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The words Aviation Education signify a multiplicity of scholarly research, applications, and operations. Aviation programs encompass the development of skills ranging from the technical to those of human interaction and decision-making. Such diversity strengthens the discipline and reflects the various demands of the industry. This diversity is recognized in the 1990 conference proceedings.

Each of the published competitive papers reflects a segment of the aviation education community. Topics, styles, and methodologies vary with the parameters of the subject area and the interests of individual members and their institutions.

The 1990 University Aviation Association Fall Conference Proceedings is the result of a competitive process. Each published paper has been blind-reviewed by at least three peer-evaluators chosen for their expertise. These reviewers remain "silent" yet essential partners who deserve special thanks for their careful and thorough efforts during the summer months.

I would like to thank everyone--authors, reviewers, and staff--who has helped to make this a successful year.

Sincerely,

C. Elaine McCoy

C. Elaine McCoy, Ph. D.
Chair, Publication Committee

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MEASUREMENT OF PARTICIPATION LEVELS OF WOMEN AND MINORITIES AS COLLEGIATE AVIATION EDUCATORS

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ABSTRACT

This study analyzes U.S. Department of Education statistics on women and minorities in higher education and data on Federal Aviation Administration (FAA) certificate holders. This data is then compared to data obtained on aviation faculty in higher education to establish whether or not women and minorities are under represented in the collegiate aviation faculty.

The data collected demonstrates that the participation of women in the aviation faculty is representative of the participation of women in aviation overall. The fact that women comprise only 6.09 percent of all FAA certificated pilots demonstrates that they are as a group, under represented in aviation in relation to their proportion in society.

Minority participation in the collegiate aviation faculty is also unrepresentative of the minority population in the United States. FAA certificate data is not maintained on ethnicity. However, data obtained on minority participation in the aviation faculty is compared to data on minority participation in higher education. The resulting fact is that minority involvement in the aviation faculty is below average in relation to the overall faculty population.

This research effort confirms the assumption that women and minorities are not adequately represented in the collegiate aviation faculty. The resulting call to action must be to increase the participation levels of women and minorities as collegiate aviation educators.

INTRODUCTION

American society has made some progress in accepting women and minorities in the work place. Successes are visible in many careers. Achievement is evident in all. However, encouragement for women and minorities to participate in aviation has not paralleled these successes.

The history of women and minorities in aviation exemplifies significant contributions too numerous to detail within the scope of this study. However, the time has come to consider the accomplishments that could have been achieved if women and minorities had been fully enfranchised into the field of aviation. This problem is especially evident among the ranks of pilots and those who educate pilots.

American Demographics (Nov. 1989) describes the phenomena of under representation by women as a "demographic wild card" which can be utilized to put more pilots in the sky. The successes which women and minorities have had in other fields has allowed increased access to flight careers.

The opportunity to become a professional aviator has never been more accessible than now. The General Aviation Task Force reports that flight instruction increased 12.5 percent in 1989. Student pilot starts in September 1989 were 10,153 compared to 7,624 the preceding year (More Student Pilots, 1990). This influx may be attributed to the widespread news that more than one-half of all airline captains will reach mandatory retirement age before the year 2000. Combine this with the fact that military pilot attrition rates have slowed to record lows and thus the career potential becomes obvious.

The material presented here is of a narrow focus to the overall problem of under representation of women and minorities in aviation. Although, this endeavor will be successful if it allows any improvement in the awareness of this problem and, consequently, addresses even one aspect of its solution.

WHY ARE WOMEN UNDER REPRESENTED IN AVIATION

Under representation in aviation by women is generally agreed to be synonymous with that of other careers which have been nontraditional for women. The FAA is circulating a monograph titled Women in Aviation and Space written by Dr. Sandra Flowers of the Alabama Aviation and Technical College which addresses this question. Possible reasons for under representation, as suggested by Dr. Flowers, are as follows:

1. Cultural and psychological barriers to nontraditional work are imposed on women, not only by society, but by

women themselves.
2. Women have not received the necessary information and training they need to prepare for nontraditional careers.
3. Nontraditional role models are few in number and are not readily available to girls and women.
4. The lack of support from family and peers negatively affects nontraditional career options for women.
5. Sex-role stereotyping in all types of media precludes an environment which supports nontraditional career choices and role models.

This clearly establishes the basis for concern. Defining the problem of under representation is certainly as complex as determining the solution. Neither can be appropriately addressed in the brevity of this forum. However, the analysis of the data to be presented may foster a greater understanding which may lead to a solution to some aspect of this problem.

MINORITY REPRESENTATION IN AVIATION

The participation of minorities in aviation is difficult to gauge. The FAA does not gather data on the ethnic background of certificate holders (Beardsley, 1990). This fact complicates the measurement of minority representation in aviation and consequently prevents the identification of success and failure. However, it is generally accepted that minorities are under represented in aviation.

The FAA recently released a publication titled, The Historically Black Colleges and Universities Program. Through this program the FAA plans to encourage and support minority participation in aviation. To facilitate this endeavor the FAA will encourage minority participation in the Airway Science Curriculum Program, Research Contract Opportunities, and Training and Internship Programs.

Comparison between two airline pilot professional organizations may offer an indication of minority participation within commercial aviation. The organization which represents airline pilots is the Air Line Pilot's Association. This organization has a reported membership of 42,000 (Mazor, 1990). The organization representing black airline pilots, the Organization of Black Airline Pilots, reports a membership of 650 (Hadden, 1990).

STUDY DESIGN

The principal objective of this report is to determine the level of participation of women and minorities in the non-engineering aviation faculty. Data will be analyzed to determine the potential similarity between the number of women pilots and the number of women faculty in colleges and universities which offer a baccalaureate degree in aviation. This analysis is not possible with the minority population because the FAA does not maintain certificate data categorized by ethnicity. However, data obtained on the number of women and minority faculty in aviation will be analyzed against data on the number of women and minorities receiving earned doctorates in aviation related fields.

Secondary data was obtained from two sources. Data on the number of women who are pilots was obtained from the FAA which publishes an annual summary of pilot demographics titled U.S. Civil Airmen Statistics. The data on women and minorities receiving doctoral degrees is periodically collected by the U.S. Department of Education. This information is reported annually in The Chronicle of Higher Education Almanac and the Digest of Education Statistics. These sources can be regularly reviewed to monitor the progress toward achieving proportional representation for women and minorities in both of these areas.

Primary data on women and minority faculty in collegiate aviation programs was obtained through a survey of baccalaureate degree granting institutions listed in the Collegiate Aviation Directory 1989. Each of the sixty-nine institutions which cited baccalaureate degree programs were contacted and asked to report the number of full-time faculty which teach aviation courses distinguishing the total number of males, the total number of females, and the total number of minorities. Sixty-five of sixty-nine institutions responded for a response rate of 94 percent.

PRESENTATION OF DATA

Women. Analysis of the change in the percentage of pilots who are women from 1978 to 1988 may offer a brief historical perspective. Table 1 will compare the ratios of female to male FAA pilot certificate holders from 1978 to 1988. This information is not released by the FAA until June 30th of the following year and distributed by the Government Printing Office later in the year. Consequently, 1988 information is the most recent data which may be evaluated.

Table 1

Total FAA Certificated Pilots

1978

	Certificates Held	Percentage
Female	49,874	6.25%
Male	748,959	93.75%
Total	798,833	100.00%

1988

	Certificates Held	Percentage
Female	42,297	6.09%
Male	651,717	93.91%
Total	694,016	100.00%

Source. U.S. Civil Airmen Statistics.

While the last ten years have seen advances in opportunities available to women, progress has not been evidenced in all piloting careers. Table 2 provides a detailed distribution of each FAA certificate category by gender. Both non-flight and flight categories are presented. A comparison between the current data and that from ten years previous is rendered.

Table 2

Female FAA Certificate Holders

Category	1978	1988
Student	26,354	17,529
Private	19,147	17,544
Commercial	3,306	4,410
ATP	270	1,745
FE	82	822
CFI	1,458	3,018
A&P	597	2,565

Source. U.S. Civil Airmen Statistics.

Although percentages of certificated women pilots are widely disproportionate, higher education is one area where women are experiencing gains toward achieving a proportionate role. One U.S. Department of Education report states that "women will be earning more doctoral degrees than men by the year 2000." (Projections, 1989). Table 3 shows the current gender distribution of women in the higher education faculty. A comparison is offered between private and public institutions.

Table 3

Faculty Distribution by Gender

	Female %	Male %	
Public	28.1	71.9	(100%)
Private	27.9	72.1	(100%)
Median	28.0	72.0	(100%)

Source. The Chronicle of Higher Education Almanac 1989.

Most fields within higher education are experiencing gains in the number of women who are receiving doctoral degrees. Within the discipline of education, this figure has surpassed 50 percent. Since there are no doctoral degrees solely devoted to aviation aside from aerospace engineering, Table 4 illustrates the number of women receiving doctoral degrees in fields related to aviation.

Table 4

Percentage of Women Receiving Doctorates in Aviation Related Fields

Business	23.4
Education	55.1
Engineering	6.5
Median All Fields	35.2

Source. The Chronicle of Higher Education Almanac 1989.

The final data to be presented on the demographics of the women faculty are the results from a survey of the 69 baccalaureate-level aviation education programs which was previously described. The information obtained through the survey offers two new sets of descriptive data about the status of these programs. First, it provides a measurement of the overall size of the faculty in baccalaureate-level aviation institutions. Secondly, the data provides the gender distribution of that group of faculty. The information provided in Table 5 describes the gender distribution of aviation faculty.

Table 5

Gender Distribution of Aviation Faculty

Gender	Number	Percentage
Female	25	(5.2%)
Male	456	(94.8%)
Total	481	(100.0%)

March 1990.

Minorities. Truly unfortunate is the fact that pilot certification data is not maintained by ethnic origin. If this data were available, analysis of minority participation in aviation fields requiring FAA certification could be measured and evaluated. Without this data, analysis of minority participation in the higher education aviation faculty will be compared to minority participation in the overall higher education faculty. Table 6 displays the distribution of the higher education faculty by minority and majority ethnic group.

Table 6

Faculty Distribution by
Minority/Majority Ethnic Group

Group	Number	Percentage
Majority	417,036	(89.9%)
Minority	47,036	(10.1%)
Total	464,072	(100.0%)

Source. Digest of Education Statistics 1989.

As previously explained, there are no doctoral degree programs exclusively oriented toward aerospace studies at the present time. Therefore, Table 7 will present the percentage of minorities receiving doctorates in aviation related fields.

Table 7

Percentage of Minorities Receiving
Doctorates in Aviation Related Fields

Business	8.3
Education	11.9
Engineering	8.8
Median All Fields	8.8

Source. Digest of Education Statistics 1989.

Table 8 describes the current state of minority representation in the aviation faculty. This information was gathered through the previously described study of 69 baccalaureate degree granting institutions with aviation education programs. The significance of this demographic data arises from the fact that a benchmark has now been established from which to measure future progress in the encouragement of minorities to become collegiate aviation educators.

Table 8

Minority Representation in the Aviation Faculty

Group	Number	Percentage
Minority	38	(8.0%)
Non-Minority	443	(92.0%)
Total	481	(100.0%)

March 1990.

CONCLUDING DATA OBSERVATIONS

Women. Having discovered that only 5.2 percent of the collegiate aviation faculty consists of women, the question of why must be considered. After reviewing Table 3 which shows faculty distribution by gender, we can see that the percentage of overall faculty which are women (28%) is not relational to the percentage of aviation faculty which are women (5.2%). This fact demonstrates that the aviation faculty is not representative of the national norm with respect to the percentage of faculty which are women.

Table 4, which exhibits data on the percentage of women receiving doctorates in aviation related fields, does not have a median (35.2%) which corresponds with the percentage of aviation faculty that are women (5.2%). However, the field of engineering which has a percentage of 6.5 percent of earned doctorate recipients being women is close to the percentage of women in the aviation faculty (5.2%). Since aviation is perceived to be a high technology field, it could be possible that these two figures have a relational tie.

Another comparison of research data is that between the percentage of women aviation faculty and the percentage of women who are pilots. Table 1 presents the fact that 6.09 percent of FAA certificated pilots in 1988 were women. When you compare this with the fact that 5.2 percent of aviation faculty are women (Table 5) an obvious relationship can be seen. The percentage of women faculty and women pilots is very similar. This bit of data may suggest that women faculty in higher education is representative of the demonstrated interest that women have in aviation. If so, it could be stated that the problem is not only that women are under represented in the aviation faculty ranks, but the problem is that women are under represented in aviation as a whole.

Another figure which offers significant correlation to the percentage of women faculty and overall women pilots is the percentage of women who are Certified Flight Instructors. In 1988 the U.S. Civil Airmen Statistics reported that 5 percent of FAA Certified Flight Instructors were women. Being close to the 5.2 percent of women aviation faculty figure may indicate a correlation. The basis for this relationship could be reasoned through the fact that the Certified Flight Instructor rating is held by those who become pilot educators. Furthermore, the Flight Instructor certificate acts as the terminal flight rating for most aviation educators.

Minorities. The median level of minority participation in the higher education faculty was shown in Table 6 to be 10.1 percent. This figure exceeds the current median of minorities receiving doctorates in all fields of higher education, 8.8 percent (Table 7). This fact should be of concern as we strive to achieve a greater level of participation by minorities in higher education. Two aviation related fields are experiencing a slightly above average participation by minorities. The fields are education (11.9%) and engineering (9.4%), as exhibited in Table 7.

Data presented in Table 8 measured the level of participation of minorities who are collegiate aviation educators as 8.0 percent. This figure represents 38 of 481 individuals. Consequently, the fact can be observed that collegiate aviation education is below the national norm of 8.8 percent in minority participation in higher education. This difference is significant in that striving to meet the national norm would still demonstrate an under representation of minorities in the population of collegiate aviation educators.

RECOMMENDATIONS: A CALL TO ACTION

Concern for the under representation of women and minorities in the aviation faculty of higher education is overshadowed by concern for the under representation of women and minorities in all of aviation. Hopefully, the data presented within this study provides recognition that the participation levels of women and minorities in the aviation faculty is inadequate and must be challenged. The resulting call to action must be to take all possible steps to increase the number of women and minority ranks of collegiate aviation educators.

The recommendations offered are not comprehensive toward the solution of the problem considered herein. However, they should offer insight toward a starting point for the solution of the problem of under representation by women and minorities in the collegiate aviation faculty. They are as follow: (1) Recruit women and minority aviation faculty to foster role models. (2) Increase the number of women and minority aviation students. (3) Work toward a means to facilitate more women and minorities to become pilots. (4) Solicit assistance from women and minority aviation organizations. (5) Encourage the aviation industry to hire more women and minorities. (6) Decrease stereotypical barriers to aviation which face women and minorities. (7) Synthesize the aviation public to the problem. (8) Develop more coordinated graduate programs in aviation.

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A COMPARISON OF FIXED BASE/PC-BASED SIMULATORS WITH TRADITIONAL MOVEABLE PLATFORM FLIGHT SIMULATORS AS A TOOL FOR TEACHING PRIVATE PILOTS RADIO NAVIGATION AND BASIC ATTITUDE INSTRUMENT FLYING SKILLS

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ABSTRACT

In flight training, attention has been focused on the useability of flight training devices. In the past such devices as the GAT-1 trainer were used. The recent development of small, inexpensive computers has resulted in the creation of smaller fixed-based devices. Further, the development of the personal computer has made it possible for all pilots and flight students to own their own computers. Software is available for the training of flight students using these devices. Unfortunately the use of PC-based devices by pilots for flight training has been restricted by the Federal Aviation Administration because of their concern about the type of software that is available and its training value. However, the use of PC-based training devices may well be a means of reducing the cost of flight training. Can these fixed-base and personal computer-based training devices be used as effectively as the GAT-1 trainer?

The intent of the study was to evaluate the capabilities of three types of flight training devices. The study compared the ability of the three trainers to teach the skills required for Private Pilot operations. The results indicated that their were no significant differences in the means. The results also showed that the PC-XT-based Novel Twist and the Frasca had a higher absolute mean than the GAT-1 Trainer and that the Novel Twist had the highest mean.

Results from the study show that the new generation of general aviation flight training devices can provide the BAI/Radio Navigation training required for Private Pilot applicants. Further, the analysis of the results suggest that additional studies should be completed to (1) verify the tabulated results, (2) determine why the computer-driven simulators rated higher than the traditional GAT-1 trainer, and (3) determine the full capabilities of PC-based desktop simulators.

INTRODUCTION

An integral part of any Private Pilot flight curriculum includes a segment that teaches a student how to fly by reference to instruments, and also how to utilize basic radio navigation techniques. Traditionally this segment of the course has been taught in either the airplane used for training or a flight simulator such as the GAT-1 Link trainer. These devices are no longer mechanically suitable or desirable. Can computer-based devices such as those utilized by the airlines be used instead? Unfortunately, these are rather expensive. Some simulator builders such as Frasca offer generic training devices in the $50-60,000 price range, also somewhat price prohibitive. Other possibilities include PC-based devices. which are inexpensive and have multiple application possibilities. If the PC-based training devices can be used, they may reduce the cost of flight training considerably.

Simulators have been present in flight training since before WW II. A concerted effort to use simulators for flight training was made by the major airlines and military in the 1940s and 50s to help reduce training costs. General aviation operators which have utilized some form of flight simulator since the 1950s unfortunately do not have the resources to afford the kind of simulators developed for military and airline operations. These devices often cost $3-18 million. Instead, a small segment of the simulator industry has developed generic flight training devices that typically range in price from $4,000 to $60,000.

The introduction of personal computers within the past ten years has accelerated the applications of microprocessor technology to the point where it is now possible for a personal computer to have the processing power of a minicomputer. The result has been the development of several successful generic training devices. While the FAA has seen fit to condone the introduction and development of microcomputer fixed-base training devices, they have not yet approved PC-based systems.

Background

Numerous previous studies have shown that simulators are effective as instrument trainers and that the transfer of training from simulators to aircraft is high. These studies have proved the concept and ability of trainers such as the GAT-1 trainer to replicate and reduce flight training time. Examples of research using these devices can be found in the proceedings of numerous aviation symposiums (Jensen 1987). Further evidence to support the concept and value of simulation training can be found in the FAA's recent authorization to allow airlines to train and check out air crews solely in a simulator. These simulators, however, are very costly, typically in the $3-18 million range, well beyond the capabilities of any primary flight training institution. In general, simulators are used to reduce training costs and to provide total control while providing an inherently safe learning environment (Gebhard 1983).

Some simulator developers, including Frasca, have developed affordable generic general aviation trainers. These trainers are fixed base and capable of simulating flight situations and conditions without motion through the use of microprocessor technology. Such simulators have control panels and radios that come as close as possible to those found in aircraft. Based on studies conducted by their own researchers, Frasca claims that if properly used the "transfer of training can result in 100 per cent transfer in many tasks. cutting total flying time by as much as 50 per cent" (Lombardo 1985:23-24).

Most simulators in use today use some form of computer technology to replicate flight situations. The recent development of personal computers that are within the budget of general aviation suggests that PCs, if properly used, could be utilized to supplement and replace some of the training currently being done in the mid-range flight simulators. There is some empirical evidence to suggest and support the training effectiveness of microcomputer-based technology in task simulation contexts. This was demonstrated by Poleman and Edwards (1983) who showed that a computer-aided, two-dimensional graphics simulator can be superior to material presented in illustrated textual material in the transfer of cockpit procedural skills.

Unfortunately few if any studies have been conducted to evaluate the capabilities of personal computers as flight training devices. Searches of numerous databases unfortunately were unable to provide any meaningful literature.

Purpose

The intent of the study was (1) to determine whether the current generation of microcomputer fixed-base simulators can replicate and provide a level of transfer of training comparable to trainers developed and used in the 1960s and 70s, and (2) to evaluate the capabilities of personal computers to provide the same level of training.

The study was limited to evaluating the capabilities of the training devices. No attempt was made to determine the various reasons for the differences, if any, in the outcomes. The study was further limited to the skills taught to Private Pilot applicants

The hypotheses for the study are as follows:

1) There are no differences among the outcomes of students taught in the GAT-1, Frasca, and Novel Twist.

2) The Frasca and Novel Twist can provide the BAI/Radio Navigation training that is required for Private Pilot applicants to the same standard as the GAT-1.

METHOD

Subjects and Instructors

Thirty subjects were randomly selected from among Aeronautical Science students enrolled in FA 105-2 . FA 105-2 is the second in a series of five courses leading to Commercial Pilot certification. Successful completion of FA 105-2 means that the student is eligible for Private Pilot certification. All of the thirty subjects held student pilot certificates.

The subjects all had completed FA 104 (the pre-solo flight course), and Lesson 3 of FA 105-2. Each student had approximately the same amount of flight experience. The subjects were randomly assigned in groups of ten to either the control Group A, or one of two experimental groups, Group B and Group C.

All of the flight instructors who volunteered to participate in the research project had approximately the same amount of training experience, between six to twelve months. The students were randomly assigned to the instructors with an attempt to ensure that each instructor taught the same number of students in each simulator.

Procedure

The experimental design compared the effectiveness of two types of low-cost simulators with a control group utilizing a standard General Aviation Trainer. The subjects were evaluated prior to and after completion of the training.

To ensure that the subjects had achieved the same standard and training experience prior to being accepted for the experiment, each student was required to have successfully completed Lesson 3 of FA 105-2, the Private Pilot Certification course at E-RAU. The study required that each group received the same instruction in Basic Attitude Instrument Flying and Basic Radio Navigation. Each subject received the same amount of flight instruction and evaluation time. The two experimental groups (A and B) received an additional .5 hr of instruction in the GAT-1 prior to evaluation for orientation purposes prior to testing. The post-test performance evaluation of all three groups was conducted in a GAT-1 trainer.

The control group, Group A, was taught in a Singer-Link General Aviation (GAT-1) Trainer. The GAT is a two-axis simulator with a movable pedestal. The flight panel replicates a generic aviation trainer, with movable controls and flight instruments. Navigation is provided by two nav/com radios. The simulator provided no visual depiction.

Experimental Group B was taught in a Frasca 141. The Frasca 141 is a fixed-axis. computer-based simulator. Input to the computer and flight instruments uses digital electronics. The flight panel of the simulator replicates a generic general aviation aircraft. Navigation is provided by two nav/com radios. No visual simulation was provided.

Experimental Group C was taught utilizing an IBM PC-XT computer with an RGB color monitor. The PC-XT was integrated with a Novel Twist Cockpit Procedure Trainer (CPT). Software was provided by the Instrument Flight Trainer, a program from Flight Deck Software. The face of the CPT controls radio frequencies, position of flaps, gear, trim, and cockpit view by touch pads. Pushing the pads results in changes seen on the computer monitor. A manual yoke and throttle control are used to change attitude and power. The PC receives its information from the cockpit procedure trainer, which in turn displays it on the monitor. Visual depiction was provided.

All three groups were required to perform maneuvers in ten areas. They were as follows: (1) Four Fundamentals, (2) VOR Orientation, (3) VOR Tracking, (4) VOR Station Passage, (5) NDB Orientation, (6) NDB Homing, (7) NDB Station Passage, (8) Signal Loss, (9) Recovery from Unusual Attitudes, and (10) Emergency Climbs and Descents.

The students were graded using a standard alphabetical system, "A"-"F", with the grade "A" representing the highest possible grade and "F" the lowest. The grades were then transferred to a numbering scale: an "A" equals a value of 4; a "B", 3; a "C", 2; a "D" 1; and an "F", 0.

To determine the effectiveness of each of the flight training devices, an ANOVA was used to evaluate the combined means of the three groups for all ten skill areas at the .05 level of confidence. An IBM-compatible statistical package was used to obtain the results (Doane: 1985).

RESULTS

The results indicate that the two experimental groups did as well as or surpassed the level of training of the control group in the GAT-1 trainer. The hypotheses, therefore, cannot be rejected. The results are presented in the following tables.

Presentation of results

The sample sizes in all of the groups remain the same at 10. The first two tables represent the overall result of all ten combined skills. The mean represents the total combined mean average of a particular group, "A", "B", or "C" in all ten areas (see Table 1).

TABLE 1

Mean Overall Standard Deviation and the Sample Size
for Groups A, B, and C

Group	Mean	Standard Deviation	N
A	27.7	3.400982	10
B	29.9	5.152134	10
C	32.5	3.922868	10
Overall:	30.03	4.537077	30

The mean average was 27.7 for group "A", 29.9 for group "B", and 32.5 for group "C". The second table shows the results of an ANOVA evaluating the means of the three groups.

TABLE 2

ANOVA Table Indicating the Overall Degrees of Freedom
and the Computed Value of F

Source	Sum of Squares	Degrees of Freedom	Variance
Between:	115.4668	2	57.7334
Within:	481.5	27	17.83333
Total:	596.9668	29	20.58506
Compute F = 3.237 with d.f. = 2 and 27			

Based on the results from the sample, the null hypothesis cannot be rejected since the calculated F value is 3.237, which is less than the critical F value of 3.49.

DISCUSSION

Interpretation and Conclusions

Overall there are no significant differences between the combined means of the three groups in the ten skill areas evaluated. Further investigation was suggested, however, because of the closeness of the computed F value 3.237 to the critical F value of 3.49. Therefore, an additional ANOVA was conducted between the combined means in each group for each of the ten skills being investigated.

The results showed that in one area the critical F value was exceeded: NDB Homing, which had an F value of 5.771. Further investigation using a Tukey (TSD) test into the reasons for the significant difference was therefore warranted. The investigation indicated that the mean for the level of training for NDB Homing in the GAT-1 was significantly lower than that in the Frasca or Novel Twist. However, because of the repeated use of the same data, the chances for a type 1 error had increased to 10% at the .01 significance level. Therefore, I am reluctant to report any firm results or conclusions.

There are several possible reasons for the results which indicate that the Frasca and Novel Twist are capable of providing equal or better training than the Singer Link GAT-1 in the areas evaluated. These are discussed below. It is possible that the level and standard of training are dependent more on the quality of instruction than on the machine. This is exemplified by the results of the Novel Twist, a machine costing considerably less than either of the other two. Another is the apparent ease of use: both the Frasca and Novel Twist were reported to be more versatile than the GAT-1. Further, the instructors indicated that it was easier to evaluate and debrief the students using the additional functions that use of a computer afforded them. Other reported advantages included the observation that both the Frasca and Novel Twist were able to replicate the airspace with which the students were familiar. The instructors were particularly impressed by the ease with which the computer-based machines were able to repeat a phase of flight in which the students were having trouble.

One area of concern that the instructors reported was the apparently slow speed at which the PC-XT machine was able to show changes in flight attitudes. Several instructors indicated that the "jerky movement" of the monitor picture made the simulation quality less than desirable. Use of a faster processor with an EGA or VGA monitor may resolve this problem.

Following the investigation and evaluation of the results, it is apparent that the new generation of fixed-base computer-driven flight training devices can provide a high level of instrument flight training at the Private Pilot level. Further, the results indicate that desk top simulators using a personal computer can also replicate the training required for a Private Pilot flight student and may also be suitable for training Instrument Pilot applicants.

The use of a PC-based simulator such as the Novel Twist would result in considerably lower costs per flight simulator hour. A possible result of the reduction in student training costs may well be an increase in the numbers of students taking flight training. Further, for those students with PCs at home, the device would allow them the opportunity to better prepare for activities in the simulator or aircraft and to replay flights completed. The training operator's PCs could also be used for purposes other than flight training, such as bookkeeping, FAA computerized testing, and maintenance of flight training records. Unfortunately one drawback to the use of the PC-based systems is that the FAA does not currently approve the use of these flight training devices; therefore, students cannot log the training time towards their Private or Commercial Certificate, and Instrument rating.

Recommendations

Based on the interpretation and conclusions five specific recommendations are made:

1) That an additional enlarged study should be conducted to verify the results.

2) That a study should be conducted to determine the reasons for the superiority of the Frasca and Novel Twist.

3) That a study be conducted to evaluate the effect of the role that the quality of flight instruction has on simulator training.

Because the use of a PC-based flight training device for flight training is not approved by the FAA, it is suggested that the following course of action may be appropriate:

4) That a study be conducted to evaluate the full capabilities of the PC-based flight training device both for Instrument Training and for maintaining Instrument currency by Instrument pilots.

5) That an additional study be conducted to determine the level of the transfer of training from the PC-based training device to an aircraft.

6) That the above studies be done using a 286- or 386-based PC, with at least an EGA monitor to enhance the speed, and the quality of resolution on the PC monitor.

7) That the FAA should fund the necessary research to establish the appropriate criteria needed to certify the use of PC-based flight training devices.

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PERCEPTIONS OF UNIVERSITY AVIATION ASSOCIATION MEMBERS CONCERNING SCHOLARLY WRITING AND PUBLICATION

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Abstract

This research study was an investigation of the perceptions of University Aviation Associations (UAA) members as to the availability and suitability of various publications sources. The publication sources in question were those that are considered by the academic community as scholarly in nature such as textbooks, research reports, journal articles, and manuals. A survey instrument was developed as a data gathering tool for the study. The survey instrument was sent to 106 members of the UAA; seventy-six percent were returned. Questions contained in the survey instrument asked the respondent to indicate the importance of scholarly writing at their institutions, their academic qualifications, and to provide information relative to whether there were sufficient outlets for scholarly writing. The respondents indicated that scholarly writing was important at their institutions and that sufficient publication sources were not available. In addition, respondents indicated that scholarly writing affected decisions on retention, promotion, tenure, and merit.

Background

"It is one of the noblest duties of a university to advance knowledge, and to diffuse it not merely among those who can attend the daily lectures - but far and wide. Daniel Coit Gilman, 1878" (Hawes, 1967, i).

Aeronautical science programs on college and university campuses in all parts of the country have become one of the most demanding and exciting of the new professions. Although established majors have existed on several campuses for many years, it has not been until the past decade that most aviation programs have emerged and become academically viable. However, "...one of the most difficult challenges that we face in collegiate aviation is that of convincing our colleagues in traditional academic disciplines of the academic validity of aviation education" (Isaacson, 1983, p. 6). Additionally, as collegiate aviation programs have grown, matured, and achieved increased visibility and vitality in academe, concerns have been expressed by certain accreditation associations as to the academic viability of such egalitarian programs.

A closely related component of the same concern appears to be the scholarly productivity of aviation faculty members at some institutions. The traditional collegiate benchmarks for faculty employment, retention, merit, and promotion have changed little over the years. The three areas most often considered in such decisions are teaching, service, and scholarly productivity in the form of research and writing. A common metaphor relative to the importance of scholarly productivity has been simply "publish or perish." However, the sole act of authorship is often not the primary question; the key component appears to be publishing in both a refereed journal and in the appropriate discipline. Schultz (1987) stated that it is not simply a matter of publication, but of the publication in refereed journals in the author's academic field.

The Publishing Chore

An author of aviation related scholarly work centered on collegiate subject areas who wishes to submit a manuscript to a refereed publications must do so in a rather tangential manner. A proven methodology might include submission to the Journal of Epsilon Pi Tau, The Technology Teacher, The Transportation Journal, The Transportation Quarterly or another publication that serves a technologically oriented audience. Several of these publications have a policy of using the preferred blind peer review method of evaluating manuscripts. However, there is no specific vehicle for the refereed publication of monographs, articles, research findings, or the results of other scholarly activity that is specifically identified as serving the unique subject area represented by higher education aviation activities.

The need to establish a refereed journal for the publication of scholarly work in collegiate aviation has become a concern with the profession. The University Aviation Association (UAA) has until this time played an important but solitary role in bringing academic integrity to college and university aviation programs.

The UAA has engaged in this mission through the activity of the Publications Committee of the Association. However, the sole committee activity to date, in the form of a referee review process, has been the annual preparation of the Proceedings of the Fall Educational Conference. While this effort has provided numerous authors with an opportunity to share new knowledge with the profession, the endeavor has not been a totally satisfactory solution to the problem of publication in the field. A "...major limitation facing all our aviation faculty in the past has been the lack of a suitable journal for the publication of papers and professional articles" (Kiteley, 1983, p. 3).

UAA Membership Survey

A number of questions were to be answered by this research project. The survey instrument used as a data gathering instrument sought to determine whether scholarly writing was important at the respondent's institution and what specific type of activity was most important. Additionally, the survey sought to directly determine whether sufficient publication sources were available and to indirectly determine whether a scholarly journal dedicated to the field of collegiate aviation should be established.

Subjects

The subjects for the study were professional and honorary members of the University Aviation Association. Professional members are those persons that are actively engaged in collegiate aviation activities and honorary members are those persons who have recently retired from active teaching. The subjects were selected from the UAA Membership List (University Aviation Association, 1988) which contained names of approximately 202 professional and honorary members. This study used a sample size of over 50% which is consistent with Bartz (1981) who stated that "...all other things being equal, a sample is more likely to be accurate as it increases in size" (p. 151). There were 31 states and the District of Columbia represented among those selected. States that were not selected did not have a professional or honorary member listed on the UAA Membership List (University Aviation Association, 1988).

Survey Instrument

The survey instrument used for this study had two sections. The first section solicited responses concerning the respondent's institution, degree(s), academic rank, position, employment status, years with their present institution, and the number of years in higher education. The second section contained the survey questions concerning scholarly writing.

A survey packet containing a cover letter, the survey instrument, and a stamped return envelope were mailed to the selected participants. The cover letter informed the potential respondent about the study and instructed them to return the completed survey in the enclosed stamped envelope. If the person did not wish to participate, they were instructed to return the unanswered survey in the enclosed stamped envelope.

Demographic Data

The survey instrument was sent to 106 of the 205 professional and honorary members of the University Aviation Association. Of those 106, a total of 81 or 76.4% were returned. The information in Table 1 reports whether the respondent was associated with a private or

Table 1
Characteristics of Respondent's Institutions

Enrollment	Private	Public	Total
Under 5000	13 (16.0)	12 (14.8)	25 (30.9)
5000 - 10000	05 (06.2)	11 (13.6)	16 (19.8)
10000 - 20000	02 (02.5)	15 (18.5)	17 (21.0)
Over 20000	00 (00.0)	23 (28.4)	23 (28.4)
Total	20 (24.7)	61 (75.3)	81 (100.0)

Note: All numbers in parenthesis are percentages.

public educational institution and the size of the undergraduate enrollment at that school. Of the 81 respondents, 61 or 75.3% were from public institutions and 20 or 24.7% were at private schools. Twenty-five or 30.9% of the respondents were associated with schools that had an undergraduate enrollment of under 5000. Twenty or 24.7% were from schools that were public institutions with an enrollment of over 20000 undergraduate students.

The information contained in Table 2 reports the highest degree awarded at the respondent's institution. The master was the highest degree awarded at eight of 20 private

Table 2
Respondent's Institution and Highest Degree Awarded

Highest Degree	Private	Public	Total
Associate	00 (00.0)	13 (16.0)	13 (16.0)
Bachelor	06 (07.4)	04 (04.9)	10 (12.3)
Master	08 (09.9)	17 (21.0)	25 (30.9)
Doctorate	06 (07.4)	27 (33.3)	33 (40.7)
Total	20 (24.7)	61 (75.3)	81 (100.0)

institutions. The doctorate was the highest degree awarded at 27 of 61 public institutions and 58 of 81 schools awarded an advanced degree. Only public institutions granted associate degrees.

Information about the employment track of the respondents is contained in Table 3. The respondent could be tenured, on a tenure track, on in a position that did not culminate in tenure. The largest group of respondents were tenured with forty-five or 55.6% represented.

Table 3
Respondent's Employment Track

Track	Private	Public	Total
Tenured	04 (04.9)	41 (50.6)	45 (55.6)
On Tenure Track	05 (06.2)	07 (08.6)	12 (14.8)
Non-Tenure Track	07 (08.6)	12 (14.8)	19 (23.5)
Missing Data	04 (04.9)	01 (01.2)	05 (06.2)
Total	20 (24.7)	61 (75.3)	81 (100.0)

Twelve or 14.8% of the respondents were on a tenure track and 19 or 23.5 % of the respondents were in positions that did not culminate in tenure.

Table 4 reports information concerning the respondent's rank and position. In cases of more than one category being indicated, the lower of the two is reported. Twenty-six of the respondents indicated that their primary duty was as faculty members. Fifty-five respondents had some type of administrative responsibility; one respondent is a vice-president.

Table 4
Respondent's Academic Rank and Position

Rank	Fac.	Chair	Dir.	Dean	VP	Total
Specialist	02	02	00	00	00	04
Instructor	03	02	01	00	00	06
Assistant Professor	09	06	02	00	00	17
Associate Professor	09	10	03	00	00	22
Professor	02	15	02	07	01	27
Missing Data	01	00	02	02	00	05
Total	26	35	10	09	01	81

Eleven of the faculty respondents held senior faculty rank of Associate Professor or Professor and twenty-five of the thirty-five chairpersons were Associate Professor or Professor.

Table 5 reports the academic rank of the respondents and their highest degree. Five of the eight respondents with a Bachelor's degree as their highest degree indicated that they held the rank of Instructor or Assistant Professor.

Table 5
Respondent's Academic Rank and Highest Degree

Rank	Bachelor	Master	Doctorate	Total
Specialist	01 (01.2)	03 (03.7)	00 (00.0)	04 (04.9)
Instructor	03 (03.7)	03 (03.7)	00 (00.0)	06 (07.4)
Assistant Professor	02 (02.5)	11 (13.6)	04 (04.9)	17 (21.0)
Associate Professor	01 (01.2)	12 (14.8)	09 (11.1)	22 (27.2)
Professor	01 (01.2)	07 (08.6)	18 (22.2)	26 (32.1)
Missing Data	00 (00.0)	03 (03.7)	03 (03.7)	06 (07.4)
Total	08 (09.9)	39 (48.1)	34 (42.0)	81 (100.0)

Twenty-three of 36 respondents with a Master's degree as their highest degree indicated that they held the rank of Assistant or Associate Professor. Of those respondents that had the Doctorate, 27 of 31 held the rank of Associate Professor or Professor. Of all respondents, 48 of 81 held the rank of Associate Professor or Professor.

The information in Table 6 reports the respondent's years in higher education and the number of years with their current educational institution. Four of the respondents had been with their present institution less than three years and in higher education a like interval. Ten

Table 6
Respondent's Years of Experience in Higher Education

	Years with Current Institution				
	< 3	3 - 5	5 - 10	> 10	
Years in Higher Education					Total
< 3	04	00	00	00	04
3 - 5	03	03	00	00	06
5 - 10	03	01	10	00	14
> 10	06	00	07	44	57
Total	16	04	17	44	81

respondents had between five and ten years in both higher education and with their current institution. Forty-four respondents indicated that they had over 10 years experience in higher education as well as with their present institution.

Opinion Questions

The following data pertain to the questions on the survey instrument that solicit responses concerning the importance of scholarly writing. A five point Likert scale was utilized for all responses in this section.

Of particular interest in the following section was whether specific groups of respondents answered differently. The difference to be tested was whether survey responses were dependent on the participant's academic rank, employment track, position, and highest degree. The null hypothesis to be tested was that there was no significant differences in how a survey participant responded as a function of the four variables stated above. The hypothesis was tested by using the cross-tabulation function of the Abstat Statistical Program with an IBM AT Computer for goodness of fit using the Chi Square Distribution; the level of significance was set at .05. Selection of this non-parametric test as appropriate was based on the fact that use of a Likert scale for opinion responses on the survey instrument yielded nominal data.

The test of significance for the responses to the opinion questions below indicated that the null hypothesis was accepted for most of the responses. There were thirty-two separate tests of significance and in all but eight, the calculated value of Chi Square was less than the critical value. In six of the eight tests in which the calculated value for Chi Square exceeded the critical value, a closer analysis supported the conclusion that sampling error was present. This sampling error appeared to be due to the large number of cells, in some cases over 40% within each separate test, that had either one response or none within that cell. The two cases where a significant difference in the manner in which the participants responded will be discussed later.

Table 7 contains the responses of the survey participants to the questions of their ranking of scholarly writing importance. Each persons was asked to indicate which of the five different activities was ranked as 1 - Most Important to 5 - Least Important. The specific activities were a research grant and the associated final report, an article in a non-refereed magazine or journal, the preparation of a departmental manual, the authoring of a text, or article in a refereed publication.

Thirty-three or 43% of the respondents ranked authoring a textbook as Most Important and 25 or 32% ranked a grant and the final report as Most Important. However, in a summary of

Table 7
Importance of Various Scholarly Writing

	Importance				
	Most 1	2	3	4	Least 5
Grant	25 (32)	25 (32)	17 (22)	04 (05)	06 (09)
Non-Refereed Article	02 (03)	04 (05)	10 (13)	28 (36)	34 (43)
Department Manual	06 (08)	13 (17)	10 (13)	23 (29)	26 (33)
Textbook	33 (43)	14 (18)	18 (24)	08 (10)	04 (05)
Refereed Article	12 (16)	23 (30)	22 (28)	14 (18)	06 (08)

responses 1 and 2, 50 or 64% ranked a grant as very important and 47 or 61% ranked a textbook as very important.

An article in a refereed journal was ranked by 12 or 16% as Most Important or as Most Important and Somewhat Less Important by 35 or 46% of the respondents. A department manual was ranked as Least Important by 26 or 33% of the respondents and an article in a non-refereed journal as ranked Least Important by 34 or 43% of the respondents.

Table 8 reports information about three of the nine additional survey questions of the study. Six questions from this section have been omitted was being inappropriate for this report. Respondents were asked to respond to each question by indicating 1 - Strongly

Table 8
Opinion Questions

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5
Scholarly Productivity in the form of writing is important at my institution				
07 (09)	08 (10)	14 (17)	20 (25)	32 (39)
Scholarly productivity in the form of writing affects decisions on retention, promotion tenure, and merit.				
06 (07)	12 (15)	12 (15)	24 (30)	27 (33)
There are a sufficient number of publication sources in aviation education.				
25 (31)	29 (36)	15 (18)	08 (10)	04 (05)

Disagree, 2 - Disagree, 3 - Neutral,4 - Agree, and 5 - Strongly Agree. Fifty-two or 64% Agreed or Strongly Agreed that scholarly writing was important at their institution. Fifty-one or 63% of the respondents Agreed or Strongly Agreed that scholarly productivity affected decisions on retention, promotion, tenure, and merit.

Fifty-four or 67% of the respondents Disagree or Strongly Disagreed that there are a sufficient number of publication sources in collegiate aviation. However, it should be noted that there was some disagreement among the respondents to this questions as a function of their employment track. Eleven of the twelve respondents that did not have tenure and were on a tenure track felt that Disagreed or Strongly Disagreed that there were sufficient publication sources. Those individuals in a non tenured position offered a wide range of responses to this question. There was also some disagreement among the participants with different academic degrees to this same question. Individuals with their highest degree a

Bachelor's degree were somewhat neutral in their response but those with Master's or Doctorates indicated that they Disagreed or Strongly Disagreed with the number of publication sources. This difference may be a result of the small number, eight or 9.9%, of the respondents with only a Bachelor's degree.

Conclusions

The profile for the UAA respondent for this study was a tenured department chair with a Master's degree at a public institution with less than a 5000 student undergraduate enrollment. That person was an Associate Professor or Professor, had over 10 years experience at that institution, and the highest degree granted at their school was a Doctorate. Although this profile can not be generalized to the entire population, it appears that it may be the norm because all percentages approached or exceeded 50%.

The respondents indicated that grant writing and the authoring of textbooks were the most important scholarly writing. However, the publication of an article in a refereed journal was also considered as important. The respondents stated that scholarly writing was becoming more important at their schools in matters of retention, tenure, merit, and promotion as well as showing a preference toward refereed over non-refereed publication. The respondents also indicated that there were not a sufficient number of publication sources in collegiate aviation.

Scholarly productivity in the form of writing appears to be as important as ever on the college campus, however, the traditional form of grant writing and the associated research reports and textbook authorship may need to be supplemented. A scholarly refereed journal may be needed in collegiate aviation. The respondents in the survey indicated support for this form of publication. The UAA or a university may wish to undertake this task; it may be very important to the membership in the future.

There is additional interest in the establishment of a refereed journal among persons associated with aviation in other than a teaching and/or research capacity. Hamilton (1987) stated that it is firmly believed "...that a professional journal (Journal of Aviation Education) could both reflect and contribute to the increasing professionalism of aviation education within institutions of higher learning" (p. 6).

Perhaps the argument that best captures the need for a scholarly journal in collegiate aviation was voiced by UAA President Hemphill (1988) in the University Aviation Association Newsletter. He stated that the need for such a publication "...would provide a forum and greatly expand the opportunities for refereed publication .... and stimulate academic interaction among our members which will strengthen and bond our unity (p. 1).

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THE FUTURE OF THE AVIATION INDUSTRY IN THE PACIFIC RIM

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ABSTRACT

The Pacific Rim is on the threshold of an extended period of extraordinary economic growth. As a result, the aerospace industry will also experience growth demands unprecedented in history. International, regional, and freight traffic are dramatically increasing. New airports are being built while old ones are expanded and renovated. This has led to a sharp growth in the aerospace manufacturing industry and an increase in the technical training being conducted to support it. Extensive opportunities exist today and in the future to assist in the expansion.

INTRODUCTION

This paper will broadly review the type of aerospace industry growth forecast for the Pacific Rim over the next 20 years. It will address regional issues concerning economic growth, the air carrier industry, airport and airspace utilization, aircraft manufacturing industry, and ab initio flight training. It is the intent of this paper to give the reader a point of departure from which individual study may be conducted within a specific area of interest.

EXPANSION

Regional Economic Growth

The Orient has always woven a spell to enchant the West. Vast, teeming, enigmatic Asia's inexhaustible riches have fired the imagination of Westerner's even before Marco Polo. Since the beginning of time, there has been a slow but steady economic movement Westward. John Hay, Secretary of State under President Theodore Roosevelt, said, "Western history began with a Mediterranean era, passed through an Atlantic era, and is now moving into a Pacific era." Stephen M. Wolf, chairman and president of United Airlines, agrees.

United, which has offered service to various Pacific Rim destinations since 1986, has become one of the U.S. leaders in this continued Westward expansion. In an article in Aviation Equipment Maintenance magazine Wolf referred to the 1980's as, "The emergence of the Pacific Century" (Worthington, 1989). We are now living in that Pacific era, a time when fiscal and human resources will be directed to an area of the world more commonly known as the Pacific Rim.

The term Pacific Rim identifies a ring of active volcanoes around the edge of the Pacific. (Aikman, 1986). For the purposes of this paper, the term Pacific Rim refers specifically to the relationship between the United States and the following countries: Hong Kong (actually a colony of Great Britain until 1997, when it reverts fully to China), Japan, Korea, China, Taiwan, Vietnam, the Philippines, Thailand, Malaysia, Singapore, and Indonesia.

The Pacific Rim is the center of world economic and political interest. Last year, the Defense Science Board called for sweeping changes in the Pentagon's policies and organizational structure. According to Hughes Aircraft Company chairman Malcom Currie, who headed the task force, "It was the Board's conclusion that national security can no longer be viewed only in military terms, but must include economic well-being as a key component" (Morrocco, 1989). While sixty percent of the world's population is in Asia (20% in China alone), it only enjoys 21% of the economic share (McDonnell, 1989). But the days of economic dominance by the West are numbered. According to research conducted by McDonnell Douglas, the Pacific Rim should economically outperform the rest of the world and, in the long run, be the fastest growing region (Fink, 1989-a).

The same study projected the Pacific Rim would have the world's highest air transportation growth rates during the period 1988 - 2010. Currently the Federal Aviation Administration (FAA) estimates transpacific flights are increasing at a rate of 4,000 a year in the North America - Pacific Rim corridor (Proctor, 1990-c). About 40% of the world's traffic, estimated to reach 2 billion passengers a year by the year 2000, will be to and from Pacific Rim countries according to Gunter O. Eser, director general of the International Air Transport Association. Recently, twelve U.S. carriers have applied to open new routes to Japan, twice the number that can be authorized by the Department of Transportation (Proctor, 1989-c).

The freight industry is equally affected as witnessed by the 1988 move of Federal Express into the region. As fax machines edge the company out of the overnight letter business, Federal Express is rapidly moving into express parcels (Pocock, 1990). The company has purchased a major interest in Daisei, a medium-sized Japanese trucking company. Even more significant, it has purchase Tiger International, a major air cargo firm that also has considerable ties to Japanese shipping (Pocock, 1990). At the same time, three other carriers are competing for a single cargo route about to be authorized between the U.S. and the Pacific Rim (Fotos, 1990).

The demand is not speculative; people and goods are already moving at ever increasing frequency. According to Michael Hewitt, past secretary general for the Orient Airlines Association (OAA), "By the year 2000, Japan will have about 25 million citizens with the discretionary income to travel internationally. Improving economies throughout the region could add an additional 100 million travelers in the same time frame" (Proctor, 1989-c). The competition for world attention is strong among Pacific Rim countries to improve those economies. Tourism is up everywhere, even in Vietnam where the welcome mat, if not very modern, is definitely sincerely displayed. All the nations are courting the business world but none more so than Singapore.

According to Singapore's Prime Minister Lee Kuan Yew, the business of Singapore is business (Haynes, 1989). Lee, who has ruled the tiny republic since its birth in 1965, boasts "Singapore offers a strike-free work force, deliveries that arrive on time, lunch breaks that don't extend far into the afternoon, and a general air of cooperation" (Haynes, 1989). Singapore, once known as Europe's gateway to the east, has became Asia's gateway to the west.

Aerospace Industry

One of the most telling indicators of the growing economic strength of the region is the increased emphasis on local manufacturing. While clothing manufacturing is very common, there is a strong move by most countries to get into the aerospace industry. Certainly, one of the most impressive attempts is by Indonesia's monopoly, the government-owned aircraft factory IPTN (Fink, 1990-b).

It is not by chance that Indonesia has focused on aerospace since its independence in 1945. The vast and diverse transportation needs of the Pacific Rim are best illustrated by Indonesia whose national motto is "Bhinneka Tunggal Ika," "Unity in Diversity." This 3,200-mile-long cluster of islands houses the world's fifth largest population. Indonesia's more than 160 million people are made up of more than 250 ethnic groups including the largest Moslem population on Earth. There is a 20% poverty rate, large-scale unemployment, and wide-spread illiteracy, particularly in urban areas. It is a country composed of 13,677 islands that approximately stretch from Australia to Vietnam (Cohan, 1987) (Fink, 1990-c).

Indonesian state minister for research and technology, Bacharuddin Jusuf Habibie strongly believes aircraft can help integrate the country's economy, culture, and society (Cohan, 1989). For these, and other reasons, since 1974, Indonesia's industrialization policy has used the aircraft industry as its cornerstone and Industri Pesawat Terbang Nusantara (IPTN) is that cornerstone. For over 10 years, they have been manufacturing the CN-212, a utility twin-turboprop transport, and more recently a 44-seat turboprop airliner the CN-235. Both aircraft are produced in cooperation with Spain's national aircraft manufacturer, CASA. IPTN has similar agreements with factories in the US, France, and Germany, and is working toward becoming a subcontractor to Boeing (Cohan, 1987).

Other countries are also moving along similar lines. Japan, the strongest economic power in the Pacific Rim, is strengthening its aerospace relationship with the U.S. as the Ishida Group plans to build a new tilt-wing transport aircraft in the United States (Brown, 1990). China's most serious challenge is to complete the modernization of it's domestic air transportation network particularly with respect toward infusing China's fledgling aviation industry with state-of-the-art technology (Fink, 1989-a). As China moves toward modernizing its industrial base with Western help it is making a fundamental shift from building military aircraft to export-oriented commercial aircraft production (Fink, 1989-b). The Shanghai Aircraft Industrial Corporation is a case in point.

Two of SAIC's factories were completely renovated to meet the United States Federal Aviation Administration's production facility certification requirements for the MD-82 program (China is assembling the MD-82 transport in Shanghai in partnership with McDonnell Douglas Corp). A new paint hangar and headquarters building also were built. The company now has one of the most modern facilities in China (Fink, 1989-a).

Airline Industry

The airlines of Pacific Rim countries are responding in kind. Only 30 years old, Indonesia's flag airline Garuda is the largest in the Southern Hemisphere with over 700 pilots. It has just begun weekly service to Los Angeles, has 10 flights a week to Tokyo, and has signed several agreements with other international carriers establishing joint operations to various Asian and European cities. Annual passenger traffic growth is in the double-digits (Cohan, 1987). Delta and Singapore Airlines "...have signed an equity exchange and marketing agreement that broadens the reach of both airlines..." The marketing agreement covers 10 years and includes cooperation in a number of areas. Both American and United are dramatically increasing their presence in the region and other U.S. air carriers are adding Pacific Rim destinations to their list. (Delta, 1989). Singapore Airlines has just placed a massive repeat order for Boeing 747-400s and could have up to 50 of the type in service by century's end. If projected growth rates prove to be correct, the airline will be bigger than Lufthansa is today, in RPK (revenue passenger kilometers) terms, by the year 2000 (Rek, 1990).

Regional figures are as impressive as international. Commuter manufacturers forecast a need for between 480 and 735 smaller transports in the region through 2005, not including the People's Republic of China. Martin Craigs, vice president of marketing in the Asia-Pacific region for Saab Aircraft International, feels "Per-capita income seems to be an indicator of commuter aircraft sales potential. In countries with high average personal wages, commuter operators can charge high enough fares to justify the purchase of more aircraft" (Proctor, 1989-c). Countries with relatively low per capita income are not necessarily excluded from a regional carrier because of high start up costs. One innovation was an attempt at a joint venture between StatesWest Airlines, a Phoenix-based independent commuter-regional airline, and an Asia-based company (O'Lone, 1990-a). While negotiations ultimately broke down, future efforts of this type are anticipated.

Airport and Airspace Capacity

If there is any down-side to the dramatic growth of the Pacific Rim it is airspace and airport capacity. A narrow airspace "gate" over Tokyo restricts flights in and out, and also routes between North America and Korea, Hong Kong, Taiwan and the Philippines. Virtually all points in Southeast Asia are accessed through those cities. The primary reason for this is a large amount of defense-related, restricted airspace surrounding the gate. Everyone agrees there will have to be changes but their exact nature is controversial. Asia, after all, is still Asia (Proctor, 1990-c). In at least one place, enmity is the major problem as controllers from the People's Republic of China refuse to hand off aircraft to controllers from Vietnam. The result is aircraft flying Hong Kong to Bangkok must fly further south, which disrupts traffic between the Philippines, Indonesia and Malaysia to Japan, Taiwan and Korea. Everyone agrees there must be short-term airspace management modifications including better inter-agency coordination and the creation of additional flight routes (Proctor, 1990-c). There is also currently a study underway to lower aircraft separation requirements. Long-term alternatives include creating an automatic satellite communication network between controllers and aircraft. This, combined with high-accuracy, satellite-based global positioning systems on aircraft, would increase airway capacity by reducing separation requirements (Proctor, 1990-c).

Most Pacific Rim airports are already suffering from congestion and delays. For example, corporate flights to Hong Kong are often required to schedule arrivals during off hours with quick off-loading times. They are then required to fly to another country (often Taiwan) to park (International Operations, 1990). "With strong traffic virtually guaranteed for the next 10 years, airlines should now concentrate on removing or reducing critical chokepoints" according to Gunter O. Eser, director general of the International Air Transport Association. "Congestion is the single biggest barrier to growth" in the Asia-Pacific market, he said (Proctor, 1990-c). Ibrahim Taib, new secretary general of the OAA agrees. He stated, "One of the largest challenges OAA airlines face in the 1990's [...is handling growth]". Charles McKee, an analyst for Hong Kong-based Avmark Asia, Ltd. says its an accumulation of a lack of passenger facilities, insufficient and inadequate runways, and an ineffective air traffic control system (Proctor, 1990-c).

On the other hand, there is a tremendous amount of new construction. Major new airports are planned for Hong Kong, Macao, and Osaka. The Japanese transportation ministry is also proceeding with plans to build 11 more regional airports during the next five years with nine more under discussion. At the same time, there are substantial renovations and upgrades planned for

Narita's new Tokyo International, Changi (Singapore), Soekarno-Hatta (Jakarta) and Don Muang (Bangkok). Singapore, for instance, will increase Changi's currently nominal capacity to 30 million passengers per year (Rek, 1990) (Proctor, 1990-c).

Current Training Situation

There is an increasing amount of training being conducted within the region rather than out of the country as in the past. Never-the-less it is difficult for most countries to fully develop their training programs, recruit good instructors, and complete enough students to satisfy the demand. An attempt has been made to meet Indonesia's requirement for pilots through its Civil Aviation Training Center near Jakarta. Opened in 1984, all of its graduates go to Indonesian airlines or the oil industry. They can't keep up with the demand (Cohan, 1987).

China has two flying colleges (Guanghan and Mianyang) but they are woefully behind in their training techniques and methodology. The ab initio schools have just recently replaced the Soviet Y-5 biplane with 12 Aerospatiale/Socata TB-20 Trinidad trainers. For the first time, they are able to train their future air carrier pilots in primary aircraft with retractable, tricycle gear (Proctor, 1989-b).

The problem is not limited to pilots alone; it's all technical skills. Michael Miles, chairman of Cathay Pacific Airways, said, "Little has been said and less done about the inefficient and poorly trained air traffic control staff in the region, or the inadequate equipment on which they rely, or about the frequent and potentially dangerous disregard of civilian air traffic control by the air forces of some countries in the region" (Jansen, 1988). There is clearly the need for more training and more expertise to help develop the necessary programs.

SUMMARY

It is obvious that the future of the Pacific Rim is one of steadily increasing economic strength. As the various countries emerge economically, they will attract more people and goods from all over the world, thereby increasing the demand for international and regional air transportation. More and more pilots, mechanics, ATC, and other technical personnel will need to be trained. The demand for technical people, particularly training specialists, will be great. It is important for individuals and corporations to take the time now to prepare for the future by learning to understand and respect the customs and cultures of different countries.

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THE POWER CURVE: TEACHING THE ESSENTIALS OF FLIGHT

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Abstract. If you were to skim through a text on classical aerodynamics for engineers, and then take a close look at one presenting basic theory of flight for pilots, you may be struck by the similarities rather than by the differences between the two. Of course, the former will contain more detailed information and give it in a much more technical and complicated way. Yet, both will be organized similarly, starting with isolated, basic components and building up to some major applications of the theory. This is the traditional way of teaching basic theory of flight to pilots. This paper proposes an alternate approach. Rather than beginning with the underlying causes of flight, it proposes to unravel basic principles by starting with the consequences of aerodynamic phenomena. Perhaps the best way of illustrating how this opposite approach may work is by presenting a simple model. Here, I show how the power curve, representing the most generalized consequence of all aerodynamic processes, could be used as a vehicle to introduce basic principles of flight to beginner pilots. This approach may allow schools to standarize teaching of basic aerodynamics and may permit students to increase their understanding of flight in a way they can effectively apply this knowledge during initial training. Although a solid understanding of how airplanes fly is not the only goal of a sound training program, gaining a high level of understanding in this vital area should be one of the most crucial requirements for ensuring competency and safety among professional pilots.

Introduction

Show me a pilot who can explain a power curve and I will show you someone who understands the very essence of flight. There is no other concept in the theory and practice of flight as fundamental and far reaching as that embodied by a power-speed relationship. It is at the heart of aerodynamic theory, aircraft design, flight-control, aircraft perfomance, and fuel economy. Commonly, a power curve defines how *the power required for straight-and-level flight changes with airspeed*, though such a relationship can be easily extended to any other steady-state phase of flight (e.g. unaccelerated climbs, descents, and turns). Most likely, all pilots have glanced at this peculiar U-shaped curve during ground-school days, or have at least been cautioned by a flight instructor during operations within the "region of reversed command" or "backside of the curve". Yet, probably only a few pilots understand *why* the power required for flight varies with airspeed or how they could use a power curve to optimize aircraft performance during flight (Miller, 1987). This lack of understanding may be due to the way basic principles of flight are traditionally presented in texts and taught in primary training courses, as well as the academic background of most civilian student pilots.

The basic principles behind power-speed relationships are of course fully explained in aeronautical engineering texts (McCormick, 1979; Milne-Thomson, 1958; Mises, 1945; Prandtl and Tietjens, 1934; Warner, 1936). Yet, for the average non-engineering aviation student, extracting the important concepts behind a power curve from such technical information can be a difficult task. Key elements of the theory and their practical meaning are simply lost among obscure technical and mathematical descriptions. On the other hand, some widely used non-technical literature, which could specifically help beginner pilots, provide incomplete explanations (FAA, 1980b; Jeppesen-Sanderson, 1988, 1989; Kershner, 1979) and, unfortunately, even misleading notions about the power-speed concept (FAA, 1980a,b; FAA,1987; Navarre 1987a,b). Only a few authors (Hurt,1965; Dole, 1989) present applied aerodynamic theory more thoroughly, and do it with as little mathematics as possible. Regardless of their level of complexity, however, all of these texts follow an approach that one could call the "engineers' approach".

What is an "engineer's approach"? In a classical sense (Warner, 1936), engineers begin by studying the isolated *causes*, as opposed to the *consequences*, of aerodynamic processes in order to understand principles they can apply to the design of aircraft. First, they focus on the physical properties of air; its behavior when flowing around objects and surfaces of different shapes; and the forces generated under varying airflows. Then, they design parts or whole structures that should generate the forces they want, under specific conditions. Finally, the prototype is tested (during flight or in wind tunnels) and, if necessary, later improved to meet with performance specifications. Thus, the "finished product" for an engineer is not just the physical aircraft *but its performance*, best encapsulated by power-curves, under different conditions of flight (Mises, 1945). The reason engineers start at the "bottom" (causes) rather than at the "top" (consequences) in their search for working principles is simply because they cannot start by measuring the performance of an aircraft that doesn't yet exist!

We can carry the engineer analogy further, not only to the way theory is presented in aviation textbooks, but also to the way principles of flight are taught in ground-training courses. Even when stripped of complicated mathematics, typically these courses follow the traditional approach by introducing and teaching basic principles as *isolated* phenomena. Only later, do a host of seemingly unrelated factors come together under the headings of "performance" or "cruise-control". This approach, however, may suffer from an inherent weakness if used for teaching the basics of flight to non-engineering students. Without the benefits of a solid background in physics and advanced mathematics, for example, a student may have a difficult time grasping the theoretical *and* practical implications of isolated, abstract concepts such as "lift" or "angle of attack", which he cannot "see" or "feel" during training flights. Later on, when the "big picture" (e.g. performance theory) is presented, several underlying elements of the theory are simply omitted, since understanding of these basic concepts is taken for granted. Often, the result is a student pilot who by this time may have acquired the necessary "skills" to fly an airplane, but who may lack satisfactory understanding of aircraft performance *and* its underlying principles. Removing this flaw from current primary flight-training programs does not necessarily mean that we have to start teaching advanced calculus and physics to beginner pilots (although some knowledge of these fields would certainly be beneficial). There is a more simple solution.

The goal of this paper is to suggest a alternate approach for introducing basic elements of flight theory to non-engineering aviation students by literally turning the engineer's approach upside-down. Rather than beginning with the underlying *causes* of flight, as an engineer would, it proposes to unravel basic principles by starting with the *consequences* of aerodynamic phenomena. And this is where power curves excel. A power curve (namely the relation between power and speed during flight) represents, after all, *the most generalized consequence of all aerodynamic processes*. Thus, the power-speed concept, once stripped from confusing technicalities and presented correctly, can itself become a powerful tool for grasping and clarifying essential principles of flight. No other concept provides such a rich framework for teaching aerodynamic theory and for putting into practice the basic principles taught in the classroom.

An analogous approach already exists in a different scientific field where power curves have been used *for research* with tremendous success. Physiologists, for example, routinely use power-speed relationships as an experimental tool to investigate basic principles underlying the mechanics and energetics of animal locomotion (Schmidt-Nielsen, 1972; Taylor et al., 1982; Tucker 1973). They begin their studies by obtaining power measurements of live animals running on treadmills, swimming in watermills, or flying in wind-tunnels at different steady speeds. The physiologists' approach for investigating basic principles of locomotion is thus diametrically opposite to that of engineers. After all, physiologists have to work with a "finished product", namely the whole, performing animal. They need to start at the "top" and work their way "down" to understand the underlying principles of animal locomotion. In an analogous manner, we can use power curves derived from aircraft performance to begin our study of the principles of mechanical flight.

We could view this "top-to-bottom" approach to studying flight as being *operator* (pilot), rather than *designer* (engineer), oriented in that the former begins with actual aircraft performance as a framework to investigate underlying principles (Figure 1). The designer oriented approach has proven ideal to teach aerodynamic theory to engineering students, but the opposite approach may be better suited for teaching the same principles to student pilots. Why? The answer lies in the actual process we need to go through in order to explain or "derive" a power curve.

We can think of the process of going from top to bottom in our search for basic principles as one that consists of going through different "levels" of explanation (Figure 1). Each level contains all the essential components that explain the immediate next level up. By starting at the top, we only need to be concerned with the level immediately *below* to begin our search for explanations. These explanations (or underlying principles), however, are only brought up in the context of the top level. This has some great advantages over the "bottom-to-top" approach in terms of teaching basic theory of flight to pilots. First, regardless of the level of complexity of a

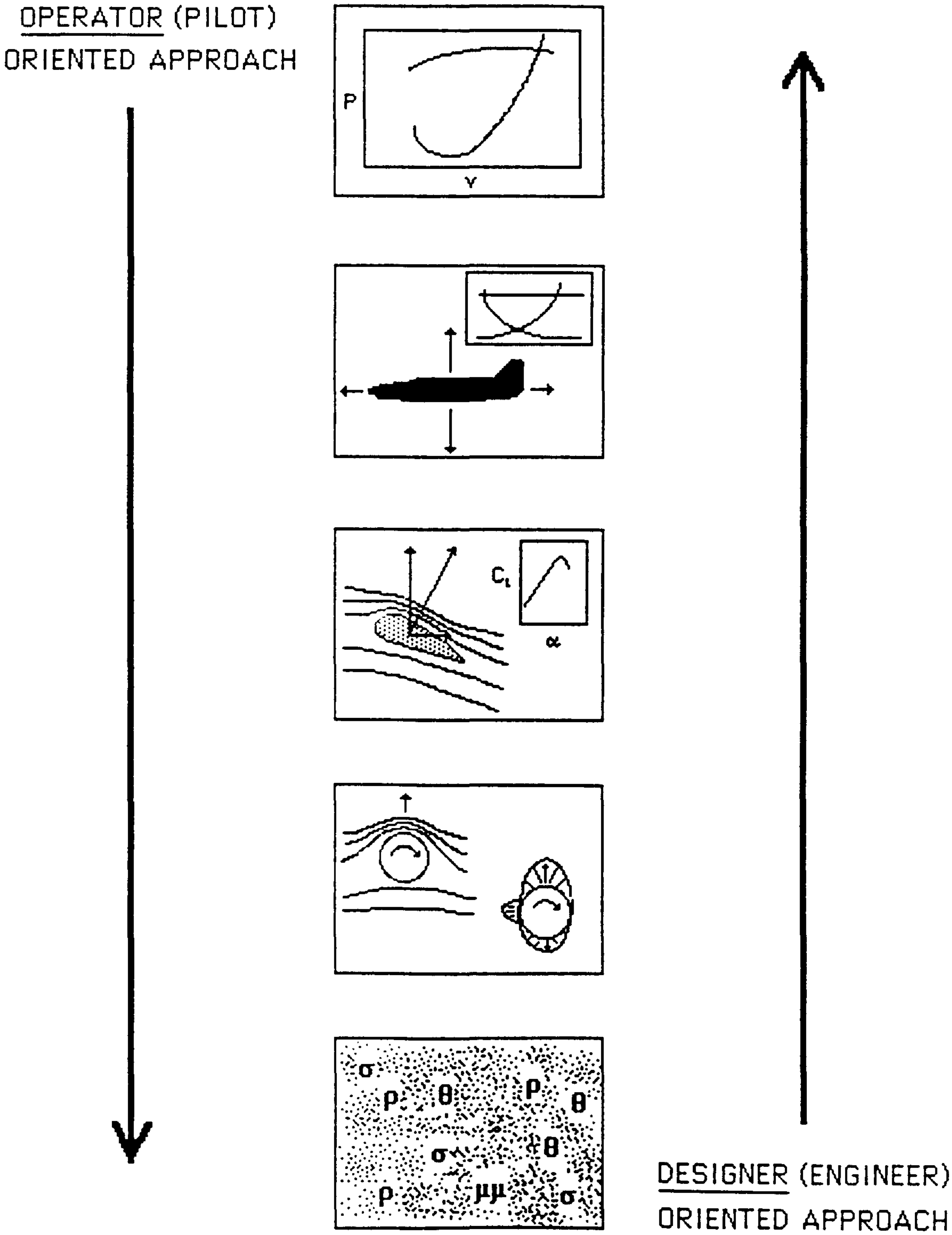

Figure 1. Schematic representation of two opposite approaches for teaching the theory of flight. The **designer** (engineer) oriented approach starts by studying the causes of all aerodynamic phenomena and proceeds up to higher-level consequences. The **operator** (pilot) oriented approach on the other hand, starts with the highest consequences of aerodynamic processes (e.g. performance) and proceeds downward to unravel underlying principles. The latter may be better suited for teaching basic theory to student pilots.

course and previous preparation of the student, the new approach enables the student pilot not only to view all the relevant components when needed, but also to appreciate the important ways in which these different components interact with one another to result in a given state of aircraft performance (e.g. low speed, level flight). The benefits from understanding how basic elements of flight *interact* go far beyond mere knowledge of some isolated facts. The student can now begin to apply this understanding to real flight situations. Second, we can proceed downward in our search for underlying principles only after the preceeding level has been fully understood by the students. This would give flexibility in the design of a course while ensuring that at least some minimum educational standards are being met. If required by the course, we can continue further down into deeper levels. Perhaps the best way to show how this "top-to-bottom" approach may work is to illustrate it by a using a simple model.

The Model

Here I illustrate how one could take full advantage of power curves to teach beginner pilots the essentials of flight theory. For brevity, the following model focuses on a typical power curve for fixed-wing propeller aircraft in straight-and-level flight. The approach, however, can be extended to illustrate almost any other facet of flight in both propeller and jet aircraft. For example, one could combine "power required" and "power available" curves to study the dynamics of unaccelerated climbs, descents, and turns. The method is also ideal to investigate the effects of many factors (e.g. weight, altitude, aircraft-configuration, wind) on aircraft performance. Finally, force curves, rather than power curves, can be used to introduce the dynamics of non-steady phases of flight such as take-off and landing rolls (see Hurt, 1965; Kershner 1985).

In the first part of the model I describe how a typical power-speed relationship is derived for level flight. The reader will note that in deriving the power curve I have omitted explanations of certain "lower level" concepts as well as all calculations. Again for brevity, I concentrate on "top" levels of explanation, with only a few incursions into deeper levels. In an actual course, the teacher/instructor will need to explain the underlying principles at any level *only* as they are introduced within the context of a power curve (this is where this method differs from traditional ones).

In the second part of this model, I focus on an important application of the power-speed concept (fuel management). Practical applications may help students realize the importance of understanding basic principles to optimize aircraft performance and control during actual flight.

Finally, it would be best to coordinate lectures with flight-training exercises where the same principles are illustrated during actual flight. These exercises may, for instance, consist of determining the power curve for the trainer aircraft under specific conditions of flight. In the final section of this model, I suggest two ways of empirically estimating the level-flight power curve for a propeller aircraft.

What is behind the power curve?

Let's examine Figure 2. If you can remember the shape of this curve (which by the way holds true for both mechanical and natural non-hovering flight - i.e. it applies similarly to a flying airplane or bird) you will be closer to unravelling the secrets of flight and understanding how a

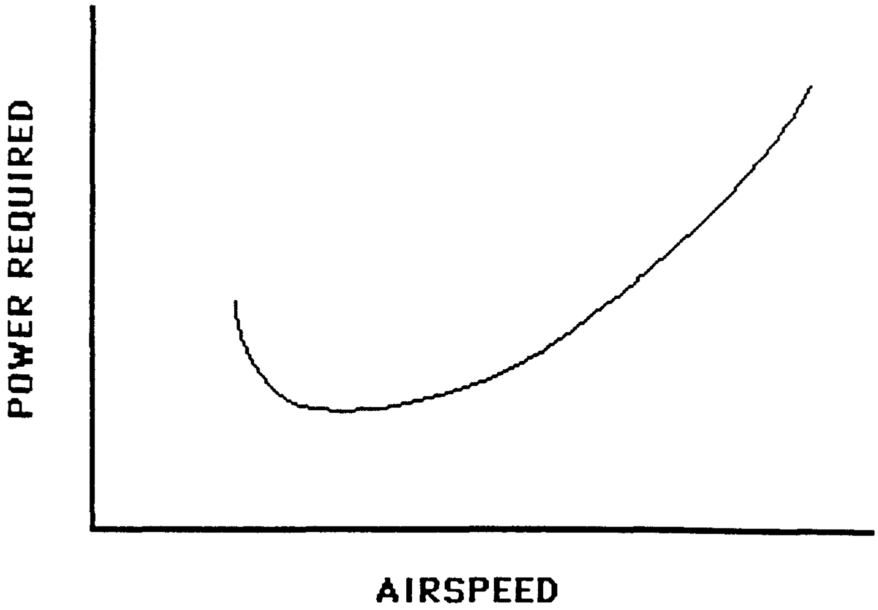

Figure 2. Power required by a propeller aircraft to maintain straight-and-level flight at different steady airspeeds.

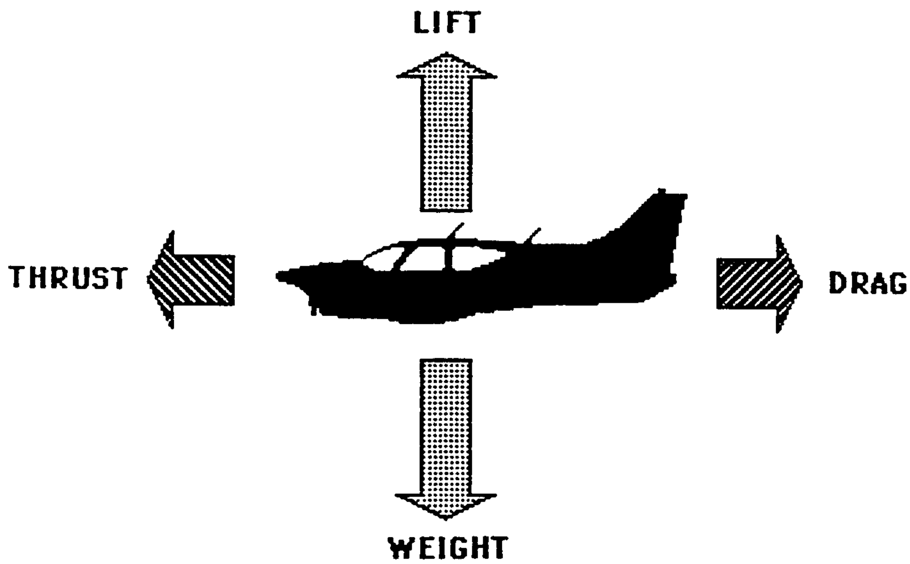

Figure 3. In straight-and-level flight at some steady speed, the four forces are in equilibrium as follows: weight is balanced by lift, and thrust is equal and opposite to drag. Notice that lift is normally much larger than thrust during level flight.

pilot can adjust power and speed to manage the aircraft's fuel in a variety of different ways. The right-hand portion of the curve (where power required increases with airspeed) intuitively makes sense. What this part of the curve says is that if you want to fly faster, more power is required in order to maintain level flight. Since fuel consumption is a function of the amount of power used (in a propeller aircraft), the power curve also reflects *fuel flow required* (gal/hr) at different airspeeds. Now look at the left side of the curve. This side of the power curve (better known as the *region of reversed command*) indicates that if you want to *slow down, more* engine power will be required to maintain level flight. How can this be? Well, in order to understand this power-speed relation we will have to dig a bit further to find out the main factors that result in this peculiar U-shaped curve.

The forces required for straight-and-level flight

The forces required for straight-and-level, unaccelerated flight are determined by the *weight* of the aircraft and the *drag* produced by it during flight. Weight, being the result of gravity, is a force that pulls the airplane downward towards the earth, while drag is a rearward, retarding force that pulls the aircraft in the opposite direction of flight. Thus, to remain aloft in forward motion, an aircraft must provide just enough *upward force* (*lift*) to support its weight , and just enough *forward force* (*thrust*) to counteract drag (Figure 3). When the forces are balanced in this way, no accelerations or deccelerations occur along any of the axes of flight and the aircraft follows a straight-and-level path as it moves forward. To determine the amount of engine power required by an aircraft flying under these conditions (and understand the power curve) we will need to know ***how these four aerodynamic forces interact to result in steady level flight at different speeds.***

Lift is the net upward force (usually measured in lbs.) produced by the dynamic action of air over and under the wings. Since the weight (also in lbs.) of the aircraft remains the same regardless of airspeed, it follows that the amount of effective lift *required* for level flight also remains constant for any speed (Figure 4a). The way by which the same amount of lift is *generated* at different *airspeeds*, however, depends on several factors. These can be best illustrated by briefly referring to the basic lift equation:

$L = 1/2 \cdot \rho \cdot S \cdot C_L \cdot V^2$, where:

L = lift
ρ = air density
S = wing surface area
C_L= coefficient of lift (dimensionless function of the angle of attack)
V = airspeed

Since we are interested in producing a fixed amount of lift at a given altitude (i.e. level flight) and aircraft configuration (i.e. clean), we can consider air density (ρ) and wing surface area (S) as constant. Lift generated then will be directly proportional to the coefficient of lift (C_L),which is nothing more than a number related to the *angle of attack*, and to the square of airspeed (V^2). This really means that if we want to change the airspeed *and* maintain the same amount of lift required for level flight we have to vary the angle of attack accordingly. We can generate the same amount of lift flying at low airspeeds with large angles of attack, or at high airspeeds with low angles of attack (Figure 4b). We can summarize this relationship by stating: (1) the generation of lift (in a fixed-wing aircraft) requires some forward motion (relative to the

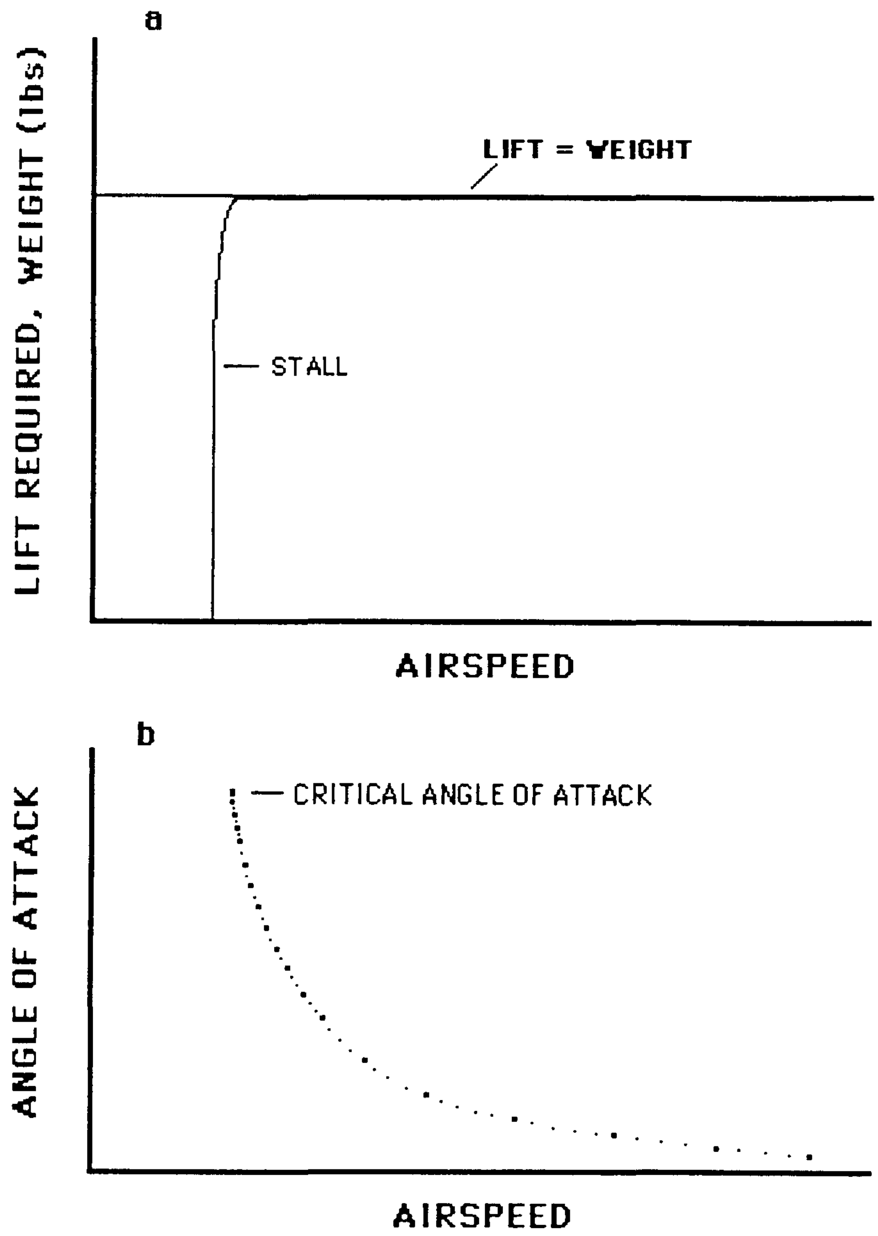

Figure 4. a) Lift required to maintain straight-and-level flight at different airspeeds. At stall speed, lift available drops precipitously. This occurs just after the critical angle of attack has been reached. **b)** The inverse relationship between angle of attack and airspeed during level flight. If angle of attack is increased, airspeed will decrease. Notice that only one angle of attack corresponds to any given steady speed. Because of this, **angle of attack is the primary control of airspeed during steady (unaccelerated) flight.**

airmass), (2) angle of attack and airspeed vary inversely and, (3) each airspeed requires a specific angle of attack to maintain steady flight.

As it turns out, ***the inverse relation between angle of attack and airspeed to produce the same effective lift is at the heart of the power curve.*** We have already seen that, aside from lift, an aircraft must produce enough thrust to counteract drag if it is to remain flying forward, horizontally (Figure 3).There are two forms of drag: *induced drag* and *parasite drag* (Figure 5). Induced drag (exclusively associated with the production of lift) varies directly with angle of attack. This can only mean that this type of drag, like the angle of attack, varies inversely with airspeed (in fact it varies inversely with the square of speed). For example, reducing airspeed by half will increase induced drag four times. Let's stop to think about this for a moment. If an airplane is to maintain adequate lift at very low speeds it must do so by an increased angle of attack. The penalty of a higher angle of attack is, of course, *greater induced drag that must be equally opposed by increasing thrust.*

Now, let's not forget *parasite drag* (caused by the disruption of airflow around all of the plane's surfaces). This form of drag, in contrast to induced drag, *increases* with increasing airspeed, thus it only becomes significant at high speeds (Figure 5). Because the high airspeeds are adequate to produce sufficient lift, the aircraft can maintain level flight with a very small angle of attack (hence low induced drag). Although induced drag plays a minimal role in the high speed range, parasite drag becomes increasingly larger opposing the forward motion of the aircraft. Thus, the penalty for providing lift at very high speeds is *increased parasite drag which must be balanced by increasing thrust.*

In unaccelerated straight-and-level flight, the amount of thrust that the aircraft must produce is determined by the sum of induced and parasite drags (Figure 6a). Since both types of drag vary with airspeed in opposite ways (as one goes up, the other one comes down), there must be an intermediate airspeed at which the total drag, thus thrust required for level flight, is minimum. This happens to be at the point where both drag-lines cross each other, largely because they vary symmetrically (induced drag decreases as $1/V^2$, and parasite drag goes up with V^2). If you remember, effective lift required to maintain level flight does not vary with airspeed. Therefore, the ratio of lift to drag is maximized (L/D_{max}) at this intermediate speed. At this airspeed the wings are most efficient in producing lift and, as we will see later, this has an important implication in terms of fuel economy.

To summarize, an aircraft flying horizontally at some steady speed has to provide sufficient lift and thrust to balance weight and drag respectively. Although the amount of effective lift required to maintain level flight does not vary with airspeed, the amount of thrust does. Thrust required is determined by the tradeoff between angle of attack and airspeed necessary to generate a given amount of effective lift. Now, let's see how we can relate changes in the force required to propel an aircraft forward to the amount of power required for level flight.

The power required for straight-and-level flight

The power required to propel an aircraft can be obtained by multiplying the forward force required (thrust) to move it *times* the airspeed at which it is being propelled. The power required (usually measured either in horsepower or foot-pounds) for flight can be expressed as follows:

Power = force x velocity, or
$Pr = T \cdot V$, where:

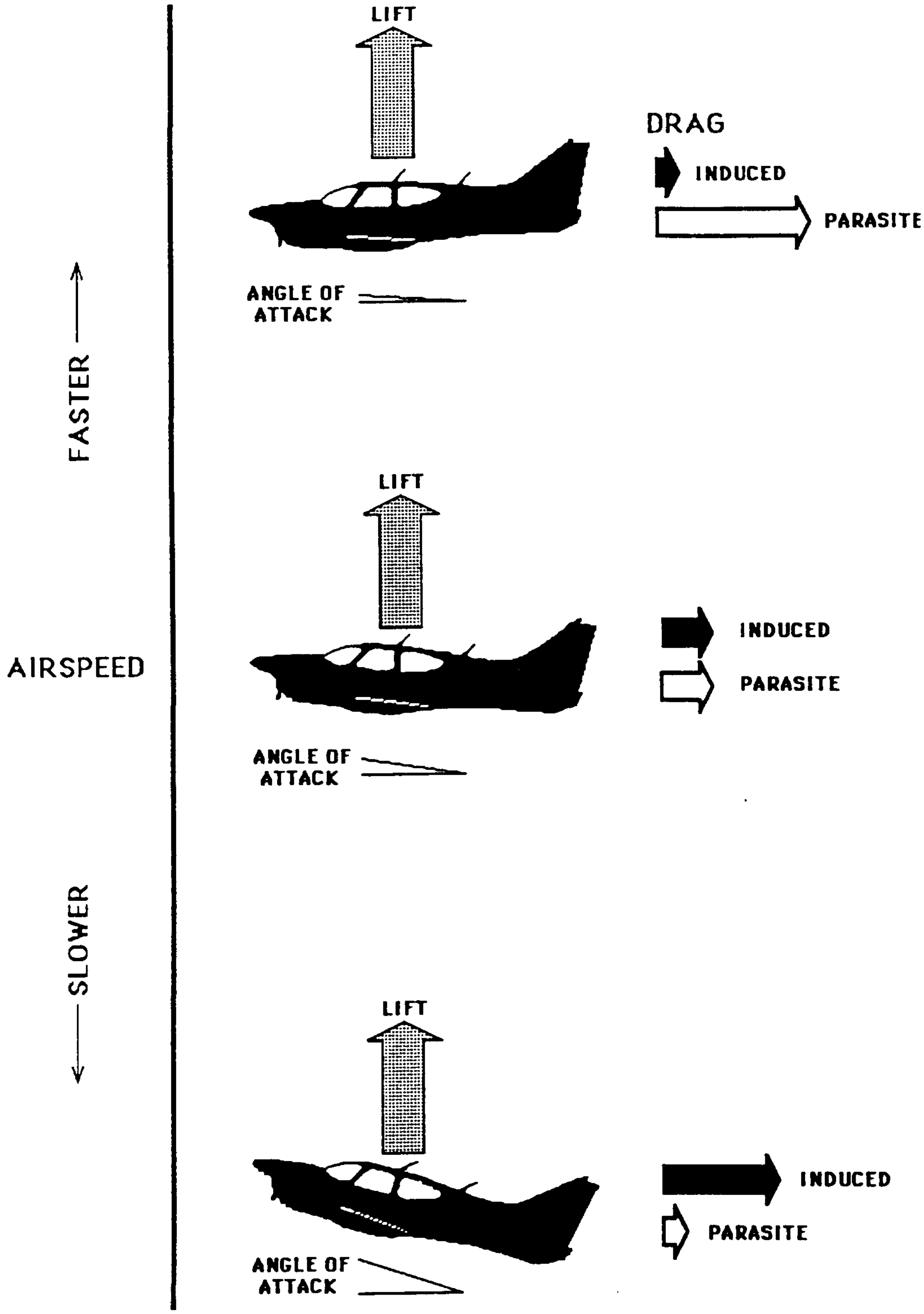

Figure 5. Induced and parasite drag as a function of airspeed during steady-level flight. Induced drag decreases with speed, while parasite drag increases. Notice that angle of attack (acute angle between the average chordline of the wing and the relative wind) decreases with airspeed, while the amount of effective lift required to maintain level flight remains constant.

Pr = Power required
T = thrust
V = airspeed

We could equally determine the power required to propel the airplane forward by multiplying *drag* (since it is equal to thrust) times airspeed. Since there are two forms of drag, we can also split total power required into two distinct components. One component would be the power required to overcome induced drag, or *induced power required* (Pr_i), and the other the power necessary to overcome parasite drag, or *parasite power required* (Pr_p). By adding these two components, the main characteristics of the power curve become apparent.

Let's take a closer look at how induced and parasite power vary with airspeed (Figure 6b). As you study figure 6, note that the airspeed at which a aircraft has the minimum thrust required (at L/D_{max}) is not the speed that results in minimum power required. Why? Well, unlike induced and parasite drag which vary inversely but symmetrically, the two components of power vary asymmetrically with airspeed. This asymmetry can be explained by taking a closer look at the formula for power required stated above:

Let's call induced drag, D_i, then:

$D_i \propto 1/V^2$ (The symbol $\propto$ simply means that D_i is proportional to the inverse of the square of airspeed)

Since $Pr = D.V$, then we can express the induced power required as:

$Pr_i = D_i.V$, or, substituing (= D_i) for ($\propto 1/V^2$):

$Pr_i \propto (1/V^2 \cdot V)$ ====================> $\mathbf{Pr_i \propto 1/V}$

Similarly, if we call parasite drag, D_p, then:

$D_p \propto V^2$ (D_p is proportional to the square of airspeed)

Since $Pr = D.V$, then we can express the parasite power required as:

$Pr_p = D_p.V$, or, substituing (=D_p) for ($\propto V^2$):

$Pr_p \propto (V^2 \cdot V)$ =====================> $\mathbf{Pr_p \propto V^3}$

We can see that while induced power decreases rather slowly with increasing airspeed (i.e. it varies with the inverse of airspeed), parasite power increases very rapidly with airspeed (i.e. it varies with the cube of airspeed). For example, doubling airspeed will cut in *half* the power required to overcome induced drag, but will increase the power required to overcome parasite drag by *eight times*! As with the drag-thrust curve we can add the induced and parasite components of power to obtain the total power required (Figure 6b). The bottom of this curve is rather skewed to the left (for the reasons given above) and consequentely the airspeed for minimum power required (P_{min}) is not the airspeed where the induced and parasite curves cross. In fact, at minimum power, the induced power is three times the parasite power. As a result of this, the airspeed for minimum power is slower than that for minimum thrust (or L/D_{max}).

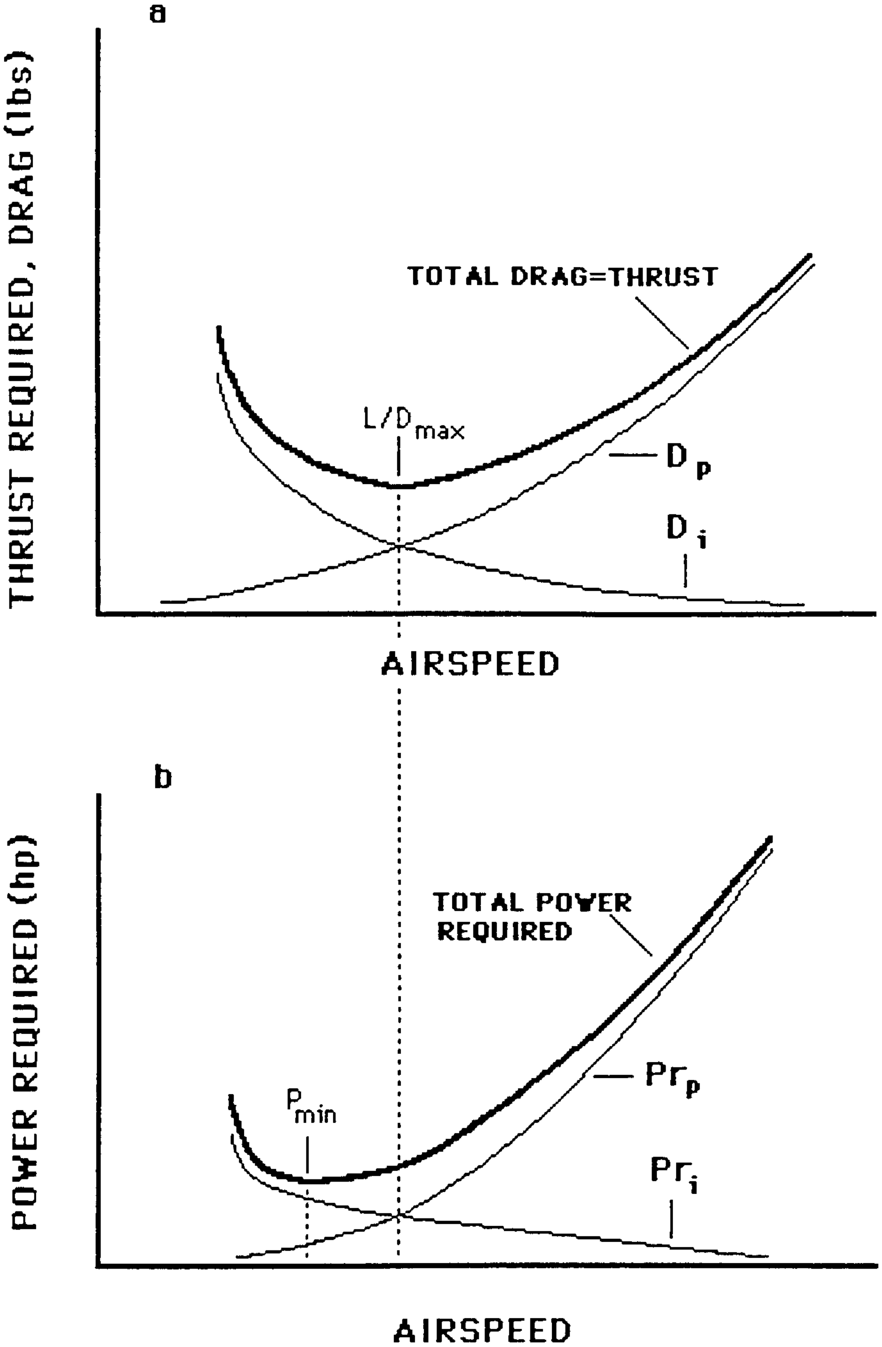

Figure 6. a) Total drag and thrust required for level flight are determined by adding the two components of drag: induced (D_i) and parasite (D_p) drag. **b)** Total power required for level flight and its two components: induced (Pr_i) and parasite (Pr_p) power. Notice that the speed for minimum power required (Pmin) is not the same as that for minimum thrust required (at L/D_{max}). Also, note that at any given steady airspeed, if power applied **exceeds** power required, the aircraft will climb (it will convert the excess kinetic energy into potential energy). On the other hand, if power applied is **less** than the power required to maintain a given speed, the aircraft will descend (it will transfer its potential energy into kinetic energy). In both cases, kinetic energy (and the resulting airspeed) will remain constant. The rate of climb or descent, however, will depend on the difference between power applied and required. Because of this, **power is the primary control of rate of climb or descent during steady (unaccelerated) flight**.

At this point, I would like to make an important distinction between power required as we have derived it, and engine power. The former represents the aerodynamic power required to propel the aircraft, and thus it is called *thrust-power*. Engine power, on the other hand, is the power output measured either at the crankshaft (in which case it is called *brake power*) or at the propeller shaft (in which case it is called *shaft power*). Engine power required to maintain level flight is always greater than thrust-power because the propeller is not 100% efficient (some energy is lost in the process of transfering engine into useful propulsive power). Knowing the propeller efficiency would allow us to estimate shaft power required for level flight. Shaft power is thrust-power divided by propeller efficiency.

Before explaining one of the applications of this power-speed relationship, I want to point out what limits both ends of the level-flight speed range. Take a look at figure 6b. At the low (left) end of the power curve, one cannot keep increasing the angle of attack forever. Once a critical angle of attack is reached (and the maximum coefficient of lift, or C_{Lmax}, is achieved), the wings suddenly lose all lift, and the plane stalls (Figure 4). The message? You cannot fly any slower than stall speed. At the high (right) side of the curve you can increase power only by so much to oppose the increasing parasite drag. At this end, the fastest level-flight speed is limited by *power available*.

Significance of the power curve to fuel management

Aircraft engines, such as a reciprocating-piston engine, convert chemical energy from fuel into usable power. This stored energy is converted to power by the oxygen-requiring combustion of fuel inside the engine. The power generated by this controlled "burning" of fuel is then used to move a propeller which in turn provides the necessary thrust force to overcome drag and propel the aircraft forward. *The rate at which fuel is burnt (in gal/hr) by the piston engine is therefore a function of the amount of power being used.*

Not surprisingly, the power curve is *the* key concept to understand the energy requirements for flight. For simplicity, let's assume we want to "manage" a fixed amount of fuel for a given flight (e.g. no refueling allowed). Usually, when managing a given amount of fuel what we are really trying to do is to maximize or minimize some variable (e.g. time or distance). Once we have decided what is it we want to maximize or minimize, the power curve will give us the answer. It will tell us where in the airspeed range for level flight we should operate to achieve our goal. Let's look at some examples from least to most significant ones (see Figure 7).

Minimum controllable airspeed

How about flying at the *slowest* possible airspeed? We have already seen this speed when we talked about stall speed (1 in Figure 7). The important message here is that flying at the slowest possible speed to maintain level flight will result in more power and fuel consumed per hour or distance than at some *faster* speeds.

Maximum cruise airspeed

Perhaps, you may want to fly at the *fastest* speed possible to *minimize time* between two points? As we stated previously, maximum cruise speed is limited by power available (4 in Figure 7). Again, not a wise decision if you care about fuel economy.

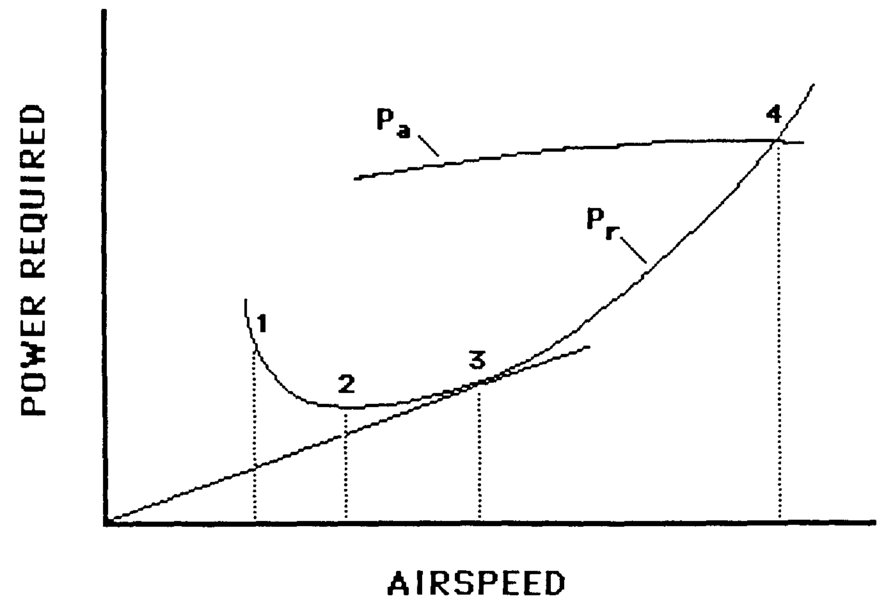

Figure 7. Power required (P_r), thrust-power available (P_a), and some important level-flight airspeeds: (1) minimum controllable, (2) maximum endurance, (3) maximum range, and (4) maximum cruise. Note that the slowest level speed is not limited by power available. At maximum cruise speed, however, the pilot is applying all of the available power (wide open throttle) in order to maintain level flight.

Maximum endurance airspeed

How about *maximizing time* that you can remain aloft? The airspeed for this should be located at the point of lowest power required (because that is where fuel consumption rate is at its lowest). It makes sense, this is where you get most hours out of your fixed amount of fuel. This airspeed (2 in Fig. 7) known as the *maximum endurance speed* is very important if you get into airtraffic/landing delays and are low on fuel.

Maximum range airspeed

Now, for the most important airspeed in terms of getting the most miles per gallon of fuel. What is the speed that will *maximize the distance* that you can fly on a given amount of fuel? What we are trying to do here is to *maximize the ratio of distance to total fuel*. Since we can divide both terms of this ratio by time, we are also trying to *maximize the ratio of airspeed to fuel rate* (which is proportional to power used). This speed, know as *maximum range airspeed*, is found by drawing a tangent line from the origin to the power curve. The point where the tangent line touches the power curve is where the ratio of airspeed to power required is maximized (3 in Fig. 7). As we know, at this speed total drag is minimized, and thus the ratio of lift to drag is maximum (L/D_{max}). In other words, this is where it is cheapest for the aircraft to support and carry its own weight from one location to another.

Measuring the power curve for level flight

Student pilots could benefit tremendously from simply attempting to determine the power curve for their trainer aircraft. First, they can further their understanding of flight dynamics by systematically experimenting with aircraft control (pitch and throttle) in order to achieve a given state of aircraft performance (e.g. level flight at different steady airspeeds). This should be particularly useful, for example, for getting a "feel" of how the different aerodynamic forces interact at different airspeeds to result in steady flight. Second, the exercise can give them the opportunity to empirically test the effects of numerous factors (weight, altitude, configuration) on aircraft performance. Finally, by plotting the power curve for their aircraft, and obtaining some "important airspeeds" under specific flight conditions, they can appreciate the usefulness of having such knowledge in terms of flight planning and management.

Here, I suggest two methods for estimating the power curve for a propeller aircraft. The first one indirectly measures engine power, while the second method measures thrust-power. Neither method is perfect. Both lead to some errors which are noticeable at certain speeds. A comparison of the results using both methods would be useful in discussing these errors. Students can also compare *maximum endurance* and *maximum range* airspeeds which they have calculated with values given in the Pilot's Operating Handbook for the trainer aircraft, or with the following approximations for single-engine, fixed-gear aircraft (Kershner, 1985):

Maximum endurance = 1.2 x power-off, clean stall speed (CAS)
Maximum range = 1.5 x power-off, clean stall speed (CAS)

When plotting the power curve it will be important to correct for airspeed errors by converting indicated (IAS) to calibrated speeds (CAS), and better still to standarize them to true airspeeds (TAS) if density altitude during flight is known.

Method 1: Engine RPM

This method relies on the fact that in fixed-pitched propeller aircraft, propeller and engine speed (RPM) are the same and can be read directly from the tachometer. One can also use this method for constant-speed propeller aircraft. But in this case, instead of using RPM, one would use manifold pressure. Both engine speed and manifold pressure give an indirect measurement of engine power output.

The idea here is to establish different steady airspeeds by varying pitch attitude (hence angle of attack), and then adjusting power as necessary to maintain level flight. Thus, it may be helpful to select a range of airspeeds (e.g. from just above stall to maximum cruise) prior to the flight. During flight, once a selected speed is established, simply record the corresponding engine RPM from the tachometer.

Method 2: Power-off glide

It may seem strange to measure power required to maintain level flight by performing power-off glides. However, this method is based on the fact, that if not enough power (thus thrust) is provided to overcome drag and maintain level flight, the aircraft will simply descend at a given sink rate. Why? Once the aircraft is trimmed to fly at a given airspeed it will continue to maintain that forward speed even if it means losing potential energy (altitude). If we supply *no* power at all, then *all* of the forward force needed to overcome drag will have to come from the force of gravity (which is nothing more than the weight of the aircraft). Under these conditions, the aircraft will simply lose potential energy at a rate equal to its weight multiplied by the sink speed. This "force-times-speed" is nothing else than the power that would be required to maintain level flight (to arrive at this, use a simple analysis of the velocity and force vectors involved in gliding flight). Thus, we can express power required for level flight as follows:

$P_r = W \cdot V_z$, where:

P_r = thrust-power required to maintain level flight
W = weight of aircraft
V_z = sink speed

Sink speed is a function of forward speed. All we need for estimating the level-flight power curve is the aircraft's forward speed, its sink speed, and its weight. Note that if you plot sink speed (y axis) versus forward speed (x axis) you will get a curve (called *glide polar*) that looks very much like a power curve. The similarity is not coincidental, and glide performance speeds (minimum sink, and maximum glide) have their equivalents in the power curve (maximum endurance, and maximum range respectively).

The idea here is to set up a number of power-off glides at different steady airspeeds and measure the time it takes to descend a given vertical distance (e.g. 300 ft). The altitude loss (read from the altimeter) divided by the time (with a stopwatch) will give you the sink speed. The weight of the aircraft can be later estimated by substracting fuel burnt up to the time of the exercise from takeoff weight.

Conclusions

The purpose of this paper was to outline a new way of teaching principles of flight to student pilots. By removing some of the initial learning obstacles encountered by beginner students, this "pilot" oriented approach may help to improve the understanding of flight theory reached by civilian pilots and in so doing, promote proficiency and safety in the skies. The educational strategy proposed here may also provide a model for standarizing ground school curricula, and for integrating theory and practice during flight training. At a time when most of the qualified professional pilots in the commercial fleet are going to be supplied by civilian training programs, a close scrutiny of all aspects of civilian pilot education in the 1990s' is timely.

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