATION

Information to develop the survey came from three sources: (a) survey research instruments developed for use outside of aviation related programs, (b) relevant literature regarding WBL within aviation oriented programs, and (c) the author's personal perceptions as an active administrator of WBL.

Multiple drafts of the research instrument were developed and the final draft of the survey was completed in March 2005. To assess instrument reliability, a pilot test was conducted in April 2005. Comments and suggestions were carefully considered and, when appropriate, incorporated into the final survey. The research instrument was subsequently reviewed and approved for use by the Southern Illinois University Human Subjects Committee.

DATA COLLECTION PROCEDURES

It was determined that the most efficient method of gathering data would be an on-line survey. To accomplish this task, Instructional Support Services (ISS) in the Department of Library Affairs at Southern Illinois University Carbondale was contacted for assistance. The ISS staff recommended the use of a software program called "Surveys" that was:

> … developed at University of Illinois Champagne-Urbana. It aids in the creation of online survey forms that can be installed on a central server for distribution over the web. Survey questions can be of many types, including multiple choice, Likert scale, short answer, or free text. Responses are sent to a database for collection and analysis. What it lacks in sophisticated control mechanisms it more than makes up for in simplicity of use. (H. Carter, personal communication, December 16, 2004)

The survey was disseminated to the 70 AVM program representatives via e-mail on May 31, 2005. The first completed instrument was received on May 31, 2005, and the last of 56 responses was received on August 15, 2005, for an 80.0% rate of return.

TREATMENT OF THE DATA

Analysis of raw data began soon after receiving the last survey. One advantage of an on-line survey is that raw data are readily compiled without having to manually code and enter the data. Conventional descriptive statistics were used to tabulate and analyze the data. Data interpretation was based upon logical and analytical means.

The questionnaire consisted of 10 Likert-type scale items. The data constituted responses that addressed each of the 10 questions. Data was summarized in two tables. Means and standard deviations were computed and displayed for each question. Likert scale means were interpreted and discussed in relation to the following approximate intervals: very important (5.0 to 4.5), somewhat important (4.4 to 3.5), important (3.4 to 2.5), somewhat unimportant (2.4 to 1.5), and very unimportant (1.4 to 0.0).

THE ROLE AND FUNCTION OF WBL

The statements included in the survey are intended to determine the degree of importance each WBL role or function is perceived to have within the AVM program. Subjects are asked to respond to a five position Likert scale ranging from Very Important (VI) to Very Unimportant (VU). To aid interpretation, numeric values from 5 (VI) to 1 (VU) were assigned to the scales, the results for which are shown in Table 1.

Nine of 10 mean ratings fall within the interval 3.5 to 4.5 indicating that respondents perceive these statements as being *Somewhat Important*. Computing a mean, however, obscures the degree of importance assigned to several statements. Therefore, Table 2 has been developed to reveal the statements rated as *Very Important* by half or more of the respondents. The most important statement is number 5, “The preparation for a career in the aviation industry that WBL provides students” which seems to be a validation of the actual function of WBL”. Thirty or more respondents each rate statements 3, 7, and 9 as *Very Important*. The ratings assigned to statements 3 and 9 reinforce the importance of the career preparation role of WBL that was noted regarding statement 5. As reflected by the responses to statement number 7, “student access to WBL opportunity/information,” dissemination of WBL opportunities and information is rated as an equally important role and function”.

Table 1. *The Role and Function of WBL*

	Statement	VI	SI	I	SU	VU	*M*	*SD*	*N*
1.	The application of WBL in an AVM program is:	27	17	9	2	1	4.20	0.95	56
2.	Making WBL a required component of the AVM program is:	15	9	14	12	5	3.31	1.32	55
3.	The value of WBL as a "bridge" between the AVM program and the aviation industry is:	30	16	7	1	1	4.33	0.90	55
4.	The connection between WBL and AVM course work is:	25	16	11	2	1	4.13	0.97	55
5.	The preparation for a career in the aviation industry that WBL provides students is:	36	13	5	1	1	4.46	0.87	56
6.	Student participation in at least one WBL experience is:	26	11	12	3	4	3.93	1.24	56
7.	Student access to WBL information, opportunity is:	31	13	11	0	1	4.30	0.91	56
8.	Clearly defined objectives of the student's WBL assignment are:	26	19	7	2	2	4.16	1.01	56
9.	The requirement that a WBL assignment provide for a professionally oriented work experience is	30	18	5	2	1	4.32	0.91	56
10.	Evaluation and documentation of WBL by the AVM program is:	26	22	5	1	2	4.23	0.94	56

Note. *N* = number of respondents.

Table 2. *Functions Rated Very Important by the Majority of Respondents*

	Statement	Very Important		
		f	%	*N*
5.	The preparation for a career in the aviation industry that WBL provides students is:	36	64.3	56
7.	Student access to WBL information/opportunity is:	31	55.4	56
3.	The value of WBL as a "bridge" between the AVM program and the aviation industry is:	30	54.5	55
9.	The requirement that a WBL assignment provide for a professionally oriented work experience is:	30	53.6	56

Note. N = number of respondents.

The lowest rated statement is 2, "Making WBL a required component of the AVM program". The lower importance assigned to this statement is probably due to a lack of enthusiasm for making WBL a "requirement" than it is to making WBL a "component of the AVM program."

Ten of 56 respondents (18%) provide additional information. Four of these respondents indicate that the role and function of WBL in their programs is "very beneficial," "extremely important," "certainly important," and "very important." And, although one respondent indicates that WBL is a required component of its program, four others indicate that it is not required. Two respondents made interesting comments indicating that: "there are some students who would not do well in this environment and would not represent the department or university well" and similarly "I have some students that I would not want representing the university at a WBL assignment."

SUMMARY AND CONCLUSION

A self-developed research instrument was used in the study. A pre-survey evaluation was employed to identify 70 AVM programs actively participating in WBL and who agreed to participate in the study. Survey participants were directed to an on-line questionnaire. Respondents to the survey varied from 55 (78.6%) for questions two, three, four, to 56 (80%) for the other seven questions. Although the population for the survey was relatively small (70 institutions) the 78.6% and 80% rates of return are considerable and provided valuable input for analysis of the roles and functions of WBL in AVM programs. Data were analyzed using conventional descriptive statistics.

The role and function of WBL in AVM programs is considered to be significant by a majority of those responding. This indicates a very strong correlation between the findings of past research on this subject as to the value of WBL programs and the perceptions of those targeted by this survey. With the exception of "making WBL a required component of the AVM program" the nine other roles and functions of WBL are considered "Somewhat Important" to "Very Important" by the majority of respondents. Four of these nine are rated "Very Important" by a significant majority of those responding. It is not clear why making WBL a requirement is considered less important than the other roles and functions. However, more respondents rated it "Important," "Somewhat Unimportant," or "Very Unimportant" than any other role or function.

From the data, it is clear that these respondents place significantly high value on the experiential component that comes from WBL to help integrate theory and conceptual knowledge into the practice of managing aviation enterprises. Research opportunities for further related research could explore the ideal ratio of classroom instruction to WBL activities for AVM students within the confines of collegiate curriculum and to examine the perceptions of institutions such as those polled here and their perceptions on making WBL mandatory in AVM programs. This additional research, combined with the findings herein, could provide further guidance to AVM program administrators in how to strike the appropriate balance between WBL activities and didactic instruction.

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