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About the Journal of Air Transportation

The mission of the *Journal of Air Transportation (JAT)* is to provide the global community immediate key resource information in all areas of air transportation. The goal of the Journal is to be recognized as the preeminent scholarly journal in the aeronautical aspects of transportation. As an international and interdisciplinary journal, the *JAT* will provide a forum for peer-reviewed articles in all areas of aviation and space transportation research, policy, theory, case study, practice, and issues. While maintaining a broad scope, a focal point of the journal will be in the area of aviation administration and policy.

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Reviewers are appointed by the Editor to represent all elements of aviation and space transportation scholarship and practice. An appointment to the Panel of Reviewers recognizes professional and academic achievement. Appointments are for a three-year term with the option of renewal. For membership consideration, submit a curriculum vita or industry resumé to Dr. Brent Bowen, Executive Editor.

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The Editors

BRENT D. BOWEN

Dr. Brent Bowen is Director and Distinguished Professor, Aviation Institute, School of Public Administration, University of Nebraska at Omaha, and the University's Director of Aviation and Transportation Policy and Research. Bowen attained his doctorate in Higher Education and Aviation from Oklahoma State University and a Master of Business Administration degree from Oklahoma City University. His Federal Aviation Administration certifications include Airline Transport Pilot, Certified Flight Instructor (Gold Seal), Advanced Instrument Ground Instructor, Aviation Safety Counselor, and Aerospace Education Counselor. Dr. Bowen's research on the development of the national Airline Quality Rating is regularly featured in numerous national and international media, as well as refereed academic publications. Dr. Bowen has in excess of 300 publications, papers, and program appearances to his credit. His research interests focus on aviation applications of public productivity enhancement and marketing in the areas of service quality evaluation, forecasting, and student recruitment/retention in collegiate aviation programs. He is also well published in areas related to effective teaching and has pioneered new pedagogical techniques. Dr. Bowen has been recognized with awards of achievement and commendation from the American Marketing Association, American Institute of Aeronautics and Astronautics, Federal Aviation Administration, Embry-Riddle Aeronautical University, W. Frank Barton School of Business, Travel and Transportation Research Association, World Aerospace Education Association and others.

IGOR KABASHKIN

Dr. Igor Kabashkin is Vice Rector of the Transport and Telecommunications Institute, Latvia and a Professor in the Aviation Department of the European Commission for Cooperation in the Field of Scientific and Technical Research. Kabashkin received his Doctor Degree in Aviation from Moscow Civil Engineering Institute, a High Doctor Degree in Aviation from Moscow Aviation Institute, and a Doctor Habilitus Degree in Engineering from Riga Aviation University and Latvian Academy of Science. His research interests include analysis and modeling of complex technical systems, information technology applications, reliability of technical systems, radio and telecommunication systems, and information and quality control systems. Dr. Kabashkin has published over 274 scientific papers, 19 scientific and teaching books, and holds 67 patents and certificates of invention.

Sorenson Best Paper Award

The *Journal of Air Transportation* is proud to present the Sorenson Best Paper Award, named in honor of Dr. Frank E. Sorenson. This award gives recognition to the author(s) with the best literary and scholarly contributions to the field of air transportation. The Editor, on the basis of reviewer rankings during the review process, grants the Sorenson Award. The manuscript with the highest overall score is awarded the Sorenson Best Paper Award. This is considered a high recognition in the aviation community.

Dr. Frank E. Sorenson was a pioneer in the field of aviation education since its early beginnings in the 1940s. A renowned educator and prolific writer, Sorenson contributed not only educational texts to the field, but also served as a consultant and innovator throughout the expanding realm of aviation education and research.

Dr. Sorenson's aviation impact and potential were recognized early on by the National Aeronautics Association when he received the Frank G. Brewer Trophy in 1946 for the most outstanding contribution to the development of youth in the field of education and training. In 1958, the University Aviation Association honored him with the William A. Wheatley Award in recognition of outstanding contributions to aviation education. These were the first of many awards and citations he would earn on a local and national level as he continued his active involvement in the field of aerospace education up until his death in 1977.

Through his involvement with the University of Nebraska-Lincoln Teachers College, Dr. Sorenson generated some of the earliest teaching materials for aviation education and textbooks for military aviators during World War II. Throughout the course of his career, he contributed over forty articles and publications related to the field of aviation education. His efforts guided the way for extensive aerospace research and scholarship from the grassroots to the global level through is participation in Civic Aeronautics Association, the World Congress on Air Age Education, and UNESCO. He has served as chairman of the Air Force Associations Aerospace Council, the Aerospace Education Forum at the First World Congress of Flight, the U.S. Air Force Air Training Command, the Men in Space book series, and NASA's Aerospace Education Advisory Committee. As a result of his visionary involvement and development of the Link Foundation, the organization has gone to provide grants now totaling over a half million dollars a year to support and advance aerospace education and training in aeronautics.

Dr. Sorenson's continuous involvement in aviation education and research laid the groundwork for many of the advancements currently taking place in the industry. His ceaseless research and educational outreach demonstrated how one person can make a difference not just today but well into the future.

Currently, several awards exist that are representative of his achievement in aerospace education and research. These include the Frank E. Sorenson Award for Excellence in Aviation Scholarship, representing the highest scholarly honor in aviation education, presented annually by the University Aviation Association; the Frank E. Sorenson Pioneers in Nebraska Aviation Education award presented annually by the University of Nebraska at Omaha Aviation Institute, as well as a memorial lecture fund and scholarship fund. A maximum of two award plaques will be given per article to the two lead authors in order of submission

PAST RECIPIENTS OF THE SORENSON BEST PAPER AWARD

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Sorenson Best Paper Award Recipient

A TOTAL FACTOR PRODUCTIVITY BASED STRUCTURE FOR TACTICAL CLUSTER ASSESSMENT: EMPIRICAL INVESTIGATION IN THE AIRLINE INDUSTRY

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ABSTRACT

In this paper we analyze and assess the efficiency of the United States (U.S.) airline industry through the total factor productivity (TFP) method. While airlines use various resources to produce a heterogeneous group of outputs, this article focuses on certain fundamental outputs as final products of selected airlines. The results from this analysis indicate that the national airlines (U.S. domestic carriers) have higher TFP as compared to the major airlines. While major airlines have drastically cut costs in the past few years, they also need to improve efficiency or risk going out of business. In this paper, we investigate the efficiency and productivity of a selection of U.S. airlines for the years 1996 through 2001. These years have been chosen as a good example of years in which the industry experienced normal growth and generally positively returns. Subsequent to 2001 the industry experienced two severe external shocks, namely, the September 11, 2001, terrorist attacks and the Iraq war. These anomalous shocks make the years after 2001 inconsistent with respect to the type of index developed in this article.

Bijan Vasigh is professor of Economics and Finance in the Department of Business Administration at Embry-Riddle Aeronautical University, Daytona Beach, Florida, and a Managing Director at ACG, Aviation Consulting Group, LLC. Dr. Vasigh received a Ph.D. degree in Economics from the State University of New York in 1984. He has written and published many articles concerning the aviation industry and has been published in the Journal of Economics and Finance, Journal of Transportation Management, Transportation Quarterly, Airport Business, Journal of Business and Economics, and Journal of Travel Research. He was consultant with the International Civil Aviation Organization and provided assistance on the evolution of aeronautical charge structure for the Brazilian Institute of Civil Aviation. He is currently a member of the international faculty at the International Air Transport Association Learning Center, where he is faculty leader of Airline Finance and Accounting Management. He is a member of the editorial board of *Journal of Air Transport Management* and *Journal of Air Transportation.* He worked on NASA Research Grants in 2001 and 2003 on *Determination of Statewide Economics Benefits of the Small Aircraft Transportation System.*

INTRODUCTION

The recent decline in airline profitability and productivity is not unique by historical standards. The magnitude of this decline,[1] however, is significantly greater due, in part, to the confluence of economic recession, SARS, the Iraq war and recent security concerns. Since the terrorist attacks on September 11, 2001 (9/11), certain airlines, such as United and US Airways, have filed for bankruptcy, while others, such as Delta and American, have flirted with the idea repeatedly, but have so far managed to avoid this fate. US Airways received $900 million in federal bailout money in March 2003 as it emerged from bankruptcy protection. However, only two years since its first filing, US Airways was forced again to return to the protection of the bankruptcy courts.

Nonetheless, even in the absence of strong traffic demand, innovative new airlines, such as JetBlue Airways, have been able to enter airline markets and successfully capture market share from incumbent airlines. For the past few years, smaller airlines have prospered as the bigger airlines rushed to bankruptcy courts. On April 25, 2003, JetBlue Airways placed a firm order for 65 Airbus A320 aircraft. Delivery of the new aircraft began in 2004 and will run through to 2011.[2] JetBlue Airways also announced an option for 50 more Airbus planes (Carey, 2003). Among the major U.S. airlines, Southwest is the only airline to remain profitable despite 9/11.[3] To ensure survivability, many airlines, such as Delta, Northwest, American and United, have slashed costs in order to improve financial and operational efficiencies. While efforts to reduce costs are not uncommon during economic recessions, the efforts undertaken by the airline industry may have been extreme. These initiatives have included massive reductions in work force, major changes to service, and significant wage concessions from employee groups. In effect, these airlines have had to substantially

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Kenneth Fleming has extensive experience in aviation operations research and economics. He specializes in analyzing airspace, air traffic control, and airline operational/management systems. A former military pilot with over 3,000 hours in nine different aircraft, he holds an FAA Commercial Pilot Airplane Single and Multi-engine Instrument Rating. During the past five years, he has been active in developing proposed new National Airspace procedures and processes. These initiatives included funded research programs that totaled $1.5M for numerous organizations including the FAA, NARI, Lockheed Martin Corporation, Harris Corporation, NASA Ames Research Center and NASA Langley Research Center. Dr. Fleming has led the development of a number of proprietary airspace and airport modeling and analysis tools used in the study of system efficiency and operational capacity. He is a published and recognized expert in aviation economics, air traffic control and air traffic management.

[1] U.S. airlines have sustained $18 billion in losses in the past two years.
[2] JetBlue has reported a profit each quarter since its public offering in April 2002.
[3] Since the 1978 airline deregulation act, 13 of the largest 20 airlines have gone out of business.

restructure themselves, operationally and financially, whether they sought the protection of the bankruptcy courts or not.

On the other hand, the success of the low cost, low frills airlines relative to their hub-and-spoke counterparts has not been limited to their financial performance. In the most recent update of their annual Airline Quality Rating study, Bowen and Headley (2004) find that the low cost, low frills carriers generally outperform the legacy hub-and-spoke carriers in terms of service measures for on-time performance, denied boardings, mishandled baggage, and customer complaints. The most recent update is based upon 2003 data reported to the U.S. Department of Transportation.

Table 1. 2004 Airline Quality Rating (AQR)

Airline	AQR	Airline	AQR
Jet Blue	(0.64)	Air Tran	(1.05)
Alaska	(0.74)	United	(1.11)
Southwest	(0.89)	ATA	(1.17)
America West	(0.89)	American	(1.24)
U.S. Airways	(0.96)	Delta	(1.24)
Northwest	(1.02)	American Eagle	(2.10)
Continental	(1.04)	Atlantic Southeast	(5.76)

Conversely, the major airlines have substantially reduced the number of flights operated, and have parked thousands of unused aircraft in the desert. American Airlines has restructured its flight schedule in order to eliminate flight banks at its major hubs (i.e., de-hubbing) in order to gain better utilization of employees and operating assets. In-flight services have been scaled-back or eliminated, including meal service on most domestic flights and complimentary cocktails on international flights. US Airways' labor force has dwindled dramatically in recent years; from 46,000 employees before 9/11 to 28,000 in 2004. The airline has gone through a bankruptcy restructuring and successfully cut costs by nearly $1 billion, including about $1 billion in concessions from employees. Further, certain major airlines have attempted to emulate their low-cost competitors with the formation of their own low-cost, no-frills subsidiaries,[4] despite limited historical success at such operations.

[4] For example Delta Air Lines' new low-fare startup airline Song is an attempt to reproduce the success of rivals Southwest and JetBlue Airways. United Airlines has also created a low-cost airline in an attempt to recapture the market share lost to low-cost competitors, including America West, Southwest and JetBlue. United has chosen the name Ted for its low-cost airline venture and it started flying in February 2004. Ted will be based at Denver International

Airlines, however, tend to operate with substantial operating and financial leverage.[5] While these efforts do reduce operating costs, the impact is mitigated by the substantially fixed nature of airline costs. Although parking aircraft in the desert allows airlines to avoid operating costs such as labor, fuel and associated maintenance, the substantial carrying cost of these assets in the form of lease payments and interest expense remains. Further, the substantial costs associated with operating hub structures are not easily reduced. Thus, the major airlines tend to enjoy higher levels of leverage, which can be beneficial in periods of economic expansion, but detrimental in periods of contraction. As the preceding discussion makes clear, not all airlines have been equally affected by 9/11.

Therefore, the question arises as to how these results might be generalized, and how to provide quantitative measures of the factors that have influenced the more successful smaller airlines during this period. If some measure of productivity that accounted for these factors could be determined, then airlines and external analysts could have benchmarks against which they could measure individual airline performance. Such measures might also provide internal indications of problems. It is the purpose of this paper to provide a methodology against which an airline could measure its performance. This methodology involves a comparison between and amongst airlines that ranks them according to productivity and efficiency.

The paper is organized as follows. In the next section, the productivity analysis and methodology are presented. This is followed by a description of the efficiency measurement methodologies. The fourth section discusses data issues and variables used in the models, while the fifth section presents the empirical results. The final section provides a summary and conclusion of the ideas discussed above relating to the TFP of the U.S. commercial aviation industry.

PRODUCTIVITY ANALYSIS AND METHODOLOGY

Despite the fact that many studies of efficiency and productivity have been conducted on airports and other industries, limited work has been completed in evaluating the efficiency of commercial airlines (Hooper &

Airport, the home of discount carrier Frontier. The Ted fleet will begin with four Airbus A320 aircraft and expand to as many as 45.

[5] A high degree of operating leverage implies that a small change in sales will result in a large change in net profit. Therefore, high operating leverage equals high business risk. Financial leverage is the degree to which a business is utilizing borrowed money or fixed assets. Companies that are highly leveraged may be at risk of bankruptcy if they are unable to make payments on their debt; they may also be unable to find new lenders in the future.

Hensher 1997; Oum, Yu, & Fu, 2003).[6] This paper seeks to fill this void by adapting the models and techniques used in these studies of other industries to evaluate the efficiency of U.S. airlines. This is of particular importance given the current concerns over the financial condition of commercial aviation and the financial viability of the industry.

Efficiency and productivity are key to the success of the commercial aviation industry, and, therefore, models that measure efficiency can be extremely useful. The available literature reports the adoption of commonly used techniques such as ratio analysis, data envelopment analysis (DEA), TFP, and stochastic frontier analysis (SFA) each with its own strengths and weaknesses.

DEA measures the relative efficiencies of Decision Making Units (DMUs) based upon a linear programming model. Inferences are drawn from optimal solutions. The critical feature of DEA is the selection of inputs/outputs, as well as the definition of the appropriate DMUs.

The DEA methodology was utilized by Charnes, Cooper and Rhodes (1978) who built on the frontier concept initiated by Farrell (1957). DEA uses linear programming techniques to calculate the Malmquist index of TFP growth, while the SFA calculates both technical efficiency and technical change components of TFP growth.

Farrell (1957) pioneered the primary ideal of the SFA to measure the efficiency of productive units. Since then, many researchers have broadened the SFA in evaluating efficiency. Nonetheless, Farrell's parametric estimation was unable to fully satisfy the particular nature of the large stochastic model. Hence, Aigner, Lovell, and Schmidt (1977), as well as Meeuseu and van den Broeck (1977), brought forth the SFA to measure efficiency.

The SFA was applied to decompose TFP into technological progress and efficiency. This enabled the model to specify the mechanism by which investment affects productivity (Cooper & Tone, 1997). The typical approach with the SFA is to draw inferences from optimizations over all observations (Cooper & Tone, 1997). The word frontier emphasizes the idea of maximally and represents the best practice approach to production.

Nero (1999) explored the extent to which a competitive advantage is secured by airlines operating large hub-and-spoke networks. Specifically, he looked at the relationship that arises among productive efficiencies and profitability when the size of the network expands. Nero found that returns to size are not constant, but rather decreasing. However, while suggesting

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[6] For example, the Air Transport Research Society (ATRS) publishes its annual Global Airport Performance Benchmarking Report. The report measures and compares the performance of three aspects of airport operation: Productivity and Efficiency, Cost Competitiveness and Financial Results, for up to 90 major airports in Asia Pacific, Europe and North America.

that an effective limit to size likely exists, Nero concluded that increasing network size still provides a competitive advantage. Ozment and Morash (1998), in their research to evaluate the relationship between productivity and performance quality in the U.S. domestic airline industry, argued that network density is correlated with productivity and lower output costs, as well as higher subjective measures of quality. On the other hand, Ozment and Morash found no such correlation between input cost efficiency, and lower output costs and quality.

Coelli, Grifell-Tatje and Perelman (2002) examined the inefficiency in profit generation (as well as the contributing components) of a sample of international airlines. Feng and Wang (2000) argued for the inclusion of financial ratios and considerations, in addition to operational measures, in evaluating airline performance. They contended that ignoring these financial considerations provides an incomplete picture of airline performance and survivability. The approach of Feng and Wang divided airline performance into production, marketing and execution efficiencies. Financial statistics are found to be best for measuring execution efficiency, while operational measures are best in measuring production efficiency. Forsyth, Hill and Trengove (1988) found that the North American airlines performed well compared to the European airlines, confirming the results of some earlier studies of airline productivity. In addition, the study discovered substantial differences across some of the European airlines.

Using the DEA methodology, Bazargan and Vasigh (2003) analyzed the performance of 45 U.S. commercial airports selected from the top 15 large, medium, and small hub airports. The results suggest that the relative efficiency of the airports is highest for small and lowest for large hub airports.

Thus, the literature shows numerous attempts to measure various aspects of efficiency. For this study, TFP will be used to measure and compare commercial airlines. The rationale for this is outlined below.

Performance can be measured based on efficiency or effectiveness. Efficiency is related to the supply side, where the technique of transformation of physical inputs (such as pilots, flight attendants, aircraft, fuel, etc.) into physical outputs of service (such as passengers, cargo, operating revenues and profits) can be assessed. Productivity is basically an efficiency measure that shows how well an airline utilizes its resources, and can be expressed in different ways.

TFP measures the productivity of all inputs engaged in the production process. This, in effect, allows us to measure its cost-efficiency and cost-effectiveness (the difference being in the selection of the measure of output).[7] TFP aggregates outputs on the basis of their revenue contribution, and inputs on the basis of their relative importance to total costs, in order to calculate the overall airline productivity as a function of these quantities.

Therefore, TFP allows us to distinguish productivity differences in airlines that arise from economies of scale as opposed to those differences resulting from managerial performance. In this paper, a Malmquist (1953) TFP index is used to investigate the efficiency and productivity of a selection of U.S. airlines for the years 1996 through 2001. The results are then used to compare airline performance.

There are many different ways of measuring productivity. For example, in a factory productivity might be measured based on the number of hours it takes to produce a product, while in the service sector productivity might be measured based on the revenue generated by an employee divided by the number of hours worked. Hence, productivity is concerned with the ratio of outputs over inputs.

Productivity measures can be categorized in two primary methods: first, TFP, which is calculated by dividing total measured outputs by total measured inputs, and second, partial productivity, which is calculated by dividing total outputs by each factor input.

We start by introducing a production function that relates different observable inputs (I_m) to output Q:

$$Q = f(I_1, I_2, \ldots, I_m, t)$$

The above production function contains a time variable t that explains the shift of the production function over time. In this paper we measure productivity by using the index number method. Productivity measures try to capture the ability of inputs to produce output.

Following Tornqvist (1936) the output quantity index is defined as follows:

$$Q^T_{st} = \mathrm{C}_{j=1}^{n} \left(\frac{Q_{jt}}{Q_{js}} \right)^{\left(\frac{1}{2}\right)(Wjs+Wjt)} \qquad (1)$$

The Tornqvist index is the weighted geometric average of the output relatives, with weights given by a simple averaging of the value of the shares

[7] It is also possible to examine economies of scale and density, as well as investigate the impact of variations of input and output prices on the performance of a DMU (Gillen & Lall, 1997).

in period s and t. In the above equation, Q_{js} represents the quantity of j^{th} output in the s period.

Input quantity indexes are defined in a similar manner:

$$I_t^T = \mathop{\mathrm{C}}\limits_{i=1}^{m} \left(\frac{I_{it}}{I_{is}} \right)^{\left(\frac{1}{2}\right)(V_{is}+V_{it})} \tag{2}$$

In general a productivity index is defined as the ratio of an output quantity index to input quantity index, that is:

$$TFP_k = \frac{\mathop{\mathrm{C}}\limits_{j=1}^{n} \left(\frac{Q_{jt}}{Q_{js}} \right)^{\left(\frac{1}{2}\right)(Wjs+Wjt)}}{\mathop{\mathrm{C}}\limits_{i=1}^{m} \left(\frac{I_{it}}{I_{is}} \right)^{\left(\frac{1}{2}\right)(V_{is}+V_{it})}} \tag{3}$$

The following TFP model, in logarithmic format, is similarly a framework introduced by Caves, Christensen and Diewert (1982). The appropriate input weights in the following equations are the contributions of each input and output in the system (Hooper & Hensher, 1997). Equation 4 represents a pair-wise comparison of two airlines in one year. To form the TFP, it is necessary to divide the output quantity indexes by input quantity indexes:

$$\begin{aligned} Ln\frac{TFP_k}{TFP_b} &= \frac{1}{2}\{\sum_j W_k(LnQ_{kj} - \overline{Ln\,Q_{kj}}) - \sum_i V_i(Ln\,I_{ki} - \overline{Ln\,I_{ki}})\} \\ &\quad -\frac{1}{2}\{\sum_j W_b(LnQ_{bj} - \overline{LnQ_{bj}}) - \sum_i V_b(Ln\,I_{bi} - \overline{Ln\,I_{bi}})\} \end{aligned} \tag{4}$$

Where:

$\overline{Ln\,I_{ik}}$ = geometric average of input over the entire observations in the sample;

$\overline{LnQ_{ik}}$ = geometric average of output over the entire observations in the sample; and

b = base airline.

Likewise, where:

Q_{jk} = is the j x k matrix of all airlines outputs
I_{jk} = is the i x k matrix of all airlines inputs
j = number of outputs, j = 1, ..., J
i = number of inputs, i = 1,...,N
k = number of airlines, k = 1, ..., K
W = weights assigned to each output

The revenue contributions of each output could be used as applicable output weights.

Where:

V = weights assigned to each input;
$\overline{Ln\,I_{ik}}$ = geometric average of input over the entire observations in the sample;
$\overline{Ln\,Q_{ik}}$ = geometric average of output over the entire observations in the sample; and
b = base airline.

EVALUATION OF AIRLINE EFFICIENCY: EMPIRICAL RESULTS

The intent of this study is to analyze and evaluate the efficiencies of major U.S. airlines and to compare them to national airlines (U.S. domestic carriers).[8] This study used the annual statistics (1996-2001) on major and national airlines from the Form 41 (Form 41, 2003).[9] On the input side, the study includes two types of variables: physical units of input, and dollar values. Five input variables were selected:

1. Available seat miles (ASM);
2. Total expense;
3. Cost per available seat mile (CASM);
4. Average number of employees; and
5. Fuel cost.

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[8]The FAA groups carriers according to the operating revenue boundaries contained in Section 04 of Part 241. Major airlines have operating revenues of over $1 billion. Airlines with revenues between $100 million and $1 billion in revenues are defined as national airlines.

[9] Large, small, and commuter certificated air carriers are required to complete Form 41 Financial and Traffic Reporting Requirements. The Office of Airline Information (OAI) within the Bureau of Transportation Statistics (BTS) collects data on the Form 41.

A total of five output variables were also selected:

1. Revenue passenger miles (RPM);
2. Yield;
3. Total revenue;
4. Revenue per available seat mile (RASM); and
5. Load factor.

Tables 2, 3 and 4 show the rankings of the major and national airlines in terms of their efficiency scores and the average TFP, for the years 1996 through 2001.

Table 2. Total factor productivity for U.S. major airlines, 1996-2001

Majors	1996	1997	1998	1999	2000	2001
American	0.13	0.13	0.01	0.07	0.17	0.09
American Trans Air	0.54	0.59	0.64	0.95	0.90	0.66
Continental	0.41	0.43	0.42	0.29	0.39	0.36
Delta	0.16	0.25	0.28	0.16	0.29	0.16
Northwest	0.30	0.49	0.17	0.19	0.29	0.25
Southwest	0.46	0.47	0.49	0.46	0.63	0.41
United	0.17	0.14	0.17	0.08	0.12	0.10
US Airways, Inc	0.32	0.36	0.45	0.28	0.24	0.34

Table 3. Total factor productivity for U.S. national airlines, 1996-2001

National	1996	1997	1998	1999	2000	2001
AirTran	0.69	0.76	0.68	0.76	0.73	0.76
Alaska	0.57	0.59	0.69	0.60	0.56	0.61
Aloha	0.85	0.83	0.89	1.00	0.85	0.92
American West	0.53	0.56	0.57	0.56	0.52	0.59
Frontier	0.83	0.64	0.83	0.89	0.84	0.84
Hawaiian	0.84	0.67	0.72	0.64	0.69	0.80
Horizon	0.85	0.84	0.85	0.93	0.81	0.91
Midwest Express	0.83	0.81	0.82	0.89	0.77	0.84
Spirit	0.90	0.86	0.85	0.82	0.87	0.85
World	0.77	0.81	0.82	0.89	0.85	0.71

During the observation period, national airlines have continuously outperformed major airlines. As the tables imply, among the major airlines, American Trans Air and Southwest Airlines have the highest productivity for all 6 years (1996-2001). However, it should be pointed out that subsequent to the period of evaluation, and as a direct result of sluggish demand, resulting from 9/11, ATA imposed a wage freeze for non-contractual personnel, furloughed 300 people and eliminated 400 jobs. It is also of interest to note that Southwest Airlines is the only major U.S. based airline to remain continuously profitable since its maiden voyage in 1971. In 2003, Southwest posted a net income of $442 million (up $78 million from 1999). On the other hand, American, United and Delta Airlines have had the lowest productivity. In 2000, American Airlines' net income was at $813 million (down $172 million from the year before), while in 2001 it reported a net loss of $1,762 Million. Also, in 2000, United Airlines reported net earnings of $50 million (down $1,185 million from 1999) while in 2001 it had a net loss of $1,762 million.[10] US Airways and United have lowered costs through bankruptcy, and American Airlines enjoyed major labor concessions from unions and avoided bankruptcy. While US Airways slashed its costs, they still are the highest in the industry. It is 11.7 cents cost per available seat mile (CASM) is about 20% above the average for the major airlines. The third worst performer, Delta Airlines, has a cost structure that is much higher than those of its competitors.

Table 4. Average total factor productivity for U.S. airlines, 1996-2001

Airline	ATFP	Airline	ATFP
Aloha	0.89	American Trans Air	0.71
Horizon	0.87	American West	0.56
Spirit	0.86	Southwest	0.49
Midwest Express	0.83	Continental	0.38
Frontier	0.81	US Airways	0.33
World	0.81	Northwest	0.28
Airtran	0.73	Delta	0.22
Hawaiian	0.73	United	0.13
Alaska	0.60	American	0.10

While the productivity rankings within the group of major airlines have remained relatively static, the productivity rankings of the national airlines have exhibited considerable variability from year to year. As smaller, less stable enterprises, these operations are subject to considerable variability in both operational and financial performance. The calculated productivity for these individual airlines is influenced by their rising and falling fortunes. However, they have still managed to be more productive than the major airlines. Some reasons for this greater productivity may be attributed to smaller fleet sizes, lower financial leverage, avoidance of congested hub airports, and a less diverse fleet.[11]

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[10] United Airlines filed for Chapter 11 bankruptcy in December 2002. US Airways, the sixth largest domestic airline, had previously filed for bankruptcy protection in August 2002, following the collapse of Midway, Sun Country and Vanguard airlines.

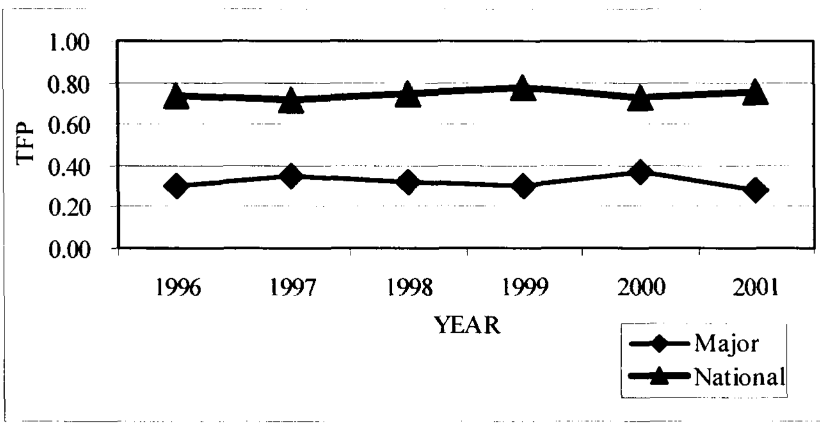
[11] Delta Airlines avoids its hubs using Song (its low-cost carrier) and flies the aircraft, B-757, more hours per day than its mainline operations.

As shown on Table 3, the top three national airlines are Aloha Airlines, Horizon Airlines, and Spirit Airlines, in that order. Alaska Airlines has been the least efficient national carrier during the period of 1996 through 2001.

Founded in 1946, Aloha operates an average of 145 daily flights with a fleet of Boeing 737 jets.[12] In 1999, Aloha improved its first-quarter profit by 10.7 percent despite a 2.7 percent drop in revenues.

This analysis has demonstrated a consistently higher productivity for the national airlines as compared to the major airlines (Figure 1). The peak productivity occurred in 2000 for the national airlines, at which time the major airlines exhibited a relatively significant lower productivity. The major airlines exhibited relatively consistent productivity as compared to the national airlines, which peaked in 1999-2000. The national airlines demonstrated a decline in productivity in 1999, but experienced an immediate recovery after that.

Figure 1. Total factor productivity for major airline and national airline, 1996-2001



These results raise questions with respect to the cost structures of airlines. The stronger productivity of the national airlines as a group, relative to the major airlines, indicates that the major airlines may have exceeded the effective limit to size suggested by Nero (1999). Further, while the hub-and-spoke system, which evolved following deregulation of the industry, has been credited with allowing for the efficient provision of air transportation to smaller markets and routes, the relative productivity rankings of this analysis

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[12] The airline's outstanding in-flight service was recently recognized as the first place Diamond Award winner in international competition conducted by Onboard Services magazine.

suggest that perhaps these hub-and-spoke systems decrease TFP. In addition to the national airlines out performing the major airlines, Southwest Airlines, a point-to-point carrier, has significantly outperformed the remaining major carriers. Southwest has been profitable by keeping costs about 20% lower than the industry average. The lower productivity of the major airlines may in fact result from the inefficient use of assets and expenses associated with the operation of hub systems, an issue American Airlines has tried to address with its de-hubbing efforts at O'Hare International Airport and Dallas-Fort Worth International Airport.

Potential explanations for the decline in productivity of the national airlines over the analysis period are less readily apparent. Harraf and Vasigh (1994) suggest a counter-cyclical beneficial impact for low-cost and start-up carriers. These airlines benefit from reduced wage rates and aircraft acquisition costs, as well as demand substitution impacts associated with periods of economic recession. These same influences negatively impact such carriers during economic expansion. Thus, under this proposal, the national airlines would have experienced increasing pressures from these factors as an economic expansion continued through this analysis period and did not wane until late-2000 or early 2001.

In January 2004, America West Airlines reported a fourth quarter net income of $6.8 million or $0.13 diluted earnings per share. This compares to a net loss of $52.0 million or $1.54 per share for the same period last year. The airline's operating expenses in the fourth quarter decreased 1.5 percent to $544.6 million. Continued cost diligence and increased capacity resulted in a 2.5 percent decrease in the airline's CASM in the fourth quarter of 2003. On a fuel exclusive basis, the airline's CASM in the fourth quarter of 2003 declined 4.3 percent to 6.44 cents.

In order to provide a further evaluation of the TFP index developed in this paper, we compared the TFP to some more conventional measures of financial performance for all of the airlines used in this study and also the major and national carriers as a group. The first of these financial measures was a simple measure of return on assets (ROA), defined as total revenue minus total cost divided by total assets, and the second measure was basically a measure of the gross profit margin (GPM), and defined as total revenue minus total cost divided by total revenue. Our hypothesis was that the TFP should track positively (in either the negative or positive direction) with the more conventional measures over the time period evaluated.

The results of this analysis are contained in Table 5. As the table indicates, and as might be expected with the data sample of this size, the results are mixed, but generally supportive of the hypothesis.

More specifically, as far as the major airlines are concerned, for those with a negative r value, or no correlation either negative or positive between the TFP and the financial measures, the t value is not significant at any meaningful level. The only exception to this is the ROA value for American Airlines, and this measure would require further investigation. The remaining major airlines have positive correlations with varying levels of significance for the two measures used. When the major airlines are aggregated, then the results are much better for both measures. In both cases the aggregated measures of correlation are significant at a better than 95% level of significance, showing a strong correlation between the TFP and the more conventional measures of performance. This may also be a reflection of the generally smaller variation of the performance measures for the major airlines that was mentioned earlier in the paper.

Table 5. Statistical analysis of measures of financial performance, for major and national airlines, 1996-2001

	ROA		GPM		Critial t	
	R	t	R	t	One tail	Two tail
Major Airlines						
American	0.94	-3.74	0.54	-0.90	2.13	2.78
American Trans Air	0.04	-0.06	0.14	0.21	2.13	2.78
Continental	0.11	0.16	0.82	2.00	2.13	2.78
Delta	0.33	-0.50	0.35	-0.52	2.13	2.78
Northwest	**0.85**	**2.27**	0.78	1.75	2.13	2.78
Southwest	0.51	0.84	0.71	1.42	2.13	2.78
United	0.05	-0.06	0.22	0.32	2.13	2.78
US Airways, Inc.	0.66	1.24	**1.00**	**24.48**	2.13	2.78
Major aggregated	0.47	1.98	**0.56**	**3.41**	1.70	2.05
National Airlines						
AirTran	0.39	-0.60	0.15	0.21	2.13	2.78
Alaska	0.73	1.51	0.75	1.62	2.13	2.78
Aloha	0.23	-0.33	0.32	-0.48	2.13	2.78
American West	**0.95**	**4.46**	**0.99**	**11.98**	2.13	2.78
Frontier	**0.98**	**7.46**	**0.93**	**3.68**	2.13	2.78
Hawaiian	0.80	1.89	**0.89**	**2.70**	2.13	2.78
Horizon	**0.85**	**2.29**	**0.84**	**2.18**	2.13	2.78
Midwest Express	0.67	1.26	0.76	1.63	2.13	2.78
Spirit	0.19	-0.28	0.12	-0.17	2.13	2.78
World	0.17	-0.24	0.78	-1.75	2.13	2.78
National aggregated	0.19	1.29	0.04	0.26	1.68	2.02
All	0.05	-0.43	0.21	-1.84	1.68	2.01

The results for the national airlines are again mixed. Just as in the case of the majors, the national airlines that exhibit negative correlations are not significant at any meaningful levels, and this is true for all of the negative values. On the other hand, for those nationals that exhibit positive correlations, the majority of the results are very significant and strong for both conventional measures. The weakest of these is the ROA correlation for Midwest Express that is not significant at conventional levels, but still exhibits a respectable *r* value of .66. All of the other values for the correlation of the financial measures with TFP are significant at a .9 or better level (five airlines and nine *t* values). However, the aggregate measure for the national airlines is not significant at all. Again, and as mentioned earlier, this result probably reflects the inherently larger variation present in all the performance measures for the national airlines.

Overall, the results from this extended analysis of the TFP index are encouraging, although it is obvious that a larger data sample (over time) will be needed to provide a more significant validation of the TFP index.

SUMMARY AND CONCLUSION

This paper espouses an embryonic process, which uses selected literature to explore the applications of different productivity measures and their limitations on the U.S. commercial aviation industry. This study highlights the relatively stronger productivity achieved by the U.S. national airlines as compared to the U.S. major airlines. This analysis did not attempt to examine the relatively poor performance of the major airline group.

It is clear that little work has been completed to date in the area of airline productivity. Yet, this industry is a vitally important element of the U.S. transportation system and exhibits a significant impact on the overall economy. Understanding that differences in productivity do exist is the first step in evaluating these differences.

It is not surprising that differences in performance exist between individual enterprises. However, it is interesting that significant, sustained differences in productivity exist between important segments within this industry. These differences raise important questions with respect to the nature, cost structure, and long-term viability of these segments. Such questions correspond to the performance of the industry as a whole, as well as the relative performances of the various segments in 2001 through the current period.

Important further study of this subject would include the analysis of productivity through the industry recession as that data becomes available. It should be expected that significant erosion in productivity would be followed by an improvement as restructuring efforts take effect. The dynamic nature of demand, with the static nature of supply and cost structure, would dictate that the near-term plunge in demand would cause a decline in productivity since the supply is necessarily slower to adjust. As predicted by these productivity measures, the major airlines have undertaken significant measures to increase productivity and to lower cost. However, these responses have been formulated in the absence of significant academic research into the reasons of the specific causes of these productivity differences. Thus, these results indicate the urgency of further research in order to formulate appropriate responses and structures to insure long-term viability.

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AIR CARRIER SAFETY AND CULTURE: AN INVESTIGATION OF TAIWAN'S ADAPTATION TO WESTERN INCIDENT REPORTING PROGRAMS

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ABSTRACT

During the summer of 2003, a descriptive study was conducted of Taiwan's air carrier flight crew members' acceptance and usage of the government's confidential incident reporting program. Survey results from 205 Taiwanese airline pilots revealed numerous problems with the incident reporting program that were directly attributable to the structure of Taiwan's airlines and safety system within the Chinese culture. It was concluded that adaptation to the principles of the United States Aviation Safety Action Program is desirable to the Taiwanese air carrier pilots, but that the current airline structure within Chinese culture is a considerable impediment.

INTRODUCTION

The role of accident investigation as a critical factor in aviation safety can be traced to the first airplane passenger fatality in 1908. The accident site was Fort Myer, Virginia; Orville Wright was the pilot who survived; and Lieutenant Thomas E. Selfridge of the United States U.S. Army was the passenger whose life was lost. In this case, Wright, the surviving pilot, knew the cause of the accident before the actual crash. "The investigation of the first air accident in which a passenger was killed took only about three seconds" (Barlay, 1970, p. 13).

The use of accident investigation as an air safety practice is approaching 100 years, and the process now involves considerable attendant data and complexity. In the U.S., during the 1970s, aviation human factors (AHF) became recognized as an important component of accident investigation and

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aviation safety (Lauber, 1993). Those air safety investigators, who have concentrated on the mechanical and environmental aspects of air carrier accidents during the last 30 years, have seldom been able to attribute causes to these two factors. Today, there is little doubt that the majority of recent air carrier accidents have involved AHF issues (Reynard, 1995).

Incidents, classified as subordinate to accidents, provide free lessons (or lessons learned) and become salient case studies for aviation safety programs (Reason, 1997). As a result, the implementation of a confidential incident reporting program for the humans involved with aviation safety has become one of the most effective tools to enhance the AHF of air carrier safety and thereby reduce the accident rate (Henrotte, 1995).

The use of confidential incident reporting systems for air carrier flight crew members has been added to the list of effective Western air safety tools. Thus, in 1999, the Republic of China (Taiwan), similar to many Western nations, established the Taiwan Confidential Aviation Safety Reporting Program (TACARE). Although the program has been in existence for 4 years, TACARE has suffered from limited funding and little flight crew member participation. This study addresses factors affecting TACARE and examines the possibility of adopting principles from the U.S. Aviation Safety Action Program (ASAP) into TACARE.

VOLUNTARY INCIDENT REPORTING

One of the most important aspects of incident investigation has been data collection. Although incidents occur more often than accidents, an incident can only be investigated if it has been reported. Thus, developing an effective incident reporting system is fundamental to incident investigation. Several Western nations, including the U.S., have developed incident collecting databases. An examination of some U.S. incident reporting databases follows.

Aviation Safety Report System

The U.S. was one of the first nations to develop an incident reporting program. The Aviation Safety Reporting System (ASRS) was established in 1975 under a Memorandum of Agreement between the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA).

Today, ASRS is one of the world's most comprehensive aviation incident collection databases. The current database receives reports from pilots, air traffic controllers, air carrier inspectors, cabin attendants, mechanics, and a variety of other individuals. Currently, ASRS averages 727 reports per week and more than 3,153 reports per month (NASA, n.d.). Due to the non-punitive nature of the program, ASRS has become one of the world's leading, effective aviation safety programs in the identification of aviation hazards and the minimization of aviation incidents and accidents.

Aviation Safety Action Program (ASAP)

Few individuals have doubted that NASA's ASRS program has been very successful in analyzing and minimizing aviation incidents and accidents. However, it became clear to the FAA and several major U.S. airlines that a carrier-specific voluntary incident reporting program was needed to further analyze the individual carriers' operations; as a result, the ASAP was created.

The goal of ASAP is to minimize accidents and incidents. The program works toward its goal by identifying flight safety concerns and achieving corrective actions. Similar to its NASA counterpart, ASAP analyzes risks, increases education and awareness, validates program effectiveness, measures system performance, and ensures accountability (American Airlines, n.d.).

Although ASAP is similar in nature to NASA's ASRS program, there are several differences between the two programs. One of the most noticeable differences is the intended participants. NASA's ASRS is a voluntary incident reporting program that accepts incident reports from both general aviation (GA) pilots and commercial air carriers. ASAP, on the other hand, is an air carrier-specific program where participants include flight crew members, dispatchers, and maintenance personnel. This discussion will be limited to flight crew members only. Unlike the ASRS, ASAP entails specific guidelines that govern the acceptance of reports.

Since ASAP's goal is to analyze and minimize incidents and accidents, it is critical to conduct continuous reviewing processes to identify potential hazards to flight safety. This is accomplished with an Event Review Team (ERT). The ERT is comprised of three members: (a) one member from the FAA, (b) a representative of the participating air carrier, and (c) a member from the employee (pilot) union. The principal function of the ERT is to conduct weekly meetings to review each ASAP on a case-by-case basis. These meetings can identify potential hazards and trends that could result in mishaps.

Even though ASAP is a relative newcomer within the group of aviation voluntary safety reporting programs, it has proven to be one of the most successful models within the commercial aviation industry. As a result of its successful American Airlines trial during 1994, several other major U.S. air carriers have chosen to adopt similar programs, the objectives of which are to enhance aviation safety through the minimization of accidents and incidents.

CROSS-CULTURAL PSYCHOLOGY

According to Lloyd (1972), cross-cultural psychology is "any field of research in which cultural variables are considered in order to clarify our understanding of a psychological process" (p. 18). Cross-cultural psychology is a relatively new discipline within AHF. Traditionally, cultural differences have often been disregarded and overlooked in the pilot training process. Many have viewed flight training as an interaction between machines (aircraft) and humans (pilots), thus flight training has been highly concentrated on a universal and standardized approach. According to Helmreich and Merritt (1998), commercial aviation consists of a complex system and carries the risk of large-scale catastrophe. Thus, it is imperative that the aviation industry should be highly regulated and standardized. As a result, air carrier pilots have become one of the most standardized professions in the world.

Although flight crew standardization ensures operational safety, as the cockpit has become a multi-cultural workplace, pilots have become aware of the effects caused by differences in national culture in the cockpit. These effects have become more apparent following the introduction of Crew Resource Management (CRM) concepts. CRM was the first safety program that concentrated on the interaction between flight crews. Although generally considered to be a great success in the U.S., CRM received mixed reviews when it was practiced overseas (Helmreich & Merritt, 1998). Consequently, it became apparent that in-depth research was necessary to further understand the impact of multi-cultural flight crews in today's cockpits.

CHINESE CULTURE

China is one of the oldest civilizations in mankind. Chinese culture originated thousands of years before most Western cultures, with the Chinese living in unison, and governed by emperors. Although emperors are long gone, certain aspects of Chinese culture today remain relatively unchanged. The following section identifies several characteristics of Chinese culture and the effects on aviation safety.

Individualism

Unlike most Western cultures that are often founded on the principal of individualism, Chinese culture is characterized by its strong emphasis on collectivism. Chinese often consider the implications of their behavior in a framework of concern that extends beyond their immediate family. According to Helmreich and Merritt (1998), people in a collectivist culture often link their behavior to the extended family or organization. A result of this cultural trait is that Chinese children are taught at a young age to listen and not speak, and speak only when spoken to—the practice of which is popularized by the Chinese saying 'God provided us with two ears and only one mouth because we should listen more and speak less' (author unknown). The resultant belief led to the development of collective thinking. The harmony of the group often becomes the primary concern; therefore, the Chinese will seldom express their individual opinions during social settings such as conferences, lectures, and intra-cockpit communications.

Social Pressure

Due to the strong emphasis on collectivism, Chinese culture has evolved into a shame culture. Chinese grow up sensitive to pressure from the society instead of their internal feelings. Many other cultures emphasize honor systems or codes of honor based on one's own judgments and internal feelings of guilt. This same type of honor system does not exist in the Chinese culture since it is the society—not the individual—that determines the belief system. For example, the practice of cutting corners is widely accepted by Chinese society. The results of this cultural characteristic can be serious. According to a study conducted by the Taiwanese Naval Academy, people in a Chinese society can easily break rules, operating procedures, and even the code of law when it is deemed acceptable by society. Due to social pressure, Chinese would view such behaviors as righteous, and would even encourage it (Lu et al., n.d.).

Authoritarianism

Chinese culture is based on 5,000 years of dictatorships. As a result, authoritarianism has been an important part within the society (Jing, Lu, & Peng, 2001). Figures of authority, such as professors, managers, and airline captains are treated with a great amount of respect by their subordinates. Unlike cultures where this relationship only exists within the working environment, Chinese subordinates treat their superiors with respect regardless of the environment and/or conditions. This relationship between superior and subordinate is routinely witnessed during daily interactions. Eye contact is an example of a daily interaction. In Western cultures it is acceptable—even encouraged—for a subordinate to make eye contact with figures of authority. In Chinese culture, a subordinate making eye contact with a figure of authority is considered disrespectful, and, thus, it is strongly discouraged.

It is also a common belief, in Chinese culture, that a figure of authority is error-free. Thus, it is considered an outrage when a Chinese subordinate challenges a figure of authority. Figures of authority will not allow such challenges, nor will they admit their errors. This is because of fear of losing face. Face in Chinese culture signifies one's dignity and prestige. It is often the subordinate's responsibility to preserve the superior's face, and thereby maintain the harmony of the group.

Profile of Taiwanese Flight Crews

There are few doubts that flight crew members, regardless of their nationalities, are often trained in the latest technologies and are typically at the technological and modernized forefront of their country's workforce (Helmreich & Merritt, 1998). According to Helmreich and Merritt, national culture will have limited effects on these individuals; however, cultural influences will continue to be evident in flight crew members' interactions and communication processes

As a result of the long history of dictatorship, Taiwanese figures of authority (e.g., professors, physicians and airline captains) are highly respected, and even feared by their subordinates, resulting in a high power distance between superiors and subordinates. Helmreich and Merritt (1998) determined that Taiwanese flight crews could be characterized as a group of individuals who have a strong preference for order (time limits, finding the one way to do a job, etc.), with a very high power distance between captains and first officers in their work environment. These traits were notably different in comparison to Western flight crew members; the Western pilots showed a strong preference for flexibility (changing work routine, no single solution, and challenging tasks).

FLIGHT SAFETY AND THE INCIDENT REPORTING SYSTEM IN TAIWAN

It is evident how some of the values and beliefs of Chinese culture could have a negative impact on Taiwan's flight safety. Thus, it is not surprising to discover that Taiwan has one of the world's worst flight safety records. According to Taiwan's Aviation Safety Council (ASC), there were 21 accidents and 300 fatalities during the years 1999-2003; this is high for a small island with only 200 commercial transport aircraft (ASC, n.d. [b]).

There is little doubt that such an accident rate is unacceptable; as a result, the Taiwanese government has begun a series of initiatives to enhance flight safety. One of the attempts has been the establishment of a Taiwanese voluntary incident reporting program for flight crew members. The following section focuses on the history and characteristics of the Taiwanese voluntary incident reporting program.

The Role of Taiwan's Aviation Safety Council

The ASC was established in 1999 as a relative newcomer to the field of aviation accident investigations. It has participated in high profile commercial aviation accident investigations, including Singapore Airlines' runway incursion at Taipei and China Airlines' in-flight breakup in 2002 (ASC, n.d. [b]) . Similar to other investigation agencies, ASC quickly realized that accident investigation is a limited resource for enhancing flight safety, and that the optimal tool to combat aviation accidents is to minimize their occurrence. Recognition of the need to minimize the number of accidents generated ASC interest in the establishment of a confidential incident reporting program for flight crew members (ASC, n.d. [a]).

The loss of an Airbus 300 and 180 lives in 1998 was the impetus for Taiwanese authorities to recognize the importance of a voluntary incident reporting program. In 1999 TACARE was established. TACARE is the government's attempt to introduce a non-punitive incident reporting program for Taiwanese flight crew members, but it has faced numerous challenges.

THE TACARE STRUCTURE

Due to Taiwan's unique aviation environment (non-existent general aviation and a relatively small, yet highly competitive, airline industry), TACARE was modeled after the British Confidential Human Factors Incident Reporting Programme (CHIRP) where the reporting program was designed specifically for air carriers (ASC, n.d. [a]).

Similar to CHIRP, TACARE consists of three committees: (a) the Core Committee, (b) the Work Group, and (c) the Technical Advisory Committee. The Core Committee has six members: the director, the executive secretary, and four consultants. The director and executive secretary are members of the ASC, and the four consultants are experienced aviation safety experts from various Taiwanese air carriers. The Core Committee serves as the overseer of all functions of TACARE and the evaluator of the effectiveness of the entire program (ASC, n.d. [a]).

The Work Group is the main workforce of TACARE; the group is charged with the operation of TACARE and responsible for receiving, analyzing, maintaining, and de-identifying actual TACARE reports. The Work Group has three members—two analysts and a database engineer (ASC, n.d. [c]).

The Technical Advisory Committee has 14 members representing a variety of special interest groups including air carrier management, air traffic controllers, pilots, and flight attendants. The principal task for the Technical Advisory Committee is technical assistance and advice to the work group (ASC, n.d. [c]).

Categorization and Processing of TACARE Reports

Categorization of incident reports is one of the most important parts in a voluntary incident reporting system. A successful program effectively categorizes submitted reports and provides valuable information for trend analysis (Chidester, 2000). TACARE adopted a human factors categorization system used by the International Civil Aviation Organization, the International Air Transport Association, and the U.S. Navy. All TACARE reports are categorized under three headings: (a) technical, (b) environment, and (c) human factors. A total of 52 sub-categories are used to analyze submitted TACARE reports (ASC, n.d. [c]). The analysis process is conducted by the Work Group with a set of procedures used to review each report. A checklist is utilized by the Work Group to properly identify the nature of the submitted reports. Upon completion of the analysis process, the report is blinded by having all identifying information removed and entered into a database for trend analysis and publication.

Meetings, where analysis and newly submitted reports are reviewed, are conducted between the TACARE Work Group and the Technical Advisory Committee on a monthly basis. The joint session issues recommendations to the appropriate agencies, and completes the process by destroying the original copies of the TACARE reports.

The problems with TACARE prompted this study. An investigation was designed to analyze the cause of difficulties from a cultural prospective and examine the possibilities of adopting other existing programs such as ASAP to enhance TACARE.

PURPOSE OF THE STUDY

The review of the literature associated with the TACARE problem resulted in three research questions:

1. How does the Taiwanese TACARE compare with ASAP in the U.S.?
2. How would Taiwanese air carrier flight crew members accept certain ASAP principles?
3. How would a Western flight safety program integrate with Chinese culture?

Although TACARE has been in existence since 1999, limited data has been generated that would determine the effectiveness of the program. The only survey that was administered to measure the effectiveness of TACARE was conducted by ASC in 2002. However, the study was for internal evaluation only, and the results have not been made available to the public. Subsequent to a thorough review of all available data, the need for this study became apparent. The new survey would be designed and administered as a measure of the effectiveness and degree of acceptance of TACARE by Taiwanese air carrier pilots.

Design of the Survey

Since many Taiwanese pilots believed that TACARE was a sensitive issue, the survey was designed to be confidential, with no publication of any of the participants' personal data. The two-page instrument measured demographics and opinions. The first 6 items gathered basic demographics (e.g., the ages of the participants, their aviation experiences, and the sources of their primary training). The 11 opinion items that followed comprised 5 multiple choice questions, and 6 Likert scale inquiries. The Likert scale is generally a five-point scale where participants choose responses ranging between Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree. A five-point Likert scale has been very popular in similar studies, but it was determined that the Neutral choice would compromise this study. As a result, the six-point Likert scale was more desirable; it eliminated the Neutral choice, and effected either an agreement or a disagreement with the statement. The six choices used on the survey instrument were: (a) Strongly Agree, (b) Agree, (c) Somewhat Agree, (d) Somewhat Disagree, (e) Disagree, and (f) Strongly Disagree. These options were numerically coded with 1 representing Strongly Agree and 6 representing Strongly Disagree.

The five multiple choice items ranged from queries of the individuals' basic understandings of TACARE's voluntary incident reporting to more complex statements evaluating the effectiveness of the program. The six Likert scale items consisted of several operating principles of ASAP. These items were designed to examine participants' acceptance of certain ASAP principles and the possibilities of incorporating such principles into TACARE. The survey's original English design was translated to Chinese and reviewed by three Taiwanese safety professionals for the administration process.

Administration of the Instrument

The survey was administered to flight crew members of four Taiwanese air carriers: Mandarin Airlines, UNI Airlines, Far Eastern Air Transport, and China Airlines. Cooperation and endorsement of the participating air carriers' safety offices enabled survey distribution to each pilot's company mailbox. An unfortunate result of the surveys being e-mailed to each participating airlines' safety office was that control and monitoring of the total number of surveys distributed was lost.

After contacting the participating air carriers, it was determined that the four carriers had distributed the survey to all of their pilots. The survey was available to the pilots for completion for 1 week in July 2003; the completed surveys were collected by each air carrier's safety office, and returned to the researcher the same month.

RESULTS AND DISCUSSION

With an apparent 1,135 surveys distributed and a total of 208 surveys (205 usable) returned, the return rate was 18%. A discussion of the results follows.

Demographics

The participants were predominantly males younger than 45 years of age, with less than 15 years of civil aviation experience. The majority of the participants received their primary flight training in the Taiwanese military and, due to the absence of GA in Taiwan, had less than 2,000 hours of total flight time. This profile of the participants characterizes the Taiwanese aviation industry. (In Taiwan, the terms aviation and air carrier are synonymous.) The absence of GA in Taiwan has resulted in less experienced flight crew members, which could be one of the contributing factors to Taiwan's high rate of air carrier accidents.

Four Representative Opinion Items

The multiple choice opinion items of the instrument were designed to measure the participants' awareness of TACARE. The results indicate that 81% of the participants were aware of TACARE, but had not submitted reports to the program. In addition, 59% of the participants indicated that they were willing to participate in TACARE in the event of an operational deviation. The results clarify that the majority of the Taiwanese flight crew members are aware of TACARE; however, there are also numerous participants who are not willing to participate in TACARE. It is noteworthy that 37% of the participants indicated that they would not submit TACARE reports after encountering an operational deviation. The survey also revealed that 53% of participants who had previously participated in TACARE indicated that they would choose not to submit a TACARE report in the future.

The first opinion item asked the question "In the event of an operational deviation, would you submit a report to TACARE." Participants could select yes or no. The majority (60%) answered yes; with fewer (37%) answering no. It is interesting to note that 2 of the participants answered both yes and no. The results are presented in Table 1.

Table 1. Number and percent of Taiwanese pilots who would submit a report to TACARE in the event of an operational deviation, 2003

	Number	Percent
Yes	122	59.5
Yes and No	2	1.0
No	75	36.6
No Response	6	2.9
Total	205	100.0

The second opinion item asked for agreement or disagreement to the statement: "Unanimous consensus must be reached by all members of the incident report review team on event reported." Table 2 displays the results. The replies indicate that 82% of the participants agreed that it is important for the incident report review team to reach unanimous consensus prior to issuing any recommendations to the flight crews. This is a critical principle for the incident review team, since unanimous consensus would signify that all participating parties are in agreement with the issued recommendations.

The third item asked for agreement or disagreement with the statement: "A union member/pilot representative should be included as part of the incident report review team." Table 3 displays the results. More than 95% of the participants agreed that a union/pilot representative should participate in the incident reviewing process. Similar to their Western counterparts, Taiwanese flight crew members expressed the importance of being properly represented during the incident reviewing process.

Table 2. Agreement with the statement that unanimous consensus must be reached by all members of the incident report team on event reported to TACARE before issuing a recommendation to flight crew members, by Taiwanese pilots, 2003

	Frequency	Percent
Strongly Agree	51	24.9
Agree	83	40.5
Somewhat Agree	32	15.6
Somewhat Disagree	22	10.7
Disagree	13	6.3
Strongly Disagree	1	0.5
No Response	3	1.5
Total	205	100.0

Table 3. Agreement with the statement that a union member/pilot representative should be included as part of the TACRE incident report review team, by Taiwanese pilots, 2003

	Frequency	Percent
Strongly Agree	112	54.6
Agree	68	33.2
Somewhat Agree	13	6.3
Somewhat Disagree	3	1.5
Disagree	6	2.9
Strongly Disagree	1	0.5
No Response	2	1.0
Total	205	100.0

The fourth opinion item asked for agreement or disagreement with the statement: "Qualified participants of the incident reporting program should be protected from legal and airline disciplinary actions." Table 4 displays the results. The current TACARE program does not provide legal protections for the participating crewmembers. The majority (94%) of the participants agreed it is imperative that reporting flight crew members be protected when submitting an incident report. Results of this item emphasize the importance of providing protections and immunity to participants of the TACARE program.

Table 4. Agreement with the statement that qualified participants of the TACARE incident reporting program should be protected from legal and airline disciplinary actions, by Taiwanese pilots, 2003

	Frequency	Percent
Strongly Agree	105	51.2
Agree	66	32.2
Somewhat Agree	16	7.8
Somewhat Disagree	7	3.4
Disagree	2	1.0
Strongly Disagree	3	1.5
No Response	6	2.9
Total	205	100.0

The results of the survey indicate that Taiwanese flight crew members accept and agree with several ASAP principles. Results confirmed the possibility of adapting ASAP principles into the current TACARE program. It was concluded that participation in the TACARE program would increase significantly with the addition of the ASAP principles.

In summary, the survey results indicate that the majority of Taiwanese air carrier flight crew members are:

1. Aware of the TACARE system;
2. Familiar with the concepts of voluntary incident reporting programs; and
3. In agreement with several ASAP operating principles.

Overall, this is an indication that certain ASAP concepts would be well accepted regardless of cultural differences, and could be adopted into the TACARE. Indications are that TACARE is currently faced with challenges, including the low participation rates from its intended users and the lack of complete immunity protection policy. Examination of the challenges and other concerns faced by TACARE follows.

TACARE'S OPERATIONAL DIFFICULTIES

TACARE has faced several operational difficulties since its 1999 introduction. Most of these challenges have been direct results of Taiwan's unique aviation industry. Unlike the deregulated airline industry of the U.S., Taiwan's air carriers have remained highly regulated. Therefore, each carrier is assigned specific operating routes. Additionally, each Taiwanese air carrier operates specific and unique types of transports. The combination of these two factors has presented a unique challenge for TACARE management regarding confidentiality.

One of the most important advantages of a voluntary incident reporting system is the ability to provide useful incident data with specific routes and type of equipment for trend analysis. The unique regulations of Taiwan's air carrier industry make it difficult to create blinded TACARE reports. According to H.C. Wang (personal communication, August 5, 2003), manager of TACARE, significant sections of information submitted in TACARE reports are considered proprietary. For example, a blinded TACARE report would not reveal the route flown and type of aircraft used, because this information would reveal the identity of the carrier involved in the incident. Consequently, limited information for trend analysis can be obtained from the blinded TACARE reports.

The success of a voluntary incident reporting program is heavily depended on support from the air carriers. An example was the European Confidential Aviation Safety Reporting Network program (EUCARE). Established in 1992, EUCARE was the European attempt to establish a voluntary incident reporting program. However, EUCARE suffered from low participation by its intended users. This was because several European carriers already had established their own incident reporting programs. Thus, many European air carriers did not support or encourage flight crew members to participate in EUCARE. The lack of participation and support from European air carriers ultimately led to the termination of the EUCARE program (*Important final announcements*, 1999). Unfortunately, TACARE is currently encountering challenges similar to its European counterpart. According to Wang, most Taiwanese airlines do not encourage their flight crew members to participate in TACARE. And since it is not encouraged by their employer nor mandatory, it is not surprising that most flight crew members neglect to submit reports to TACARE.

The Punishment Culture

Many flight crew members who participated in the TACARE survey expressed their fear of disciplinary action by their companies as a result of submitting TACARE reports—a direct effect of the Chinese punishment culture. Unlike Western cultures where disciplinary actions are the last resource of corrective actions, in Taiwan, punishment is often the only solution to most problems regardless of the root causes. In fact, the punishment culture is not concerned with identifying the root cause of a problem, but rather utilizes forms of punishment to prevent further similar occurrences. This punishment culture is commonly practiced in the Taiwanese society, an example of which has been the Flight Operation Quality Assurance (FOQA) program.

The FOQA program was developed to assist flight operations management discover unfavorable trends in airline flight operations, and analyze such problems for countermeasures. However, following its introduction to Taiwanese air carriers, FOQA has become a primary means for fleet managers to identify and punish those flight crew members who have deviated from standard operating procedures. This punishment culture explains the hesitation among the Taiwanese flight crew members to participate in TACARE.

Repetition of Reporting Programs

A key ingredient of a successful voluntary incident reporting program is the willingness of flight crew members to submit reports after encountering operational deviations. The ASAP and ASRS programs have been successful because they offer protection for the reporting individuals; hence, both programs have experienced high participations rates.

There have been three reporting programs similar to TACARE in use by Taiwanese airlines. TACARE was viewed by many flight crew members as a repetition of the many reporting programs that have produced limited results. In the event of an operational deviation, it has been mandatory for the air carrier to submit a report for the aviation safety database of the Taiwanese Civil Aviation Administration (CAA). Although the report was mandatory, the CAA would waive certain punitive actions against reporting carriers (but not the flight crew members). The CAA's aviation database contains considerable incident data, but due to a lack of resources, the data have not been utilized for trend analysis to prevent similar occurrences. Furthermore, the CAA's database has been inaccessible in nature; consequently, air carriers and ASC personnel have not obtained data from the CAA's database. The database has become a massive storage of incident reports and, yet, has contributed little toward the goal of improved flight safety.

In addition to the CAA's mandatory incident reporting database, each Taiwanese air carrier has adopted its own version of an aviation safety reporting program. These systems are managed by the air carriers' safety offices, with individual databases similar to the CAA database. It has been mandatory for flight crew members to submit detailed incident reports to these air carrier databases. Unlike Western reporting programs, these safety reports are designed to reveal the identities of the involved flight crew members, and have often been used in combination with FOQA data by flight management personnel as evidence for disciplinary action for the flight crew members.

Taiwan's CAA has also maintained a reporting system for flight crew members to submit safety incidents on a voluntary basis. The Administrator's Mailbox has been available for all aviation personnel (flight crew members, maintenance personnel, and air traffic controllers) to report concerns regarding flight safety. Although the Administrator's Mailbox has been in existence for more than 10 years, it also suffers from a lack of participation. Furthermore, this CAA voluntary reporting system is often misused by its intended participants, with issues not related to flight safety being reported.

IMPLICATIONS FOR TACARE AND ASAP

Taiwan's TACARE is experiencing a lack of participation by its intended users, the Taiwanese air carrier flight crew members. The following implications are a product of the first investigation of Taiwanese flight crews members' use of TACARE and the flight crews members' acceptance of ASAP principles into the current TACARE.

The analysis of the survey results indicates that a significant number of TACARE participants would choose not to submit TACARE reports in the future. This was a direct result of the repetition of various incident reporting programs currently in existence within the Taiwanese air carrier industry. Furthermore, the majority of flight crew members are not confident with the current immunity policy. Thus, many Taiwanese pilots fear disciplinary actions as a result of submitting TACARE reports. This factor is a direct contributor to the lack of participation in Taiwan's TACARE.

The survey results demonstrate that Taiwanese flight crew members have no difficulties accepting certain ASAP operating principles evidenced by an overwhelming majority of participating flight crew members in agreement with the specific ASAP principles that were presented. This suggests that participation in TACARE could be improved by incorporating a number of ASAP principles.

One of the fundamental challenges to incorporating ASAP principles into TACARE is the current structure of TACARE. There are limited benefits to the Taiwanese flight crew members' participation in TACARE, because the ASC is the managing agency for TACARE. The survey participants agreed that TACARE should incorporate ASAP management principles, and function as an airline-specific program. An airline-specific voluntary incident reporting program would present a win-win situation for both airline management and flight crew members. An airline-specific incident reporting program such as ASAP would protect participants from disciplinary action; concurrently, increased participation would allow airline safety personnel to obtain a better perspective of the current and potential hazards and develop a more accurate trend analysis, thereby enhancing overall flight safety.

Economic concerns and financial support remain essential components of the decision making processes of every air carrier. In Taiwan, safety has become a lesser concern for the success of the Taiwanese carriers. Thus, it becomes questionable whether an individual air carrier would be willing to provide additional resources and funding to support a separate reporting system, especially with most Taiwanese air carriers being satisfied with their current incident reporting systems.

Another challenge to incorporating ASAP operating principles into TACARE is the absence of a culture in which individuals are presumed to be not guilty of willful infractions. A significant factor that led to the success of ASAP in the U.S. is the fundamental belief of presumed innocence and the non-punitive nature of the program. Indications are that there would be fundamental difficulties in maintaining this nature of ASAP in Taiwan. The dramatic differences in culture continue to be impediments. As previously mentioned, the Taiwanese often believe punishment is the ultimate solution to most problems. Thus, most Taiwanese air carriers select disciplinary action as the best practice to prevent reoccurrence of operational deviations. It is possible that ASAP—or other similar reporting programs—would become an effective punishment tool for Taiwanese air carriers to identify and punish the flight crew members involved in the incident. Of course, using the incident information to punish those involved is a clear deviation from ASAP's original intent, and use of the information in this way would create a negative impact on Taiwan's air carrier flight safety.

Another of the contributing elements of ASAP's success in the U.S. is the inclusion of pilot union representatives in the ERT. This practice allows pilots to be represented by their union members, and also provides additional protection for ASAP participants. The presence of a pilot representative on the ERT has increased participation in ASAP. Taiwanese flight crew members have expressed a similar interest in having a union/pilot representative be present during the incident review process. However, there are several challenges to adopting this concept into TACARE. Several Taiwanese air carriers do not allow labor unions. Consequently, Taiwanese flight crew members do not have the protection of labor unions. Pilot representatives should be part of the incident review process; however, such practice would indicate an increasing labor influence within a Taiwanese air carrier, which would be undesirable for management.

Throughout the study, fundamental differences in the utilization of voluntary incident reporting systems by Western and Chinese cultures were identified. Western nations traditionally emphasize the importance of discovering the root cause of the problem, and utilize voluntary incident reporting systems such as ASAP as a means of identifying potential dangers and safety hazards. However, in Taiwan, voluntary reporting systems are used as effective evidence gathering tools used to punish program participants. Therefore, it is hardly surprising to discover that Taiwan's TACARE is suffering from a lack of participation.

CONCLUSION

In summation, ASAP principles would be well-accepted by Taiwanese flight crew members. However, certain Chinese cultural beliefs—in combination with the current unique environment of the Taiwanese aviation industry—create a situation that is not suitable for any voluntary incident reporting program. Certain fundamental reforms are required within the Taiwanese aviation industry to properly utilize a voluntary incident reporting system such as ASAP. Unfortunately, the concept of utilizing incident data to improve flight safety is still not accepted by the mainstream Taiwanese airline managers. However, once Taiwanese aviation safety personnel understand the full potential of voluntary incident reporting systems, they will become the most effective tools to enhance flight safety in Taiwan.

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CONFIDENCE IN AIRLINE PERFORMANCE IN DIFFICULT MARKET CONDITIONS: AN ANALYSIS OF JETBLUE'S FINANCIAL MARKET RESULTS

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ABSTRACT

This paper examines the stock market's reaction to JetBlue's Initial Public Offering (IPO) and subsequent price movements of the stock. In particular, we examine whether the euphoria surrounding JetBlue's IPO carried over to other firms in the sector by testing whether the shares of JetBlue's competitors showed a significant price reaction to JetBlue's IPO. JetBlue's IPO took place just a few months following September 11, 2001. These events resulted in dramatic changes in the airline industry and had significant implications on the economic gains of airlines. We examine JetBlue's accounting and stock performance and compare it to the relative performance of Southwest Airlines (SWA), a representative of the low-cost carrier group. In addition, we compare both JetBlue's and SWA's financial condition and the relative performance of their stock to two mainline U.S. carriers, Continental and Northwest, representatives of the conventional-cost carrier group. We analyze whether there are any performance differences among the low-cost carriers and between low-cost carriers and conventional-cost carriers. In particular, we examine whether low-cost carriers were able to sustain the economic impacts of 9/11 better than the conventional-cost carriers.

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"Keep an eye on JetBlue. That could prove to be a successful operation"
Herb Kelleher, Co-founder, Southwest Airlines (Top Entrepreneurs, 2001, p. 84)

INTRODUCTION

JetBlue Airways was one of the best-funded start-up airlines in U.S. aviation history. Its initial capitalization was $130 million. The airline was founded in early 1999 by David Neelman, who is currently its Chief Executive Officer. Before JetBlue David Neelman founded Morris Air and after selling Morris Air to Southwest Airlines (SWA) served as an executive vice president of SWA. He also worked as a consultant for West Jet Airlines.

JetBlue started operations in February 2000 and went public in April 2002, in what was described as one of the most successful initial public offerings (IPO) of the year. Following a very successful road show for its IPO, JetBlue, in connection with its lead underwriters Morgan Stanley and Merrill Lynch, filed several amendments to its initial S-1 filing with the Securities and Exchange Commission (SEC), in which it revised its offering price upward from an initial price range of $22 - $24 to $27 per share. JetBlue sold 5.87 million shares at this price, raising more than $158 million for the firm. Despite the upward revisions in the firm's offering price, JetBlue's stock soared another 67 percent and closed at $45 on its first day of trading (Boorstin, 2002).

During 2001, JetBlue's second year of operation, and arguably one of the worst in U.S. aviation history, the airline turned profitable, earning $38.5 million on revenues of $320 million. This fact alone may explain why JetBlue's shares were in very high demand. Only two other airlines in the U.S. were also profitable in 2001: SWA and AirTran. Although experiencing a stock price decline since its highs in June 2002, JetBlue has stood up well to its expectations, increasing sales in 2002 to $635 million with a year-end profit of $49 million.

This paper examines the stock market's reaction to JetBlue's IPO and subsequent price movements of the stock through the present. In particular, we look at whether the euphoria surrounding JetBlue's IPO carried over to other firms in the sector by examining whether the shares of JetBlue's competitors showed a significant price reaction to JetBlue's successful IPO. We focus on the relative performance of the stock and compare it with the stock performance of a similarly successful low-cost carrier, SWA, and two mainline full-service U.S. carriers, Continental and Northwest. These airlines are used as comparison baselines. The mainline full-service carriers were picked randomly and based on the fact that, to date, neither has filed for bankruptcy protection as a result of the systemic shocks of the events of September 11, 2001 (9/11).

We find JetBlue's accounting and stock performance to be significantly better than that of its mainline conventional-cost rivals, Continental and Northwest, but in similar lines with its low-cost rival SWA. Based on this finding, we assert that there is something unique to the low-cost model, which both SWA and JetBlue follow, that sets them apart from their conventional-cost competitors and renders them more successful in difficult market conditions. We do not advocate that the low-cost model is monolithic. In many ways JetBlue resembles a younger, smaller version of SWA (Boorstin, 2002). Like SWA, JetBlue flies busy routes between secondary airports, has a low-cost structure, and emphasizes customer service. But while SWA usually sticks to a single region, JetBlue flies cross-country. And while SWA is based at Dallas' smaller airport, Love Field, JetBlue is based at New York's Kennedy International Airport (JFK). Furthermore, SWA can be characterized as a low-frills airline, whereas JetBlue is a lifestyle seller with more finesse, even though both are low-fare.

Our argument is that the low-cost model, in its generic manifestation, can be differentiated from the conventional-cost model along three dimensions. These dimensions, coupled with some unique operational features that low-cost airlines have (which will be identified in the next paragraph), help explain, theoretically, why low-cost carriers outperform their conventional-cost rivals. These dimensions are: (a) adopting a viable strategic position, (b) leveraging organizational capabilities, and (c) re-conceiving the value equation (Lawton, 2002).

Low-cost airlines establish a viable strategic position in the market by finding an appropriate strategy that acts as a mediating force between them and the environment in which they operate. For example, both SWA and JetBlue serve price- and convenience-sensitive passengers only. Low-cost airlines, once they establish their position, move toward securing their competitive advantage by capitalizing on capabilities that cannot be used by rivals. These capabilities are quality in customer service, operational efficiency, innovation, and responsiveness to customers.

Zorn (2001) advances the argument that low-cost carriers are more resilient than conventional-cost carriers in times of economic downturn. Our analysis focusing on JetBlue's performance validates this point, and Zorn's analysis helps us demonstrate it theoretically. Zorn cites several reasons for the resilience of low-cost carriers in times of recession: first, lower overall and more variable cost structures; second, lower breakeven load factors; and, third, business and leisure traveler migration from conventional-cost airlines to low-cost airlines. Our financial analysis substantiates this point to its fullest. We found that markets value low-cost airline stocks (focusing on JetBlue and SWA) as growth stocks, whereas conventional-cost airline stocks are treated as cyclical. Even though affected, low-cost carriers emerged from 9/11 in a stronger market position than their full-fare rivals.

What interests us from an academic point of view is the relative confidence of the public in JetBlue's stock (as measured by price movements) right after the IPO, as compared to both SWA and the mainline carriers. We build a model, test several hypotheses on why there was stock performance divergence, and explain these differences based on the data, controlling for extraneous variables.

The paper is organized as follows. The first section briefly describes the series of events surrounding our period of analysis and sets the stage for our analysis. The second section discusses JetBlue's strategy and the state of the airline industry in the U.S. during the period of our analysis. The third section describes the data. The fourth section explains the methodology used to test several hypotheses concerning the performance of JetBlue's stock. The results are presented in the fifth section and the findings are summarized in the final section.

JETBLUE AND THE STATE OF THE AIRLINE INDUSTRY

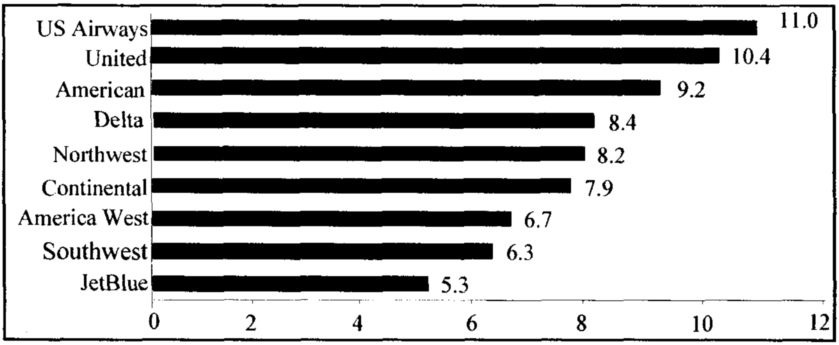
JetBlue's strategy is to combine common sense with strategic and operational innovation through the use of the most appropriate technology to "bring humanity back to air travel" (Gittell & O'Reilly, 2001, p. 2). To accomplish this, JetBlue aimed to be one of the first completely paperless airlines, deploying information technology for every single aspect of its operations from flight operations and maintenance to ticketing and reservations. The two pillars of JetBlue's strategy are efficiency and service. According to its founder, David Neelman, "We like to think of ourselves as customer advocates. We believe that all travelers should have access to high quality airline service at affordable fares" (Gittell & O'Reilly, 2001, p. 2). JetBlue's hub city, New York City, represents a very large population center at the heart of several underserved markets. More specifically, New York City lacked the service by a low-cost carrier; therefore, fares were, on average, quite high and its true traffic potential unrealized. JetBlue chose JFK, a slot controlled and heavily used airport, as its hub, which was quite an unconventional choice for a low-cost, start-up carrier that would normally opt for a smaller airport as its basis of operations. When JetBlue moved to JFK, the slot controls were only in effect from 3:00 p.m. to 8:00 p.m., while the rest of the day JFK was underutilized. Furthermore, more terminal space was opening up at the airport due to TWA's reduction of operations at JFK. Thus, JetBlue was able to secure slots, through political concessions, without going through the process of purchasing them from one of the airlines already holding these slots.

JetBlue operates a single-type aircraft, the A320 series made by Airbus Industries. Through the use of a single-type aircraft, JetBlue realizes operational savings in the areas of maintenance and crew training. Every JetBlue mechanic can work on any aircraft and every pilot can fly any of

JetBlue's planes. JetBlue's operational strategy includes quick aircraft turnarounds, which help in improving operational performance and, thus, efficiency by maximizing aircraft utilization. JetBlue keeps its planes in the air longer than any other airline, more than 12 hours a day. Only SWA comes close to this, with about 11 hours of block time.

JetBlue's cost per available seat mile in 2002, seen on Figure 1, was 5.3 cents. This was the lowest in the U.S. airline industry. For example, the cost for US Airways was more than double (11 cents), United 10.4 cents, and American 9.2 cents. These three topped the chart and two of them (US Airways and United) filed for bankruptcy protection under Chapter 11 in the months following 9/11. The cost for Northwest was 8.2 cents and Continental 7.9 cents, the two conventional-cost airlines that we used for the baseline comparison. SWA had the second lowest cost per available seat mile to JetBlue with 6.3 cents.

Figure 1. Cost per available seat miles, in cents: U.S. major carriers comparison, 2002



Source: Tully, Shawn (2003). The Airlines' new deal: It's not enough. *Fortune Magazine*, April 28, p. 79 -81.

JetBlue has built its corporate culture, discussed on its Web site at http://www.jetblue.com/workhere/culture.html, around five core values: Safety, Caring, Integrity, Fun, and Passion. The airline is non-unionized. This is quite an unconventional practice in the U.S. airline industry, 80 percent of which is unionized. JetBlue follows a customized human resource management approach that tailors jobs, pay, and benefit packages to the different needs of distinct employee groups rather than the more conventional, universal type human resource management system.

DATA

We use accounting data from January 1996 to March 2003. We collected this data from quarterly 10Q filings[1], which are available online through the SEC's "Edgar Online" database (http://www.edgar-online.com). For our analysis of relative stock performances pre- and post-JetBlue's IPO, we use daily price data (adjusted for dividends and stock splits) from January 2000 to April 2003, which we retrieved from the Center for Research in Security Prices (CRSP) database from the University of Chicago Graduate School of Business (http://gsbwww.uchicago.edu/research/crsp). To measure market performance during our sample period, we use the CRSP value-weighted market index.

Finally, we use weekly 3-month Treasury Security indexes as calculated by the Treasury Department and reported by the Federal Reserve in publication H.15 as a proxy for the risk-free interest rate during our sample period (http://www.federalreserve.gov/releases/h15). Since August 21, 2000, the Federal Reserve's Publication H.15 no longer reports yield data for the 13-week (3-month) U.S. Treasury Bill auction average. Starting from this date, we use Treasury security yields adjusted to a constant maturity of 3 months, as provided by the Treasury's Public Debt Web site (http://www.publicdebt.treas.gov).

METHODOLOGY

Financial markets bring together potential investors who vote every day on the future profitability of the firm and the relative merits of managers' strategic decisions. Simply put, if investors think that corporate decisions will lead to increases in long-run profitability, news of events such as a takeover will cause a firm's stock price to rise. Conversely, news that investors believe will lower future profits will result in a fall in a firm's equity value.

The finance literature refers to the idea that news is quickly impounded in security market prices as the *efficient market hypothesis*, first described by Fama, Fisher, and Jensen (1969). The assumption that markets are efficient implies that security prices reflect all relevant information known to investors and thus provide us with the best estimate of a firm's future profitability. There is significant empirical support of the efficient market

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[1] 10Q filings are quarterly company reports filed with the Securities and Exchange Commission. 10Q reports provide detailed information on a firm's quarterly earnings results and must be sent to the Securities and Exchange Commission within 45 days of the end of the quarter.

hypothesis including the Carter and Simpkins' (2002) study of airline stocks following 9/11.

If we assume that markets are efficient, and therefore set rational prices, we can measure whether the corporate strategy of such low-cost carriers as JetBlue and SWA, post-9/11, was in the best interest of shareholders by examining the firms' profitability and stock price performance in the months after 9/11 and compare them to the performance of other airlines that follow a conventional-cost business model (Continental, Northwest). Our methodology follows the event study procedure described in Brown and Warner (1985), Peterson (1989), and Schweitzer (1989). Event study methodology measures the abnormal return of the stock, the difference between the *actual return* and the *expected return*, around the time of the event. If an announcement such as news of increased profits is taken as good news, abnormal returns will be positive, signaling the market's belief that firm value has increased. A negative abnormal return is evidence of bad news, indicating that the market believes the event will decrease the firm's future profitability.

To estimate the abnormal return of a stock on day t, we subtract the expected return on the stock from its actual return on that day:

$$AR_t = R_t - E(R_t) \qquad (1)$$

Where:

AR_t is the abnormal stock return;
R_t is the actual stock return; and
$E(R_t)$ is the expected stock return, all on day t.

In turn, we assume that the return of a stock is conditional on the return of the market and model $E(R_t)$ as:

$$E(R_t) = R_{f,t} + \beta_t [E(R_{m,t}) - R_{f,t}] \qquad (2)$$

Where:

$E(Rm,t)$ is the expected return of the market on day t;
Rf,t represents the risk-free rate as measured by the return on 90-day U.S. Treasury Bills on day t; and
t is the estimated slope coefficient from a linear regression of the stock's past returns on the returns of the market.

Equation 2 is also called the capital asset pricing model (CAPM) and is based on Sharpe (1964) and Lintner (1965). In this paper, we estimate the CAPM using both 60 and 360 daily returns that precede our event window. We employ a linear market model that illustrates the relationship between

JetBlue's stock return and the market (as proxied by the CRSP value-weighted market index) during a normal period.

We calculate daily abnormal returns for JetBlue and the other three airlines following JetBlue's IPO on April 12, 2002. In addition, we measure cumulative abnormal returns, $CAR_{t,t+n}$, the sum of abnormal returns over a window of *n* days:

$$CAR_{t,t+n} = \sum_{i=t}^{t+n} AR_i \tag{3}$$

Cumulative abnormal returns enable us to measure the market's reaction to the performance of the airline in a time frame that encompasses the entire period from the event under study to the present.

Earlier industry research has largely focused on airline stock returns following a plane crash. Davidson, Chandy, and Cross (1987) find statistically significant negative returns for airlines on the day of the crash. This appears to be a short-term effect, however, and is reversed on the days following the event. Chance and Ferris (1987) examined 46 plane crashes, and discovered that in 29 cases the carrier had a significant negative return. A crash does not appear to have an effect beyond the initial reaction, nor does it affect the stock price of the airline's competitors. Chance and Ferris also found a negative correlation between the airline's abnormal return and the number of fatalities in the crash.

More recently, Carter and Simpkins (2002) investigated the stock market's reaction to the tragedies of 9/11. They noted the potential psychological effects of the attack and tested whether financial markets reacted rationally to news of the event. Carter and Simpkins found that despite the psychological horrors the market was able to discern among airlines based on firm characteristics, including the ability to cover short-term obligations. Their results support rational pricing and have important implications for our work, which seeks to examine JetBlue's financial performance and stock performance in the aftermath of 9/11.

To serve as a further control in estimating the market's reaction to JetBlue's performance post 9/11, the analysis compares the abnormal returns of JetBlue's stock to the abnormal returns of SWA, on one hand, and Northwest and Continental, on the other hand. We choose SWA because it uses a low-cost business model similar to that of JetBlue, and Continental and Northwest because they use a conventional-cost business model and have done so quite successfully. These firms should provide a good benchmark for examining the industry's reaction to JetBlue's successful IPO and help us answer the question of whether JetBlue's IPO was able to instill new hope in an industry sector that was otherwise devastated by the events of 9/11. We do not consider United Airlines and US Airways since they weathered financial difficulties and eventually filed for bankruptcy protection under Chapter 11 during our sample period. American Airlines, too, came very close to filing for Chapter 11.

Adjusting for Risk: The use of Beta as a Measure of Systematic Risk

In considering risk changes, we calculate beta, the part of a firm's risk that is related to changes in the market. Beta is a measure of systematic risk, the risk that investors must be compensated for, and, thus, is related to a firm's cost of capital. If 9/11 led to the airline industry being a more risky business, we would expect the betas of airline stocks to increase after 9/11. The calculation of each airline's $beta_i$ can be found from the following formula:

$$\beta_i = cov(r_i, r_m) / \sigma_m^2 \qquad (4)$$

Where:

$cov(r_i, r_m)$ is the covariance between firm i's returns and returns on the market; and

σ_m^2 is the variance of market returns.

Cornell, Hirshleifer, and James (1997) reviewed several practical issues in beta selection and the application of regression-based asset-pricing models to estimating equity cost of capital. They provide assistance for resolving many of the conventional problems with beta estimation, such as selection of the risk-free rate, the time period for estimation, and the inclusion or exclusion of dividends.

Corgel and Djoganopoulos (2000) perform direct statistical comparisons of beta estimates calculated by large financial data vendors such as Bloomberg, Compustat, Dow Jones, and Ibbotson. They find that the different procedures used by these commercial services produce the same results when simple tests of differences of means are used to evaluate them. They observe that most data vendors use ordinary least squares regressions of the returns of the firm against those of the market, where the security's return serves as the dependent variable, and the independent variable is a user-selected index. They point out, however, that users of financial software packages typically have some flexibility and can select the time period for estimation, the market index against which they want to measure returns, the data frequency (daily, weekly, monthly, etc.), and whether they want to include dividends or not.

Because the finance literature is divided on the issue whether short-term or long-term estimates should be used in CAPM estimation, we use a rolling window of both 60 and 360 calendar day returns to calculate covariances and variances. Although there is no consensus on what time period should be used to estimate beta, most authors and financial data vendors use long-term betas calculated over periods of three and more years. However, given the limited data availability for young firms such as JetBlue and the rapidly changing environment for the airline industry, we found short-term estimates to be more appropriate.

Expected Market Returns: Historical versus Prospective Estimates

Before we can address the question of how we estimate expected market returns, we have to define what we mean by market. In his famous critique of CAPM testing, Richard Roll (1977) indicates that the market portfolio to be used in CAPM estimation should contain all financial and non-financial assets available to investors and states that an accurate test of the CAPM will never be possible because of this requirement.

Despite Roll's criticism, most authors and financial data services use only U.S. common stocks to proxy for the market portfolio and rely heavily on the Standard and Poor's 500 (S&P 500) index to represent the market. Because Taylor and Paolone (1997) and Corgel and Djoganopoulos (2000) observe that the power of the regressions producing the betas improve noticeably when a broader market index than the S&P 500 is used, we decided to use the CRSP value-weighted market index for calculating both our beta estimates and market returns. The CRSP value weights index covers more than 10,000 publicly traded U.S. firms, and is extensively used in the financial literature.

Furthermore, when developing an estimate of the expected market return $E(R_m)$, one has to decide whether to use historical data, assuming that past performance is the best predictor of future performance, or make an attempt to forecast a return for the market, which would require an accurate estimate of future dividend growth. As with most other studies in this field, we do not consider ourselves wise enough to forecast future market returns, but rather we rely on past returns as an estimate of future returns. Another question we had to address in our estimation was which time period to use to calculate past market returns. Given the fact that both the events of 9/11 and JetBlue's IPO occurred relatively recently and that our return data after both events is limited, we decided to use the geometric average of market returns during the past 360 calendar days as an estimate of future market returns. To test the robustness of our results, we also calculated 60-calendar-day returns, but arrived at the same conclusions as we did with our long-term estimates.

In a long-term study of historical market risk premiums, Ibbotson and Sinquefield (1976) find that the average risk premium for the S&P 500 index during the period from 1929 to 1976 was about 8.4 percent. During our sample period from January 1996 to April 2003, we find a similar market risk premium of 8.15 percent. A closer examination reveals, however, that the market risk premium pre-9/11 was 14.9 percent, influenced in part by the booming economy during the 1990s and the 1999/2000 stock market bubble, and that it dropped to -19.4 percent after 9/11.

RESULTS

Accounting Performance

The first part of our analysis focuses on the relative performance of JetBlue and its competitors from an accounting standpoint, by comparing various accounting measures and financial ratios for the four firms over time. An analysis of the stock performance of the four airlines follows in the next section.

Table 1. Selected accounting data and financial ratios for selected airlines, 2000-2003

Time Period	2000	2001	2002	2003-Q1
Panel A: JetBlue				
Total Revenue ($M)	104.6	320.4	635.2	217.1
Net Income ($M)	(21.3)	38.5	54.9	17.4
Current Ratio	0.7	0.7	1.0	1.0
Quick Ratio	0.6	0.7	1.0	1.0
Return on Assets (ROA)	-6.2%	5.7%	4.0%	4.8% *
Return on Equity (ROE)	n.m.	n.m.	13.2%	16.0% *
Profit Margin	n.m.	n.m.	8.6%	8.0%
Asset Turnover Ratio	0.3	0.5	0.5	0.7 *
Accounts Receivable Turnover Ratio	4.8	15.4	43.0	47.3 *
Interest Coverage Ratio	-6.4	7.9	5.5	5.9
Panel B: Southwest Airlines				
Total Revenue ($M)	5,649.6	5,555.2	5,521.8	1,351.0
Net Income ($M)	603.1	511.1	241.0	24.0
Current Ratio	0.6	1.1	1.6	1.5
Quick Ratio	0.6	1.1	1.4	1.4
Return on Assets (ROA)	9.0%	5.7%	2.7%	1.2% *
Return on Equity (ROE)	17.5%	12.7%	5.4%	2.0% *
Profit Margin	10.7%	9.2%	4.4%	1.8%
Asset Turnover Ratio	0.8	0.6	0.6	0.5 *
Accounts Receivable Turnover Ratio	34.0	47.2	31.7	37.0 *
Interest Coverage Ratio	15.6	12.9	5.4	3.1

Table 1. Selected accounting data and financial ratios for selected airlines, 2000-2003 (continued)

Time Period	2000	2001	2002	2003-Q1
Panel C: Continental Airlines				
Total Revenue ($M)	9,899.0	8,969.0	8,402.0	n/a
Net Income ($M)	342.0	(95.0)	(441.0)	n/a
Current Ratio	0.8	0.7	0.8	n/a
Quick Ratio	0.7	0.6	0.7	n/a
Return on Assets (ROA)	3.7%	-1.0%	-4.1%	n/a
Return on Equity (ROE)	29.5%	-8.2%	-57.5%	n/a
Profit Margin	3.5%	-1.1%	-5.2%	n/a
Asset Turnover Ratio	1.1	0.9	0.8	n/a
Accounts Receivable Turnover Ratio	15.7	15.0	15.5	n/a
Interest Coverage Ratio	3.3	0.6	-0.9	n/a
Panel D: Northwest Airlines				
Total Revenue ($M)	11,415.0	9,905.0	9,489.0	n/a
Net Income ($M)	256.0	(423.0)	(798.0)	n/a
Current Ratio	0.6	0.9	0.8	n/a
Quick Ratio	0.5	0.8	0.8	n/a
Return on Assets (ROA)	2.4%	-3.3%	-6.0%	n/a
Return on Equity (ROE)	110.8%	n.m.	n.m.	n/a
Profit Margin	2.2%	n.m.	n.m.	n/a
Asset Turnover Ratio	1.0	0.8	0.7	n/a
Accounts Receivable Turnover Ratio	17.8	15.6	12.4	n/a
Interest Coverage Ratio	2.2	-1.0	-2.0	n/a

n.m. = not meaningful
* = annualized
Note: We used income statements from quarterly company reports, i.e. 10Q filings with the Securities and Exchange Commission which are available online through the SEC's "Edgar Online" database (http://www.edgar-online.com), to calculate all ratios. First quarter-2003 data was not yet available for Continental and Northwest at the time of our analysis. Whenever meaningful for comparison purposes, we annualized (i.e., projected) the first-quarter-2003 ratios for JetBlue and Southwest for the entire year.

The accounting figures and financial ratios in Table 1 are based on quarterly 10-Q filings from January 2000 to the present. As we can see, JetBlue managed to grow revenues and net income consistently during our sample period despite 9/11. SWA managed to remain profitable on slightly declining sales, while Continental and Northwest registered significant losses on falling revenues.

JetBlue's liquidity ratios (current ratio and quick ratio) are mostly below those of SWA, but exceed those of Continental and Northwest. The profitability ratios [return on assets (ROA), return on equity (ROE) and profit margin] of JetBlue are comparatively healthy after 9/11, although they remain below the profitability levels that SWA showed in 2000 before 9/11. SWA experienced a considerable decline in its profitability after 9/11, while Continental and Northwest show very strong signs of weakening.

JetBlue's activity ratios (asset turnover and accounts receivable turnover) increased significantly during our sample period, while they deteriorated somewhat for the other three airlines. JetBlue remains well able to cover its interest expenses, as is reflected by its interest coverage ratio that remains well above 5 after 9/11. While SWA's interest coverage ratio drops significantly during our sample period (from 15.6 in 2000 to 5.4 in 2002), the financial impact of 9/11 on Continental and Northwest's ability to make their interest payments is tremendous: both airlines have negative ratios in 2002, indicating that both airlines have significant difficulties making their interest payments.

Stock Performance

In order to examine whether investors put more confidence into low-cost carriers such as SWA than into airlines that follow a conventional-cost model such as Continental or Northwest, we examine the stock price performance of the three airlines in the aftermath of 9/11. In particular, we examine how the industry reacted to JetBlue's highly successful IPO on April 12, 2002, in which JetBlue's stock soared about 67 percent during its first day of trading in an otherwise uneventful IPO year. Table 2 presents quarterly and yearly returns for the four airlines and the market as proxied by the CRSP value weighted market index.

The data clearly show the impact of 9/11 on the airline industry and the market. We observe a highly negative return for the airlines and the market index during the third quarter of 2001, followed by six quarters of high volatility when compared to the pre-9/11 period. Continental was hardest hit during the third quarter of 2001 and most of 2002, while SWA underperformed the market to a much lesser extent.

Since the returns in Table 2 are not adjusted for risk, we cannot yet draw any conclusions about the significance of these performance differences. To measure differences in risk levels between the airlines and examine how those risk levels changed after 9/11, we calculate beta coefficients for the airlines pre-9/11 and post-9/11. The resulting beta estimates are presented in Table 3.

Panel A presents our beta estimates for two subperiods: (1) from January 1, 2000, to September 10, 2001 (pre 9/11); and (2) from the resumption of trading on September 17, 2001, to March 31, 2003 (post 9/11). For JetBlue, we started our estimation from the closing price on its first day of trading on April 12, 2002. In Panel B, we report test results for the equality of means and medians across groups: p-values are reported for the significance of difference in means and Mann-Whitney p-values are reported for Mann-Whitney tests for the significance of difference in medians. These tests are based on 60-day trailing betas calculated for each firm. Although not reported here, we also calculated betas using longer estimation periods. We observe similar, highly significant increases in systematic risk for our long-term estimates.

Table 2. Quarterly and yearly return data, for selected airlines, 2000-2003

Quarter	JetBlue *	Southwest	Continental	Northwest	Market Index **
2000-Q1	n/a	29.13%	-7.89%	1.66%	2.65%
2000-Q2	n/a	-8.97%	15.02%	34.57%	-3.17%
2000-Q3	n/a	28.04%	-3.36%	-19.32%	-0.88%
2000-Q4	n/a	38.34%	13.62%	22.64%	-8.42%
2000 Total	n/a	20.12%	3.86%	7.87%	-2.54%
2001-Q1	n/a	-20.58%	-19.81%	-24.90%	-10.81%
2001-Q2	n/a	4.18%	18.96%	11.63%	5.36%
2001-Q3	n/a	-19.73%	-69.54%	-54.81%	-14.49%
2001-Q4	n/a	24.58%	74.73%	37.60%	9.43%
2001 Total	n/a	-4.63%	-15.59%	-15.03%	-3.16%
2002-Q1	n/a	4.72%	8.05%	21.46%	0.48%
2002-Q2	n/a	-16.46%	-44.28%	-36.76%	-13.29%
2002-Q3	-11.46%	-19.14%	-65.84%	-44.61%	-16.98%
2002-Q4	0.41%	6.44%	34.51%	9.88%	8.41%
2002 Total	-5.71%	-6.85%	-27.48%	-17.31%	-5.90%
2003-Q1	2.63%	3.38%	-29.38%	-5.99%	-3.57%

JetBlue went public on April 12, 2002. Thus, quarterly return data is not available until the third quarter (Q3) of 2002.

** Quarterly and yearly return data on the Center for Research in Security Prices (CRSP) value-weighted market index. Calculations are performed using daily closing price data obtained from the CRSP from the University of Chicago Graduate School of Business database (http://gsbwww.uchicago.edu/research/crsp). All returns are adjusted for dividends and stock splits.

Not surprisingly, we find that the beta coefficients of SWA, Continental, and Northwest increased considerably after 9/11. We tested whether the increase was significant using a standard t-test for differences in means and a Mann-Whitney test for the significance of differences in medians. Although the beta of SWA increased less than that of Continental and Northwest, we find that all increases are significant at the one percent confidence level. JetBlue's beta, calculated from price data available after its IPO, is only 0.72, well below the betas of SWA (1.14), Continental (2.19) and Northwest (1.71).

To calculate how the returns compare between the airlines after adjusting for risk, we employed event study methodology and calculated the risk-adjusted cumulative abnormal returns for each airline before and after JetBlue's IPO in a CAPM framework. Table 4 provides an overview of the data that were used to calculate expected returns. We used 90-day U.S. Treasury Bill rates as a proxy for the risk-free rate and historical market returns based on 60 and 360 calendar days to forecast expected market returns. The last row of Table 4 provides the standard deviation of our estimates, indicating that the short-term estimates are significantly more volatile than long-term historical returns.

Table 3. Differences in risk levels between selected airlines, before and after September 11, 2001

	JetBlue	Southwest	Continental	Northwest
Panel A: Estimated Beta Coefficients				
Pre-9/11	n/a	0.77	0.73	1.01
Post-9/11	0.72	1.14	2.19	1.71
Panel B: Tests for Equality Across Groups				
p-value	n/a	0.001 *	0.000 *	0.000 *
MW p-value	n/a	0.002 *	0.000 *	0.000 *

* Significant at the one percent confidence level

Note: We estimate beta coefficients for the four airlines in our sample as $\beta_i = cov(r_i, r_m) / \sigma_m^2$, where $cov(r_i, r_m)$ is the covariance between the returns of firm i and the returns on the market, and σ_m^2 is the variance of market returns. We use daily returns based on adjusted price data of the Center for Research in Security Prices (CRSP) value-weighted market index to proxy for market returns and price data for individual firms that has been adjusted for dividends and stock splits (http://gsbwww.uchicago.edu/research/crsp).

We base our calculations on weekly 3-month Treasury Security indexes as calculated by the Treasury Department and reported by the Federal Reserve (http://www.federalreserve.gov/releases/h15). Since August 21, 2000, the Federal Reserve's Publication H.15 no longer reports yield data for the 13-week (3-month) U.S. Treasury Bills' auction average. Starting from this date, we use Treasury security yields adjusted to a constant maturity of 3 months, as provided by the Treasury's Public Debt Web site (http://www.publicdebt.treas.gov). In our later estimations, we calculate historical market returns as the geometric average of daily market returns during the previous 60 (360) calendar days. These returns are used as a forecast of the expected market return in our CAPM estimation. All returns below are aggregated by quarter and are not those actually used in our estimation. We also report the standard deviation for each column. In the case of Treasury Bills, the standard deviation is based on weekly data; for all other series we report the standard deviation for daily returns.

Table 4. Return estimates used in the capital asset pricing model, by quarter, 2000-2003

Quarter	Average 90-Day Treasury-Bill Rate	Market Return During Previous 60 Days	Market Return During Previous 12 Months
2000-Q1	5.72%	7.99%	14.42%
2000-Q2	5.68%	24.26%	13.07%
2000-Q3	6.21%	12.46%	10.81%
2000-Q4	5.84%	-21.81%	4.65%
2000 Average	5.86%	5.72%	10.74%
2001-Q1	4.32%	-14.21%	-6.50%
2001-Q2	3.55%	4.21%	-14.77%
2001-Q3	2.39%	-23.29%	-17.73%
2001-Q4	1.73%	-8.01%	-21.42%
2001 Average	3.00%	-10.32%	-15.10%
2002-Q1	1.82%	13.03%	-12.72%
2002-Q2	1.71%	-12.87%	-9.68%
2002-Q3	1.65%	-45.61%	-20.45%
2002-Q4	1.18%	22.12%	-17.66%
2002 Average	1.59%	-5.83%	-15.13%
2003-Q1	1.17%	-19.63%	-22.25%
St. Dev.	1.56%	45.80%	21.20%

Note: This table presents quarterly summary statistics for the variables used in our estimation of the capital asset pricing model.

Table 5 presents non-risk-adjusted returns of the airlines for various time periods after 9/11 and JetBlue's IPO. We observe that all airlines were negatively impacted by the events of 9/11, with Continental performing the worst, losing over 49 percent on the first trading day following 9/11 and over 89 percent within 18 months of 9/11. In comparison, SWA lost only 24 percent on the first trading day after 9/11 and about 27 percent within 18 months. All airlines show a medium-term recovery three to six months after 9/11, with SWA actually registering a 16 percent gain during that period.

When examining the stock market's reaction to JetBlue's successful IPO, we find that all airlines showed sizable gains on JetBlue's IPO date. Within one year of its IPO, JetBlue held on to most of its first-day gains and dropped only 2.9 percent from its closing price on April 12, 2002. All other airlines performed considerably poorer, with Continental still being the hardest hit. Thus, while creating some short-term euphoria for the airline industry, JetBlue's IPO does not appear to have taken investors' eyes off the long-term effects of 9/11 that continued to erode investor confidence in the airline industry following JetBlue's IPO.

Table 5. Non-risk-adjusted returns following JetBlue's initial public offering, April 12, 2002 – April 12, 2003

Time Elapsed	JetBlue	Southwest	Continental	Northwest	Market
1 Day	66.7% *	5.0%	5.9%	4.4%	0.7%
2 Weeks	-0.3%	0.3%	-3.8%	2.1%	-1.0%
1 Month	4.9%	-8.4%	-24.0%	-16.1%	-4.4%
2 Months	8.0%	-7.0%	-29.8%	-19.8%	-7.8%
3 Months	-6.3%	-26.1%	-55.9%	-47.5%	-15.7%
6 Months	-20.7%	-33.4%	-84.3%	-69.5%	-26.7%
1 Year	-2.9%	-19.1%	-77.8%	-64.7%	-18.9%

JetBlue's 66.8% return on its first day of trading represents its Initial Public Offering (IPO) underpricing level, that it, it is measured relative to the IPO offering price. The long-term (i.e., 2 weeks to 1 year) return calculations for JetBlue do not include this underpricing but are calculated relative to JetBlue's closing price on its first day of trading (April 12, 2002). The returns are adjusted for stock splits and dividends, but not for risk.

Table 6. Risk-adjusted returns using short term estimates, following JetBlue's initial public offering, April 12, 2001, to April 12, 2002

Time Elapsed	JetBlue	Southwest	Continental	Northwest
2 Weeks	n/a *	-4.65%	-8.88%	-0.33%
1 Month	n/a *	-8.19%	-23.73%	-12.26%
2 Months	n/a *	-12.79%	-46.44%	-28.44%
3 Months	-14.41%	-29.90%	-86.83%	-63.79%
6 Months	-36.85%	-25.16%	-168.00% **	-105.09% **
1 Year	6.70%	-0.51%	-96.89%	-62.44%

The risk-adjusted short-term returns cannot be calculated for JetBlue because we require 60 days of past performance to estimate JetBlue's beta.

** Returns of less than -100% appear nonsensical at first, but may occur in a risk-adjusted cumulative return context.

Note: This table presents risk-adjusted cumulative abnormal returns during various time periods following JetBlue's Initial Public Offering (IPO) on April 12, 2002. We calculate daily abnormal returns as the difference between actual returns observed on each trading day minus expected returns based on the capital asset pricing model (CAPM). The results in this table represent a *short-term* approach to estimating the variables for the CAPM: we use *60-calender-day* trailing betas for each firm and estimate market risk premiums by using *60-calender-day* historical returns on the Center for Research on Security Prices value-weighted market index minus interpolated average yields on 90-day Treasury Bills during each week.

Table 6 presents risk-adjusted returns following 9/11 using 60-day trailing betas and market risk premiums estimated using 60-day historical returns. Although negative in the short run, we find that the risk-adjusted cumulative abnormal returns (CARs) for SWA are positive in the medium and long run (2 to 18 months after 9/11). Although Continental and Northwest show some positive CARs in the medium term (3 to 6 months after 9/11), they become negative in the long run. Following JetBlue's IPO, we find that JetBlue and SWA again outperformed Continental and Northwest, with JetBlue actually having positive CARs within one year of its IPO.

Table 7 presents a long-term approach for estimating the inputs in our CAPM model. Here, we calculate risk-adjusted returns by using 360-day trailing betas and market risk premiums based on 360-day historical returns. The results are similar to those presented in Table 6. SWA outperforms Continental and Northwest on a risk-adjusted basis after 9/11 and after JetBlue's IPO.

Table 7. Risk-adjusted returns using long-term estimates, following JetBlue's initial public offering, April 12, 2001, to April 12, 2002

Time Elapsed	JetBlue	Southwest	Continental	Northwest
2 Weeks	n/a *	-5.06%	-9.51%	-1.48%
1 Month	n/a *	-7.94%	-23.35%	-12.47%
2 Months	n/a *	-12.27%	-45.28%	-28.08%
3 Months	n/a *	-30.59%	-86.87%	-64.54%
6 Months	n/a *	-32.58%	-175.21% **	-113.25% **
1 Year	n/a *	-4.95%	-98.08%	-64.54%

Note that the risk-adjusted long-term returns cannot be calculated for JetBlue because we require 360 days of past performance to estimate JetBlue's beta.

** Returns of less than -100% appear nonsensical at first, but may occur in a risk-adjusted cumulative return context.

Note: This table presents risk-adjusted cumulative abnormal returns during various time periods following JetBlue's Initial Public Offering (IPO) on April 12, 2002. We calculate daily abnormal returns as the difference between actual returns observed on each trading day minus expected returns based on the capital asset pricing model (CAPM). The results in this table represent a *long-term* approach to estimating the variables for the CAPM: we use *360-calender-day* trailing betas for each firm and estimate market risk premiums by using *360-calender-day* historical returns on the Center for Research on Security Prices value-weighted market index minus interpolated average yields on 90-day Treasury Bills during each week.

CONCLUSION

Notwithstanding the fact that JetBlue has been an innovative operation and, as the numbers and our analysis shows, quite successful, will it be able to maintain its success, in the future, through long periods of sustained growth? What would it take for JetBlue to meet its growth targets while maintaining productivity and flexibility? These questions cannot be successfully answered without an appropriate passage of time that will ultimately validate JetBlue's model.

We explain JetBlue's overall success (and that of other low-cost carriers) from an operational standpoint through its lower and more variable cost structure, its lower breakeven load factor, and the business and leisure traveler migration from conventional-cost airlines to low-cost airlines. Our financial analysis substantiates this point to its fullest. We find that markets value low-cost airline stocks as growth stocks, whereas conventional-cost airline stocks are treated as cyclical. Even though affected, low-cost carriers emerged after 9/11 in a stronger market position than their conventional-cost rivals. From a management standpoint, we believe that adopting a viable strategic position, leveraging organizational capabilities, and re-conceiving the value equation are critical in defining the comparative advantage of low-cost carriers.

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THE EFFECT OF LINE MAINTENANCE ACTIVITY ON AIRLINE SAFETY QUALITY

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ABSTRACT

One of the arguments against deregulation of the airline industry has been the possibility that financially troubled carriers would be tempted to lower line maintenance spending, thus lowering maintenance quality and decreasing the overall safety of the carrier. Given the financial crisis triggered by the events of 9/11, it appears to be a good time to revisit this issue. This paper examines the quality of airline line maintenance activity and examines the impact of maintenance spending on maintenance quality and overall safety. Findings indicate that increased maintenance spending is associated with increased line maintenance activity and increased overall safety quality for the major U.S. carriers.

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INTRODUCTION

One of the key concerns of opponents of airline deregulation in the U.S. was that once carriers were free to compete based on the price of their goods rather than on the quality of their service, the quality of their safety would decline as the pressure to reduce costs increased (Lee, 1996; Rose, 1992). The question of safety quality in the airline industry has provoked intense debate over issues as basic as the definition of safety quality itself and as complex as the relationship between safety and financial performance. In the wake of 9/11, there is not only renewed interest in airline safety quality, but concern that financially troubled carriers burdened with additional security expenses might be forced to reduce safety spending and line maintenance activity. The purpose of this research is to explore the role of maintenance spending and line maintenance activity in the production of airline safety quality.

Background

Prior to 1978, the Civil Aeronautics Board (CAB) regulated both airline service quality and airline safety quality, establishing minimum standards for both. With the passage of the Airline Deregulation Act of 1978, U.S. airlines were free to determine market entry and exit, flight frequency, aircraft type, capacity, aircraft configuration, and the level of amenities provided (e.g., meals, entertainment, and seat pitch), based on market forces.

Establishing minimum standards and auditing for compliance is one of several ways to define and measure service quality. An airline survey such as those conducted by the publishers of Frequent Flyer and Condé Nast Traveler is another way. These surveys typically ask a cross-section of frequent flyers to rank airlines on key issues of customer satisfaction. Questions generally address the following ten factors of customer satisfaction: on-time performance, airport check-in, schedule/flight accommodations, seating comfort, gate location, aircraft interior, flight attendants, post-flight services, food services, and frequent flyer programs (Glab, 1998). While these surveys are an important source of information, it is difficult to compare the results of different surveys or to examine trends over time to gain a historical perspective of airline service quality. Aside from the quality awards created by the airlines themselves (e.g., the Grand Slam or Triple Crown), the most common method of defining and examining airline service quality is to use the results of the U.S. Department of Transportation's (DOT) monthly publication, *Air Travel Consumer Report*. This publication contains information on flight delays, mishandled baggage, over-sold flights, and consumer complaints filed with the DOT. In 1991, the Aviation Institute at the University of Nebraska at Omaha began using this data in its *Airline Quality Rating (AQR)* report (Bowen & Headley, 1991).

This report also includes key indicators of safety quality as well as financial stability. Unlike the survey method, the *AQR* and other studies using the data from the *Air Travel Consumer Report* have been criticized for focusing on basic service quality issues rather than the amenities (e.g., seating comfort and food service) that form a larger component of the typical survey (Perkins, 1998). The advantages of the *Air Travel Consumer Report* are its consistent historical reporting of data and public availability.

While airlines were now free to determine their own level of service quality, safety continues to be regulated by the Federal Aviation Administration (FAA). The FAA has authority to establish Federal Aviation Regulations (FARs) relating to: a) the design, manufacturing, and certification of aircraft, including their engines and other systems; b) the certification of airlines; and c) the certification of personnel who directly affect the safe operation of the aircraft, including pilots and mechanics. The National Aviation Safety Inspection Program was created to conduct focused inspections of airlines and maintenance facilities to insure compliance with all FARs. However, "there is also universal acknowledgement that full compliance with applicable safety regulation cannot be ascertained with existing or conventional methods of compliance surveillance" (Ozdener, 2000). Researchers have variously defined safety quality in terms of fatal accidents, accident rate and/or incident rate. Proxy measures of safety quality include operating profit margin, maintenance expenditure, and inspection results (Barnett & Higgins, 1989; Kanafani & Keeler, 1989; Rose, 1989; 1990; 1992).

According to the U.S. General Accounting Office (GAO), there are four factors that affect the safe operation of airlines: a) financial stability, b) maintenance quality, c) management attitude, and d) pilot competence (GAO, 1988; 1996). While pilot competence and managerial attitude have been cited in antidotal reports of accident investigation, there is little empirical data examining this link. One company, FlightSafe Consultants Ltd., does attempt to assess management effort as it relates to safety, but the assessment is subjective and not available to the public (Pasztor & Michaels, 2004). Research on the relationship between safety and overall financial performance has been mixed (Graham & Bowes, 1979; Kanafani & Keeler, 1989; Lee, 1996; Moses & Savage, 1990; Rose, 1990;1992). The most commonly used measure of safety quality has been the level of maintenance expenditures, although this raw number can be misleading. Airline maintenance spending levels can be affected by a number of factors including the age of the aircraft in the fleet, the type and mix of aircraft, and the level of outsourcing (GAO, 1988; O'Toole, 1992). In short, to understand the issue of maintenance spending it is necessary to understand the nature of airline maintenance programs.

AIRCRAFT MAINTENANCE PROGRAMS

In an effort to maintain a comfortable degree of safety, a scheduled maintenance program is established for each transport category aircraft. For large aircraft, such a program is a process that can take up to five years to complete, and requires very close coordination between the aircraft manufacturer and operator (Hessburg, 2001).

The advent of modern scheduled maintenance programs began in the late 1960s with the Boeing 747. The sophistication and operating capabilities of the Boeing 747's aircraft systems and engines reached a point where maintenance programs currently in place were no longer considered effective. The Air Transport Association (ATA) created a Maintenance Steering Group (MSG) consisting of representatives of ATA-member airlines. This group created a document that became known as MSG-1. MSG-1 was process-and-procedures oriented. MSG-1 was soon followed by MSG-2, which was used with both the McDonnell Douglas DC-10 and the Lockheed L-1011 aircraft.

With the development of more sophisticated aircraft utilizing higher performance engines, glass cockpits, and advanced materials, the MSG-3 was introduced. The MSG-3 is a task-oriented rather than process-and-procedure-oriented document. Originally intended for the Boeing 757 and 767, MSG-3 has undergone three revisions, the latest including the Boeing 777 (Friend, 1997; Hessburg, 2001; Transportation Systems Consulting Corporation, 1999).

The actual purpose of MSG-3 is to establish the methodology that will be used to prepare the maintenance plan for a particular aircraft. An Industry Steering Committee (ISC) and various working groups are then established to create the plan. The purpose of the ISC is to oversee the activities of the working groups, each of which are composed of specialists in the various systems such as avionics, mechanical systems, structures, engines, and flight controls (Hessburg, 2001). The working groups in turn determine Maintenance Specific Items (MSIs) and specific tasks for their inspection and maintenance (Friend, 1997). Close cooperation between the regulatory agencies, the manufacturer, and the airlines is essential throughout the process.

The key to the process occurs early with a listing of the MSIs, that is, items that require specific inspections as determined by the appropriate specialists. After the list of MSIs has been determined, an analysis—known as decision tree logic—is performed on each item, with the key function being to differentiate between safety-related failure and economic failure. Servicing and maintenance requirements are determined at this time and include checks, inspections, lubrication, and when to discard. These requirements—known as tasks—are studied to the point where maintenance intervals can be defined in units of time called intervals. Intervals may include hours, cycles, and calendars. The final product of the ISC and working groups are specific maintenance recommendations that include a list of items, tasks, and intervals. These recommendations are then presented to an FAA Maintenance Review Board that has approval authority, after which the necessary documents are developed (Hessburg, 2001).

The primary focus in aircraft maintenance, according to the FAA, is to provide continued airworthiness. Part 25 of the Code of Federal Regulations (CFR) prescribes airworthiness standards for the issuance of type certificates for Transport Category aircraft. The essence of the FAA regulation is that the instructions for continued airworthiness for each aircraft must contain inspection and maintenance information for not only the airframe, but also for every part of the aircraft, for example, appliances, engines, and propellers Continued airworthiness data are typically in the form of manuals in paper, microfilm, microfiche, and/or CD-ROM format and organized in a specific manner. There will be general descriptions of the aircraft and its systems, basic operation of components and systems, servicing information regarding lubrication and capacities, troubleshooting information, methods of removing and replacing components, testing procedures, and specific details relating to inspections, maintenance, and servicing (FAA, 2003). Once the complete inspection package is developed, it is submitted to the FAA for approval. An FAA approved inspection program is then implemented as specified and takes the form of a number of different processes.

AIRCRAFT INSPECTIONS

For large aircraft, inspections fall into two broad categories: scheduled and special. Scheduled inspections include service checks, letter checks, phased checks, and calendar checks. The composition, scheduling, and even the titles of each inspection will vary with each operator. Regardless of the method used, the objectives behind such inspection programs are both safety and to increase aircraft availability.

Special inspection programs are the other major category of inspections performed on transport category aircraft, and, essentially, supplement existing scheduled programs. Special inspection programs—often the result of new technology or accidents/incidents—are approved by the FAA and coordinated with the aircraft and/or engine manufacturer. Aging aircraft inspections, corrosion control programs, Extended Twin-Engine Operations, low aircraft utilization, and Global Position Systems for navigation, are all cases where special inspection programs are utilized (Hessburg, 2001).

Scheduled Inspections

The most basic of the scheduled inspections is the service check. A service check includes checking and replenishing fluids, and inspecting for apparent deterioration, damage and security. These cursory inspections are made at certain times during an aircraft's operating day. These inspections are made by line personnel, rather than by certificated technicians and are called, depending on their purpose, such names as preflight, throughflight, postflight, and overnight. Service checks are accomplished according to calendar time or flight hours depending on the requirements of the inspection program.

The most widely known type of inspections are the A-D letter checks, with an A Check being the most basic and frequent, and a D Check being the most comprehensive. All of these checks are accomplished at specified maintenance stations with the lower checks being accomplished along the route structure and the higher checks at a major maintenance base. The detailed and idiosyncratic nature of an inspection program is such that some items, for example on a B Check, may be accomplished every second or third check rather then each time a B Check is performed. Letter checks, as well as all other approved inspection programs, are customized to both the aircraft as well as the operator.

The A Check involves more detailed inspection than a service check, and focuses on servicing and periodic inspections of certain components on a daily basis. Some special tools and test equipment are required and the technicians performing them will have appropriate certifications. Fluid checks, system operations, and Built-In Test Equipment are all common with A Checks. A Checks typically occur twice per month, take 36 labor hours, and keep the aircraft out of service for approximately 12 hours (Hessburg, 2001) The B Check, which is no longer employed in many inspection programs, involves more in-depth servicing and testing. When performed, a B Check will take up to a 40 hour labor week to complete, are accomplished every four months or so, and keep the aircraft out of service for up to 12 consecutive scheduled flight hours (Hessburg, 2001). Items formerly performed in this type of check have been incorporated into either A Checks or C Checks.

The two remaining letter checks (C and D) are known as heavy checks and involve extensive inspection, testing, tools, and training. The C Check is the most common heavy check and is typically performed every 12 months or so. C Checks require approximately 450 labor hours and keep the aircraft out of service for as much as four days (Hessburg, 2001). Typical tasks performed during a C Check include detail visual inspections, specified systems functional testing, and major component lubrication. The most in-depth scheduled inspection is the D Check, which is predominately a major structural inspection designed to detect corrosion and fatigue failure through the use of sophisticated techniques such as Non-Destructive Testing. D Checks require as much as 1,500 labor hours and take a week or more to complete (Hessburg, 2001). Most operators have discontinued the D Check and have incorporated the various tasks into C Check intervals. An example would be to inspect wing attached bolts every eighth C Check (or 16,000 flight hours). It is also important to note that each higher check includes all lower checks; for example, technicians performing a C Check would include items in both A Checks and B Checks as well as various service items.

A common way to distribute items contained in the heavy checks is to utilize a phased inspection program. A phase check is where parts of C Checks and D Checks are incorporated into lower A Checks and B Checks. For example, an inspection item scheduled to be performed in a C Check (which is typically performed every year or approximately 1,600 flight hours), will be incorporated into a B Check. While it will lengthen the B Check by perhaps a few hours, it will still only need to be performed once per year and the next B Check will include another part of the C Check. Over the period of a year, each C Check item is completed only once and the aircraft will not be out of service for the typical four consecutive days required for a complete C Check. When establishing a scheduled maintenance plan, the MSG will essentially describe tasks and intervals. The actual packaging of the inspection program into logical groupings is determined by the operator.

Service Difficulty Reports

Under 14 CFR section 121.703 and 135.415 of Title 14 (Code of Federal Regulations available at www.gpoaaccess.gov/cfr/index.html) each holder of an airworthiness certificate must submit "reports on certain failures, malfunctions or defects of specific systems and on all other failures, malfunctions, or defects that, in the opinion of the certificate holder, have endangered or may endanger the safe operation of the aircraft." These difficulties may be discovered during the course of operations, or during inspections. Service Difficulty Reports (SDRs) are the publicly available record of line maintenance activity performed at repair stations, both those directly managed by the airline itself and outsource repair stations. This data are a key source of safety information for FAA inspectors as well as manufacturers interested in issues relating to the reliability and problems encountered with aircraft components.

Regulations require certificate holders to report specifically on matter relating to: a) a fire or fire warning system, b) an engine exhaust system, c) any aircraft component that causes the circulation of smoke or harmful vapors, d) any engine flameout or shutdown, e) a propeller feathering system, f) a fuel-dumping system, g) a landing gear system, h) a breaking system, i) any component or system that results in a rejected takeoff or emergency action, j) any emergency evacuation system or component, and k) the autothrottle, autoflight or flight control system. 14 CFR section121-704 deals with reporting related to structural defects or failures. These reports must specify the nature of the problem and the action taken. They must also identify any precautionary or emergency measures (called *procedures*) taken to address the problems in question citing the categories above for reference (Rohrbach, 2004). From a glance at the above categories and those listed below for reportable procedures, the safety implications behind such actions as engine shutdown or a failure in the landing gear should be reasonably clear.

The reported data are entered and compiled into a database for weekly distribution to aircraft manufacturers, air carriers, repair stations, and the general aviation community. The raw data in the SDRs are available to the public through the FAA Web site (www.faa.gov) or other related Web sites such as www.landings.com. The FAA Aeronautical Center uses these reports to identify trends and significant safety issues. Based on this review of the database, the FAA may propose changes to existing procedures after due comment and may then issue an airworthiness directive or service bulletin.

In this study, we examined SDR history for the major U.S. carriers in order to understand the relationship between this measure of line maintenance activity (quality), maintenance spending, and safety outcomes, namely the number of procedures reflected on the SDRs. The historical nature of the data on the SDRs, their public availability, and close link to safety-related problems in maintenance appear to make them an excellent proxy for safety-related maintenance activity. Specifically, we wished to determine whether maintenance spending does improve the quality of line maintenance activity as reflected in the SDRs.

METHODS AND RESULTS

Data on safety outcomes were gathered from the FAA safety databases on accidents, incidents, and near mid-air collision. These data and the annual number of departures per carrier are contained in work previously conducted by Rhoades and Waguespack (1999; 2000; 2001). Data on line maintenance activity were collected from the Web site www.landings.com, which obtains the publicly available information directly from the FAA. Information collected included the total number of yearly SDRs filed and the total number of procedures by category. The categories are: a) unscheduled landing, b) aborted takeoff, c) aborted landing, d) engine shutdown, e) emergency descent, f) return to blocks, and g) deployment of emergency oxygen and/or fire activation systems. Information on maintenance spending was gathered from the *Air Carrier Financial Statistics Quarterly, compiled by the Bureau of Transportation Statistics and published by the U.S. Department of Transportation.* Information on the operational statistics (departures, miles, hours) was collected from the *Air Carrier Traffic Statistics Monthly* and the Bureau of Transportation Statistics. These data were used to normalize the safety and maintenance spending data for each carrier.

Table 1 shows the calculated figures for maintenance spending per mile flown for the carriers in this study. The last row on the table shows the mean maintenance spending per year. Spending rates below the industry mean are indicated. It should be noted that maintenance spending per year has increased for the industry overall between 1994 and 2000.

Table 1. Maintenance spending per mile flown, for U.S. airlines, 1994-2000

Airline	1994	1995	1996	1997	1998	1999	2000
Alaska	.0009*	.0008*	.0008*	.0010*	.0010*	.0012*	.0015*
AmericaWest	.0008*	.0009*	.0009*	.0012*	.0014*	.0016*	.0018*
American	.0014*	.0015	.0015	.0020	.0020	.0019	.0021
Continental	.0017	.0014*	.0014*	.0015*	.0016*	.0016*	.0016*
Delta	.0015	.0014*	.0013*	.0014*	.0015*	.0016*	.0018*
Northwest	.0017	.0018	.0021	.0021	.0025	.0024	.0029
Southwest	.0010*	.0010*	.0011*	.0010*	.0011*	.0013*	.0012*
TWA	.0019	.0019	.0021	.0020	.0020	.0020	.0020*
United	.0021	.0022	.0022	.0022	.0024	.0024	.0024
USAir	.0018	.0018	.0019	.0021	.0023	.0022	.0022
Mean	*.0015*	*.0015*	*.0015*	*.0017*	*.0018*	*.0018*	*.0020*

* Spending rate is below the industry annual mean
Note: The raw data are from *Air Carrier Financial Statistics Quarterly*, 1994-2000, Washington DC: U.S. Department of Transportation Center for Transportation Information.

Table 2 provides the ratio of procedures to total number of SDRs for these same carriers. If SDRs in general reflect the performance of routine maintenance, then—all other things being equal—a carrier performing more maintenance should demonstrate a higher level of maintenance quality, and thus a smaller number of procedures. A higher number of procedures, on the other hand, would not be a desirable outcome. We would expect the ratio of SDRs to procedures to be one indication of overall maintenance quality. In this case, Southwest stands out as being above the industry mean for 1994-1998, despite an excellent reputation for quality and an excellent record of safety.

Analysis of the relationship between maintenance spending, SDRs, and safety quality reveals a number of interesting findings. There does not appear to be a significant correlation between maintenance spending per departure, mile or hour and the total number of SDRs filed each year by the major carriers. There was a small correlation (.362) between maintenance spending per average haul and total SDRs. This is to be expected for two reasons. First, A Checks and B Checks are performed whenever a flight lands or terminates; airlines with short average hauls (total miles divided by departures) would be expected to perform more of these checks. Second, much of the wear and tear on an aircraft is the result of the pressure changes experienced during ascending and descending. Aircraft flying short hauls can be expected to experience more of this type of stress.

Table 2. Ratio of reportable procedures to total service difficulty reports, for U.S. airlines, 1994-2000

Airline	1994	1995	1996	1997	1998	1999	2000
Alaska	9.24	11.35	21.63	12.17	59.78	101.44	53.10
America West	6.87	4.19	7.54	8.31	7.38	5.23	10.90
American	4.96	4.96	10.71	5.14	13.01	7.93	7.81
Continental	1.91	2.80	8.05	7.40	19.98	25.41	38.06
Delta	14.55	12.39	6.31	4.76	8.08	4.53	3.40
Northwest	3.41	3.08	5.82	3.90	3.64	5.44	3.85
Southwest	14.73	8.80	12.82	9.61	20.96	10.95	13.05
TWA	4.23	2.02	3.97	6.15	8.26	16.76	20.00
United	2.71	1.82	3.12	2.75	1.97	1.96	2.07
USAir	3.60	3.98	3.38	3.07	3.96	7.86	8.41
Mean	*6.62*	*5.54*	*8.34*	*6.33*	*14.70*	*18.75*	*16.06*

Note: The raw data on SDRs are collected from http://www.landings.com.

These same maintenance rates do show a significant, moderate correlation (.273-.522) with the number of reported yearly procedures indicating that maintenance spending increases with the level of procedures experienced in a given year. It is unknown whether increasing levels of procedures generate more maintenance costs to carriers or whether carriers increase maintenance spending as a result of increasing levels of procedures. Examining the relationship between the ratio of procedures to SDRs and maintenance spending, we found a significant negative relationship (-.328), that is, as the level of maintenance spending increases then the ratio of procedures to SDRs declines. Maintenance spending was also negatively associated with the total safety rate, that is, as maintenance spending increases the number of safety problems per year decreases.

DISCUSSION

Our analysis demonstrates that there is a relationship between maintenance spending rates and the level of both SDRs in line maintenance and the safety outcomes of the major carriers in the U.S. airline industry. As maintenance spending increased, carriers decrease the ratio of procedures to total SDRs. This is good news in several respects. Good routine maintenance appears to help lower the level of emergency and precautionary procedures. This in turn lowers the overall level of maintenance spending.

Increased maintenance spending also appears to decrease the number of safety problems experienced by airlines. This is the good news. As one articles recently stated, "[a]ircraft maintenance matters--a lot" (McCartney, 2004).

The bad news is that this relationship is not as simple as it would seem, nor does it appear to hold for all major carriers, leading to questions about the maintenance process itself. Southwest consistently posts a level of maintenance spending well below that of comparable major carriers and yet has an exceptional safety record. In part, this is due to the nature of their fleet which consists solely of B-737s. Maintaining a single aircraft fleet allows them to benefit from economies of scale in parts and equipment purchasing as well as lower training costs. United Air Lines, on the other hand, has posted a relatively high level of maintenance spending without any apparent improvement in safety outcomes. Of course, spending is not enough to guarantee safe outcomes nor can the total spending alone be used to judge maintenance quality since it is a function of fleet mix and age as well as the efficiency of the overall process and the stage at which potential safety problems are detected and corrected. Several recent articles have pointed to a key weakness in the maintenance field, namely FAA inspection. SDRs, while required of all repair stations, are covered under a fairly broad set of regulation. However, an effort by the FAA to tighten reporting to include a wider range of routine repairs and failures provoked an outcry from repair station operators (Rohrbach, 2004). Since reporting is and continues be subject to interpretation and individual carrier discretion, then active oversight of repair station operations is critical to ensure standards are met. Unfortunately, the FAA has been heavily criticized in recent years for its failure to provide adequate oversight, particularly of outsourced and foreign repair stations (McCartney, 2004; Pasztor, 2004; Alexander, Reed & Mellnik, 2003).

No study is without its limitations. In relying on SDRs, it is clearly possible that we have not fully captured the quality of line maintenance activity. The concept of quality in any area is a complex, multifaceted one. Maintenance quality is presumably a function of well-trained mechanics equipped with the proper tools and/or systems, utilizing parts that meet industry standards, and installing and maintaining them in ways proscribed by their manufacturer. However, these aspects of quality are not available to researchers. Data on the level of qualifications of the personnel hired by individual carriers are not available. Likewise, there is no source other than the airlines themselves (through voluntary reporting to researchers) of the level of corporate spending on training. Finally, as noted above, we must consider the accuracy of the SDRs themselves and the variation that exists between in-house and outsourced maintenance activities.

Future research should address the impact of fleet mix and age on maintenance spending as well as the actual reporting process itself. Based on our review, there appears to be a good deal of variation both within and between carriers in the number and type of events reported. The relationship between maintenance quality, as reflected by SDRs and procedures should be examined to understand their relationship to direct safety outcomes such as accidents and incidents. Other issues that should be addressed include the effect of aircraft utilization and maintenance training on overall maintenance spending and safety quality. This study should also be extended to examine these relationships for national and regional carriers.

Safety quality has been seen as an economic good that is both desired by consumers and costly to provide. Viewed in this context, "it no longer follows that the socially desirable level of safety is the highest that is both technologically and humanly possible," (Ozdener, 2000, p. 18) since such a level would be prohibitively expensive. Even when a consensus can be reached on an acceptable level of safety, it is difficult to observe safety directly. Regulators, firms, and researchers have tended to observe safety outcomes such as accidents, incidents, and near mid-air collisions and relate these to safety inputs such as financial condition, maintenance spending, and training spending. This study is only one step in understanding the complex process of airline line maintenance activity. This process has come under increasing scrutiny in the last several years due to a series of high profile accidents (e.g., Alaska Airlines Flt 261[2000], Flash Airlines Flt 504[2004]). While U.S. airlines continue to be some of the safest in the world, there is always room for improvement. Before this improvement can begin, it is necessary to develop a better understanding of the factors that affect maintenance quality and the processes that could be used to improve it. National and international organizations have been criticized for their failures to adequately oversee airline safety, particularly maintenance practices. Unfortunately, "outside groups and academics have made limited efforts to fill the gap" (Pasztor & Michaels, 2004, p. A14). This paper is one attempt to fill this very large gap. A gap we believe must be filled in order to provide consumers with the safety they expect and deserve.

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AN EXAMINATION OF THE INDIANA STATE UNIVERSITY AEROSPACE ADMINISTRATION PROGRAM

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ABSTRACT

Declining enrollments in the Indiana State University (ISU) aerospace administration program prompted this case study, which evaluates the program in comparison with parallel programs at other universities, industry standards, and an independent audit. Survey instruments were administered to graduates, faculty, and employers for their views on competencies of an excellent aerospace administration program. Results show the deficiency of the ISU program. Graduates, faculty, and employers rated all competencies—from moderate to considerable importance—similarly for an excellent program. Recommendations for program improvement were made, and suggestions for further research include studies to evaluate the effectiveness of a revised aerospace administration program.

INTRODUCTION

Only after students graduate are they able to step back and evaluate the value of their program's curriculum in their careers. Faculty may be so busy teaching and performing administrative duties that they do not take the time to examine the adequacy and sufficiency of the current program. Also of significance in evaluating a program is feedback from employers once graduates are out in the field. Thus, an evaluative case study of a given university program involving graduates, faculty, and employers is most appropriate for assessing the value of that program.

The following case study of the Indiana State University (ISU) aerospace administration program is such a study. The structure of the study,

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methods used, and findings are presented here as a model for other universities to define and explore their own programs and make best use of the feedback obtained from graduates, faculty, and employers. In turn, this feedback may be used for recommendations to improve a given program toward greater applicability to current industry standards, university accreditation, and student and graduate satisfaction.

STATEMENT OF THE PROBLEM

This case study examined possible sources of declining enrollment over the past 10 years in the ISU aerospace administration program. In 1991, as reported in 1991 by the Dean the ISU School of Technology (SOT), of approximately 350 students in the Department of Aerospace Technology, the aerospace administration program had an enrollment of 105 students, representing approximately 30% of the total enrollment. After a period of declining enrollments, total department enrollments recovered and increased to 239 students making the Department of Aerospace Technology the largest in the SOT. However, the number of students in the aerospace administration program decreased to 29, or only 12% of the department total.

PURPOSE

The research reported here is part of a larger case study, which evaluated and made extensive recommendations for improvement of the aerospace administration program at ISU, with the goal of accreditation by the nationally recognized Council on Aviation Accreditation (CAA). The paper reports primarily on the several ways in which the program was evaluated and offers several pertinent recommendations.

This case study evaluation of the ISU aerospace administration program took place through five modes. These were benchmarking; comparisons with criteria for excellence in aerospace administration programs, as mandated by the CAA; comparisons with other CAA-accredited university aerospace administration programs; the results of surveys administered to graduates, faculty, and potential employers of ISU aerospace administration graduates; and an external audit of the aerospace administration program by the University Aviation Association (UAA). The case study approach is particularly appropriate in evaluations of programs, with systematic study and multiple qualitative and quantitative methods (McMillan & Schumacher, 1997).

RESEARCH QUESTIONS

Four research questions were formulated to guide this case study.

1. What does the literature review provide as the appropriate and valid criteria for an excellent aerospace aviation management

program, as indicated by accrediting agencies, professional industry organizations, and other university programs?
2. What instrument is appropriate to measure graduate, faculty, and employer feedback with regard to the present aerospace administration program?
3. Do significant gaps exist between the established criteria for excellence of an aerospace administration program and the present program at ISU?
4. What recommendations can be made to enhance the quality of the aerospace administration program at ISU?

Limitations and Delimitations

This case study was designed to evaluate the gaps between CAA accreditation standards and the aerospace administration program at ISU. Thus, findings can be generalized only to highly similar settings. Given the unique nature of the ISU aerospace administration program, it is unlikely that this study is completely replicable at another institution. However, efforts were made to ensure a substantial framework of detail and discussion for replication.

With regard to the comparison of the ISU program with those of the four CAA-accredited programs at sister universities, although close review of program coursework was conducted, review of these universities' self-studies was not conducted. Thus, it is possible that some conclusions concerning how certain programs met CAA standards were inaccurate. Nevertheless, in each case, all programs had met CAA standards and received CAA accreditation.

With regard to the instruments, although selection and development of some survey items were based on informed recommendations of the expert committees and the researcher, other relevant items may have been omitted, such as employers' formal aviation industry education or graduate school experience. In addition, each survey instrument was developed for a specific subject base and field-tested with small samples. Thus, survey results may lack some reliability and validity.

LITERATURE REVIEW

Benchmarking

Among the central methods implemented in the accreditation process is benchmarking. This is a method of identifying the best practices of similar institutions or programs and comparing them with the institution or program being assessed. As Rothwell (1996) points out, benchmarking is "the search for industry best practices that lead to superior performance" (p. 116). Benchmarking is widely advocated and accepted across many fields to compare and contrast best practices to identify areas for improvement in programs (Camp, 1998). Czarnecki (1998) observes that comparisons focus on key performance gaps, rallying support internally around findings to create consensus to move forward.

Accreditation

Excellence in aerospace administration programs is an important aspect of the health of the national aviation industry. Accreditation has two fundamental purposes: (a) to ensure the quality of the institution or programs, and (b) to assist in the improvement of the institution or program (CAA, 2003). With accreditation, students are assured of receiving quality education and training, which prepare them for performing a broad range of professional responsibilities. Further, graduates are assured that their educational degree program has met desired industry standards. Although accreditation is a voluntary process, accrediting decisions are used as considerations in many formal actions by governmental funding agencies, scholarship commissions, foundations, employers, counselors, and potential students (CAA, 2003).

The CAA was recently recognized by the Council for Higher Education Accreditation (CHEA). CHEA is a private, nonprofit, national organization that coordinates accreditation activity in the United States. The Council represents more than 3,000 colleges and universities and 60 national, regional, and specialized accreditation associations (CAA, 2002).

North (1999) encourages university aviation departments to acquire aviation accreditation because traditional academic accreditation falls short of the specialized focus needed in the aviation industry. North also suggests that aviation industry representatives play an advisory role in universities to help faculty develop curricula of immediate and practical value to students who enter the industry.

Recruitment literature for students considering an airline career appears to show a bias toward accredited programs. The Airline Pilots Association (ALPA) specifically suggests that students who desire careers with airlines should seek out university aviation departments that have achieved accreditation from the CAA. To become a pilot or manager with an airline is an often stated goal of the vast majority of aviation students, and the ALPA recruitment brochure states that programs without CAA accreditation are at a distinct disadvantage for their graduates' acceptance into the industry (ALPA, 2002).

Criteria of Excellence for Aerospace Administration Programs

Central to the present case study was the comparison of industry-recommended CAA curriculum requirements with ISU aerospace administration requirements. CAA requires that any accredited program's curriculum be designed to allow a graduate to function as an aviation professional (CAA, 2001). An aviation professional is one who uses the knowledge gained for "the design, management and operation of safe, efficient, and comprehensive national and international aviation and aerospace systems" (p. 8).

Because of the broad scope of the aviation professional's duties, CAA mandates criteria addressing interdisciplinary studies that include general education, aviation core, aviation option, business management, and a capstone experience course (CAA, 2003). The program requirements for each of these are described below.

General education

CAA recommends sequential coursework that culminates in advanced assignments. The purpose of this curriculum is to prepare students to be able to identify and solve problems. All programs must incorporate courses that require students to demonstrate mastery of written and verbal communications; mathematics, including calculus; science, including physics or chemistry appropriate to the level of aviation option pursued; and competence in computers. CAA requires 12 semester credits in this curriculum area (CAA, 2003).

Aviation core

The program must have a foundation of essential as well as specialized knowledge of aviation systems. The purpose of this component is to ensure students' foundation in essential knowledge appropriate to the aviation degree. CAA requires 12 semester credits in this curriculum area. Topics may be addressed in entire courses or in portions of courses (CAA, 2003).

Aviation option

This component supplies students with a coherent series of courses that provide specialized knowledge for preparation as aviation professionals. CAA approves the following baccalaureate degree option areas: (a) aviation management, (b) aviation electronics, (c) aviation studies, and (d) flight education. CAA requires 36 semester credits in this curriculum area (CAA, 2003).

Business management

Because an aviation professional's duties encompass a wide range of knowledge, CAA specifics a number of business management courses for the aviation management program. These courses include the following: (a) accounting, (b) micro and macro economics, (c) finance, (d) management, (e) business law, and (f) human resource management (CAA, 2001). CAA requires 36 semester credits in this curriculum area (CAA, 2003).

Career focus

Each institution has some flexibility in program design, but to meet the CAA standards, the curriculum must focus on a potential career field rather than provide a generalized extension of the aviation core area. Career focus may address various industry areas, such as airport management, maintenance management, aviation management, or air carrier management. Each area should be developed with the assistance of industry representations, appropriate industry associations, and professionals in the field.

Regardless of career focus, the aviation management option track requires a combination of business and aviation coursework. This track requires significant upper-level experience in aviation management, with a minimum of 3 semester credit hours. These may be fulfilled by a capstone course, an internship, or a special project that build upon prior coursework.

Table 1. Four-year educational institutions with programs accredited by the Council on Aviation Accreditation, as of 2004

Institution	Year First Accredited	Year Most Recently Accredited
Arizona State University	2000	2000
Auburn University	2003	2003
Central Missouri State University	1995	2001
Daniel Webster University	2001	2001
Embry-Riddle Aeronautical University, FL	1992	2001
Embry-Riddle Aeronautical University, AZ	1999	2001
Florida Institute of Technology	1992	2002
Hampton University	2002	2002
Louisiana Tech University	1993	2004
Middle Tennessee State University	1992	2002
Parks College	1996	2001
Purdue University	1998	2003
Saint Cloud State University	1994	2004
University of Nebraska-Omaha	2002	2002
University of North Dakota	1992	2002
Utah State University	2004	2004
Western Michigan University	2002	2002

Note. Of the 19 educational institutions accredited, 2 are two-year community colleges, Mercer County Community College, NJ, and North Shore Community College, MA, and are not listed here. Council on Aviation Accreditation (2004): http://www.caaaccreditation.org/programs.html

Comparison with Other University Aerospace Administration Programs

As of October 2004, CAA accredited aviation programs at 19 educational institutions in the U.S., 17 four-year programs and 2 two-year programs. These offer a variety of programs that include flight training, aircraft maintenance, aircraft dispatch, air traffic control, and aviation management. Table 1 lists these institutions.

For the present study, detailed information was gathered from curriculum brochures listed on the Internet for analysis of four directly competitive CAA-accredited universities. These were Purdue University, Middle Tennessee State University, Central Missouri State University, and Saint Cloud State University (Table 2).

Table 2. Overview of selected Council on Aviation Accreditation accredited educational institutions with aerospace administration or parallel programs

Institution and Program Title	Semester Hours
Central Missouri State University, Warrensburg, MO Aviation Management	124
Middle Tennessee State University, Murfreesboro, TN Aerospace Administration	124
Purdue University, West Lafayette, IN Aviation Administration	128
Saint Cloud State University, Saint Cloud, MN Aviation Management	120

Source: Council on Aviation Accreditation (2004). Available at www.caaaccreditation.org/013102.htm.

A comparison reveals that not all of the institutions required the same coursework but each met the CAA requirements by various means. With regard to the general education requirement, each required courses in speech, English composition, business writing, computers, and some form of calculus. Additional CAA requirements were met through combined coursework.

With regard to the aviation core requirement, each required a basic flight course, current issues, aviation safety, and introduction to technology. In some cases, universities appeared to meet CAA requirements through combined coursework.

Additional aviation core coursework varied by institution, as did preparatory coursework. In addition, although many course options were available, no consistency was found among the institutions reviewed. It is possible that aviation core offerings varied because of availability of faculty to teach a specific class or series of classes.

With regard to the aviation option curriculum, each institution required complete coursework in one of the selected aviation option areas. These were the baccalaureate option areas listed above.

With regard to the business management curriculum, each institution required complete coursework in microeconomics, macroeconomics, introduction to accounting, managerial/cost accounting, and introduction to law. Several business-related courses were required by all of the reviewed institutions, such as microeconomics, introduction to accounting, and statistics. Additional business management coursework varied by institution, as did preparatory coursework. As with other categories, although many class options were available, there was no substantial consistency among the institutions. It is possible that the institutions' business management offerings varied because of faculty availability or departmental problems in obtaining a course from the appropriate campus department, possibly because of specific course content required by CAA.

With regard to the CAA capstone requirement, each university used a different method of fulfillment. CAA allows some flexibility in this requirement, provided that coursework is addressed and documented within other course areas (CAA, 2004).

Evaluations of Other Aerospace Administration Programs

Evaluations of aviation management programs for case study are sparse. However, Ruiz et al. (2000) surveyed 806 individuals who graduated from the aviation management program at Southern Illinois University Carbondale between 1985 and 1996. Graduates were asked for their perceptions of the usefulness of the program and evaluation of the program regarding their achievement of occupational and/or life goals.

Results for major courses in aviation management indicated that airline management and aviation maintenance management were considered the most valuable, and airport planning and general aviation operations were considered the least valuable. Recommendations based on results of this survey included a number of changes in the curriculum. At the time of article publication, changes were "under consideration or have been made to the . . . program" (Ruiz et al, 2000, p. 58). This study provided a model for the present case study, especially the survey of university graduates.

Flouris and Gibson (2002) conducted a similar study of 59 graduating seniors, focusing on aviation management job placement. Subjects surveyed were graduating from one of four major university aviation management programs. Results showed that the students were most interested in major airlines, regional airlines, fixed-based operations, and corporate flight departments. Students also indicated more interest in operations positions rather than staff responsibilities. Recommendations included adding internships for students to gain a more realistic view of career and workload responsibilities.

Graduates' and employers' ratings on important items varied considerably. For example, employers rated the candidate selection areas highest, such as ability to prioritize, plan, and organize, whereas graduates focused on medical insurance and retirement pension plans. Employers stressed the importance of the basic general education curriculum and favored communication, leadership, and computer skills, whereas graduates were more interested in operations (Flouris & Gibson, 2002).

Based on these results, Flouris and Gibson (2002) made several recommendations. Most important was better student preparation through a solid academic foundation that integrates general education and a comprehensive aviation core, such as programs accredited by the CAA. Also important was the recommendation that students engage in internships, capstone, or cooperative education opportunities to gain greater experience in the field before actual employment.

Prospective employers of aviation program graduates were surveyed by Kaps and Ruiz (1997). Thirty presidents of airline companies were asked what they felt students who are seeking an airline career should study. Results indicated that airline presidents placed the most value on courses stressing a better understanding of fiscal requirements, legal aspects, and airline operations. The presidents also stressed the importance of an understanding of operating in a global marketplace environment. Respondents placed less importance on airport planning, airport management, professional development, and general aviation operations.

Kaps and Ruiz (1997) also compared the importance of the CAA's recommended curriculum with the presidents' views on what a new aviation management graduate most needed. The CAA curriculum was used by Kaps and Ruiz as representative of the best criteria for comparing required courses to competencies necessary in the aviation industry. Results mirrored the previous comparisons: the importance of a solid business base was highlighted, coupled with intensive aviation studies, as outlined by the CAA. However, in both comparisons, Kaps and Ruiz (1997) found that the airline presidents rated airport management, general aviation, and aviation history low in importance compared to the other CAA recommended courses.

Thus, the case studies reviewed generally agree on the recommendation on student preparation for aviation careers. Each case study reflected high emphasis on a solid general education, with additional knowledge in aviation and business courses equally important, for graduates' employability in the industry.

METHODOLOGY

Survey Development

A cross-sectional survey design was used for this study. The survey was conducted from May to July 2003. Three groups of ISU-related individuals were surveyed: graduates of the program, current faculty, and current and potential employers in the state of Indiana. The survey was developed with reference to the literature and input and advice in aviation and education from ISU faculty and industry representatives. The final survey was divided into two main sections, the first on demographic information, and the second on the five aerospace administration competencies—general education, aviation core, aviation option, business management, and aviation capstone. At the end of the surveys, respondents were invited to comment.

The surveys for the three groups varied slightly because items were customized. For example, the graduate survey included items on reason for selecting the aerospace administration degree program, demographic information, employment position, and salary levels. The faculty survey included items on demographic information, professional rank and teaching experience, and expert knowledge areas. The employer survey included items on demographic information, occupational category, position title, and comparisons of ISU graduates to graduates of other programs. All survey instruments asked respondents to rate the importance of aerospace administration competencies noted above. The graduate survey contained 43 items, the faculty survey contained 38 items, and the employer contained 40 items. For all three surveys, each item was scored on a Likert-type scale, from 1 indicating no importance to 5 indicating great importance.

Field-testing took place with a sample of 10 graduates, 5% of the total to be surveyed; 5 faculty members, 30% of the total; and 10 employers, 10% of the total. After revisions for clarity and consistency, the final survey, the Aerospace Administration Program Evaluation Survey (AAPES), was administered by the researcher to graduates, faculty members, and employers (see Appendix for sample survey).

Administration of Surveys

Surveys were mailed to 204 graduates of ISU's aerospace administration degree program, 17 current faculty associated with teaching the aerospace administration degree program, and 100 actual and potential employers of graduates within the state of Indiana. The names of the graduate students were obtained from the ISU alumni office. The names of the employers were obtained from state aeronautics records. Follow-up mailings took place at 2 weeks. Responses were received from a total of 61 graduates (33% response rate), 17 faculty (100%), and 41 employers (41%).

RESULTS

Comparison of ISU Program with CAA Standards

The present ISU program fell short in each curriculum area when compared with CAA standards. In the general education curriculum, physics or chemistry and calculus requirements were lacking. In the aviation core area, although the program contained 16 credit hours, meeting the 12 credit hours minimum, this curriculum did not meet the CAA standards for aircraft systems, airspace, or meteorology.

Table 3. Characteristics and responses to the Indiana State University Aerospace Administration Program Evaluation Survey, of respondents who are graduates of the program, 2003 (N = 66)

	Number	Percent
1. Highest degree held		
Bachelor	65	98.5
Master	1	1.5
2. Age		
24-26	10	16.2
27-30	14	21.2
31-35	33	50.0
3. Sex		
Male	52	78.8
Female	14	21.2
4. Ethnic background		
Caucasian	62	78.8
African American	1	1.5
Hispanic	1	1.5
Asian	1	1.5
Other	1	1.5
5. Primary reason for selecting a degree from ISU Dept. of Aerospace Tech		
Federal government	8	12.1
Local or authority government	2	3.0
Airline pilot	18	27.3
Airline management	20	30.3
Airport management	10	16.2
Air traffic control	2	3.0
Military assignment/advancement	1	1.5
Post-military education	1	1.5
Salary advancement	1	1.5
6. Your technology degree prepared you for first job		
Very well	18	27.3
Adequately	34	51.5
Poorly	4	6.1
Not at all	7	10.6
7. Current employment status		
Full-time employed	56	84.8
Part-time employed	2	3.0
Self-employed	2	3.0
Armed Forces	3	4.5
8. Current salary		
\$20,000 to \$29,999	7	10.6
\$30,000 to \$39,999	16	22.7
\$40,000 to \$49,999	7	10.6
\$50,000 to \$69,999	8	13.6
Greater than \$70,000	14	21.2

Table 3. Characteristics and responses to the Indiana State University Aerospace Administration Program Evaluation Survey, of respondents who are graduates of the program, 2003 (N = 66) *(continued)*

	Number	Percent
9. Occupational category that most closely describes your present job		
Military	6	9.1
Federal government	5	7.6
Air carrier	13	19.7
Airport-based business	1	1.5
Aviation manufacturing	2	3.0
Airport	4	6.1
Corporate aviation	2	3.0
Self-employed	2	3.0
Other area in aviation industry	10	15.2
Employed outside of the aviation industry	19	28.8
10. Skills essential for your current job*		
Management skills	36	29.0
Oral communications	32	26.0
Written communication	19	15.0
Human relations	15	12.0
Mathematical skills	12	10.0
Human relations	11	9.0

Total percentage exceeds 100% because of rounding.
* Top six skills indicated by subjects. Total number equals 125 because many graduates listed more than one skill.

The aviation option area did not exist as part of the aerospace administration degree. Thus, the program had only 18 credits hours of the 36 credit hours requirement. In the business management area, only one of the seven course areas met CAA standards. Finally, no requirement for a capstone course existed in the program, as required by CAA standards.

Comparison of ISU Aerospace Administration Program with Similar CAA-Accredited Programs

Detailed comparisons of the CAA-accredited programs at Purdue University, Saint Cloud State University, Central Missouri University, and Middle Tennessee State University compared with the ISU aerospace administration program revealed substantial gaps in each of the five competency areas. Each of the four reviewed universities has a well-defined general education curriculum that includes coursework in physics and calculus, an aviation core curriculum that includes coursework in aircraft systems and meteorology, an aviation option curriculum that includes career tracks in airline management and airport management, a business management curriculum with coursework in finance and marketing, and a capstone requirement that includes coursework in internship and airport certification.

In comparison, at ISU, as noted, the general education curriculum lacked a physics or chemistry course and a calculus course. The aviation core curriculum lacked an airspace course and aircraft systems course. The present program also did not have a specific aviation option track. The business management track lacked accounting, finance, and marketing courses. The program did not have a capstone requirement. Thus, in comparison with the four programs at the CAA-accredited programs reviewed, the ISU aerospace administration program had many deficiencies.

Results of the Aviation Administration Program Evaluation Survey for Graduate, Faculty, and Employer Respondents

Results of the survey of graduate respondents (AAPES-G)

Table 3 shows the demographic composition and responses of the graduate sample (N = 66). Most graduates, 98.5% (n = 65), possessed a bachelor degree, followed by 1.5% (n = 1) with a master degree. The oldest group of graduates, 50.0% (n = 33), was 31 to 35 years old; followed by those between 27 to 30, 21.2% (n = 14); and those 24 to 26, 16.2% (n = 10). Most subjects were male, 78.8% (n = 52), with 21.2% (n = 14) female. Caucasian graduates were the largest group represented, 78.8% (n = 62), with 1.5% (n = 1) each African American, Hispanic, Asian, and Other.

The largest categories of graduates' reasons for selecting a degree from the ISU Department of Aerospace Technology were to pursue a career in airline management, 30.3% (n = 20); airline pilot, 27.3% (n = 18); airport management, 16.2% (n = 10); and the federal government, 12.1% (n = 8). The smallest categories were air traffic control, 3.0% (n = 2); and military assignment/advancement, post-military education, and salary adjustment, each 1.5% (n = 1).

When indicating how well the technology degree prepared them for their first job, 51.5% (n = 34) indicated that the degree prepared them adequately, followed by 27.3% (n = 18), who felt very well prepared. The smallest percentage of graduates felt they were not at all prepared, 10.6% (n = 7), and poorly prepared, 6.1% (n = 4).

Over four-fifths, 84.8% (n = 56) of the graduate respondents were employed full-time, with 4.5% (n = 3) reporting service in the armed forces. A total of 3.0% (n = 2) each indicated part-time employment and self-employment. The two largest income categories were $30,000 to $39,999, at 22.7% (n = 16), and greater than $70,000, 21.2% (n = 14). The next three largest income categories were $50,000 to $59,999, 13.6% (n = 8); and $20,000 to $29,900 and $40,000 to $49,900, each 10.6% (n = 7).

Graduate respondents indicated a variety of occupational categories. The four largest groups were employed outside of the aviation industry, 28.8% (n

= 19); air carrier, 19.7% (n = 13); other area in aviation industry, 15.2% (n = 10); and military, 9.1% (n = 6). Smaller categories are federal government 7.6 % (n = 5); airport, 6.1% (n = 4); and aviation manufacturing, corporate aviation, and self-employed, each 3.0% (n = 2). The smallest category of occupation was airport-based business, 1.5% (n = 1).

Graduate respondents selected six top skills considered essential for the current job. Management skills, 29.0% (n = 36), was the largest; followed by oral communications, 26.0% (n = 32); written communication; 15.0% (n = 19); human relations, 12.0% (n =15); mathematical skills, 10.0% (n = 12); and human relations, 9.0% (n = 11).

Table 4 shows the results of the curriculum competencies section of the AAPES-G. The mean for general education was 4.0 (SD 1.1), for aviation core 3.8 (SD 1.1), for aviation option 3.9 (SD 1.1), for business management 4.0 (SD 1.0), and for aviation capstone 4.2 (SD 1.0). For the total survey, the mean was 3.9 (SD 1.1). These means indicate that the graduate respondents felt that the items in the survey were between moderate importance and great importance for an excellent aerospace administration program.

Table 4. Results of Indiana State University Aerospace Administration Program Evaluation Survey, for respondents who are graduates of the program, 2003 (N = 66)

Competency	Mean	Standard deviation	Range	Mean value
General Education	4.0	1.1	16-29 (6-30)	24
Aviation Core	3.8	1.1	17-57 (12-60)	46
Aviation Option	3.9	1.1	0-20* (4-20)	16
Business Management	4.0	1.0	0-30* (6-30)	24
Aviation Capstone	4.2	1.0	0-5* (1-5)	4
Total Survey	3.9	1.1	75-136 (29-145)	114

Note. Means are based on scoring scales: 1 = No importance, 2 = Little importance, 3 = Moderate importance, 4 = Considerable importance, 5 = Great importance. Numbers in parentheses indicate total range possible.
* Actual minimum is 0 because some subjects did not respond to items within competency.

Additional comments from the graduate respondents reflected their feelings that the department needed to reinforce the present curriculum with additional requirements that would help future graduates of the program. This gap corroborates the deficient courses in business management compared to CAA standards. Graduates commented that this area offered them the least preparation to enter the workplace with confidence. Graduates recommended additional courses, including speech and writing, accounting, public media relations, finance, and required student participation in internships.

Results of the survey to faculty respondents (AAPES-F)

Table 5 shows the responses and demographic composition of the faculty sample. The majority, 58.8% (n = 10), possessed a master degree, and 41.2% (n = 7) a doctorate degree. The largest group of faculty members, 35.3% (n = 6), were ages 46 to 50, followed by those over 50, 29.4% (n = 5). Most faculty members were male, 76.5% (n = 13), with 23.5% (n = 4) female. Caucasian faculty members were the largest group represented, 88.2% (n = 15), with 5.9% (n = 1) each African American and Asian. A total of 47.1% (n = 8) of the faculty held a tenure-track position, and 47.2% (n = 7) held tenured positions. Only 11.8% (n = 2) held full-time temporary nontenure-track positions.

Table 5. Characteristics and responses to the Indiana State University Aerospace Administration Program Evaluation Survey, respondents who are faculty of the program, 2003 (N = 17)

Characteristic	Number	Percent
1. Highest degree held		
Doctorate	7	41.2
Master	10.5	58.8
2. Age		
46-50	6	35.3
More than 50 years	5	29.4
3. Sex		
Male	13	76.5
Female	4	23.5
4. Ethnic background		
Caucasian	15	88.2
African American	1	5.9
Asian	1	5.9
5. Employment status		
Full-time faculty member, tenured	7	41.2
Full-time faculty member, tenure track	8	47.1
Temporary full-time, nontenure track	2	11.8
6. Occupational category		
Dept. of Aerospace Technology	6	35.3
Dept. of Industrial Technology Education	6	35.3
Dept. of Mfg and Construction Technology	2	11.8
Dept. of Electronics and Computer Technology	3	17.6
7. Current job title*		
Assistant Professor	12	70.6
Professor	2	11.8
Associate Professor	1	5.9
Instructor	1	5.9

Regarding faculty respondents' occupational categories, which reflect their teaching departments, 35.3% (n = 6) each were in the Department of Aerospace and the Department of Industrial Technology Education. A total of 17.6% (n = 3) were in the Department of Electronics and Computer Technology, followed by 11.8% (n = 2) in the Department of Manufacturing and Construction Technology. Over two-thirds, 70.6% (n = 12) were assistant professors, 11.8% (n = 2) were professors, and 5.9% (n = 1) each were an associate professor and instructor.

Table 6 shows the results of the curriculum competencies section of the AAPES-F. The mean for general education was 4.4 (SD 0.8), for aviation core 4.4 (SD 0.8), for aviation option 4.4 (SD 0.7), for business management 4.5 (SD 0.6), and for aviation capstone 4.6 (SD 0.5). For the total survey, the mean was 4.4 (SD 0.7). These numbers indicate that faculty respondents felt that the items in the survey were between considerable importance and great importance for an excellent aerospace administration program.

Table 6. Results of Indiana State University Aerospace Administration Program Evaluation Survey, for respondents who were faculty of the program, 2003 (N = 17)

Competency	Mean	Standard deviation	Range	Mean value
General Education	4.4	0.8	22-29 (6-30)	2
Aviation Core	4.4	0.8	42-60 (12-60)	53
Aviation Option	4.4	0.7	12-20 (4-20)	18
Business Management	4.5	0.6	21-30 (6-30)	27
Aviation Capstone	4.6	0.5	4-5 (1-5)	5
Total Survey	4.4	0.7	108-143 (29-145)	128

Note. Means are based on scoring scale: 1 = No importance, 2 = Little importance, 3 = Moderate importance, 4 = Considerable importance, 5 = Great importance.
Numbers in parentheses indicate total range possible.

Some of the faculty respondents added written comments. These reflected feelings that the present curriculum was deficient and additional courses should be added to help future graduates prepare for industry employment. Examples of such reinforcement include student participation in internships, research project, or industry certification. Most faculty respondents felt the department's coverage of the general education, business management, and aviation option coursework appeared to be satisfactory, although not all respondents agreed.

Results of the survey of aviation employers (AAPES-E)

Table 7 shows the demographic composition of the employer sample (N = 41). Most employers, 58.5% (n = 24) possessed a bachelor degree, followed by 17.1% (n = 7), with a master degree. The largest group of employers, 36.6% (n = 15), was more than 50 years old, followed by those between 41 and 45, 17.1% (n = 7); and 36 to 40 and 46 to 50, each with 4.6% (n = 6). Most subjects were male, 70.7% (n = 29), with 29.3% (n = 12) female. Caucasian employers were the largest group represented, 95.1% (n = 39), with 2.4% (n = 1) African American. Over four-fifths, 87.8% (n = 36) were employed full-time, with those employed part-time 7.3% (n = 3). Employers indicated a variety of occupational categories. The four largest were airport, 48.8% (n = 20); airport-based business, 12.2% (n = 5); employed outside of the aviation industry, 9.8% (n = 4); and other area in aviation industry, 7.3% (n = 3). A total of 4.9% (n = 2) each were in the federal government, air carrier, and corporate aviation. The smallest category of occupation was that of self-employment 2.4% (n = 1). Almost the majority, 43.9% (n = 18), had been in their position for 1 to 5 years; followed by 17.1% (n = 7) for 6 to 10 years; and 14.6% (n = 6) more than 20 years.

Almost three-fourths, 73.2% (n = 30) did not employ any ISU graduates. A total of 7.3% (n = 3) employed four or more ISU graduates, and 2.4% (n = 1) each employed two and three ISU graduates. When asked to compare ISU graduates to other university graduates, 61.0% (n = 25) of the employers indicated that no ISU graduates were employed. A total of 17.1% (n = 7) indicated ISU graduates were about the same as those from other universities, and 9.8% (n = 4) indicated ISU graduates were better than some. The smallest category, 4.9% (n = 2), indicated ISU graduates were better than most.

Table 7. Characteristics and responses to the Indiana State University Aerospace Administration Program Evaluation Survey, of respondents who were actual and potential employers within the state of Indiana of graduates of the program, 2003 (N = 41)

Characteristic	Number	Percent
1. Highest degree held		
Bachelor	24	58.5
Master	7	17.1
2. Age		
36-40	6	14.6
41-45	7	17.1
46-50	6	14.6
More than 50 years	15	36.6
3. Sex		
Male	29	70.7
Female	12	29.3

Table 7. Characteristics and responses to the Indiana State University Aerospace Administration Program Evaluation Survey, of respondents who were actual and potential employers within the state of Indiana of graduates of the program, 2003 (N = 41) *(continued)*

Characteristic	Number	Percent
4. Ethnic background		
Caucasian	39	95.1
African American	1	2.4
5. Current employment status		
Full-time Employed	36	87.8
Part-time Employed	3	7.3
6. Occupational category*		
Federal government	2	4.9
Air carrier	2	4.9
Airport-based business	5	12.2
Airport	20	48.8
Corporate aviation	2	4.9
Self-employed	1	2.4
Other area in aviation industry	3	7.3
Employed outside aviation industry	4	9.8
8. Years in present position		
1-5 years	18	43.9
6-10 years	7	17.1
11-15 years	5	12.2
16-20 years	4	9.8
More than 20 years	6	14.6
9. Number of ISU graduates currently employed by firm		
0	30	73.2
2	1	2.4
3	1	2.4
4 or more	3	7.3
10. Assessment of ISU graduates compared to other university graduates		
No other graduates employed	25	61.0
About the same	7	17.1
Better than some	4	9.8
Better than most	2	4.9

Note. Numbers of characteristics follow numbers of items in Aviation Administration Program Evaluation Survey—Employers (AAPES-E)
* Titles are collapsed for brevity.

Based upon industry experience, employers also provided written comments about the present ISU aerospace administration program. Most employers felt the curriculum was lacking in a number of components essential for successful employment. Employers suggested additional courses such as speaking and people skills, marketing, writing, finance, and required student participation in internships.

Table 8 shows the results of the curriculum comparisons of the AAPES completed by the employers. The mean for general education was 4.1 (SD 1.0), for aviation core 4.0 (SD 0.9), for aviation option 4.0 (SD 0.9), for business management 4.0 (SD 0.9), and for aviation capstone 4.3 (SD 1.0). For the total survey, the mean was 4.0 (SD 0.9). These means indicate that employer respondents felt that the items in the survey were between considerable importance and great importance for an excellent aerospace administration program.

Table 8. Results of Indiana State University Aerospace Administration Program Evaluation Survey, for respondents who were actual and potential employers within the state of Indiana of graduates of the program, 2003 (N = 41)

Competency	Mean	Standard deviation	Range	Mean value
General Education	4.1	1.0	18-30 (6-30)	24
Aviation Core	4.0	0.9	37-60 (12-60)	48
Aviation Option	4.0	0.9	10-20 (4-20)	16
Business Management	4.0	0.9	12-30 (6-30)	24
Aviation Capstone	4.3	1.0	0-5* (1-5)	4
Total Survey	4.0	0.9	96-141 (29-145)	117

Note. Means are based on scoring scales: 1 = No importance, 2 = Little importance, 3 = Moderate importance, 4 = Considerable importance, 5 = Great importance. Numbers in parentheses indicate total range possible.

*Actual minimum is 0 because some subjects did not respond to items within the competency.

Results of UAA audit of the ISU Department of Aerospace Technology

In the fall of 2002, the ISU department chairperson requested an independent audit by the UAA of the entire department, including reviews of curriculum programs, facilities and equipment, contractor operations, and faculty with particular interest and evaluation on the aerospace administration program. This was the first external agency review of the department since 1992 and the first review ever conducted by an aviation organization. In the spring of 2003, the UAA audited the aerospace department and provided a report that corroborated the underlying problem identified in this study (University Aviation Association, 2003).

Table 9 displays the curriculum areas reviewed by the UAA audit. Except for the aviation option area, all evaluated areas fell short of CAA standards. Within the general education curriculum, the audit noted that ISU must add both calculus and physics to meet the CAA standards. The audit also noted that since the aerospace administration program lacked any cohesive management content courses, the program should more appropriately be termed an aviation studies program rather than an administration or management program. The audit team specified that for the aerospace administration program to meet CAA standards, addition of a comprehensive list of management content courses would be needed.

Table 9. Selected results of University Aviation Association audit of Indiana State University Aerospace Administration Program, 2002

Aerospace Administration	Competency Met	Noted
General Education Curriculum	No	Lack of calculus Lack of physics
Aviation Core Curriculum	Yes	
Aviation Option Curriculum	Unknown	Not reported
Business Management Curriculum	No	Lack of any management content courses
Aviation Capstone Curriculum	No	Lack of segment focus

Source: University of Aviation Association. 2003. *Indiana State University: Department of Aerospace Technology Audit Report.* Auburn, AL: University Aviation Association Press.

DISCUSSION

As this case study demonstrated, to achieve CAA accreditation a program must meet specialized accrediting criteria and standards. Programs that have been awarded CAA accreditation are recognized to have achieved a high level of quality. The results of the present study, as determined by comparisons with CAA standards, a detailed program review, survey results, and a UAA audit visit, demonstrated substantial gaps between ISU's aerospace administration program and the industry-recommended standards of CAA.

The Surveys

Graduates, faculty, and employers responded similarly with regard to the contents necessary for an excellent aerospace administration program, as indicated by the means for each group: graduates, 3.9; faculty, 4.4; and employers, 4.0. These means show that all three groups rated the items in all competencies from moderate to considerable importance for incorporation into an excellent aerospace administration program.

Graduate survey

In the curriculum areas of the survey, the graduate respondent means for all five curriculum areas were between 3.9 and 4.2, with aviation capstone, general education, and business management the highest (see Table 4). The overall mean was 3.9, indicating that all areas were of moderate to considerable importance to graduates for an excellent program.

These results corroborate those of the program review, in which business management and capstone CAA requirements were severely lacking in the ISU aerospace administration program. The program, in fact, had no capstone experience. These results indicate that graduates recognized the importance of strength in these curriculum areas for substantial employment preparation.

Faculty survey

Faculty respondent means for all five curriculum areas were slightly higher than graduate respondents' means; between 4.4 and 4.6, with the highest means also for business management and capstone (see Table 6). The faculty total mean was 4.4. This mean indicates that faculty respondents evaluated all coursework specified as of considerable to great importance in an excellent aerospace administration program.

Employer survey

The employer respondent results were also similar; their means were between 4.0 and 4.3, with general education and capstone the highest (see Table 8). The overall means was 4.0, comparable to the ratings of the other two groups. Thus, the employer respondents' mean indicates that they evaluated all coursework specified as of considerable to great importance in an excellent aerospace administration program.

Thus, graduates, faculty, and employers all rated CAA-required curriculum components similarly, with regard to both individual curriculum areas and overall means. These results imply the strong support by all groups for the revision of the present ISU aerospace administration program.

Qualitative feedback also supported these results. Graduate respondents commented most on the business management curriculum, stating that the addition of accounting, marketing, and public relations would improve the program. Some remarked that the aerospace administration program needed to raise its standards so that graduates would enter the workforce better prepared.

Faculty respondents commented that the most glaring omission was the capstone course requirement. One faculty respondent even suggested that the program should be elevated to a master degree program, suggesting that most students could not secure administrative positions in aviation without advanced training.

Employer respondents commented that additional emphasis should be placed on speaking and briefing skills as well as addition of a capstone experience. Employers respondents provided the most specific advice of the three groups, suggesting that more interpersonal and leadership skills courses should be developed and required within the business management.

The UAA Audit

Results of the site visit by the UAA audit team in May 2003 further corroborated the gaps identified in the present aerospace administration program and the need for program revision. The report noted within the general education curriculum the lack of required physics and calculus courses. In addition, although the report stated that the aviation core curriculum appeared to meet CAA standards, the auditors also noted that they had not completed a course matrix that would verify compliance with CAA standards.

Further, the team observed that because the present program does not contain a specific aviation option, that area could not presently meet CAA standards and therefore the option could not be evaluated. As a result, the program also does not meet the CAA capstone requirement. In support of the survey results, the UAA audit was the most critical of the present business management coursework, noting that the program lacked cohesive business management focus.

Thus, the results of survey respondents and the UAA audit report provide concurrent evidence that the present aerospace administration program shows major gaps in essential aviation curriculum, and that extensive revision is warranted. Especially in conjunction with the reviews of aviation programs at competitive universities, these findings suggest the basis for the steadily declining enrollment at ISU.

Significance of the Study

Based on the study results, five implications are evident. First, the present aerospace administration program does not meet current industry standards as determined by the literature review, comparisons with other universities, CAA standards, and surveys completed by graduates, faculty, and employers. This gap indicates one possible reason for the aerospace administration program's history of declining enrollments.

Second, unless the curriculum is revised, the department could experience continued loss of enrollments in the aerospace administration program.

Third, without revision, the current and future aerospace administration graduates will not meet industry expectations. Thereby, both the department and its graduates will be at a competitive disadvantage. Revision of the current curriculum would almost certainly place the program at a more competitive market advantage.

Fourth, if the department elects to revise the program to meet CAA standards, the program should then meet current industry standards. Such a revision, with proper marketing and recruitment efforts, would likely reverse the trend of declining enrollments.

Fifth, if the department considers accreditation, the study results and recommendations should provide a curriculum blueprint for the required changes necessary. These curriculum changes would reduce the timeline necessary to complete the CAA-directed self-study as part of the accreditation process.

A decision to pursue CAA accreditation was not considered as part of the present study, and no support for such effort from the respondents was requested. However, as demonstrated in this study, the CAA standards are recognized as valid criteria as judged by the formative and summative committees, industry, as well as the respondents of the survey instrument completed for the present research.

RECOMMENDATIONS

A number of recommendations stem from the study findings. First, within the ISU aerospace technology department, the curriculum committee should receive a report of the findings so as to consider extensive revision of the aerospace administration degree program.

Second, the department should pursue CAA accreditation, beginning with a CAA self-study. This self-study would consider and incorporate the curriculum recommendations stemming from this study.

Third, based on the gaps identified in the UAA report, the department should utilize UAA for future department external audits. The UAA audit process was an effective method of gaining an outside perspective on the status of the department and especially the aerospace administration program.

Study results prompt several directions for further research. First, for greater insight into appropriate revision of the aerospace administration program, a study of graduates' occupations compared with the skills they most valued in the program should be conducted. Second, with curriculum revisions in place, a follow-up AAPES of recent graduates after they have been employed for 1-2 years should take place. Replication and comparison with present study results would show effectiveness of the revisions and provide assessment of the program's improvements and its adequacy in preparing students for employment in the aviation industry.

Third, this study surveyed 100 aviation employers, specifically airport managers or individuals directly supporting them, such as operations staff, security, and airport consultants in Indiana only. To enlarge the scope of the employer's responses, the study should be replicated with a larger number of employers to include air carrier managers both in and out of the state.

Fourth, a similar study should be conducted of the department's other degree program in professional aviation flight technology. The present research appears to have been the most comprehensive undertaken of the aerospace administration program, and results indicate a substantial revision to the aerospace administration program. A parallel study of the professional aviation flight technology degree program could yield similar valuable results.

It should be noted that examination and evaluation such as those conducted in this study might produce considerable uneasiness and concern within departments, since previous policies, procedures, and decisions become open to scrutiny. For the present study, much lively debate and even disagreement accompanied the data gathering and review of information. Nevertheless, even with strong programs not subject to declining enrollment, periodic evaluations can helpful for currency and revitalization.

With additional goals such as accreditation, program reviews become even more important. The present study was undertaken as a first step toward the goal of accreditation, as well as to strengthen the aerospace administration program. Through examination of CAA standards, comparisons with competitive universities, surveys of significant groups, and a professional audit, the study demonstrated that the present ISU aerospace administration program requires extensive revision in highly specific curriculum areas. These findings have been shared with the university administration, and the process has been initiated for ISU to offer an excellent aerospace administration curriculum that meets industry standards and thoroughly prepares its graduates for responsible employment in aviation. Other universities and departments of aviation may find the procedures described here useful for comprehensive evaluation of their aviation curricula toward substantial improvement and industry accreditation.

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APPENDIX

AEROSPACE ADMINISTRATION PROGRAM EVALUATION SURVEY—GRADUATES (AAPES-G)

The purpose of this study is to obtain your views on how well the Indiana State University Department of Aerospace Technology Aerospace Administration Program prepared you for your present work in the aviation industry. Your responses will help the department meet the needs of future students who, like you, seek to become well prepared for a successful career in aerospace administration. Please read and sign the attached consent form prior to beginning this survey.

Your input will assist us in identifying important factors in the aerospace administration program for inclusion, deletion, or revision. Your experience in the field makes your opinions of great value to us, and we appreciate your input.

DEMOGRAPHIC INFORMATION

Please circle your preferred response.

1. The highest degree you now hold:
   A. Bachelor degree
   B. Master degree
   C. Doctorate degree

2. Your current age:
   A. 21-23 years
   B. 24-26 years
   C. 27-30 years
   D. 31-35 years
   E. 41-45 years
   F. 36-40 years
   G. 46-50 years
   H. More than 50 years

3. Sex:
   A. Male
   B. Female

4. Your ethnic background:
   A. Caucasian
   B. African American
   C. Native American
   D. Hispanic
   E. Asian
   F. Pacific Islander
   G. Other, please specify ____________

5. Number of years you attended ISU:
   A. 1 year
   B. 2 years
   C. 3 years
   D. 4 years
   E. 5 years
   F. 6 years
   G. 7 years
   H. 8 years or more

6. Your primary enrollment status while attending ISU:
   A. Full-time student
   B. Part-time student

7. Number of years since you (last) graduated from ISU:
   A. Less than a year
   B. 1-9 years
   C. 10-14 years
   D. 15 to 19 years
   E. 20 to 24 years
   F. 25 to 30 years

8. Primary reason you selected a degree from the Department of Aerospace Technology:
   A. Aviation Industry Employment
      1. Federal government
      2. State government
      3. Local or authority government
      4. Airline pilot
      5. Airline management
      6. Airport management
      7. Air traffic control

B. Other Reasons
   1. Military assignment/Advancement
   2. Post military education
   3. Salary advancement
   4. Personal enrichment

9. Your current employment status:
   A. Full-time employed
   B. Part-time employed
   C. Self employed
   D. Student
   E. Armed Forces
   F. Homemaking
   G. Not working by choice
   H. Retired
   I. Unemployed

10. Your current annual salary:
   A. Less than $14,999
   B. $15,000 to $19,999
   C. $20,000 to $29,999
   D. $30,000 to $39,999
   E. $40,000 to $49,999
   F. $50,000 to $59,999
   G. $60,000 to $69,999
   H. Greater than $70,00

11. Occupational category listed below that most closely describes your present job:
   A. Military
   B. Federal government
   C. Air carrier
   D. Airport-based business
   E. Aviation manufacturing
   F. Airport
   G. Corporate aviation
   H. Self-employed
   I. Other area in the aviation industry
   J. Employed outside of the aviation industry

12. Skills essential for your current job (select 3 most important)
    A. Use of physical sciences
    B. Mathematical skills
    C. Written communications
    D. Hands-on skills
    E. Management skills
    F. Supervisor skills
    G. Human relations
    H. Technical skills
    I. Computer skills
    J. Oral communications

13. Please list your current job title:

14. Your technology degree prepared you for your first job:
    A. Very well
    B. Adequately
    C. Poorly
    D. Not at all

AEROSPACE ADMINISTRATION COMPETENCIES

Please indicate your views about the importance of the following competency areas on the skills an aerospace administration student should be learning as part of an excellent program of study. Note that the competencies are categorized into five areas: general education, aviation core, aviation option, business management, and capstone.

Using the scale provided, indicate your level of agreement with each of the following statements. Please circle your preferred response.

RATING	MEANING
1. No Importance	Completely not needed
2. Little Importance	Nice to know but of little value
3. Moderate Importance	Desirable to acquire if time permits
4. Considerable Importance	Not essential but of great value to acquire during a college program
5. Great Importance	Essential that competency be acquired during a college program

General Education Curriculum

This area addresses the basic education foundation all students might complete as part of an excellent aerospace administration degree.

15. Demonstrates a basic understanding of chemistry or physics.
1 2 3 4 5

16. Applies mathematics that could include technology-based calculus skills.
1 2 3 4 5

17. Demonstrates effective communication skills, i.e., persuasion, logic, discussion.
1 2 3 4 5

18. Leads a group/team discussion.
1 2 3 4 5

19. Demonstrates skills needed for using computer systems for problem solving
1 2 3 4 5

20. Demonstrates effective written communication skills through reports, letters, emails, and business communication.
1 2 3 4 5

Aviation Core Curriculum

This aspect of training encompasses a broad understanding of aviation in general as a foundation for advanced coursework that follows.

21. Develops skills needed when interviewing for a job.
1 2 3 4 5

22. Develops skills needed as a manager to interview a job candidate for a position.
1 2 3 4 5

23. Recognizes professional titles, and develops a general knowledge of their job description.
1 2 3 4 5

24. Demonstrates knowledge of the types of organizations in the aviation industry.
1 2 3 4 5

25. Demonstrates basic flight knowledge.
1 2 3 4 5

26. Demonstrates knowledge of airports.
    1 2 3 4 5

27. Demonstrates knowledge of air traffic control and airspace.
    1 2 3 4 5

28. Shows generalized understanding of national and international aviation law and regulations.
    1 2 3 4 5

29. Identifies key components of aircraft design, performance, operating characteristics of aircraft.
    1 2 3 4 5

30. Identifies key components of general maintenance of aircraft.
    1 2 3 4 5

31. Demonstrates an understanding of meteorology.
    1 1 1 1 1

32. Demonstrates an understanding of environmental issues
    1 2 3 4 5

Aviation Option Curriculum

This aspect of training provides an additional degree of specialization and identifies specific career tracks students might want to pursue.

33. Is able to provide in-depth knowledge of the major career employment tracks as components in aviation.
    1 2 3 4 5

34. Is able to discuss concepts of general aviation, corporate aviation, airports, manufactures, air carriers, and military aviation.
    1 2 3 4 5

35. Analyzes how technological evolution has shaped the industry and the outlook for new technologies.
    1 2 3 4 5

36. Analyzes the impact of limited airspace and airport capacity on the aviation industry
    1 2 3 4 5

Business Management Curriculum

This area encompasses advanced business management skills to provide students the ability to conduct operations in the business environment, such as airport management, airline management, and fixed-based operations.

37. Recognizes marketing research principles and analyzes the significance of the results.
    1 2 3 4 5

38. Demonstrates ability to interpret and analyze accounting statements, financial control concepts, and decision and control activities.
    1 2 3 4 5

39. Recognizes micro and macro economic market conditions and demonstrates ability to apply cost benefit analysis.
    1 2 3 4 5

40. Demonstrates ability to employ Human Resource Management techniques.
    1 2 3 4 5

41. Recognizes key finance terms and fundamentals.
    1 2 3 4 5

42. Applies advanced management concepts in the aviation industry.
    1 2 3 4 5

Aviation Capstone Curriculum

This area encompasses the final phase of training and is demonstrated through advanced coursework showing that key components of the training have been mastered and integrated.

43. Demonstrates ability that is an apparent result of a comprehensive education degree program and reflects multiple levels of training applied to aviation knowledge. Examples include a research paper, internship, or industry certification.
    1 2 3 4 5

Comments you wish to make:

Thank you very much for your participation.

SYSTEM SAFETY IN EARLY MANNED SPACE PROGRAM: A CASE STUDY OF NASA AND PROJECT MERCURY

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ABSTRACT

This case study provides a review of National Aeronautics and Space Administration's (NASA's) involvement in system safety during research and evolution from air breathing to exo-atmospheric capable flight systems culminating in the successful Project Mercury. Although NASA has been philosophically committed to the principals of system safety, this case study points out that budget and manpower constraints—as well as a variety of internal and external pressures—can jeopardize even a well-designed system safety program. This study begins with a review of the evolution and early years of NASA's rise as a project lead agency and ends with the lessons learned from Project Mercury.

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Donald Pitts, Colonel, USAFR, is the senior reserve advisor on the USAF Chief of Safety's staff. Assigned to Headquarters U.S. Air Force, Pentagon, he is a command pilot with 19 years operational fighter experience and a graduate of the Air War College. Since leaving active duty he has flown as a commercial pilot for American Airlines. His aviation experience outside of the cockpit includes formal training in aircraft accident investigation, aircraft maintenance, and flight safety. As Chairman of the Allied Pilots Association, National Safety and Training Committee, Colonel Pitts led an organization of pilot volunteers and staff that addressed commercial aviation safety hazards faced worldwide by nearly 14,000 pilots. He is a Charter member of the Commercial Aviation Safety Team – an industry-government coalition designed to support the FAA Safer Skies program. This team addresses the national goal of reducing commercial aviation fatal accidents by 80% over a 10-year period. Additionally he served on the NASA Aviation Safety Program Executive Council and the FAA's Aviation Rulemaking Committee addressing data driven safety processes for commercial aviation. He also serves as an adjunct faculty member to the Engineering and Technology Management program of the College of Engineering, Architecture and Technology, Oklahoma State University.

INTRODUCTION

The concept of system safety is well known today but there are valuable lessons to be learned in examining the historical roadmap of aeronautical safety methodologies, specifically system safety programs, which have evolved from origins within and around the aviation industry. The value in this review is to better understand what programs and processes have been successfully employed and more importantly how to preserve the benefits of those expensive lessons learned. Hopefully this effort will help to identify some of the best practices that have evolved over the past century and produce a basis for system safety program managers to emulate in all applications.

METHODOLOGY

The term case study can have more than one meaning that includes the description of a particular organization or a research methodology. According to Bromley (1990), it is a "systematic inquiry into an event or a set of related events which aims to describe and explain the phenomenon of interest" (p. 302). Yin defines the scope of case study research as an empirical inquiry that investigates a contemporary phenomenon within its real-life context (Yin, 2002). The unit of analysis for this study is the National Aeronautics and Space Administration (NASA), specifically the early years of the manned space program. This study is focused on an exploration and description of NASA's use of system safety during the early years of the man in space program and not in formulating any specific propositions.

The Beginning

The first four decades of powered flight proved that a piecemeal, rearview mirror approach to safety is ineffective and expensive. Early airplane pioneers such as the Wright Brothers, Samuel P. Langley, Glenn Curtiss, and others practiced the fly-fix-fly approach to safety. Although aircraft performance improved dramatically during these early years, so too did the military accident rate. The U.S. Army Air Service reported in 1921 "that the Air Service desires to perfect preventive accident measures to the fullest possible may be readily appreciated from the fact that during the calendar year 1920, 51 officers and enlisted men of the Air Service lost their lives in airplane accidents, [and] 312 airplanes were damaged or destroyed" (p. 25).

This early expression of concern was soon translated into the first practical steps toward a formal accident prevention program. In December 1925, Major Henry "Hap" Arnold identified the need for a systematic approach to aircraft maintenance. Military leadership stressed a systematic discipline, which focused on a proactive effort, seeking to identify hazards, analyze them for risk, and then to control them as known quantities. The focus of this approach is to establish an acceptable level of safety, designed into the system as a whole before production or operation. This approach then seeks to identify and evaluate hazards before an incident or accident causes a loss—anything less is arguably a gamble. The current definition of system safety seeks to optimize all aspects of safety within constraints of effectiveness, time, and cost throughout all phases of the system life cycle. The significance of the emphasis on all phases of the system life cycle will become apparent in the following history of NASA.

An interesting case study presents itself while examining these early years of system safety practice. The marked contrast between what was available and what was employed, in terms of system safety management and engineering, is so striking that it calls for a more in- depth look. As with any program, gaining acceptance and support with subsequent administrations almost always requires an effort to convince the new management team that the old management team knew what they were doing. Egos and narcissism are plentiful in the aviation industry; the humorous quip, "You can tell a pilot – you just can't tell him much" is true even among those who manage pilots, and the systems they fly.

NACA History

In the 1920s and 1930s, the National Advisory Committee for Aeronautics (NACA) was demonstrating worldwide leadership in aeronautical sciences. They concentrated their research in aerodynamics and aerodynamic loads, with lesser attention to sub-systems and components such as structures and power plants. During this era, NACA worked closely with the military services in joint projects that were its contractual lifeblood. Even as late as 1939, NACA was a relatively small organization with an annual budget of $4.6 million and a total workforce of approximately 500 people, of which slightly over one-half were researchers (Swenson, Grimwood, & Alexander, 1966).

In 1941, Jerome C. Hunsaker, head of the Department of Aeronautical Engineering at the Massachusetts Institute of Technology (MIT) and a member of the Main Committee of NACA, assumed the NACA chairmanship. As the U.S. geared its industrial might for war, NACA watched as Germany and the United Kingdom led aviation in areas such as jet propulsion and high-speed flight. Going into the war years, the majority of NACA's research effort was oriented toward improving current designs or quick fixes to military aircraft already in production (Hunsaker, 1956). This organizational culture would follow NACA into the next decade.

After the close of WW II, the cold-war years continued to place demands for research, acquisition, and the fielding of new systems.

> By 1946, NACA had grown to approximately 6,800 personnel with an annual budget of $40 million. Chairman Hunsaker and others on the Main Committee felt that NACA's principal mission should be research into the fundamentals of aeronautics, however, the aircraft industry continued to rely on NACA as a problem-solving agency. The pressure and culture for quick fixes prevailed within the agency as the United States entered the conflict in Korea—war justified the need for expediency in solving various performance challenges and resulting system problems. (Hunsaker, 1956, pp. 267-268)

Closer inspection reveals that at this time in aviation industry's history, the valuable lessons learned in the previous decade had not proliferated broadly into the overall aviation industry culture.

The windfall discovery of extensive German aeronautical research programs after WW II compelled both the Army Air Force (AAF) and NACA to propose airplane research programs to Congress. For the AAF, struggling to achieve independence from the U.S. Army, the proposed new role was founded on justification that no other agency could do its flight research and development. The AAF's safety program development since the earliest days of aviation lends credibility to that position. The mission was also a logical one for NACA as an extension of the research roles they had established in aeronautical systems development.

In 1946, a team was assembled at Muroc Army Air Field, California [present day Edwards Air Force Base (AFB)] to begin the effort between the AAF, NACA, and research project manufacturer Bell Aircraft. Major General Albert Boyd, commander of Wright Field Flight Test Division and later the Flight Test Unit at Edwards AFB, reflecting on the success of the X-1 research vehicle, said of the accomplishment, "[This work stands] as a monumental tribute to both the USAF and the NACA, since the sonic barrier monster was not only completely licked, but a blow-by-blow account of its defeat was recorded for future use" (Air Force-NACA Conference, 1948).

President Harry S. Truman recognized the partnership's accomplishments and presented the Collier Trophy for significant contributions in aerospace research to United States Air Force (USAF) Captain Chuck Yeager, Mr. Larry Bell of Bell Aircraft, and John Stack of NACA.

The methodologies employed during the research conducted at Edwards AFB, including the work of the U.S. Navy (USN) and NACA on the Douglas Aircraft Company D-558, affected the designs of future military aircraft, which profited from the system acquisition approach employed by the military services. Follow-on tests of improved versions of the X-1 and a new design, the X-2, methodically tested the outer regions of supersonic flight in an effort to better understand hypersonic flight, which had to be mastered to escape the bounds of earth. Proven designs found their way into future aircraft systems. More reliable systems translated to lower mishap rates and by the early 1950s the entire aviation industry (commercial and military) were profiting from this research. Incorporating a proven acquisition process with system safety engineering at the basis, the military services and NACA were moving forward on a new experimental aircraft that would employ a rocket propulsion system capable of flying to nearly 400,000 feet—the upper boundaries of the atmosphere where the traditional knowledge of aerodynamics were almost unrecognizable (Swenson et al., 1996)

The assault that took place on the upper regions of the atmosphere was arguably second only to the Wright Brothers conquering of sustained flight just 50 years previous. In 1952, Robert Woods of Bell Aircraft Corporation began efforts to promote manned space flight by urging the U.S. to analyze the basic problems of space flight. He further recommended research into a suitable test vehicle for space flight. Unfortunately, the urgency and resources for such an endeavor were simply not available at that time.

By March 1954, however, the combined efforts of the USAF, USN and NACA's laboratories at Langley, Ames, and the High Speed Flight Station at Edwards AFB produced contracts to study the concept and ready the studies for hypersonic flight. Using a cradle-to-grave approach, the first feasibility studies were used to identify all major hazards in detail and initiate means to either eliminate or reduce the severity of those known threats. Recognizing there were regions of flight that could not be duplicated in wind tunnels, the test program established goals that recognized materials and technology limitations, while leaving enough flexibility to modify the program as they discovered new facts. NACA Langley requested that boundaries to the development be established, calling for a flight research tool to be used to obtain the maximum amount of data for the development of follow-on systems in a three-year time limit. This was a brute force effort on its part to obtain flight information as soon as possible (Stillwell, 1964).

History highlights a culture of expediency pervading within NACA and its successor NASA. This could be as a result of the motivating factors during WW II and the Korean War that provided contracts to NACA for quick fixes. Additionally, their use of unmanned test vehicles launched to gather test points had been successful but lacked the motivation or oversight of those who manage human lives. In the interest of time, higher risks can be accepted during unmanned test flights in a fly-fix-fly approach to testing, however the paradigm might be a difficult one to break when attempting to reduce the overall system risk in later human endeavors. Clearly, NACA's focus was test data.

It is difficult to prove, but certainly noteworthy, that it appears the NACA research engineers were willing to accept more risk than those who would fly the aircraft. In the design of the X-15, NACA:

> Emphasized that the airplane should not become encumbered with systems or components not essential to flight research. These requirements were tempered by knowledge that a three-year development schedule would leave little or no time to perfect systems and subsystems before first flight. (Stillwell, 1964, p. 3)

With Department of Defense (DoD) oversight, a Memorandum of Understanding was signed between the military services and NACA establishing guidelines for the program, with lines of authority and control. Establishing these fundamental understandings among the various agencies "had no small effect on the successful pursuit of the research. In essence, it states briefly that each partner agrees to carry out the task it is best qualified for" (Stillwell, 1964, p. 5).

The USAF Aeronautical Systems Division (formerly the Wright Air Development Center) provided a shepherding role during concept development. In December 1954, an agreement between the military services and NACA was accepted with operational arrangements similar to those in the X-1 and other experimental flight tests conducted at Edwards AFB. The USAF was responsible for finding a contractor and supervising design and construction; both the USAF and the USN would fund the project. Technical direction would come from NACA.

The Los Angeles Division of North American Aviation, Inc. (NAA) won the design based on past performance and safety records. (NAA had already demonstrated system safety approaches in development of other systems and Los Angeles was the aerospace Mecca of system safety engineers.) Although NACA studies had possible solutions for major technological concerns, the basic challenge of how to build an airplane capable of Mach 6 speeds flying to 250,000 feet was not precisely defined and the aerodynamic information necessary was incomplete or simply not available. Throughout this phase, the DoD program managers were continually forced to provide a reconciliation of differing viewpoints as each partner in the project had different objectives. The X-15 was to become the product of one year of study, one year of design and one year of construction. These types of broad milestones are frequently used in the early phase of system safety planning groups.

The preliminary hazard identification effort during the design concept phase did not limit safety concerns to only the X-15 pilot. The potential danger to the B-52 crew (stage 1 propulsion system) also had to be considered, as an explosion of the X-15 during separation and initiation of self-powered flight could be a serious threat to the launch vehicle. For this reason, safe operation of the X-15 (stage 2 propulsion systems) became a primary objective. Reaction Motors Inc. (soon to become a division of the Thiokol Chemical Corporation) was chosen for the task. Reaction Motors had designed and built many rocket engines for X-series research projects and, in over 384 flights, had never had a catastrophic engine failure. The technical specifications for the X-15's XLR-99 engine outlined that:

> Any single malfunction in either engine or propulsion system should not create a condition which would be hazardous to the pilot. [Engineers set about an exacting design philosophy]... endeavoring to prevent malfunctions... [by designing] the engine so that the conditions following any malfunctions would be controlled before they became hazardous. (Stillwell, 1964, p. 5)

The result of these efforts was a 96% reliability rate, a figure that shames other missile engines in this era. This is the essence of system safety philosophy in the concept and design phases, clearly demonstrating its practice within the military services, NAA, and the rocket motor division of the Thiokol Corporation in 1954.

A vibrant product improvement and development program continued throughout the operational life cycle of the X-15. In 1956 the aerodynamic design was established, while NAA pushed the limits of available materials with heat resistant Inconel-X to complete the structural design. In 1958 the introduction of new fabrication techniques happened, while the development-test program during the years 1959 to 1964 produced many examples of product improvement during the operational phase of use.

Using a system approach to design and acquisition does not guarantee a risk-free program without unexpected surprises. However, the frequency, severity, and total cost of such an event should be a calculated risk—not a gamble—accepted by someone at the appropriate level of decision making. The X-15 project had a few surprises. One aircraft broke in half on landing. A more spectacular event occurred during ground tests of the XLR-99 engine when the engine violently exploded due to a sub-component failure. This mishap would most certainly have cost test pilot Scott Crossfield his life had this occurred in-flight, however the controlled environment in which the test was conducted (land based) combined with the cockpit design, aircraft structure, and the life support systems built into the design allowed him to survive (Stillwell, 1964).

The flight test program progressed from flight to flight on foundations of discovery. Since testing involved venturing into the unknown, operational considerations required an answer to every possible issue. What-if questions involved many man-hours of fault tree analysis before allowing a pilot to potentially face such a critical event in flight. Analog and then digital computers were used to simulate flights on the ground, thus allowing pilots and engineers to work literally side by side as they test-flew a mission on the ground before any actual flight attempt. The operational margin of safety was the governing issue of the program. Each flight became an extrapolation of previous experience to more stringent parameters.

The significant accomplishments of the X-15 program are often compared to those of the unmanned efforts in space exploration during this era. The advantages or disadvantages of human versus automated machine are often at the center of the debate and continue to this day. However, the success rate at achieving research objectives over a five-year period, covering 120 flights with a 92% mission success rate certainly speaks highly of the reliability designed into the X-15 program. Was it the man in the cockpit or the men on the ground and the value they placed in human life aboard the research vehicle that contributed to the success of this project? Did the fact that the Flight Controller, responsible for the coordination and control of the complete mission, and one of the experienced test pilots, insure the tough issues were resolved with an err toward conservativeness? How were these conflicting positions resolved when the cultural differences between the various organizations represented in the research project gridlocked in a heated debate? Were system safety processes responsible for the differences noted between this and other programs outside of DoD management? These and other behind-the-scenes issues are outside the scope of this study; however, the strong commitment to safety of those in leadership positions far outweigh less formal processes left to resolve differences on their own. Clear-cut guidance from above is essential when the tough questions surface, as they inevitably do.

The successes of the X-planes programs, managed by the collaborative effort of the military services and employing system safety processes, even though it was still an evolving process, boosted the prestige of NACA as a research agency. The reputation for thorough aeronautical research that NACA quietly built in the interwar period of the 1920s and 1930s continued to grow until the organization transformed into a new space agency, almost overnight, when President Eisenhower signed the Space Act on July 29, 1958 (National Aeronautics and Space Act of 1958).

USAF Leadership into Space

The X-15 operated in what was termed the near-space equivalent. (Its pilots wore astronaut wings and dealt with re-entry issues much more demanding than a capsule re-entry from space into the earth's atmosphere.). However, the expediency felt by some to simply place a man into orbit around the earth compelled research engineers to seek other solutions to the goal as winged craft were taking too much time to accomplish that objective.

In one camp, aerodynamicists were working on a hypersonic research aircraft with delta wings to handle the heat of atmospheric re-entry using a program managed by the USAF. The other camp was reviewing how to quickly modify an Intercontinental Ballistic Missile (ICBM) launch vehicle (also managed by the USAF) to propel a ballistic capsule system, irreverently referred to as man in a can, into low Earth orbit. The capsule method was nothing more than an extension of re-entry vehicles used in the development of ICBMs. The limiting factor for adding a man was payload capabilities of existing launch vehicles and the weight of the capsule with its life support systems. Reliable missile technology did not currently exist with an ability to lift the heavier (winged) hypersonic-glide vehicle into orbit. For this reason, industrial firms were mainly investigating the ballistic capsule option as the quickest solution to orbiting a manned vehicle even though winged craft were already operationally testing the lower regions of space. In late 1956, NACA agreed in principle with the USAF Air Research Development Command (ARDC) to cooperate on the manned glide rocket research system. By January 1957, the NACA Ames group reported conclusions that a rocket-powered vehicle for efficient hypersonic flight was feasible. A minority report from a NACA Langley aerodynamicist in the Flight Research Instrument Research and Pilotless Aircraft Research Division (PARD), recommended a spherical capsule be considered for global flight before a glide rocket. There was little interest expressed in work on this proposal within the main body of NACA at this time (Swenson et al., 1966).

NACA study groups continued the investigation of manned glide rocket concepts. A 1957 study on the Preliminary Investigation of a New Research Airplane for Exploring the Problems of Efficient Hypersonic Flight (NACA) supported a raised-top, flat-bottom glider configuration. Soon thereafter, on October 4, 1957, the opening bell of the space race sounded. The U.S.S.R. had launched a satellite into earth's orbit and altered our nation's attitude about space exploration.

Even though the official position of the Eisenhower Administration was a no race policy, a new urgency was adopted and efforts to expedite space exploration were accelerated. On October 15, 1957, representatives from the various NACA laboratories met at the Ames center in an effort to resolve conflicts in aerodynamic thinking. Dubbed the Round Three Conference, the meeting produced the fundamental concept for the X-20 project. A small contingent returned to Langley convinced that maximum concentration of effort to achieve manned orbital flight as quickly as possible meant use of the ballistic-capsule approach. Dr. Maxime A. Faget, speaking to the entire conference, declared that NACA had misplaced its research emphasis on the hypersonic-glide option and should work on orbiting a man as fast as possible (Swenson et al., 1966).

In December 1957, Lieutenant General Donald L. Putt, USAF Deputy Chief of Staff for Development, moved to establish a directorate-level program for aeronautics within the USAF. The effort was quickly opposed by the Secretary of Defense, who was not supportive of any military services venturing into astronautics despite their ongoing research efforts. The newly appointed DoD Director of Guided Missiles accused the USAF with trying to grab the limelight and establish a position. It is interesting to note the

Secretary of Defense, a political appointee of President and retired General Dwight D. Eisenhower, would fail to recognize the value added from the DoD's own acquisition program and chide the USAF for continuing to do what President Truman had spoken so highly of in the effort to break the sound barrier. It appears the politics of space exploration had overridden common sense.

The directorate idea was shelved and USAF Headquarters (HQ) ordered the ARDC to prepare a comprehensive review of the astronautics program, including estimates of funding and space technology projections over the next five years. ARDC had already been working on a 15-year plan for USAF research and development in astronautics and quickly reduced its finding down to a 5-year plan. General Putt wrote to NACA Director Hugh L. Dryden on January 31, 1958, formally inviting NACA to participate with the USAF in both the boost-glide research airplane (the Dyna-Soar) and a manned one-orbit flight in a vehicle capable only of a satellite orbit.

> Dryden informed General Putt that NACA was working on their design for a manned space capsule and would "coordinate" with the USAF later when they completed their studies. By this date, NACA had already developed its own goals of managing manned space exploration and was beginning to spread its wings. (Swenson et al., 1966, p. 74)

Behind the scenes, NACA HQ administrators saw an opportunity for the agency to broaden their activities by moving into astronautics. Some managers within NACA wanted to leave behind its principal role in research projects and expand into system development and flight operations, despite having only been a participant in such programs with no managing experience. Seeking a leadership role in the uncertain world of contracts, full-scale flight operations and public relations, NACA fixed their sights on a broad-based national space program with a principal objective to demonstrate the practicality of manned space flight. During the ten months between the first Sputnik launch and the establishment of a manned space program under a newly designated agency, NACA leadership continued to ensure their current role in traditional research and consultation while at the same time unleashing an ambitious team of engineers scattered throughout the NACA establishment to allow themselves to take a dominant role in the nation's new objective in space (Swenson et al., 1966). The DoD was slowly abdicating its ability to positively influence the nation's space efforts. At least five years of successful system safety management was soon to be pushed aside as project management of space exploration was handed over to a new entrant into the big leagues of government contracts, public relations and Congressional oversight.

President Eisenhower's stated U.S. policy held that space activities should be conducted solely for peaceful purposes. The objectives of guided missile projects of the time reflected this policy. In a letter to Soviet Premier Nikolai Bulganin, dated January 12, 1958, the President stated;

> Outer space should be used only for peaceful purposes... Can we not stop the production of such weapons which would use or, more accurately, misuse, outer space, now for the first time opening up as a field for man's exploration? Should not outer space be dedicated to the peaceful uses of mankind and denied to the purposes of war? (Eisenhower letter to Nikolai Bulganin, 1958)

By April 1958, members of Congress would introduce a total of 29 bills and resolutions calling for re-organization of the nation's space efforts. The Senate Preparedness Investigating Committee under Senator Lyndon B Johnson summarized its findings with recommendations to establish an independent space agency. During these times of transition, the military services dutifully continued their planning of space programs using proven system acquisition practices in the hope of securing their role in future space programs and with the knowledge that a newly formed organization would take several months if not years to take the reigns currently held by the various research program managers within the armed services.

NACA Covets a Leadership Role

Consistent with Eisenhower's peaceful space policy, the Advanced Research Projects Agency (ARPA) of the DoD had been used as an interim oversight agency pending establishment of a new civilian-controlled aerospace management organization. Top-level management of these programs shifted from the DoD to a completely new organization in short order. President Eisenhower ordered an 18-member Presidential Scientific Advisory Committee (PSAC), chaired by James R. Killian, Jr., President of MIT, for advice on these matters. Eisenhower's directions to this committee were to draw up two documents: (a) a broad policy statement justifying government-financed astronautical ventures and (b) a recommendation for organizing a national space program. The early PSAC work was dubbed the Killian Committee and was divided into two subcommittees. One subcommittee was charged to develop policy and was headed by Edward H. Purcell, a physicist and executive vice-president of Bell Telephone Laboratories; the other subcommittee developed an organizational structure and was led by Harvard University physicist James B. Fisk. (Swenson et al., 1966).

Two physicists, one a corporate leader and the other an academic, developed the policy and organizational structure of a neophyte flight research, development, and operations organization charged with conquering this new flight environment called space. The organizational work was completed first and the subcommittee produced a crucial report to the PSAC in February 1958. A new agency built around NACA would be created to manage a comprehensive national program in astronautics, emphasizing peaceful, civilian-controlled research and development. The PSAC report, titled Introduction to Outer Space, was published in March, and stated, "the compelling urge of man to explore and to discover, the defense objective, national prestige, and new opportunities for scientific observation and experiment are four factors which give importance, urgency, and inevitability to the advancement of space technology" (PSAC, 1958, p. 2).

The President's intense conviction that space should be primarily reserved for scientific exploration, not military exploitation, called for the establishment of a "National Aeronautical and Space Agency...which would absorb NACA and assume responsibility for all space activities...except... those projects primarily associated with military requirements" (Swenson et al., 1966, p. 84). A single executive and a 17-member advisory board called for extension of the NACA Main Committee concept with a centralized authority that would "have not only research but development, managerial, and flight operational responsibilities" (Swenson et al., 1966, p. 83). This was a significant executive decision that launched a loosely woven group of research scientists and engineers into a national agency, unlike its NACA predecessor, with extensive authority for contracting research and development projects. The USAF and USN lost management control of the research programs into outer space and would take a subordinate advisory or support role in non-atmospheric flight operations. Would the valuable experience in flight test and research program management be transferred as well?

NACA's Focus

In addition to their contract work to date, engineers at all NACA installations had been stepping up research in materials and aerodynamics preparing for large-scale development and operational activities. The primary purpose of NACA's work to this point in its history had always been to improve the performance of piloted aircraft. Different philosophies existed within the various NACA labs and not everyone was convinced that the agency's best interests lay in managing programs and carrying out satellite launchings. Many of the more focused research engineers endorsed the official NACA HQ position that, "with respect to space it neither wanted not expected more than its historic niche in government-financed science and engineering...it should remain essentially a producer of data for use by others" (Swenson et al., 1966, p. 77). The prevailing attitude within the Ames Research Center about the prospect of managing programs was exceedingly distasteful. The Ames engineers enjoyed the quasi-academic focus on research, the outside-of-the-box thinking it was noted for and the freedom from political pressures. This same attitude did not exist at the other two labs or at the High Speed Flight Station at Edwards AFB. The years of direct participation with USAF/USN and research aircraft manufacturers provided Walter Williams and his staff at the Flight Station a rather clear operational orientation. The NACA Lewis and Langley staffs apparently understood the magnitude of the effort, but seemingly minimized it as they only stated it would be quite a challenge to manage a program versus simply advising the military or industrial providers. Most of NACA did approve of the scientific measures provided by President Eisenhower to Congress espousing their ideas.

In the various NACA Flight Research facilities at Langley, Wallops Island, and Lewis, there were engineers who had experience in operational issues while developing airfoils, however, they had always turned those research findings over to DoD management. Now, enticed by the prospect of national prominence, vast amounts of government funding, and the surge of emotions delivered by the Soviet's first-in-space achievements, it is easily recognizable why an ambitious group of research engineers seized the opportunity to put their expertise to work.

Man in a Can Prevails

In the months following the Soviet satellite launchings, NACA's attention to spacecraft design accelerated as they realized their nose-cone research for ICBMs was applicable and transferable to manned vehicles as well. While still working with the USAF on plans for a manned orbital project in March 1958, they had in fact been given official sanction to provide work they had already been accomplishing. Thus the Langley engineers had found a clever way to perform early development work for their own ambitious enterprise—Project Mercury.

The primary advocate behind much of this activity was Dr. Faget, head of the Performance Aerodynamics Branch in PARD, who embodied the traditional Langley research culture that preferred to test aerodynamic theories on instrumented free-flight vehicles versus wind tunnel testing. Dr. Faget was on record favoring the quickest solution to space, the capsule option, while NACA Ames was avidly pushing the semi-lifting body concept, without the responsibility to build the vehicle or manage the program.

The choice between the semi-lifting configuration (X-20 concept) favored by the Ames group and the capsule device really was an academic one to supporters of the capsule option. Accepting the assumption that a manned satellite should be placed into low-earth orbit as quickly as possible, the Atlas ICBM would have to serve as the launch vehicle for the relatively lighter capsule. The Atlas ICBM was undergoing a rigorous systematic review toward status as a reliable rocket (per military specifications) and it was the only launch vehicle near operational readiness. These questionable caveats limit the choices and build a paradigm around the option, which allegedly uses the simplest, quickest, and most dependable approach—ruling out the heavier, semi-lifting vehicle that would have required adding an extra stage to the Atlas rocket. Interestingly enough, Faget did not have detailed data on the Atlas' design performance; such information was highly classified and he lacked clearance.

While the engineers at NACA accelerated their designs, tests, and plans, and Congress received Eisenhower's space bill, the organizational transformation of NACA began. After the White House Advisory Committee on Government Organization recommended that a national civilian space program be built around NACA, Director Dryden and his subordinates in Washington began planning the revamping that would have to accompany the reorientation of NACA functions. On April 2, 1958, as part of his space message to Congress, Eisenhower instructed NACA and the DoD to review the projects then under ARPA to determine which should be transferred to the new civilian space agency (NASA, n.d.).

NACA and DoD representatives, in consultation with Bureau of the Budget officials, reached tentative agreements on the disposition of practically all the projects and facilities in question, with the notable exception of manned space flight. In accordance with Eisenhower's directive that NACA "describe the internal organization, management structure, staff, facilities, and funds which will be required" (Rosholt, 1966, p. 8), NACA set up an ad hoc committee on organization. The Space Act additionally called for a civilian-military liaison, appointed by the President, to ensure "full interchange of information and data acquired in NASA and Defense Department programs" (Swenson et al., 1966, p. 98).

The U.S. military systems management experiences of the past decade would not make the transition. The handoff from DoD management of flight research, especially in the area of system acquisition and safety, to the new national space exploration agency was not going to be a clean one. Ambitious research engineers, dividing their attention between their traditional roles in support of government projects and total management of their new enterprise, essentially failed to capture valuable lessons learned by the USAF and USN management of the activities at Edwards AFB. Political pressures within NASA to fulfill this new destiny forced many of those dissenting opinions to join the team that was now taking control of a program in support of a national objective. The pressure to think as the group thought must have been tremendous for those researchers and engineers who had been educated in the school of hard-knocks at the various military test facilities over the last decade. This was certainly not the last time that group-think would become problematic for the space agency.

Quantitative System Safety Programs

In 1958 while NACA engineers were maneuvering to take over research and development as the lead organization in the space race, the USAF was pressing ahead with the successful acquisition programs that had been evolving for the past five decades. The first quantitative system safety analysis effort to address hazard prevention in new designs was initiated with the X-20 Dyna-Soar program. Due to its design criteria to fly beyond the atmosphere, the X-20 was recognized to have unique emergency, rescue, and survival problems. Fulfilling a safety objective that states each person should be allowed to live and work under conditions in which hazards are known and controlled to an acceptable level of potential harm, system safety pioneers such as USAF Colonel George Ruff, of the Ballistics System Division, participated in initiating the first system safety programs required of prime contractors. (Roland & Moriarty, 1983) Unfortunately, NACA management did not learn this during their operational exposure at Edwards AFB. Predictably it was not transferred to their follow-on agency, NASA.

While safety experts struggled with hazards, politicians dealt with their own threats—the budget. That same year, the USAF attempted to invite NACA to join them in the man in space program on either the boost-glide (X-20) or the manned capsule (Mercury) projects. Director Hugh Dryden signed a formal agreement on the boost-glide research while rejecting the offer to join in the capsule option, as they were working on their own designs. This somewhat disingenuous act was self-serving for NACA, and readily points to how the X-20 program was overcome by politics and leapfrogging national priorities. Without doubt, the X-20 program would have escorted system safety concepts into the exploration of outer space, just like those ballistic missile programs managed by DoD. The budget for the X-20 was restricted. Funding waned as the nation embraced the man in a can approach. Ultimately, in December 1963 Secretary of Defense Robert McNamara canceled the project and a majority of USAF/USN participation in the exploration of space (Swenson et al., 1966).

The military services never abandoned their commitment to system safety, and continued to use a system approach as ballistic missile development pressed ahead during the late 1950s and early 1960s. In July 1960, a system safety office was established at the USAF Ballistic Missile Division in Inglewood, California. In April of that year, the USAF had published the first system-wide safety specification titled BSD Exhibit 62-41 (Stephenson, 1991). The Naval Aviation Safety Center was the first to become active in promoting an inter-service system safety specification for aircraft, using BSD Exhibit 62-41 as a model. By 1962, system safety was identified as a contract deliverable item on military contracts and that same year Roger Lockwood held organizational meetings in the Los Angeles area of what would become the System Safety Society—a professional organization incorporated as an international, non-profit organization dedicated to the safety of systems, products, and services. (Stephenson, 1991). By 1964, The University of Southern California had developed a Master's degree program to support industry demands for these specialties. BSD Exhibit 62-41 was broadened in September 1963, as MIL-S-38130, which in 1969 became the model for MIL-STD-882, a standard that has been updated over the years and exists today (USAF, 2000).

Project Management by Trial and Error

The rapid growth of NASA from a research-support agency to that of primary agency and program management for space exploration points to a hazard in itself and offers hindsight into the executive decision to make such a bold move. Almost certainly there was no intent to abandon the successful programs and relationships forged by the USAF/USN and even NACA, but the reality of politics is that once you lose control of the purse strings you often lose input to the direction of a program. Almost immediately discussions between the managing NASA agency and the manufacturer of various components of the ballistic capsule option highlight the lack of understanding and commitment, from the top down, to maintain previously established DoD relationships with the contractors. Debates of semantics broke out and a numbers game was tagged to some of the developmental efforts to quantify various engineering decisions. Some complained that reliability was a slippery word, suggesting more than could be proven. Of course in other endeavors, including aviation and missile acquisition, it had already achieved a recognized discipline as an engineering practice

In mid-1959, well after design and development work on major systems of the Mercury capsule were well under way, a search for a means of predicting failures and increasing reliability was modestly undertaken by NASA's Space Task Group (STG) and McDonnell Aircraft Corporation (MAC) engineers. This paradigm was consistent among other groups working in support, which also had not used formal processes to achieve quality control in various systems and sub-systems. "Mathematical analyses of the word *reliability* both clarified its operational meaning and stirred resistance to [a] statistical approach to quality control" (Swenson et al., 1966, p. 178).

Aviation research and development in the 1950s had witnessed a remarkable growth in the application of statistical quality control to ensure the reliability of various systems. The science of operations analysis and the art of quality had emerged by the end of the 1950s as special vocations. Amazingly, in what can only be viewed as a narcissistic not-invented-here attitude, STG executive engineers overlooked DoD examples and studied new methods for more scientific management of efficiency provided by the automobile industry.

By 1959, when it was finally decided to organize engineering design information and data on component performance, the definition of critical parts had to be established. The STG and MAC worked to create that definition while analysis suffered. NASA HQ sought outside help and USAF systems engineers were used. They pointed to certain semantic problems in the primitive concepts being used for reliability analyses by NASA.

Amazingly, some of the debates centered on questions such as, what constitutes a system, and how should we define failure. An indication of a more mature process was the question, what indices or coefficients best measure overall system performance from subsystem data (Swenson et al., 1966, p. 179).

Indications of the level of resistance to these proven methodologies were the positions taken by some creative engineers who felt the features of reliability prediction were so subjective that many seriously questioned the validity and even the reliability of reliability predictions. One apologist in this field admitted, "Reliability engineering may seem to be more mysticism and black art than ...down-to-earth engineering. In particular, many engineers look on reliability prediction as a kind of space-age astrology in which failure rate tables have been substituted for the zodiac" (Swenson et al., 1966, p. 179).

Although a skeptical attitude did exist within STG, newly arrived Associate Administrator Richard E. Horner brought a staff of mathematicians and statisticians led by Nicholas E. Golovin, who transferred from the USAF to NASA some of the mathematical techniques lending quantitative support to demands for qualitative assurance. NASA HQ and the Langley laboratory worked at cross-purposes for nearly a year as reliability and safety were debated. NASA HQ worked aggressively to align the STG and MAC worked to change their methods. Increasing the level of reliability became a major goal during testing in 1960.

Sorting Wheat from Chaff

Statisticians, and actuaries, working with large and statistically significant amounts of data, have long been able to achieve excellent predictions (as witnessed in the insurance industry's successes) by defining reliability as probability. However, this has never provided the ability to predict what would happen in a specific instance. STG and MAC managers working a specific system or project ridiculed probability theory and continued to reference the numbers game, failing to accept the statistical value of such efforts. They felt that reliability could be demonstrated as ability. Harry Powell, the senior statistician at Space Technology Laboratories for the Atlas weapon system, elaborated on this debate while man-rating the Atlas rocket.

> If reliability is to be truly understood and controlled, then it must be thought of as a device, a physical property which behaves in accordance with certain physical laws. In order to insure that a device will have these physical properties it is necessary to consider it first as a design parameter. In other words, reliability is a property of the equipment, which must be designed into the equipment by the engineers. Reliability cannot be tested into a device and it cannot be inspected into a device; it can only be achieved if it is first designed into a device. Most design engineers are acutely aware that they are under several obligations—to meet schedules, to design their equipment with certain space and weight limitations, and to create a black box (a subsystem)

> which will give certain outputs when certain inputs are fed into it. It is imperative that they also be aware of their obligation to design a device which will in fact perform its required function under operation conditions whenever it is called upon to do so. (Swenson et al., 1966, p.180)

A generally accepted standard in probability theory states the reliability of a system is exactly equal to the product of the reliability of each of its subsystems in series. The obvious way to mitigate risk (a hazard with measured probability multiplied by severity) is to place two mission critical components in parallel to perform the same function. If one system fails, the other assumes the critical function. Redundancy is a favored technique used to ensure reliability.

The MAC production of the Mercury capsule was taking longer to build than forecast primarily as a result of limited system integration within the project. Fuzzy lines of authority and communications without the benefit of the sharing of intelligence across organizational lines of reporting among the various activities involved in the program were hindering an efficient process. Even with these strong indicators of a flawed acquisition management style, STG and MAC felt the basic dispute over safety versus success, or positive versus negative redundancy, could be settled only with actual flight test experience, that is, a fly-fix-fly approach.

A precaution for safety program managers is highlighted by this historical event. Even though safety programs are in place, a lack of standardization and commonality of purpose among line organizations will result in non-effective monitoring, evaluation, and eventually loss of control in safety efforts throughout an organization.

As Project Mercury matured, the costs of solutions to technological and training problems rose. NASA administrators appeared frequently before Congressional oversight committees and admitted their growing concern with manned space flight, as opposed to other space activities. T. K. Glennan requested a supplemental $23 million appropriation to the fiscal year 1960 NASA budget of $500.6 million and justified $19 million of that extra sum on the basis of the urgent technological demands of Project Mercury. "It would be no exaggeration to say that the immediate focus of the U.S. space program is upon this project" (Swenson et al., 1966, p. 180), stated Glennan, waving the national objective in front of those with the purse strings in hand.

In February 1960, at NASA HQ in Washington, a high-level debate over the meticulous versus the statistical approach to reliability was vigorously discussed between NASA HQ, STG, and MAC representatives. They met in conference to decide what weight to give the numbers game in a frank and confidential estimate of readiness. The Chief of Reliability, John C. French, defended STG's practical procedures against the theoretical approach of NASA HQ's Nicholas E. Golovin. Eugene Kunznick also outlined the particulars of the prime contractor's quality control measures, and delivered the third revision of MAC's reliability program. Walter Williams presented STG's latest views on operational flight safety, and STG generally endorsed MAC's reliability program review as its own. At the conclusion of the meeting, NASA HQ was not convinced with the efforts taken by STG and MAC.

> Reliability issues caused scheduling delays and raised eyebrows toward the end of June 1960, when the qualification flight tests had been postponed by at least six months. Capsule system testing needed a completely new process, including organization, procedures, and test equipment. The top technical managers of Project Mercury and STG began to recognize some of their flawed thinking regarding reliability and admitted that quality control and reliability testing had to be raised to a new level. This effort targeted not only man and machine but man-rating (ensuring the equipment is certified safe for humans) and machine-rating (ensuring the human can safety operate the machine) processes as well. (This is consistent with today's 5-M model, which addresses the man, machine, media, management and mission as part of the entire human performance equation in system approaches.) A NASA HQ internal note recorded some of the issues:

> One of the major problems facing Mercury management is the conflict between a real desire to meet schedules and the feeling of need for extensive ground tests. The MAC capsule systems tests are not meeting this need since they were not intended for this purpose and since the pressure of time sometimes forces bypassing of some details (to be caught later at the Cape). Further, there has not been time available (or taken) on the part of MAC to study and update the CST [Capsule System Test] procedures and SEDR's (sic) [Service Engineering Department Report]. It was concluded that a group (mostly MAC effort) should be set up to review and update the CST and SEDR procedures. It is also firm that no details will be bypassed in the Cape checkout without the express approval of STG management (Swenson et al., 1966, p. 258).

Risk management was evolving at NASA. At the highest level within NASA, Administrator Glennan and associates recognized that the opportunity to make significant changes in NASA's organization and procedures would not exist much longer. A report written by a consultant firm McKinsey and Company revealed that NASA's record in supervising out-of-house efforts was spotty. Their findings highlighted that NASA had neglected to manage certain basic prerequisites in their oversight of the various contractors. NASA had failed to provide comprehensive statements of work, sufficient funding, ill-defined tasks, and ineffective contractor supervision, as well as failing to provide properly focused technical responsibilities—a NACA strong suit in previous DoD programs. (A basic problem was NASA's tendency to establish two channels of supervision—one from HQ, the other from the field center.

New Leadership

January 1961 saw a change in the nation's administration and a change at NASA HQ. President-elect Kennedy commissioned an ad hoc committee on space, chaired by Jerome B. Wiesner. The press received the hastily prepared report with mixed reactions.

> Roscoe Drummond, a syndicated columnist... charged that no Kennedy representative had consulted NASA to study the workings of the agency nor had any Kennedy official read or listened to briefings that had been prepared for the new leaders by outgoing Administrator Glennan and his staff. (Swenson et al., 1966, p. 360)

The press was also highly critical of the political transition process, noting that Administrator Glennan had departed from Washington on Inauguration Day, January 20, 1961, with no one named as a successor. In accordance with Washington protocol, Hugh L. Dryden had resigned as well.

The report was tacitly adopted when President Kennedy appointed Jerome Wiesner Chairman of the PSAC for the new administration, although Aviation Week stated that President Kennedy had rejected the committee's advice and decided to accept the risk if the first manned shot failed (Hotz, 1961). This kind of executive decision with full knowledge of a formal risk analysis is certainly within bounds of a system safety program. However, Drummond further charged that no persons representing the Kennedy administration had read or been briefed regarding the workings of NASA as prepared by the outgoing Administrator. This coupled with a superficial review of the workings of such an immense project as Project Mercury is insufficient to adequately allow for an informed decision and absent these kinds of review, accepting risk at this point appears to be more politics than science.

An interesting sidebar to this political intrigue is that the Eisenhower administration's last budget recommendation for manned space flight research and development was to cut $190.1 million from NASA's fiscal 1962 $1.1 billion total budget. The Bureau of the Budget in January allowed a total NASA request of $919.5 million, only $114 million of which was earmarked for manned space flight, including Project Mercury. Some $584 million was requested for military astronautics within the DoD budget that same fiscal year. (Swenson et al., 1966)

On February 2, 1961, Senator Robert S. Kerr, chairman of the Senate Committee on Aeronautical and Space Sciences, presided over the confirmation hearings for a new NASA Administrator. James Edwin Webb, experienced businessman, lawyer, Director of the Bureau of the Budget, and Under Secretary of the Department of State from 1949 to 1951, who had also served as a director of MAC. Armed with a resume full of bureaucratic qualifications, Mr. Webb certainly had a technical challenge facing him. It was felt that even though his background was not that of a scientist, he was widely known in governmental and industrial circles for having worked with scientists and engineers. From history's recordings, one can feel safe in presuming that during Mr. Webb's stint at MAC he was not exposed to a comprehensive background in system safety management. The Senate confirmed Webb's nomination after he severed all his business connections with MAC.

Even as NASA struggled to launch unmanned test vehicles, it was apparent Project Mercury's ends were merely a means to the greater goal of landing on the Moon. The funding for Project Apollo was under review in Congress as U.S.S.R. Major Yuri Gagarin's flight provided a tremendous impetus to the desires of Americans to continue the race that was now officially a race. Congress appeared willing to appropriate more money than NASA could spend. Robert Seamans, third in command of NASA as Associate Administrator and general manager, actually had difficulty restraining the House space committee's demands for an all-out crash program for a lunar landing. President Kennedy, consistent with one of his campaign promises, reacted to the U.S.S.R.'s manned orbit of earth by saying, "We are behind...the news will be worse before it is better, and it will be some time before we catch up (Swenson et al., 1966, p. 336)."

On March 9, 1961, Representative Overton Brooks wrote to President Kennedy regarding reports in trade journals that the space program might turn toward military oversight. Representative Brooks was concerned the Wiesner report pointed to this as he was also aware of a special PSAC investigating committee of scientists led by Donald F. Hornig. This committee was conducting a top down review of the manned space program. In his letter, Brooks reminded President Kennedy of the spirit and intent of the 1958 Space Act which was to:

> Ensure that control of space research remain in civilian hands so that resulting information and technological applications would be open for the benefit of all enterprise, both private and public. [Further,] too much information would become classified if the military were preeminent in space research, development, and exploration. (Swenson et al., 1966, p. 325)

President Kennedy gave reassurance that NASA's conduct of space exploration would not be placed subordinate to the military. For better or worse the marriage of the neophyte NASA management team and space exploration was now consummated.

Project Mercury Lessons Learned

Project Mercury lasted 55 months, from authorization through Gordon Cooper's final MA-9 mission. The earliest planned orbital mission ran 22 months past its originally scheduled launch date and achieved its original objectives (placing a man in low-earth orbit) with John Glenn's MA-6 flight 40 months after formal project approval. From some perspectives this was a good record compared to advanced missile or aircraft development programs, however there were critics who denied the validity of such a comparison given the national priority and virtually limitless funds made available for Project Mercury.

On October 3-4, 1963, NASA and the Manned Spacecraft Center (MSC) held a gala affair in Houston, Texas, called the Mercury Summary Conference. They covered program management, mission performance, astronaut preparation, network operations, and the most recent successes of the MA-9 experiments. Much to NASA's chagrin, along with the official press releases came another document publicly released by four MSC engineers. They outlined procedures following delivery of the MA-9 capsule and necessary actions prior to launch. The authors spoke of quality assurance and component defects found by processes designed to prevent errant components from being installed in various systems. These inspections had produced approximately 720 system or component discrepancies; 536 attributed to faulty workmanship, in the MA-9 mission alone! The unofficial engineer's release stated:

> Thousands of man-hours were expended in testing, calibration, assembly, and installation of a variety of hardware that later failed to meet performance specifications or that malfunctioned during systems tests in a simulated space environment... [Unnecessary delays could have been avoided if] adequate attention to detail during manufacture or thorough inspection before delivery had been exercised. (Swenson et al., 1966, p. 507)

The history of Mercury spacecraft system acquisition presented a good object lesson in how not to manage a major program. The tone of the public relations coming from NASA was to attack the industry, failing to see their role in the oversight of those contractors. The Government Accounting Office was criticizing NASA and fueling attacks on the upcoming great *moondoggle*, as it was irreverently being called. NASA failed to recognize exactly what had gone wrong.

Post Project Mercury Lessons Learned

The effort to place man in orbit required 12 prime contractors, 75 major subcontractors, and approximately 7,200 sub-subcontractors. NASA employed approximately 650 workers from STG and 710 from MSC and, conservatively, 18,000 DoD personnel supporting each individual Project Mercury mission. The scope of managing the total manpower figure of approximately 2,020,528 highlights the difficulties facing project managers. Knowing what is known today about the management techniques employed by NASA in this conquest it certainly becomes easy to see why the program ran behind schedule and over budget.

Total cost estimates of Project Mercury, delivered in October 1963, show that Project Mercury "had cost $384,131,000 throughout the program, of which 37% went for the spacecraft, 33% for the tracking network, and 24% for launch vehicle procurement" (Swenson et al., 1966, p. 508). Flight operations, research and development costs made up the remainder. The co-mingling of Project Mercury and Project Gemini costs during 1962 and 1963 complicated the final cost accounting. It is generally agreed that through MA-9 NASA estimated the total costs of Project Mercury at roughly $400 million, not considering the hundreds of millions spent by DoD in space research with NACA/NASA contracts.

NASA engineers and physicians listed three primary lessons learned for manned space flight from their experience with Project Mercury. Their medical objectives had been fulfilled through demonstrations that human beings could function normally in space if adequately protected. The X-15 missions had also demonstrated most of this knowledge. The main medical problems to be addressed were simple personal hygiene in flight

Second, Project Mercury had also demonstrated that launch preparations were highly time consuming in an effort to ensure readiness and reliability of both the machines and men (the holistic system). NASA subsequently designed an automated digital system, Acceptance Checkout Equipment, to reduce human error in testing and the time required on the flight line.

Third, mission control requirements had grown to encompass real-time telemetry, tracking, computing, and data display systems. Two more controlling agencies came into being. One was the new Mission Control Center at Houston. The other was the Ground Operational Support Systems, both new organizations reflecting the degree of complex system integration and automation being installed for positive ground control of future space flights. (Swenson et al., 1966).

It appears that the most valuable lessons learned may have been listed in the other section of the report. In the internal reviews on improving their performance for succeeding programs, NASA management spoke of other valuable technological and managerial lessons from Project Mercury. In system design they had encountered problems with safety margins, redundancy, accessibility, interchangeability, and with materials whose behavior under unfamiliar environmental conditions had not been wholly predictable. Regarding qualification of systems and components, they believed there should be more analysis in an effort to make techniques conservative, complete, integrated, and functional. Fabrication and inspection standards carried over from development into manufacturing work should be made still more rigorous, detailed, current, and enforced. Engineers called for continuous upgrading of tests, inspections, and other validation procedures, particularly with respect to interface compatibilities between systems. In configuration control, NASA developers recognized weight control problems and their need to become more responsive and aware of leading indicators in the production and fabrication phases. The managers of Project Mercury now acknowledged, "that methods of management that had worked well enough in the first American manned space project would not suit Gemini and Apollo, already in motion" (Swenson et al., 1966, p. 509).

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Articles

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