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The Effects of Male-Based Anthropometric Cockpit Designs on Self-Reported Female Aircrew Accommodation

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THE EFFECTS OF MALE-BASED ANTHROPOMETRIC COCKPIT DESIGNS

ON

SELF-REPORTED FEMALE AIRCREW ACCOMMODATION

by

Edith Marie-Anntoinette Dylewska

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This thesis was prepared under the direction of the candidate's thesis committee chairman, Dr. Charles Richardson, Department of Aeronautical Science, and has been approved by the members of her thesis committee. It was submitted to the Office of Graduate Programs and was accepted in partial fulfillment of the requirements for the degree of Master of Aeronautical Science.

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DEDICATION

To my parents,

without whom my existence and this thesis would not have been possible. Thank you for the endless encouragement, constant support, and unconditional love. You have taught me the value of hard work and shown me the simplicity of happiness. Here is hoping your investment in this retirement plan is the most rewarding...

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ABSTRACT

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The purpose of this study was to examine the effects of male-based anthropometric cockpit designs on self-reported female aircrew accommodation. A descriptive survey research method was used to collect the required data. The instrument utilized was a self-developed questionnaire/opinionnaire. It contained both Likert-type and open-ended questions. The 153 subjects were selected from the population of active, civil, female pilots in the United States of America, who hold a Federal Aviation Administration (FAA) Airline Transport Pilot (ATP) Certificate. The responses provided to the Likert questions were analyzed using a goodness-of-fit statistical method. The data collected did not support the research hypothesis that female aircrew accommodation is reduced by current male-based anthropometric cockpit designs.

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LIST OF ABBREVIATIONS

AEDR	[United States] Army Epidemiology Data Register
AFAMRL	Air Force Aerospace Medical Research Laboratory
AGARD	Advisory Group For Aerospace Research and Development
ATC	Air Traffic Control
ATP	Airline Transport Pilot
CAPE	Computerized Accommodated Percentage Evaluation
DoT	Department of Transportation
FAA	Federal Aviation Administration
GAMA	General Aviation Manufacturers Association
ICAO	International Civil Aviation Organization
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
RAF	Royal Air Force
WASP	Women Air Force Service Pilots

Statistical Abbreviations:

D	Maximum Deviation
p	Probability
M	Mode
SD	Standard deviation
$\overline{X}$	Mean

Introduction

The history of women in military aviation dates back to the 1940s (Lyons, 1992). During World War II, 1,147 U.S. women served in non-combat aviation roles such as ferrying aircraft and flight instructing (Granger, 1990). These 1,147 women were know as the Women Air Force Service Pilots or WASPs (Carmien & Ponczek, 1994). After World War II, the U.S. military stopped training women for piloting duties. The training of female pilots resumed in the 1970s and the combat restriction was only recently lifted. Currently within the North Atlantic Treaty Organization (NATO) nations, there are approximately 1,000 female military aviators (Advisory Group for Aerospace Research and Development [AGARD], 1990).

The history of women in civilian aviation professions has mirrored the history of women in military aviation. Today women constitute approximately two percent of the pilots flying for the seven largest airlines in the U.S. (Busey, 1991). Women employment in non-flying aviation professions includes two percent of air carrier operations safety inspectors, eight percent of aerospace engineers, fourteen percent of aviation electronics technicians, and seventeen percent of safety inspectors in aviation manufacturing (Busey, 1991). These percentages are the result of steady increases that are expected to continue well into the future.

Because females represent only a small percentage of the aviation workforce, most workspaces have been designed without the consideration of female accommodation. Aircraft cockpits are designed to accommodate 95 percent of the user population (Bittner, 1976; Reeps, Pheeny, & Brady, 1990).

Until very recently, the population utilized has been exclusively male and the 95 percent design has been based on male only anthropometric data.

In 1990, the Federal Aviation Administration (FAA) reported that 40,515 females held pilot certificates. These females exhibit significant anthropometric differences from the design male. Studies on the accommodation of females in male-based anthropometric cockpit designs have shown that imposing design critical limits based on male only characteristics excludes a very large percentage of the female population (Lane, 1974; Bittner, 1976; Buckle, David, & Kimber, 1990).

The validity of using gender-related difference to predict aviation performance, however, still remains unknown (Lyons, 1992). The basic requirement of any cockpit design is that the operator is able to perform the required duties efficiently, safely, and without discomfort (Bullock, 1973). Optimum aircrew-cockpit compatibility depends on the successful integration of the operator's anthropometric dimensions and cockpit geometry (Hendy, 1990).

With the increasing number of females entering the world of aviation, the accommodation of female aircrew in male-based anthropometric cockpit designs must be thoroughly examined and evaluated. It is imperative to determine if current cockpit designs still allow safe and efficient operations.

Statement of the Problem

The purpose of this study is to examine the effects of male-based anthropometric cockpit designs on self-reported female aircrew accommodation. For the purpose of this research, male-based anthropometric cockpit design is defined as the design of a cockpit that accommodates 95 percent of a male-only user population. Female aircrew accommodation is defined to include both normal operating situations and emergency situations.

Review of Related Literature

The subjects of male-based anthropometric cockpit design and female aircrew accommodation are only scarcely addressed simultaneously in aviation research literature. As the availability of such research is limited, this review of literature takes a little broader approach. Its aim is to examine the underlying foundation and rationale of gender related cockpit design factors. For this purpose, it is divided into the following four sections: cockpit design limits, anthropometric factors in cockpit design, accommodation of female aircrew, and cognitive factors in cockpit design.

Cockpit Design Limits. This first step in examining the effects of male-based anthropometric cockpit designs on female aircrew accommodation is to analyze the factors which influence aircraft cockpit design. In the series of books titled *Aircraft Design*, Roskam (1989) provides the methodology and decision making involved in the process of designing aircraft. In part III of this series, *Layout Design of Cockpits, Fuselage, Wing and Empennage: Cutaways and Inboard Profiles*, Roskam details the considerations which play an important role in the layout of cockpits. These considerations include the following: crew members being in a position which allows them to reach all controls comfortably, crew members being able to see all essential flight instruments without undue effort, communication between crew members by voice or touch must be possible without undue effort, and crew member visibility from the cockpit must adhere to certain minimum standards.

In an attempt to implement these considerations in cockpit design, certain standards and criteria are established. The United States military human engineering standard, MIL-STD-1472 (DoD, 1974), requires the accommodation of approximately 90 percent of a user population. This standard, which is also utilized in civilian aircraft manufacturing, imposes the 5th and 95th percentile critical limits on aircraft designs. These percentile critical limits are, however, based on male-only survey data. The FAA aircraft airworthiness standards for civil aircraft do not list any percentile critical limits for personnel accommodation (Aircraft Technical Publishers, 1994).

Percentile critical limits result in restrictions on anthropometric features of the potential user population. Moroney and Smith (1972) studied U.S. Naval aviators to determine the reduction in potential users resulting from restrictions on anthropometric features. They found that 52 percent of the 1964 population would be excluded by imposing the 5th and 95th percentile critical limits. When the 3rd and 98th percentile critical limits were utilized, the excluded total was reduced to 32 percent.

In 1979, McConville published a report detailing guidelines for the fit testing and evaluation of U.S. Air Force personal and protective clothing and equipment. This report stated that when an item is designed to protect from life-threatening hazards, it must achieve this protection for at least 98 percent of the user population.

Anthropometric Factors in Cockpit Design. Research on the application of anthropometric data in aircraft design dates back to the 1950s. Morant (1955) was among the first to consider the importance of body measurements in aircraft cockpits. Morant identified six body measurements to be of greatest value in connection with workspaces in aircraft design.

These included: stature, sitting height, arm length, thigh length, leg length, and seat breadth. Morant was also among the first to consider demographics as a factor in anthropometric variance. A minimum height standard imposed in selecting pilots for the Royal Air Force would exclude the following percentages of candidates accepted for flying duties in other countries: Netherlands 6 percent; Denmark 8 percent; Belgium 17 percent; and, France 25 percent. Morant concluded that in determining the most suitable dimensions for a standard cockpit reference must be made to accurate anthropometric data for the community of potential operators.

Stewart (1955) also presented a study addressing the utilization of human factors in aircraft design. Stewart stated that the ideal cockpit dimensions, from the anthropometric viewpoint, can be basically achieved through standardization that accommodates the full range of personnel. Some cockpit items that were suggested for standardization included: clearance above the head, degree of vision over the nose, position of the sighting line, and position of the instrument panel. Stewart concluded by crediting the great advances made in aviation in the post-war years to the combined efforts of engineers, physicists, applied psychologists, physiologists, medical test pilots, and anthropometricians.

Whillans (1955) recognized human factors as being critically important and limiting factors in the design of aircraft. Some of the human factors listed as having an significant influence on aircraft design included: space requirements, visual requirements, G-force tolerances, sound tolerances, temperature tolerances, and altitude tolerances. Whillans also stressed the importance of teamwork between aircraft design engineers and human factors engineers in the development and completion of any aircraft design.

A 1973 research study by Bullock addressed pilot accommodation and the accessibility to controls in cockpit design. One of the aims of the study was the determination of arm reach boundaries for placement of manual controls within a cockpit. The study consisted of 407 questionnaires which were sent out to Queensland commercial and private pilots. A total of 196 replies were received. The results of the study indicated that some modifications to the aircraft or its installations were necessary to ensure the provision of safe restraints for pilots while allowing them to reach all controls. Bullock suggested an increase in the adjustibility of cockpit design items to cater to a wider range of pilot sizes.

In a study of computerized accommodated percentage evaluation (CAPE) models, Bittner (1976) identified 13 anthropometric features specific to cockpit design. These include: sitting height, sitting eye height, sitting shoulder height, functional reach, bideltoid diameter, sitting buttock-knee length, sitting buttock-popliteal length, sitting hip breadth, sitting knee height, sitting popliteal height, shoulder-elbow length, forearm length, and elbow rest height. The results of the study indicated that when these anthropometric features are considered the 5th and 95th percentile limits exclude 33.9 percent of the potential population, while with the 3rd and 98th percentile limits, the figure is reduced 14.1 percent to 19.8 percent. Bittner stressed the advantages of utilizing CAPE models to estimate the effects of imposed limits on the accommodated proportion of a population.

In 1978, the National Aeronautics and Space Administration (NASA) compiled and published the *Anthropometric Source Book*. NASA compiled the information as an indication of its understanding that the quality of the interface between man and machine frequently determines the ability and ultimate performance of the man-machine system. The anthropometric data included defines the physical size, mass distribution properties, and dynamic capabilities of the U.S. and selected foreign populations. The measurements provided are those of adult males and females of various age groups, social-economical background, races, and ethical background. The data is presented by male and female percentiles and includes such dimensions as stature, sitting height, sitting eye height, foot length, functional leg length, and thigh clearance. The three volumes of this reference publication provide a comprehensive, up-to-date tabulation of anthropometric data. Sample gender related anthropometric data contained in volume II of the *Anthropometric Source Book* is provided in Table 1.

Table 1

Gender Related Anthropometric Data (from NASA, 1978, p.II-27)

Variable	**Male**		**Female**		**Difference**	
	5th%	95th%	5th%	95th%	5th%	95th
Weight (lbs)	140.2	210.8	102.3	156.3	37.9	54.5
Stature (in)	65.8	73.9	60.0	67.8	5.8	6.1
Sitting Height (in)	34.7	38.8	31.7	35.8	3.0	3.0
Crotch Height (in)	30.8	36.2	26.8	32.0	4.0	4.2
Buttock-Knee Length (in)	22.1	25.6	20.9	24.4	1.2	1.2
Sleeve Length (in)	33.5	38.1	29.2	33.5	4.3	4.6
Hand Length (in)	7.0	8.1	6.7	7.9	0.3	0.2
Foot Length (in)	9.9	11.4	8.7	10.2	1.2	1.2
Hand Circ. (in)	7.9	9.1	6.6	7.8	1.3	1.3

A 1981 book by Croney, *Anthropometry for Designers*, further details the anthropometric difference between females and males, as applicable to workspace design. Croney presents a range of human biological topics in order to provide information on human factors relevant to anthropometric methodology. The anthropometric data reported by Croney is compiled from British and American surveys and includes both static and dynamic measurements. Croney stresses that a successful designer must understand the variety of human physique and the limitations of human performance.

In 1989, Schrimsher and Burke provided a summary of both male and female anthropometric measurements found in the United States Army Epidemiology Data Register (AEDR). The AEDR was developed in 1983 as a computer-accessible repository of medical information on the Army aviation population. It contains 20 anthropometric measurements of 22,000 male flight school applicants, 29,000 male aviators, 800 female flight school applicants, and 600 female aviators. The data is reported in a tabular format which indicates the 1st, 5th, 50th, 95th, and 99th percentile values. This data was compiled to provide human factors input to engineers developing aircraft, weapons, and life support equipment.

Accommodation of Female Aircrew. Several research efforts in the area of workspace design have identified specific anthropometric differences between females and males. These differences must be understood and utilized in the design of equipment, clothing, and workspaces that are to be used by both men and women. A report by Schafer and Bates (1988) provides an anthropometric comparison between the body measurements of men and women. This report documents some differences in the body proportions of men and women in the regions of the torso and legs. The data for this report was acquired from the Air Force Aerospace Medical Research Laboratory (AFAMRL) Anthropometric Data Bank Library. The variables studied included: weight, stature, axilla height, bustpoint height, waist height, buttock height, sleeve inseam, sleeve outseam, shoulder circumference, sitting height, sitting knee height, hip circumference, flexed biceps circumference, waist circumference, back arc, intercye front, bust circumference, ankle circumference, and waist back length. Results reported in this study show that men and women are proportioned so differently that it is nearly impossible to have a single sizing system for clothing or equipment.

In 1975, Choi and Trotter conducted a study which examined race-sex related anthropometric differences among fetal skeletons. This study evaluated 21 measurements on each of 115 American white and negro fetal skeletons. The results of this study showed that differences between sexes were more marked than between different races.

A study by Mital and Sanghavi (1986) compared the maximum volitional torque exertion capabilities of males and females using common hand tools. The 55 subjects included 30 males and 25 females. Unfit subjects were screened out by a personal data form and an oral interview prior to the start of data collection. The 540 measurements were collected which included various combinations of five tools, two postures, three heights, three reach distances, and six angles. The results of this experiment indicated that gender differences were highly significant. On the average, the peak torque exertion capabilities of females were 66% that of males.

In their 1987 study, Miller and Freivalds examined gender and handedness in grip strength. The subjects included 30 white college students of good health (seven dominant right-handed females, seven dominant left-handed females, eight dominant right-handed males, and eight dominant left-handed males). The subjects squeezed a dynameter alternately with both dominant and non-dominant hands. The results of the study reported that the grip strength of the female was 53% that of the male.

A study on the dynamic lifting strengths of teams was conducted by Karwowski (1987). Fifteen two-member teams and 20 three-member teams participated in the study. These teams were either all male or all female, no combination teams were included. Team strength values were compared for dynamic back extension and dynamic lifting strength. On the average, female two-member teams exhibited 38 percent to 35 percent less strength than male two-member teams. Female three-member teams were 28 percent to 21 percent weaker than male three-member teams.

A study of maximal control force capability of female pilots was conducted by Karim et al. (1972). A sample of 25 female pilots was examined to determine the maximal voluntary forces that could be exerted on each flight control. The results obtained indicated that maximum allowable force levels, as permitted by current regulations, may be too high in relation to the strength capabilities of a portion of the female pilot population. The results of this study also indicated that most present general aviation cockpits do not accommodate the range of seat, wheel, and rudder control adjustment needed by many female pilots.

Differences in the anthropometric measurements of females and males seem to present the main problem in the compatibility of female aircrew to today's cockpit designs. Hicks (1990), of the Canadian Medical Board, found that medical assessment data indicated that a greater number of females failed to meet the medical standards for pilot. Hicks stated that the only reason for this is in the area of anthropometry. Of the 149 female aircrew candidates rejected from the Canadian Forces for medical reasons, 41 percent were rejected due to anthropometry. Once selected, female aircrew performed equally with their male peers during training and in operational flying.

In a 1990 study of the Royal Air Force (RAF) aircrew minimum entry limits, Turner attempted to identify problems with the introduction of female aircrew. RAF aircraft manufactured after 1970, have all been designed to accommodate the 3rd and the 99th percentile range of key dimensions of the male aircrew population. RAF standards for aircrew acceptance are reflective of this design objective. Turner found that today's aircraft dimensions exclude approximately 50 percent of the female population. The RAF aircrew minimum entry limit for sitting height excluded 60 percent of the female population, the limit for functional reach excludes 50 percent, and the limit for buttock-knee length excludes 30 percent.

Buckle, David, and Kimber (1990) also examined anthropometric considerations in flight deck design and pilot selection. The subjects were representative of the British population. The flight deck designs evaluated were those of the Boeing 737-200, Boeing 747, Boeing 757, and Lockheed TriStar. The measured variables included seated eye height, buttock-knee length, forward grip length, overhead reach, buttock-heel length, thigh clearance, abdominal depth, and minimum hand width. Bubkle, David, and Kimber concluded that limitations in flight deck design considerably reduce the pool of potential recruits. The results of the study indicated that current aircrew selection criteria, based on functional seated eye height, excludes 73% of the female population between the ages of 19 and 65.

A U.S. Naval Air Development Center study on aircraft emergency equipment (Reeps, Pheeny, & Brady, 1990) also named anthropometric differences as the main problem in accommodating females in today's male-based anthropometric cockpits. This study mainly addressed the accommodation of female aircrew in U.S. Navy protective flight clothing and equipment which has been designed for an exclusively male population. Reeps, Pheeny, and Brady concluded that these male-based anthropometric designs must be redesigned, not just be resized, to accommodate female aircrew. The authors also stressed the need for an accurate anthropometric data base for female aircrew.

The previously mentioned study by Bittner (1976) also examined the accommodation of females in a workspace designed to male standards. This study estimated the multivariate effects of applying 2nd and 98th percentile male accommodation ranges to a female population. The impact of eight successive, cockpit-related, anthropometric restrictions on a female population was determined. The eight anthropometric features measured were sitting height, sitting eye height, sitting buttock-knee length, functional reach, bideltoid diameter, sitting buttock popliteal, sitting popliteal height, and elbow rest height. The results of the study indicated that when considering the eight anthropometric restrictions, 90 percent of the female population would be excluded.

Bittner's (1976) study supported the results on a 1974 investigation conducted by Lane. Lane attempted to estimate the proportion of women excluded by current, male-based anthropometric, fighter aircraft designs. Lane reported that 65 percent of the female population is excluded by male-based anthropometric cockpit designs. This figure is expected to increase to the 80-85 percent level under the full impact of multivariate exclusions.

A 1990 research report by Hendy perhaps best represents the results of related research on the topic of accommodating female aircrew in today's cockpits, and establishes an aim for current research. This report examined aircrew-cockpit compatibility as an interaction between the anthropometry of individual aircrew members and the geometry of the cockpit, realizing that this is a multivariate problem requiring a multivariate solution. Hendy argued that cockpit design must be based on an extensive sampling of human characteristics in order for the full range of interactions, between various anthropometric dimensions and the workspace, to be represented.

A 1992 research report by Lyons supported that presented by Hendy. Lyons examined the aeromedical considerations of women in aviation. The study reviewed scientific literature pertinent to the role of women in military aviation between the years 1966 and 1991. This examination revealed only minor operational differences between men and women. When an allowance was made for size, strength, and fitness, gender differences relating to work performance, G-force tolerance, heat stress, and injury rates disappeared. Lyons concluded that aeromedical selection criteria for aircrew should address individual characteristics without reference to gender.

Cognitive Factors in Cockpit Design. In the area of female aircrew accommodation, there have also been research studies conducted on the cognitive differences between males and females. These studies have yielded mixed results. Goeters and Eissfeldt (1990) conducted a study addressing sex differences concerning the performance and personality traits of applicants for highly qualified operator functions in aviation. The subjects in this study were 402 West German applicants for air traffic control (ATC) training. The subjects were examined through a psychological evaluation which is a required part of the application process for ATC personnel. The results of this study reported significant differences between the cognitive abilities of males and females. Females revealed deficiencies in the areas of spatial orientation, technical comprehension, mathematical reasoning, vitality, and dominance.

Females, however, scored higher in the areas of emotional instability, empathy, and achievement motivation.

A 1990 study conducted in Spain by Marquez de la Plata attempted to evaluate female and male aircrew applicants using a cognitive psychomotor test. This study considered certain cognitive and psychomotor processes as being significant in the task of piloting an aircraft. These processes included attention, perception, information processing, decision-making, and psychomotor response. Contrary to the results of Goeters and Eissfeldt's study, Marquez de la Plata found no significant differences between the cognitive performance of males and females.

In a study on gender differences and cognitive ability in the transfer of training of basic flying skills, McCloy and Swiney (1982) investigated 18 subjects, 10 male and 8 female. Subject trained and tested on a desktop flight simulator. Subjects were also given a written test to obtain information relating to the factors of field dependence, perceptual speed, spatial relations, visualization, and distractibility. The results of the study indicated that males and females maintain basic instrument flying skills equally well.

Summary. Numerous research efforts have examined the topics of cockpit design limits, anthropometric factors of cockpit design, gender related anthropometric differences, and the accommodation of female aircrew. In reviewing these studies, it is apparent that significant evidence exists which questions the accommodation of females in male-based anthropometric cockpit designs. With the increasing number of females entering the world of aviation, a necessity prevails to thoroughly examine and evaluate this evidence.

Statement of the Hypothesis

A review of research literature shows that females are significantly anthropometrically different from the design males utilized to establish current cockpit design limits. Current cockpit designs are based on male only anthropometric data; therefore, it is hypothesized that female aircrew accommodation is reduced by current cockpit designs.

Method

Subjects

The subjects for this study were selected from the population of active, civil, female pilots in the United States of America, who hold a Federal Aviation Administration (FAA) Airline Transport Pilot (ATP) Certificate. The entire population, as obtained from the FAA Airmen Directory File, was sampled. The sample size was 153 active female certificate holders. The population variables were broken down into nine subgroups by FAA region. Figure 1 indicates the FAA regional boundaries for the nine regions. The percentage of the sample designated for each region was representative of the percent of the population within that region. The nine FAA regions include the Alaskan (2%), Central (4%), Eastern (13%), Great Lakes (11%), New England (5%), Northwest Mountain (9%), Southern (21%), Southwest (11%), and Western-Pacific Region (24%). Table 2 lists the numbers and percentages of subjects sampled from each FAA region. All nine regions were included in this study to account for anthropometric variance.

Prior to the beginning of this study, Aerodata Incorporated provided a copy of the FAA Airmen Directory File on magnetic computer tape. The Airmen Directory File contained the records of each certified airman who had been issued a valid airmen medical certificate within the preceding 25 months. This file is updated semi-annually and contained data as of December 31, 1992.

Figure 1. FAA Regional Boundaries (from FAA, 1990, p.xi).

Table 2

Demographic Characteristics of Subjects Sampled

Region	Number (N)	Percentage (%)
Alaskan	3	2
Central	6	4
Eastern	20	13
Great Lakes	17	11
New England	8	5
Northwest Mountain	14	9
Southern	32	21
Southwest	17	11
Western-Pacific	36	24
Totals	153	100

The Embry-Riddle Aeronautical University Data Processing Department sorted the data and provided a listing of all airmen included in the FAA Airmen Directory File who held an ATP certificate. The FAA Directory File did not provide a field specifying the gender of airmen listed. A manual sort was, therefore, required to obtain a listing of all female airmen who held ATP certificates. The procedure utilized for the manual sort was one of examining the first names of airmen. Only airmen with names almost exclusively assigned to females were chosen for the mailing list. A book titled *Baby Names* by the Globe Communications Corporation (1993) was utilized to aid in this process. The procedure required the elimination of all airmen with first names which could be used for either gender. Some of the first names eliminated included: Beverly, Chris, Dana, Francis, Gene, Glenn, Kim, Lauren, Lynn, Robin, and Tracy. All airmen whose first names consisted only of initials were also excluded. Every effort was made to insure that the questionnaire was received by female aircrew only. The manual sort yielded a list of only 153 names.

The figure of 153 names appeared inconsistent with researcher expectations. *U.S. Civil Airmen Statistics: Calendar Year 1990* (FAA, 1990) reported 107,732 pilots holding ATP certificates on December 31, 1990, of which 2,082 were designated female. *The General Aviation Statistical Databook: 1992 Edition* (General Aviation Manufacturers Association [GAMA], 1992) also reported 107,732 APT certificated pilots for the year 1990. The Airmen's Directory provided by Aerodata Incorporated contained only 5709 ATP pilots (5462 with U.S. addresses). After some investigation, it was found that the FAA and GAMA were reporting total number of pilots holding certificates, while the Airmen's Directory contained only those who were active (had been issued a valid airmen medical certificate within the preceding 25 months). Further examining the figures provided by the FAA, it was calculated that 2,082 (female ATPs FAA data) is 1.9% of 107,732 (total ATPs - FAA data), while 153 (female ATPs - Airmen's Directory data) is 2.7% of 5709 (total ATPs - Airmen's Directory data). These percentages are closely related, therefore it was assumed that 153 is a realistic representation of the total active female ATP pilot population. All 153 female airmen included in the listing were sampled. No sampling bias was anticipated.

Instrument

The measuring instrument utilized in this study was a self-developed questionnaire/opinionnaire. This instrument was developed to adequately collect the unique data required for this research study. The specific purpose of this instrument was to determine the effects of current male-based anthropometric cockpit designs on self-reported female aircrew accommodation.

Determining the content validity of this instrument was accomplished through a two step process. The first step was a pilot study. Version 1 (see Appendix A) of the questionnaire/opinionnaire was administered to a selected group of Embry-Riddle Aeronautical University graduate students who were considered knowledgeable in the topic areas covered. The results of this pilot study were evaluated to determine the instrument's applicability in gathering data relevant to the stated hypothesis that female aircrew accommodation is reduced by current male-based anthropometric cockpit designs. During this pilot study, confusing and ambiguous language, poor structure, and inapplicable content were identified and modified. Changes to version 1 included: the addition of a 'Notice of Confidentiality' statement to encourage responses; the offering of study results to encourage responses; the bracketing of answer options for easier completion; the addition of a 'Body Type' question with petit, small, medium, large, and x-large answer options which could easily be related to clothing sizing and provide reach data; some language change to questions for better clarity; and, the inclusion of two additional open-ended questions to address reach problems and safety/efficiency problems. The result of this pilot study, version 2 of the questionnaire/opinionnaire, is provided in Appendix B.

Step two of determining the content validity of the instrument was accomplished by obtaining additional insight from a select group of Embry-Riddle Aeronautical University faculty who are considered experts in the fields of aviation research and human factors engineering. Modifications made during step two included: the revision of cockpit design questions to isolate specific problems/issues such as rudder pedal reach, overhead controls reach, sitting height, visibility, hand width, foot size, and strength; the revision of cockpit design question wording to include "you" and "your" in an attempt to eliminate confusion of whether questions referred to individuals answering the questionnaire or female pilots in general; the elimination of one cockpit design question due to ambiguity; and, some modification of open-ended questions for clarity. The final version of the questionnaire/opinionnaire is provided in Appendix C.

The final version of the instrument utilized to gather data consisted of four sections. The first section collected personal information, offered subjects a copy of study results, and contained a notice guaranteeing subject confidentiality. The second section gathered anthropometric data and flight experience information. The third section was an eleven item Likert-type opinionnaire dealing with cockpit design attitudes. The Likert-type questions offered five answer options; strongly agree, agree, undecided, disagree, and strongly disagree. A point value assigned to each option was used for totaling and analyzing the responses to formulate study results. Section three addressed several anthropometric factors designated by previous research to be specific to cockpit design. These factors included sitting height, strength, leg length, hand width, reach, and foot size. The fourth section was a six item, open-ended questionnaire designed to provide further insight into the issues addressed in the third section dealing with the accommodation of female aircrew in male-based anthropometric cockpit designs.

The final instrument was mailed to all selected, active, civil, female pilots in the U.S. who hold a FAA ATP certificate. The instrument was accompanied by a cover letter signed by the researcher. The three successive revisions of the cover letter are provided in Appendix D, Appendix E, and Appendix F, respectively. These revisions were necessary to unsure proper syntax, effective explanation of the problem, and identification of the value and importance of potential results.

Design

The research method used in this study was the descriptive survey method as outlined in the textbook, *Educational Research*, by Gay (1992). The limited published literature and unique nature of data required for this research study necessitated the use of the descriptive method of research. This method of research was the most economical and efficient means available of collecting the needed data. Choosing this type of research method permitted the examination of the topic through the use of a questionnaire/opinionnaire. The use of a questionnaire/opinionnaire allowed the current status of the subject to be obtained and the stated hypothesis to be tested.

The instrument used in this study was self-developed to adequately collect the required data. This instrument was pretested through a pilot study. The subjects for this study were selected from the population of active, civil, female pilots in the U.S. who hold a FAA ATP Certificate. This population was believed to possess the information required by the researcher.

The main measured variable for this study was that of self-reported accommodation. Measurement data was collected through 11 Likert-type questions which dealt with specific anthropometric factors. These factors were selected from previous research literature which identified them as both factors in aircraft design and potential factors in the accommodation of females in current male-based anthropometric cockpit designs. These anthropometric factors included sitting height (visual reference), strength, leg length (rudder pedal reach), hand width, arm reach, and foot size. Two of the 11 Likert-type questions were designed to address the factors of safety and optimum performance directly. The significance of the collected data was determined through a statistical analysis utilizing the Kolmogorov-Smirnov One-Sample Test at p = .05 (Siegel, 1956). The Kolmogorov-Smirnov One-Sample Test was chosen because of the ordinal nature of the frequency data collected and was used to test the null hypothesis applicable to each question. The results from the analysis of the 11 Likert-type questions were then utilized to test the overall research hypothesis.

The information obtained from the six open-ended questions was used to provide further insight into the analysis of collected data. The purpose of these open-ended questions was the identification of specific problem areas and aircraft types. The summarization of given responses provided the desired information. The only uncontrolled variable was that of response rate.

Procedures

Prior to the beginning of this study, the researcher obtained from the FAA a listing of all active, civil, female pilots in the U.S. who hold a FAA ATP Certificate. This listing was provided on magnetic computer tape and was converted to printed material by the Embry-Riddle Aeronautical University Data Processing Department. The subjects for this study were selected from the population in the listing. The sample size for this study was 153 active female ATP certificate holders. The population variables were broken down into nine subgroups by FAA region. All nine regions were included in this study to account for anthropometric variance. All members of the population were classified as members of one of the subgroups.

The instrument utilized for this study was a self-developed questionnaire/opinionnaire. This instrument was developed to adequately collect the unique data required for this research study. Determining the content validity of this instrument was accomplished through a pilot study and the consultation of experts from the fields of educational research and human factors engineering. A selected group of Embry-Riddle Aeronautical University graduate students was utilized for the pilot study and administered the questionnaire/opinionnaire. The results of the pilot study and consultation were evaluated to determine the instrument's applicability in gathering data relevant to the stated hypothesis. The instrument was modified prior to its final application.

The questionnaire/opinionnaire was mailed to the selected subjects. The questionnaire/opinionnaire was color coded to signify FAA regions as follows: Alaskan (2%) - yellow, Central (4%) - red, Eastern (13%) light pink, Great Lakes (11%) - purple, New England (5%) - orange, Northwest Mountain (9%) - dark pink, Southern (21%) - ivory, Southwest (11%) - gray, and Western-Pacific Region (24%) blue. Color coding allowed for the analysis of data according to region without the necessity of requiring subject to provide their addresses. The mailings included a stamped, self-addressed envelope and a cover letter signed by the researcher. The cover letter gave a requested response date in order to control the time interval of this study. A time interval of 30 days was allowed for responding. Confidentiality of response was guaranteed through a statement at the beginning of the questionnaire and subjects were given the option of including their names and addresses. The subjects were offered a copy of the results as an incentive for responding.

When the deadline was reached, 64 questionnaires had been received. Eight additional ones had returned marked 'return to sender' due to mailing address difficulties. Of the 64 questionnaires received, four had arrived with comments indicating that the receiver was not a female. Another two were returned incomplete and had to be eliminated from the study. This resulted in a final number of 58 questionnaires which could be included in the study. The figure of 58 represented a 37.9% return rate.

The obtained results were compiled and entered into a Excel data spreadsheet file designed by the researcher specifically for this study. The data obtained from the first section of the questionnaire was analyzed using the traditional statistics of mean ($\overline{X}$) and standard deviation (SD) as outlined in *A Programmed Introduction to Statistics by Elzey* (1971). The data obtained from the Likert-type questions was analyzed using the Kolmogorov-Smirnov One-Sample Test as outlined in *Nonparametric Statistics for the Behavioral Sciences* by Siegel (1956) and *Nonparametric Statistical Inference* by Gibbons (1971). The Kolmogorov-Smirnov One-Sample Test allowed the ordinal frequency data to be examined for significance. These results were then utilized to test the research hypothesis which stated that since current cockpit designs are based on male only anthropometric data, female aircrew accommodation is reduced. A summarization of the results obtained from open-ended questions was used to identify specific problem areas and aircraft types. Conclusion were drawn and recommendations were made.

Analysis

The analysis of results is broken down into three main sections. The first section represents the second part of the questionnaire/opinionnaire, Flight Experience, which was designed to collect demographic, anthropometric, and experience data on subjects. This data is analyzed using the traditional statistics of mean ($\overline{X}$) and standard deviation (SD) as outlined in *A Programmed Introduction to Statistics by Elzey* (1971).

The second section represents data collected from the third part of the questionnaire/opinionnaire, Cockpit Design Questionnaire. These Likert-type questions were designed to collect subject attitudes/opinions regarding cockpit design. The Kolmogorov-Smirnov One Sample Test is used to allow the ordinal frequency data to be examined for significance as outlined in *Nonparametric Statistics for the Behavioral Sciences* by Siegel (1956) and *Nonparametric Statistical Inference* by Gibbons (1971). Each question is analyzed separately. The total number of responses per question may vary due to all subjects not responding to every question.

The third and final section represents the fourth part of the questionnaire/opinionnaire, Open-Ended Questions. This section consists of a summarization of the answers generated to the open-ended questions. Each question is again analyzed individually.

Subject Data

Subject data is further divided into seven section for analysis. These sections are FAA region, age, height, body type, years flying, total flight time, and type of aircraft flown for hire.

FAA Region. The FAA region in which the subject resided was determined by the color of the received questionnaire. There were no responses received from the Alaskan region nor the Central region. The 58 responses received represented the remaining seven FAA regions as follows: Eastern-7(12.1%), Great Lakes-8(13.8%), New England-2(3.5%), Northwest Mountain-6(10.3%), Southern-15(25.9%), Southwest-6(10.3%), and Western-Pacific-14(24.1%). Appendix G provides a complete listing of each subject's FAA region.

Table 3 provides a representation of response totals and percentages from each FAA region. The two regions best represented were the Southern with 25.9% and the Western-Pacific with 24.1%. These two regions accounted for 50% of the questionnaires received.

Age. The answer options to the request for subject age were bracketed into six categories. These categories were <20, 20-30, 31-40, 41-50, 51-60, and >60 years. Appendix H provides a complete listing of each subject's response regarding age.

Table 4 shows the number and percent of subject responses in each age category. Thirty-five (60.4%) subjects were between the ages of 31 and 40, and 14 (24.1%) were between the ages of 41 and 50. This resulted in 84.5% of the subjects being between the ages of 31 and 50. The mean ($\overline{X}$) age was 37.4 years, the standard deviation (SD) was 7.20 years.

Table 3

Subject Demographic Data Received by FAA region

Region	Number (N)	Percentage (%)
Alaskan	0	0
Central	0	0
Eastern	7	12.1
Great Lakes	8	13.8
New England	2	3.5
Northwest Mountain	6	10.3
Southern	15	25.9
Southwest	6	10.3
Western-Pacific	14	24.1
Totals	58	100.0

Table 4

Age Distribution of Subjects

Years	Number (N)	Percentage (%)
<20	0	0.0
20-30	7	12.1
31-40	35	60.4
41-50	14	24.1
51-60	1	1.7
>61	1	1.7
Totals	58	100.0

Height. The answer options to the request for subject height were bracketed into seven categories. These categories were <50, 50-55, 56-60, 61-65, 66-70, 71-75, and >76 inches. Appendix I provides a complete listing of each subject's height response.

Table 5 shows the number and percent of subject responses in each height category. Twenty-three (39.7%) subjects reported being between 66 and 70 inches, 18 (31.0%) reported being between 61 and 65 inches, and 10 (17.2%) reported a height between 56 and 60 inches. This resulted in 87.9% of the subjects being between the height of 56 inches and 70 inches. The mean ($\overline{X}$) height was 64.3 inches, the standard deviation (SD) was 5.13 inches.

Table 5

Height Distribution of Subjects

Height (inches)	**Number (N)**	**Percentage (%)**
<50	0	0.0
50-55	3	5.2
56-60	10	17.2
61-65	18	31.0
66-70	23	39.7
71-75	3	5.2
>76	1	1.7
Totals	58	100.0

Body Type. The answer options to the request for subject body type were bracketed into five categories. These categories were petit, small, medium, large, and x-large. Appendix J provides a complete listing of each subject's response.

Table 6 shows the number and percent of subject responses in each category. The category of x-large was not chosen by any subject. Thirty-five (60.4%) subjects reported a medium body type, while 12 (20.7%) reported a small body type. This resulted in 81.1% of the subjects being accounted for by these two body type categories.

Table 6

Body Type Distribution of Subjects

Body Type	Number (N)	Percentage (%)
Petit	5	8.6
Small	12	20.7
Medium	35	60.4
Large	6	10.3
X-Large	0	0.0
Totals	58	100.0

Years Flying. Total years flying reported by subjects ranged from 4 to 35 years. Appendix K provides a complete listing of each subject's response. The mean ($\overline{X}$) for data given by all 58 subjects was 15 years and the standard deviation (SD) was 5 years.

Total Flight Time. The subjects reported total flight time from 2,000 to 26,000 flight hours. A complete listing of responses provided by subjects is available in Appendix L. The 58 responses given resulted in a mean ($\overline{X}$) of 6,099 flight hours and a standard deviation (SD) of 3,663 flight hours.

Type Aircraft Flown for Hire. A variety of aircraft types flown for hire were reported. They ranged from a C-152 to a B-747-400. For a complete listing of aircraft flown for hire by subjects see Appendix M. The aircraft type reported most by subjects was the Boeing 737. With 11 listings, it was flown for hire by 19.0% of the subjects. The second most listed aircraft type was the Boeing 727 with eight (13.8%) subjects flying it for hire.

Likert-Type Cockpit Design Questions

The Likert-type cockpit design questions were designed to examine specific anthropometric factors which were designated by previous research to be significant in the design of cockpits and in the accommodation of females in current cockpit designs. Two questions were also included to address safety and optimum performance directly. In effect, each question tests a separate null test hypothesis specific to the factor addressed. The analysis of each question includes a statement of the null test hypothesis. Some overlap occurred due to the research's desire to provide a balance of positive and negative questions and, therefore, eliminate subject bias. The overall null hypothesis for the study was *"There is no effect of female aircrew accommodation by current male-based anthropometric cockpit designs."*

Subjects were given five response options to indicate their experience as relating to each statement. These were strongly agree (SA), agree (A), undecided (U), disagree (D), and strongly disagree (SD). Directions on the top of the questionnaire indicated that all questions should be referred to the aircraft that the subject was flying for hire.

The responses to cockpit design questions 1-11 were analyzed according to their frequency data. For each question a mode and response percentages were calculated, and the Kolmogorov-Smirnov One-Sample Test was applied. A mode was calculated to determine the most recurring or most frequent response option. Response percentages were calculated to determine the distribution of response options. The Kolmogorov-Smirnov One-Sample Test was utilized due to the ordinal nature of the frequency data.

The Kolmogorov-Smirnov One-Sample Test is a test of goodness of fit and is concerned with the degree of agreement between the observed distribution and some specified theoretical distribution (Siegel, 1956). It consists of specifying the theoretical cumulative frequency distribution and comparing it with the observed cumulative frequency distribution. The theoretical cumulative frequency distribution represents what which is expected if the null hypothesis is true. The Kolmogorov-Smirnov One-Sample Test determines the point at which the observed and theoretical distributions show the greatest divergence and indicates whether such a divergence is likely on the basis of chance. The Kolmogorov-Smirnov One-Sample Test was chosen over the Chi Square technique because it treats individual observations separately and, therefore, does not lose information through the combining of categories.

Due to the fact that the overall research hypothesis stated a direction of difference, a one-tailed test was necessary (Wallop, 1983). The results of questions 1-11 were tested at the 95% confidence level ($p = .05$), which indicates that the chance of getting the obtained results by chance was only 5%. In order to perform a one-tailed test, the probability levels listed for a two-tailed test were divided by two (Elzey, 1971). Therefore, the critical value for a one-tailed test at $p = .05$ appeared in the column headed $p = .10$. The critical values table utilized was that listed in *Nonparametric Statistics for the Behavioral Sciences* by Siegel (1956).

Question 1

SA A U D SD *Even when adjusted to its upmost position, the cockpit seat does **not** allow you an adequate/safe outside visual reference.*

This question was designed to evaluate the significance of sitting height in the accommodation of females in male-based anthropometric cockpit designs. This anthropometric factor has been a focus in much research of cockpit design (Morant, 1955; Stewart, 1955; Whillans, 1955; Bittner, 1976; Shafer & Bates, 1988; RAF, 1990; Buckle, David, & Kimber, 1990). NASA (1978) stated that the sitting height of a 5th% male is 34.7 inches while the sitting height of a 5th% female is only 31.7 inches. The 95th% male sitting height is 38.8 inches while the 95th% female sitting height is 35.8 inches. This represents a difference of 3 inches between the sitting heights of males and females. In this question, the accommodation of female sitting heights in current cockpit designs was examined through subject experience with the range of cockpit seat adjustments. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit seat design/sitting height."*

The response frequencies were distributed among the five response options as follows: SA-3(5.2%), A-4(6.9%), U-0(0.0%), D-25(43.1%), and SD-26(44.8%). Appendix N provides a complete listing of subject responses.

Figure 2 gives a graphic representation of the data distribution. The most favored response (mode) was SD with a frequency of 26. The D and SD response options accounted for 87.9% of all subject responses received.

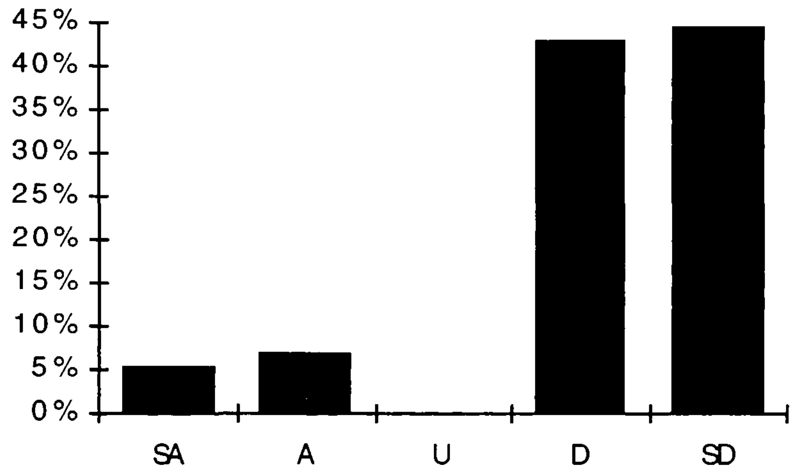

Figure 2. Data Distribution Cockpit Design Question 1.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit seat design/sitting height, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 58 responses received, the expected frequency for each option was 11.6. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.479 and occurred at the U response option. Using the critical values table for D, it was found that 0.479 is higher than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at $p = .05$ and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit seat design/sitting height. The results indicate that there is a significant effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit seat design/sitting height. However, due to the negative wording of the question and the maximum deviation occurring at the "undecided/neutral" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 2

SA A U D SD *Strength required to operate aircraft controls (e.g., control wheel, reverse thrust levers) is within your capabilities.*

The purpose of question two was to evaluate the significance of strength in the accommodation of females in male-based anthropometric cockpit designs. Past research efforts have shown this factor to be representative of gender performance differences. Mital and Sanghavi (1986) reported that, on the average, the peak torque exertion capabilities of females were 66% that of males. Miller and Freivalds (1987) reported that grip strength of females was 53% that of males. Karim et al. (1972) showed that the maximum control force capabilities of female pilots were lower then the maximum allowable force levels permitted by regulations. In this question, the accommodation of female strength capabilities in current cockpit designs was examined through subject experience with the forces required to operate cockpit controls. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew accommodation due to forces required to operate cockpit controls/strength."*

The response frequencies were distributed among the five response options as follows: SA-30(51.7%), A-23(39.7%), U-4(6.9%), D-1(1.7%), and SD-0(0.0%). Appendix O provides a complete listing of subject responses.

Figure 3 gives a graphic representation of the data distribution. The most favored response (mode) was SA with a frequency of 30. The SA and A response options accounted for 91.4% of all subject responses received.

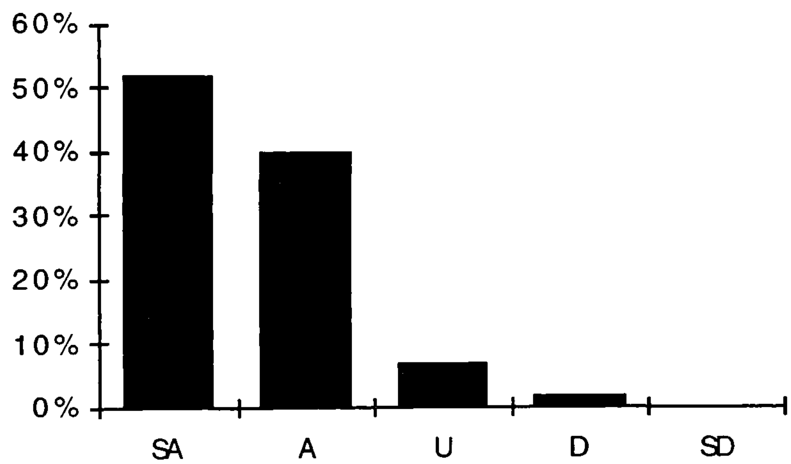

Figure 3. Data Distribution - Cockpit Design Question 2.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to forces required to operate cockpit controls/strength, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 58 responses received, the expected frequency for each option was 11.6. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.534 and occurred at the A response option. Using the critical values table for D, it was found that 0.534 is higher than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at $p = .05$ and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to forces required to operate cockpit controls/strength. The results indicate that there is a significant effect on self-reported female aircrew accommodation due to forces required to operate cockpit controls/strength. However, due to the positive wording of the question and the maximum deviation occurring at the "agree" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 3

SA A U D SD *It is physically possible for you to operate the rudder pedals through their full range.*

Question three examined the significance of leg length in the accommodation of females in male-based anthropometric cockpit designs. This anthropometric factor has also been identified in much research of cockpit design (Morant, 1955; Bittner, 1976; Shafer & Bates, 1988; RAF, 1990; Buckle, David, & Kimber, 1990). NASA (1978) stated that the crotch height of a 5th% male is 30.8 inches while the crotch height of a 5th% female is only 26.8 inches. The 95th% male crotch height is 36.2 inches while the 95th% female crotch height is 32.0 inches. This represents a difference of 4 inches at the 5th% level and 4.2 at the 95th% level between the crotch heights of males and females. In this question, the accommodation of female leg length in current cockpit designs was examined through subject experience with the full range of rudder pedal operation. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew accommodation due to male-based anthropometric rudder pedal design/leg length."*

The response frequencies were distributed among the five response options as follows: SA-33(56.9%), A-18(31.0%), U-1(1.7%), D-4(6.9%), and SD-2(3.5%). Appendix P provides a complete listing of subject responses.

Figure 4 gives a graphic representation of the data distribution. The most favored response (mode) was SA with a frequency of 33. The SA and A response options accounted for 87.9% of all subject responses received.

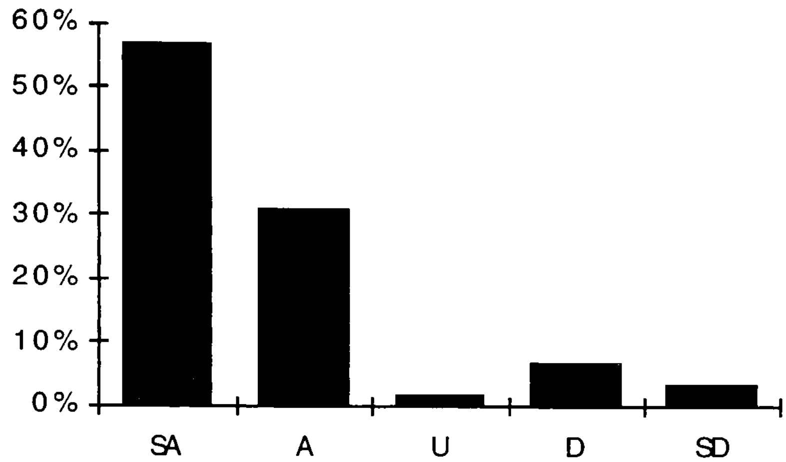

Figure 4. Data Distribution Cockpit Design Question 3.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to male-based anthropometric rudder pedal design/leg length, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 58 responses received, the expected frequency for each option was 11.6. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.479 and occurred at the A response option. Using the critical values table for D, it was found that 0.479 is higher than that listed for p = .05. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at p = .05 and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to male-based anthropometric rudder pedal design/leg length. The results indicate that there is a significant effect on self-reported female aircrew accommodation due to male-based anthropometric rudder pedal design/leg length. However, due to the positive wording of the question and the maximum deviation occurring at the "agree" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 4

SA A U D SD *The back pressure required to operate the control wheel during takeoff does* ***not*** *allow you to manipulate it with one hand.*

Question 4, similar to question 2, also addresses the factor of strength in the accommodation of females in male-based anthropometric cockpit designs. Unlike question 2, however, it takes a negative approach. This balancing of positive and negative questions is incorporated into the questionnaire in order to eliminate subject bias and add validity to the testing method. In this question, the factor of female strength capability accommodation in current cockpit designs was examined through subject experience with the control pressure required to operate the control wheel. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew accommodation due to the control pressure required to operate the control wheel/strength."*

The response frequencies were distributed among the five response options as follows: SA-0(0.0%), A-7(12.3%), U-1(1.7%), D-22(38.6%), and SD-27(47.4%). Appendix Q provides a complete listing of subject responses.

Figure 5 gives a graphic representation of the data distribution. The most favored response (mode) was SD with a frequency of 27. The D and SD response options accounted for 86.0% of all subject responses received.

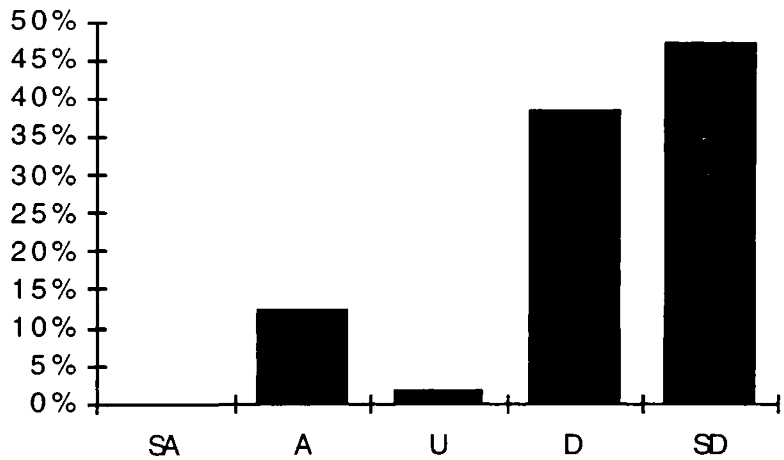

Figure 5. Data Distribution - Cockpit Design Question 4.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to the control pressure required to operate the control wheel/strength, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 57 responses received, the expected frequency for each option was 11.4. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.460 and occurred at the U response option. Using the critical values table for D, it was found that 0.460 is higher than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at $p = .05$ and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to control pressure required to operate the control wheel/strength. The results indicate that there is a significant effect on self-reported female aircrew accommodation due to control pressure required to operate the control wheel/strength. However, due to the negative wording of the question and the maximum deviation occurring at the "undecided/neutral" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 5

SA A U D SD *The hand width required for the satisfactory operation of the throttle levers in within your physical capabilities.*

This question was designed to evaluate the significance of hand width in the accommodation of females in male-based anthropometric cockpit designs. Hand width has been identified by some research as being a significant anthropometric factor (Buckle, David, & Kimber, 1990). Although its coverage in research literature is limited, experience and comments made during the questionnaire pilot study suggested the inclusion of this factor in the study. NASA (1978) stated that the hand circumference of a 5th% male is 7.9 inches while the hand circumference of a 5th% female is only 6.6 inches. The 95th% male hand circumference is 9.1 inches while the 95th% female hand circumference is 7.8 inches. This represents a difference of 1.3 inches between the hand circumferences of males and females. In this question, the accommodation of female hand widths in current cockpit designs was examined through subject experience with throttle levers operation. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew accommodation due to the hand width required to operate throttle levers."*

The response frequencies were distributed among the five response options as follows: SA-23(39.6%), A-30(51.7%), U-2(3.5%), D-2(3.5%), and SD-1(1.7%). Appendix R provides a complete listing of subject responses.

Figure 6 gives a graphic representation of the data distribution. The most favored response (mode) was A with a frequency of 30. The SA and A response options accounted for 91.3% of all subject responses received.

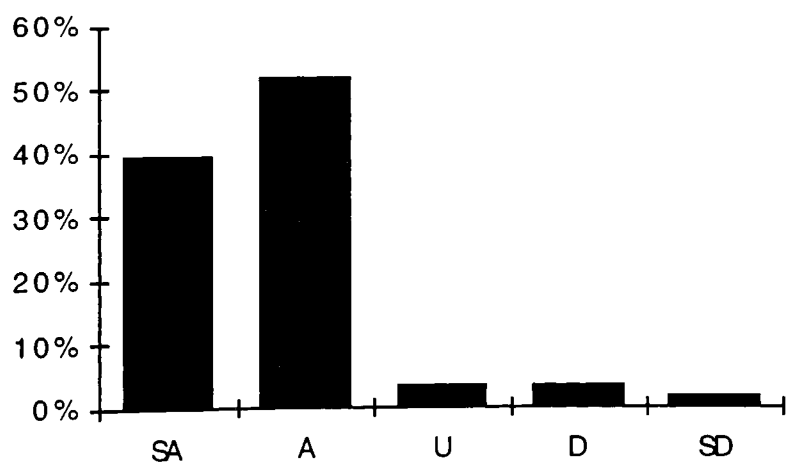

Figure 6. Data Distribution Cockpit Design Question 5.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to the hand width required to operate throttle levers, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 58 responses received, the expected frequency for each option was 11.6. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.514 and occurred at the A response option. Using the critical values table for D, it was found that 0.514 is higher than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at $p = .05$ and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to the hand width required to operate throttle levers. The results indicate that there is a significant effect on self-reported female aircrew accommodation due to the hand width required to operate throttle levers. However, due to the positive wording of the question and the maximum deviation occurring at the "agree" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 6

SA A U D SD *The position of overhead controls **inhibits** your efficient and timely operation of these controls.*

Question six evaluates the significance of reach capabilities in the accommodation of females in male-based anthropometric cockpit designs. The anthropometric factor of arm length or reach has been a focus in much research of cockpit design (Morant, 1955; Bittner, 1976; Shafer & Bates, 1988; Roskan, 1989; RAF, 1990; Buckle, David, & Kimber, 1990). NASA (1978) gives the following measurements for sleeve length: 5th% male - 33.5 inches, 5th% female 29.2 inches, 95th% male 38.1 inches, and 95th% female 33.5 inches. This represents a difference of 4.3 inches at the 5th% level and 4.6 inches at the 95th% level. What is interesting to note here, is that the 95th% female sleeve length measurement is equivalent to the 5th% male sleeve length measurement. In this question, the accommodation of female reach capability in current cockpit designs was examined through subject experience with overhead controls. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew accommodation due to male-based anthropometric overhead control design/arm length."*

The response frequencies were distributed among the five response options as follows: SA-0(0.0%), A-6(10.7%), U-7(12.5%), D-21(37.5%), and SD-22(39.3%). Appendix S provides a complete listing of subject responses.

Figure 7 gives a graphic representation of the data distribution. The most favored response (mode) was SD with a frequency of 22. The D and SD response options accounted for 76.8% of all subject responses received.

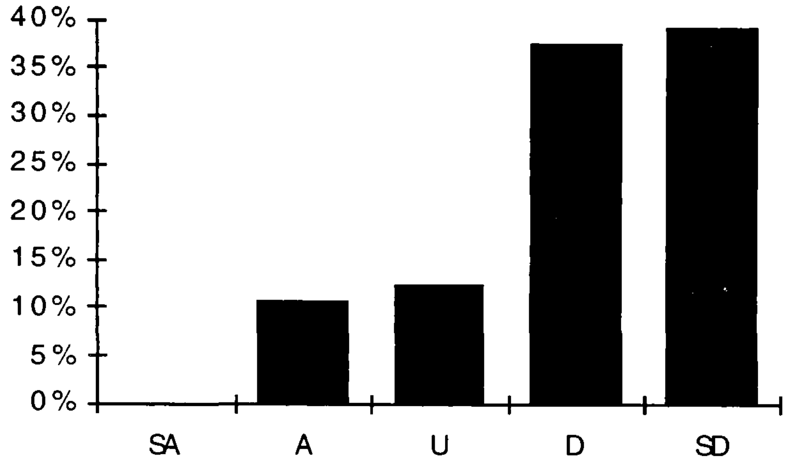

Figure 7. Data Distribution - Cockpit Design Question 6.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to male-based anthropometric overhead control design/arm length, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 56 responses received, the expected frequency for each option was 11.2. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.368 and occurred at the U response option. Using the critical values table for D, it was found that 0.368 is higher than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at $p = .05$ and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to male-based anthropometric overhead control design/arm length. The results indicate that there is a significant effect on self-reported female aircrew accommodation due to male-based anthropometric overhead control design/arm length. However, due to the negative wording of the question and the maximum deviation occurring at the "undecided/neutral" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 7

SA A U D SD *Your foot size presents a physical* ***problem*** *in manipulating rudder pedals.*

This questions was designed to evaluate the significance of foot size in the accommodation of females in male-based anthropometric cockpit designs. Although past research in the field of cockpit design has not specifically identified this anthropometric factor, experience and comments made during the questionnaire pilot study supported its inclusion in the study. NASA (1978) stated the following measurements for foot length: 5th% male 9.9 inches, 5th% female - 8.7 inches, 95th% male - 11.4 inches, and 95th% female 10.2 inches. This represents a difference of 1.2 inches between the foot lengths of males and females. In this question, the accommodation of female foot size in current cockpit designs was examined through subject experience with the manipulation of rudder pedals. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew accommodation due to* *male-based anthropometric rudder pedal design/foot size."*

The response frequencies were distributed among the five response options as follows: SA-2(3.5%), A-4(7.0%), U-0(0.0%), D-21(36.9%), and SD-30(52.6%). Appendix T provides a complete listing of subject responses.

Figure 8 gives a graphic representation of the data distribution. The most favored response (mode) was SD with a frequency of 30. The D and SD response options accounted for 89.5% of all subject responses received.

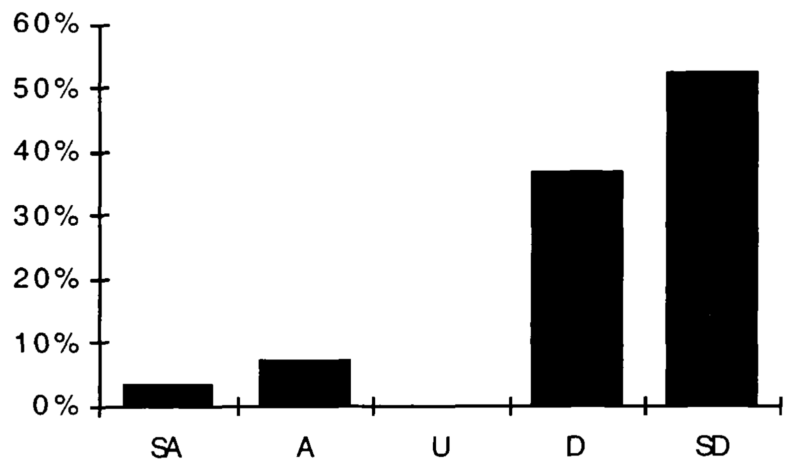

Figure 8. Data Distribution - Cockpit Design Question 7.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to male-based anthropometric rudder pedal design/foot size, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 57 responses received, the expected frequency for each option was 11.4. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.495 and occurred at the U response option. Using the critical values table for D, it was found that 0.495 is higher than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at $p = .05$ and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to male-based anthropometric rudder pedal design/foot size. The results indicate that there is a significant effect on self-reported female aircrew accommodation due to male-based anthropometric rudder pedal design/foot size. However, due to the negative wording of the question and the maximum deviation occurring at the "undecided/neutral" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 8

SA A U D SD *Current aircraft control designs (e.g., rudders, yoke, throttles) allow you to safely control the aircraft.*

This questions was designed to evaluate the subjects' opinion regarding safety in current male-based anthropometric cockpit designs. It dealt with an overall anthropometric accommodation of females rather than any specific anthropometric factor. In this question, the issue of safety was examined through subject experience with current aircraft control designs.

The null test hypothesis for this question was *"There is no effect on self-reported female aircrew safety due to current male-based anthropometric aircraft control designs."*

The response frequencies were distributed among the five response options as follows: SA-29(50.0%), A-24(41.4%), U-3(5.2%), D-2(3.4%), and SD-0(0.0%). Appendix U provides a complete listing of subject responses.

Figure 9 gives a graphic representation of the data distribution. The most favored response (mode) was SA with a frequency of 29. The SA and A response options accounted for 91.4% of all subject responses received.

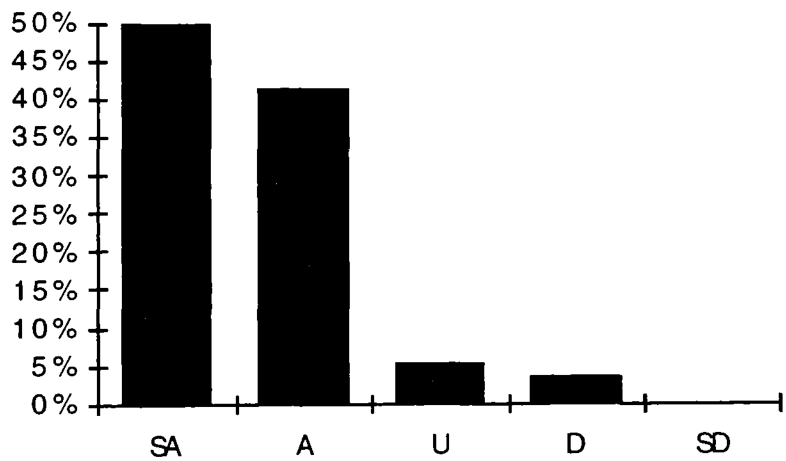

Figure 9. Data Distribution Cockpit Design Question 8.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew safety due to current male-based anthropometric aircraft control designs, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 58 responses received, the expected frequency for each option was 11.6. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.514 and occurred at the A response option. Using the critical values table for D, it was found that 0.514 is higher than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at $p = .05$ and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew safety due to current male-based anthropometric aircraft control designs. The results indicate that there is a significant effect on self-reported female aircrew safety due to current male-based anthropometric aircraft control designs. However, due to the positive wording of the question and the maximum deviation occurring at the "agree" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 9

SA A U D SD *Cockpit seat adjustments allow for a sufficient range of operation to accommodate your sitting height.*

Question nine, similar to question one, also addresses the anthropometric factor of sitting height in the accommodation of females in male-based anthropometric cockpit designs. Unlike question one, however, it takes a positive approach. This balancing of positive and negative questions is incorporated into the questionnaire in order to eliminate subject bias and add validity to the testing method. In this question, the factor of female sitting height accommodation in current cockpit designs was examined through subject experience with the range of cockpit seat adjustments. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit seat designs/sitting height."*

The response frequencies were distributed among the five response options as follows: SA-25(43.1%), A-20(34.5%), U-1(1.7%), D-9(15.5%), and SD-3(5.2%). Appendix V provides a complete listing of subject responses.

Figure 10 gives a graphic representation of the data distribution. The most favored response (mode) was SA with a frequency of 25. The SA and A response options accounted for 77.6% of all subject responses received.

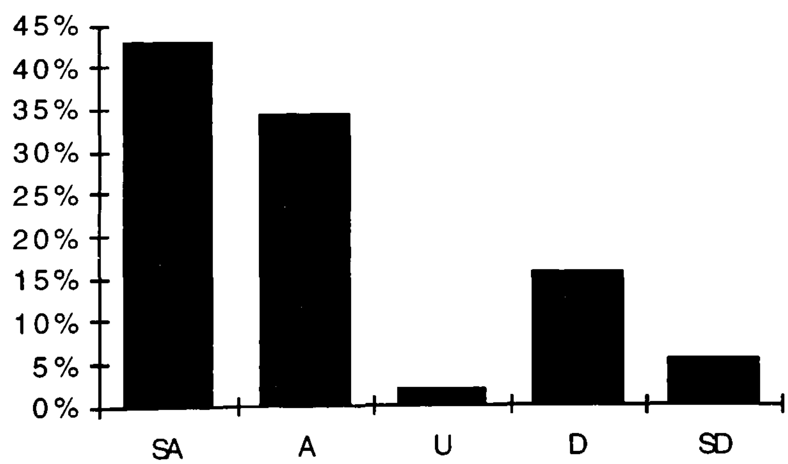

Figure 10. Data Distribution - Cockpit Design Question 9.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit seat designs/sitting height, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 58 responses received, the expected frequency for each option was 11.6. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.376 and occurred at the A response option. Using the critical values table for D, it was found that 0.376 is higher than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at $p = .05$ and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit seat designs/sitting height. The results indicate that there is a significant effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit seat designs/sitting height. However, due to the positive wording of the question and the maximum deviation occurring at the "agree" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 10

SA A U D SD *The strength required to operate aircraft controls during*

> *an emergency situation (e.g., aborted takeoff, engine failure) is* ***too excessive*** *to allow you to safely control the aircraft.*

Question 10, similar to questions four and two, also addresses the factor of strength in the accommodation of females in male-based anthropometric cockpit designs. In this question, the factor of female strength capability accommodation in current cockpit designs was examined through subject experience with the control pressure required to operate the aircraft during an emergency situation. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew safety due to the control pressure required to operate the aircraft during an emergency situation/strength."*

The response frequencies were distributed among the five response options as follows: SA-0(0.0%), A-0(0.0%), U-2(3.5%), D-25(43.9%), and SD-30(52.6%). Appendix W provides a complete listing of subject responses.

Figure 11 gives a graphic representation of the data distribution. The most favored response (mode) was SD with a frequency of 30. The D and SD response options accounted for 96.5% of all subject responses received.

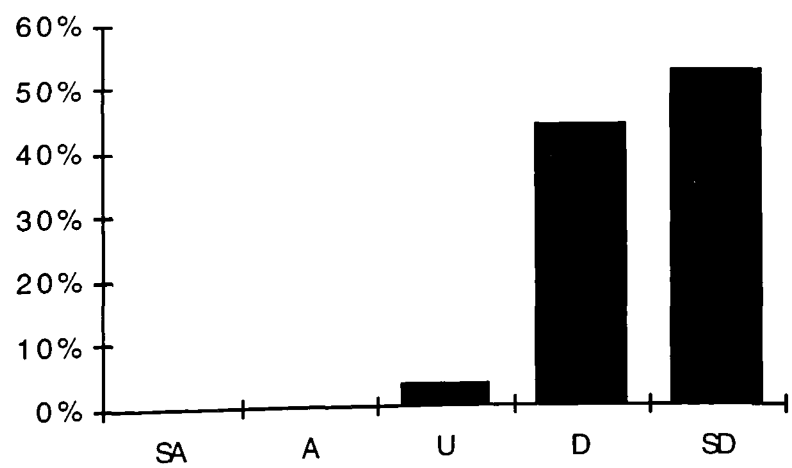

Figure 11. Data Distribution - Cockpit Design Question 10.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to the control pressure required to operate the aircraft during an emergency situation/strength, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 57 responses received, the expected frequency for each option was 11.4. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.565 and occurred at the U response option. Using the critical values table for D, it was found that 0.565 is higher than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was significant at $p = .05$ and not due to sampling error. This called for a rejection of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to the control pressure required to operate the aircraft during an emergency situation/strength. The results indicate that there is a significant effect on self-reported female aircrew accommodation due to the control pressure required to operate the aircraft during an emergency situation/strength. However, due to the negative wording of the question and the maximum deviation occurring at the "undecided/neutral" response option, the results indicated that the observed effect is positive and not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The response percentage distribution further supported this observation.

Question 11

SA A U D SD *Your optimum performance can be achieved with current cockpit design.*

This questions was designed to address the factor of optimum performance directly. Its purpose was to evaluate the subjects' opinion regarding optimum performance in current male-based anthropometric cockpit designs. As a summary question, it dealt with an overall anthropometric accommodation of females rather than any specific anthropometric factor. The null test hypothesis for this question was *"There is no effect on self-reported female aircrew optimum performance due to current male-based anthropometric cockpit designs."*

The response frequencies were distributed among the five response options as follows: SA-17(29.3%), A-15(25.9%), U-6(10.3%), D-18(31.0%), and SD-2(3.5%). Appendix X provides a complete listing of subject responses.

Figure 12 gives a graphic representation of the data distribution. The most favored response (mode) was D with a frequency of 18, closely followed by SA with a frequency of 17. This question showed the most uniform frequency distribution of all 11 questions.

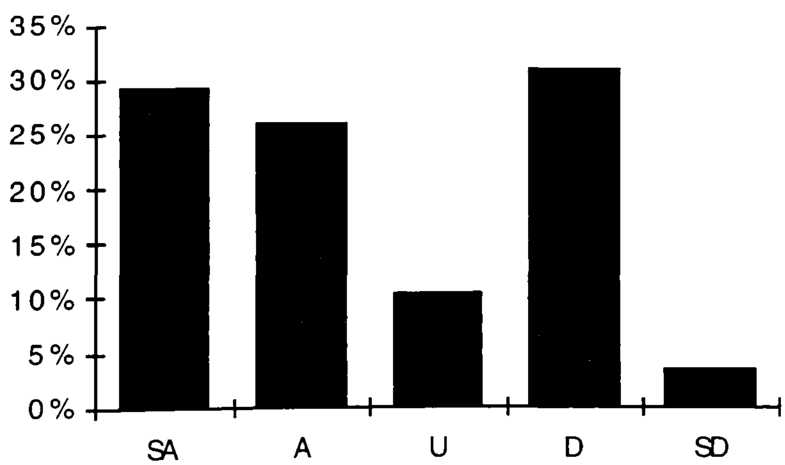

Figure 12. Data Distribution - Cockpit Design Question 11.

In order to test the null hypothesis utilizing the Kolmogorov-Smirnov One-Sample Test, an expected theoretical cumulative frequency distribution had to be calculated. It was expected that if there was no effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit design, then the responses would be evenly distributed among the five response options. This resulted in the expected frequency for each option to be the total number of responses divided by five. With a total of 58 responses received, the expected frequency for each option was 11.6. The Kolmogorov-Smirnov One-Sample Test showed that the maximum deviation (D) was 0.166 and occurred at the D response option. Using the critical values table for D, it was found that 0.166 is lower than that listed for $p = .05$. Which indicated that the difference between the observed frequencies and the expected frequencies was not significant at $p = .05$ and was due to sampling error. This called for an acceptance of the null hypothesis that there is no effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit design. This result was not in agreement with the overall research hypothesis that self-reported female aircrew accommodation is reduced by male-based anthropometric cockpit designs.

Several additional comments were made regarding the Likert-type cockpit design questions 1-11. They are listed in Appendix Y.

Open-Ended Questions

Open-ended questions were included in this study in order to obtain as complete of a picture as was possible regarding the effects of male-based anthropometric cockpit designs of self-reported female aircrew accommodation. Their aim was to provide additional data on the factors addressed in the Likert-type questions and to identify specific problems and aircraft. Directions for this section included a request for completeness and the inclusion of aircraft type. The analysis of the six open-ended questions consists of a summarization of obtained comments. Representative comments are included for each question to illustrate predominant opinions. A complete list of all answers provided to the open-ended questions 1-6 is reproduced in Appendices Z-AE, respectively.

Question 1

Describe any problems you have had physically managing aircraft controls.

A total of 55 subjects provided answers to question one. Of these 55, 17 (30.9%) reported no problems. The remaining 38 reported a wide variety of problems in physically managing aircraft controls. The most prevailing problem was that of cockpit seats. Eight subjects reported aspects of the inadequacy of cockpit seat design and the need to use cushions to achieve proper management of aircraft controls. Some of the comments made included:

- Even small aircraft such as the C172 quite often requires me to use a cushion to adjust myself forward to fully manipulate the rudders. The Citabria is the same way and the C310. In the Gulfstream I use two hands to rotate. In the HS25-800 I find it difficult to go to lift/dump. The reverses are difficult to lift up. (I have weak hands) (004).

- The only aircraft I had problems physically managing was a C172XP. The controls were very difficult for me to reach. And, I felt unsafe without the use of extra cushions etc. (008).

DC3: Unable to get full rudder, even with seat full forward. Both feet on 'good' rudder with engine out until trimmed. BE18: With 2 pillows behind back and one under butt, still unable to see 1 o'clock on taxi or get full rudder (021).

I refer to meet all aircraft I have flown. Boeing seat adjustments are much better however they still should have a better range of adjustments. Control sizes 727 awkward. In some aircraft had to use pillows behind my back in order to use full movement of throttles or power levers and also to get better visibility and full rudder control. Some airplanes seemed particularly heavy in steep turns where I would prefer to use both hands instead of trimming. Power levers feel awkwardly large (057).

The second most mentioned problem in physically managing aircraft controls was that of excessive control pressure necessary during cross-wind approaches and landings. Seven subjects listed this as a problem and several also specified that they were unable to perform cross-wind operations with only one hand on the yoke. Additional comments made by subjects regarding cross-wind operations indicated that it was their belief that this was not a gender specific problem. Comments made included:

- For x-wind lndgs in the Shorts [SD3-Shorts 360], I cannot handle the yoke + throttles at the same time (007).

- KC-135: w/ strong crosswinds need both hands on yoke for control during landing but male pilots do too (020).

Convair 580 was a very heavy aircraft to fly w/ one hand on yoke particularly in a x-wind but the difficulties were encountered by both sexes (024)!

Only on Short 330-360 models at max x-wind. It took both hands to control the ailerons. But the men couldn't do it alone either. One pilot would work the ailerons - the other pilot would work the rudders and throttles (031).

Other problems listed frequently by subjects in physically managing aircraft controls included forces required to operate thrust reverses (five subjects), awkward yoke shapes and small hand sizes (five subjects), and strength required to operate cockpit controls (four subjects). The prevailing theme was that problems were not gender unique. The following are representative of comments made:

Yoke on the jets is too big + uncomfortable for my size hand. Even the BE-99 was a little wide at the grip. Also I can not reach across all four throttles (DC-8) (009).

The throttles on most multi engine aircraft are too big to grasp easily (018).

Control yoke switches electric trim, control wheel steering, AP disconnect are sometimes hard to reach because my hand is smaller there are grooves in the yoke for fingers can't do both (032).

The Convair 580 is an old aircraft with unboosted controls and was not designed when women were active in aviation. It takes a great deal of strength -- even for a male pilot (012).

On CE-441, felt like I needed a little more upper body strength to move thrust reverses quickly + easily, although I didn't feel it was a safety issue (033).

A manual reversion in a 737 requires <u>extreme</u> physical strength. (No hydraulics) Southwest allowed me to use a male crew member to assist. The 737 normally is no problem to handle, but occasionally I will tell myself I need to lift weights. After a hardful approach x wind, etc. (050).

Question 2

Describe any problems you have had with the range of adjustments of any cockpit item.

Of the 51 responses to this question, 25 subjects indicated no problems with the range of adjustments of any cockpit item. This represented 49.0% of those responding. Of the remaining 26 responses, 24 specifically designated the range of cockpit seat adjustments as a problem. This represented 47.1% of all subjects responding and 92.3% of subjects indicating a problem with the range of adjustments of any cockpit item. This problem was not specific to any aircraft. Aircraft listed as having problems with the range of cockpit seat adjustments included: B-727, B-737-200, B-747, BE-18, Convair 580, C-172, C-182, DC-8, G-159, HS25-800, King Air, MD-80, Navajo, Swearnjen Metro, and T-38. Only one subject listing the range of cockpit seat adjustments as a problem stated that it was not a gender specific problem. The two other cockpit range of adjustment problems provided were seat belts and rudder pedals. Both of these are directly related to the range of cockpit seat adjustments. Representative comments included:

Seat adjustments in the HS25-800 don't allow me to see out and comfortably use the rudders/brakes. The same with the King Air. A lot of aircraft do not allow you to adjust the seat forward enough. I quite often use a cushion behind my back (004).

- Seat (G159) needs to move forward another inch for better application of full rudder. Can't reach all switches that need to be reached with shoulder harness fastened. The cockpit of the G159 is very roomy - which means everything is spread out (005).

- The seats on the DC-8 + 727 are manual adjust + never very comfortable. (I need the seat full up on the 8 + my feet don't touch the floor.) The L-1011 are electric + easier to control. On the non-jet a/c it would have been nice to have a vertical adjustment because so much of that kind of flying relies on using the nose-to-horizon as a visual cue (009).

- Seats on smaller General Aviation airplanes are terrible. In my early days of flying I always had to use cushions under my rear + behind my back just to reach the controls (031).

- B737 Overhead cockpit panel difficult to reach and see, unless adjustment from normal seat position is changed. Seat - vertical motion up or down is often difficult for seat, due to my light body wt. Seat does not always respond unless I actually bounce on seat - B737-200 (038).

- Cockpit seat is not designed for my size. I use pillows for lumbar support etc. The range is not complete (058).

Question 3

Describe any problems you have had reaching or manipulating any cockpit control.

Of the 51 subjects responding to question three, 24 indicated no problems reaching or manipulating any cockpit control. This represented 47.1% of the given responses. The remaining 27 subjects provided a variety of encountered problems. The problem most commonly listed was the reaching and manipulation of overhead and side panels. This was indicated as a problem by nine or 33.3% of the subjects reporting problems. The aircraft operated by these subjects included the BE-18, Convair 580, DC-3, Gulfstream I, and King Air. Some of the remarks included:

Overhead panels require a long reach and often moving seat rearward in the Convair 580 (012).

- BE80: unable to reach circuit breakers with shoulder harness on. DC3: unable to reach feather button on opposite side. (All other overhead switches, too) (021).

- Overhead panel neck breaking (038).

Aft overhead panel must get out of seat to reach. Cannot reach cross cockpit. In DHC-8, couldn't reach emergency gear stuff (044).

The second most listed problem in the cockpit was the manipulation of throttles. Seven subjects, 25.9% of those indicating problems, reported throttle manipulation to present a problem. The aircraft mentioned as having this design problem were the Cessna Conquest II, the C-141, the Fokker 100, and the G-159. Responses given included:

- See #2. Basically, I've used my body in some cases of where I've needed to use full travel of controls; i.e. I've "scrunched" down in my seat in order to get full travel on rudders. Result is much more difficulty with full travel of yoke/throttles, etc. than what anyone should have. Also means my seat belt isn't as tight as it should be so I can change position in the seat to get needed leverage (017).

I recall a Cessna Conquest II, CE-441 having throttle levers that were extremely difficult to move into reverse (030).

The C-141 has four throttles that must all be lifted over a detent prior to using reverse thrust. They are about 7-8" wide & it can be difficult to lift them all at the same time. But it's also hard for men to do this, so I'm not sure if it applies. The C-141 was designed in the 1950's & I don't think Lockheed was very aware/or concerned with ergonomics (047).

The remaining 11 subjects listed reaching and manipulation problems to include fuel selector operation, rudder full range manipulation, yoke control, the raising and lowering of flaps, seat adjustment limits, engine anti-ice control operation, emergency gear extension hand crank manipulation, and the range of rudder operation. Only two of the 51 respondents indicated that problems were not gender specific. Example responses include:

- Fuel selectors in Navajo impossible to pull up & move quickly (002).

- Rudder pedals commonly too high off floor. Distance between position needed to steer on ground and position needed to brake too great (054).

Through the years I have learned to compensate in many aircraft such as using pillows behind my back in order to reach the rudder pedals to get full control movement. In the Boeing aircraft the rudder pedals do move forward but I feel ridiculous having to always adjust the seat to max forward position + rudders max forward + seat height. My height is 5'3" and I am by no means the shortest female (057).

On PA-34 (Seneca II), have difficulty moving manual flap lever to "full flap" position. Also, in the event of a go around w/ full flaps it would be almost impossible to retract the flaps from the "40o" or "full" position, creating a safety hazard. Even the guys I fly with admit it takes a lot of strength. Therefore, I just don't use 40o flaps in the Seneca on landing, so no danger will exist. (I believe the males don't usually use 40o flaps either) (033).

Question 4

Describe any situation in which you feel that your safety or efficiency had been reduced due to aircraft cockpit design.

A total of 49 subjects responded to this question. Of these, 25 indicated no situation in which they felt that their safety or efficiency had been reduced due to aircraft cockpit design. These 25 subjects represented 51% of all responding. The remaining 24 subjects describe situations involving a variety of cockpit controls. The most mentioned control once again was the cockpit seat. The range of adjustments was considered a safety issue by eight or 33.3% of the subjects indicating problems. The involved aircraft included the BAe-3101, the G-159, and the Navajo. The following are some representative examples:

General discomfort with takeoff & landing in Navajo due to seat too far aft. In an emergency would have difficulty opening aft cabin door (002).

Excessive torque situations such as an engine failure at rotation (G159) may be difficult to deal with due to heavy, difficult to manipulate controls + seat position not being as far forward as I would like (005).

- The seats in the BAe-3101 are uncomfortable. After occupying the seat for several hours many pilots complain of severe backaches (023).

- Visibility could be improved. Raising seat height may be inadequate. Providing more windshield, lower panel, less blind spots may be helpful (026).

The second most listed aircraft control adversely effecting safety and efficiency was the range of rudder operation. It was listed by four or 16.7% of subjects indicating problems. Aircraft in which this problem had been experienced included the BE-18, C-172, C-310, Citabria, DC-3, and King Air. Remarks provided included:

- Strong crosswinds in DC3 + BE18 needed differential power in part because of rudder pressure and/or distance. Instructor needed to take landing roll out from me in C185 once in crosswind, with no pillow, I couldn't get enough rudder (021).

Engine out many aircraft require excessive rudder pressure for 1 foot/leg (054).

The remaining 12 subjects reported problems pertaining to a variety of cockpit control items. These includes the manipulation of throttles, the reaching of switches and circuit breakers, cross-wind operations, instrument penal set-up, the opening and closing of cockpit doors, yoke shape and manipulation, flap lever operation, and the design of sun visors. Three out of the 49 respondents indicated that the specified problems were not gender related. Representative remarks include:

In aircraft where I could not reach the rudders (C172, C310, Citabria) without a cushion presented a problem especially when instructing when it is vital to be able to reach the controls promptly but you don't want to make the student nervous by looking as if you are always in a position to grab them. During aborts the design of lift/dump and reverse in the HS25 make it difficult to smoothly execute an abort. In the HS25 and the King Air and GIV the rudder/brake pedals are very large. In order for me to use the brakes and rudders concurrently I have to take my feet off then move them up with my heels off the floor. Since I have to have my seat far forward my ankles have to bend at an uncomfortable angle to accomplish this (004).

I set T.O. power on both the 8 + 1011. I have had to slip out of the shoulder harness on some a/c's to reach the throttles (009).

I do not like the manual flap lever on the Piper aircraft. I don't like having to duck below the windscreen to manipulate the control, both when lowering or retracting. (This is not because I'm female + smaller I don't feel.) i.e. I think a male would agree (033).

Question 5

Do you feel that current aircraft cockpit designs allow for your optimum performance? Please explain.

This question was answered by 50 subjects. The answers were categorized in order to facilitate the presentation of obtained data. The three categories were "yes" - current cockpit designs allow optimum performance , "no" - current cockpits do not allow optimum performance, and "undecided". When a response did not indicate a negative or positive, it was placed in the undecided category.

Of the 50 responding subjects, 31 indicated that they did feel that current aircraft cockpit designs allowed for their optimum performance. This represented 62.0% of all subjects responding and constituted the "yes" category. Explanations provided with these positive responses included:

Yes. I am taller than many women, however, and seem to correspond to the shortest/smallest acceptable size. (Delta, e.g., won't hire folks shorter than 5'6". Which is invariably a subtle way to reduce # of women, some think. I think they're just absurd about "Image". I fear your study will be fuel for their fire rather than a redesign! Fire but...so be it) (003).

Yes there are <u>always</u> certain things you'd change "if you could design the cockpit," but for the most part, the design on the 747-400 is good. Rudder pedals are large, which makes for a little clumsiness in normal ops, but is great for max braking, eng. failure, etc. (024).

Yes, in particular, military + air transport a/c. Having been trained in naval flight training, an early prerequisite was to be able to reach + manipulate all controls in a mock cockpit. One had to fit to go on with flight training (046).

Yes. Especially newer cockpits, they are much more compact & efficiently designed. If you compare the huge, poorly designed cockpit of a C-141 to something like a MD-80/DC-9 I think you'll see a <u>huge</u> improvement (047).

Eight subjects, of the 50 responding, indicated that they felt that current aircraft designs did not allow for their optimum performance. This "no" category represented 16% of all subjects responding. Explanations provided with these negative responses included:

No. All captains at company are men. They have no difficulty with aircraft. It's difficult enough being a woman in aviation, without having to ask for help in the cockpit (002).

- No. Everything is too large and spread out. Seats don't adjust to allow you to comfortably reach everything (004).

- No. While I have learned to compensate I feel my performance would be better if all aircraft seats moved forward enough, high enough to where I could be closer & see higher over the panel without compensating. Lesser control pressures would not be required but definitely helpful instead of <u>having</u> to be in great shape. Power levers such as Boeing are awkward in size & I usually would have to compensate to bring all power levers forward equally. I also feel the yoke and rudder sizes are overly large (Boeing) (057).

The remaining 11 subjects did not indicate a positive nor a negative response. This "undecided" category represented 22.0% of the 50 total subjects responding. Some of the responses provided by these subjects included:

1. Most of my problems have been with old airplanes (DC3 + BE18). 2. The men who fly the BE80 can't reach some things, too. 3. In the newer (relatively) equipment (BE80 + C411) the controls seem ok mostly (021).

- Hard to answer. Visibility is my primary problem, but increasing visibility might result in unwanted trade-offs (026).

I am not sure one design can cover all the ranges of people flying it. The CV cockpit is smaller than most and could be better (032).

In the sim my leg starts to get fatigued after more than five minutes of engine out work without rudder trim. If I was in a real emergency with prolonged muscle stain, it may be too much (043).

Question 6

If you could change one item of current cockpit design, which do you feel would be the most important.

The 49 responses provided to this question covered a wide range of cockpit items. The one item of current cockpit design that was selected most was the range of adjustment and design of cockpit seats. It was indicated as the most important item to change by 12 or 24.5% of all respondents. Comments made concerning the design and necessary modification of cockpit seats included:

- Most important would be seat adjustments; a better range is required (002).

- Design the seats in such a way to reduce fatigue i.e. lumbar support, and to allow full range of motion of the controls (013).

Coordinate the range of seat adjustment with the position of the rudder pedals, so that with the seat in the forward position, and raised to the highest position, it is still possible to push the rudder pedals at an angle that allows full movement - Also, the knees should not hit the instrument panel or parking brake (018).

Other items of current cockpit designs selected for improvement and modification included: yoke design (six responses), rudder pedal design and range of operation (five responses), cockpit and console area layout (five responses), humidifier, cooling, and ventilation systems (three responses), overhead control layout and switch placement (three responses), sun visor design (two responses), throttle design (one response), flap handle operation and design (one response), aircraft window design (one response), communication radios placement (one response), and the utilization of heads-up displays (one response). Examples of suggested changes include:

Make the yoke a <u>stick</u> - a much easier control (003)!!

Rudders would be more adjustable. I would adjust them to be closer to the seat, higher so that I can raise the seat while still having the rudder @ the correct angle + they would have a built in heel rest. The latter is important because frequently I cannot rest my heels on the floor while flying my feet are too small. Because I rest them (my feet) solely on the rudder to compensate this means my legs and feet are in am unnatural position resulting in discomfort (017).

Make all Piper aircraft with manual flaps change to electric (or redesign the lever so it's easier to reach and not difficult to move in + out of 40o range) (033).

More use of the heads up display. Have fewer or no items overhead, beyond a "glance up" range. In other words, not having to tilt your head back to physically look at an item (034).

Eight of the 49 respondents indicated that either there was no change needed or that they were undecided on whether change was necessary. Representing 16.3% of all subjects responding, they offered the following explanations for their responses:

I feel that it will be impossible to design a cockpit that will accommodate people as short as 5' and as tall as 6'7" or greater all in the same seat. In my profession, I definitely feel that my height at 69 1/2" has been a great asset (046).

- I cannot select just one item. The airplanes need to accommodate a larger height range. It would be nice to feel like I was closer to the panel (057).

Nothing having to do with being female but lots of ideas as a pilot. Sorry (036).

I can not think of any one design I would change. I adapt to each cockpit. It has not been a problem (042).

Conclusions

The purpose of this study was to examine the effects of male-based anthropometric cockpit designs of self-reported female aircrew accommodation. This study was based on past research efforts addressing the accommodation of female aircrew in current male-based anthropometric cockpit designs. The conclusions that follow are based upon the results of the data gathered during the research process.

The second section of the questionnaire/opinionnaire provided demographic, anthropometric, and experience data for the subjects. This data indicated that subjects represented the FAA geographic regions well and were highly experienced with an average of 15 years flying and 6,099 total flight hours. Subject experience also spanned across many types of aircraft. Age data indicated that most subjects were in the 31-40 age group (60.4%). Anthropometric data showed that most subjects considered themselves "medium" (60.4%) and were in the 66-70 inch height range (39.7%). It was concluded that the subjects were representative of the female ATP certificated aircrew population, but there was some speculation of whether data could by generalized to the entire female aircrew population.

Section three of the questionnaire/opinionnaire consisted of 11 Likert-type questions pertaining to cockpit design. It collected subject experience/opinion data through statements addressing specific factors of cockpit design. Eight questions focused on specific anthropometric factors believed to be significant in the design of cockpits. These factors included sitting height (two questions), strength (three questions), leg length (one question), hand width (one question), and foot size (one question). Question eight gathered data on subjects' opinions regarding the safety of current male-based anthropometric cockpit designs, and question 11 directly addressed subjects' opinions regarding their optimum performance in current cockpits. Each question tested a individual null test hypothesis specific to that question.

The statistical analysis results obtained from the application of the Kolmogorov-Smirnov One Sample Test indicated that, for 10 out of the 11 questions, the observed results were significantly different from those expected under the null hypothesis. This indicated that current male-based anthropometric cockpit designs had a significant effect on self-reported female aircrew accommodation. An examination of the maximum deviation points and response percentage distributions indicated that this effect was a positive one and was not in agreement with the overall research hypothesis that female aircrew accommodation is reduced by male-based anthropometric cockpit designs. The only question indicating a non-significant maximum deviation was question 11 which addressed subject opinion regarding optimum performance directly. The results of this question accepted the test null hypothesis that there is no effect on self-reported female aircrew accommodation due to male-based anthropometric cockpit designs. Based on the combined results obtained from question 1-11, it was concluded that self-reported female aircrew accommodation is not reduced by current male-based anthropometric cockpit designs.

Section four of the questionnaire/opinionnaire was designed to provide a more in-depth understanding of answers obtained in section three, and collected data on specific design problems and aircraft types through six open-ended questions. The results obtained for question one through four indicated that the majority of subjects did not experience any problems in the addressed areas. The results obtained from questions one, two, and four indicated that of those subjects reporting problems with the physical management of aircraft controls, the range of adjustment of cockpit items, and safety and efficiency concerns, the majority listed cockpit seats as the number one problem. The results of question four indicated the design of overhead and side panels as the primary problem experienced in reaching or manipulating cockpit controls. When asked by question five whether their optimum performance is allowed by current male-based anthropometric cockpit designs, 62% of responding subjects indicated a positive response. The one item of current cockpit design most reported as requiring a change, question six, was the cockpit seat. In answering question 1-6, several but not a majority of subjects, indicated that they felt that reported problems were not gender unique. On the basis of the data obtained through open-ended questions 1-6, it is concluded that a majority of female aircrew do not feel that their accommodation is reduced by current male-based anthropometric cockpit designs. Of those cockpit items which do present problems for female aircrew, the seat design is the most significant. As reported problems spanned a variety of aircraft, it is also concluded that these problems are not aircraft specific but more general design issues. The conclusions obtained from the open-ended questions support those obtained from the Likert-type questions.

In examining the results of section two, three, and four of the utilized instrument, the researcher speculated that one certain factor of the research design significantly effected the obtained results. This factor was the consistency of the selected sample. Several comments made during the open-ended questions indicated that it is an airline industry practice to exclude from consideration any aircrew below a certain height minimum (5'6"). Because the selected sample only consisted of ATP certificated females, it is concluded that in a manner it was pre-selected by the airline industry. This conclusion was supported by the height data gathered in the second section of the questionnaire (the 66-70 inches height category received the most responses (39.7%)).

In summary, the obtained results have led the researcher to reject the overall research hypothesis that self-reported female aircrew accommodation is reduced by current male-based anthropometric cockpit designs. This conclusion, however, must by moderated by the fact that the results of this research study were based exclusively on subject opinions. The reader is cautioned against attributing precise statistical significance to the presented conclusions. The purpose of this study was not to provide specific measurements of female aircrew accommodation in male-based anthropometric cockpit designs, but rather an overall current status of the subject. The researcher's objective was to provide some basis and direction for further research studies. For that purpose, the following section provides a non-exclusive list of recommendations.

Recommendations

Recommendations for Cockpit Design

From a human factors point of view, for optimal aircrew-cockpit compatibility to be achieved the operator must not be fit to the machine but the machine to the operator, both male and female. For the purpose of achieving this, the following recommendations are made for the design of aircraft cockpits:

1. Establish aircraft critical design limits on the basis of anthropometric data from both genders.

2. Establish FAA airworthiness standards which require civil aircraft to meet critical design limits for personnel accommodation.

3. Increase the range of cockpit seat adjustments to accommodate a greater spectrum of the entire aircrew population, both male and female.

Recommendations for Further Research

The following recommendations are made in order to provide some guidance for further research in the area of female aircrew accommodation in male-based anthropometric cockpit designs:

1. The study should be repeated utilizing a wider sample of the female aircrew population in order to obtain a better understanding of the accommodation of all females in current aircraft.

2. The study should be repeated utilizing a male control group to determine if identified problem areas are gender unique or applicable to the entire aircrew population.

3. A study should be conducted to precisely measure the performance of female aircrew in male-based anthropometric cockpit designs, perhaps utilizing a aircraft simulator.

4. A study should be conducted to examine the role of current male-based anthropometric cockpit designs in the drop-out rate of primary student pilot applicants.

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APPENDIX A

COCKPIT DESIGN QUESTIONNAIRE/OPINIONNAIRE - VERSION 1

THE EFFECT OF COCKPIT DESIGN ON FEMALE AIRCREW PERFORMANCE

GENERAL PERSONAL INFORMATION (optional)

Name: ____________________

Mailing Address: ____________________

____

Telephone # (Daytime): ____________________

(Evening): ____________________

FLIGHT EXPERIENCE

Your age: _______ Your height (inches): ____________

Years Flying: _______

Total Flight Hours (approx.): ____________

Current Pilot Certificate Held: ____________________

Types of Aircraft Flown: ____________________

____

____

Type of Aircraft Flown Most (most flight hours in):

____

Type(s) of Aircraft Currently Flying:
For Hire: ____________________
Personal Use: ____________________

COCKPIT DESIGN ATTITUDE QUESTIONNAIRE

SA = Strongly Agree
A = Agree
U = Undecided
D = Disagree
SD = Strongly Disagree

Please circle the letter on the left which best indicates your attitude toward each statement. Refer all statements below to the aircraft which you are currently flying for hire.

SA A U D SD 1. Even when adjusted to its most up position the cockpit seat still does not allow an adequate outside visual reference

SA A U D SD 2. Strength required to operate aircraft controls (e.g. control wheel back pressure) can be easily exerted by female aircrew

SA A U D SD 3. Full range of rudder pedal operation can be accomplished by female aircrew

SA A U D SD 4. The back pressure required to operate the control wheel during takeoff does not allow one hand manipulation

SA A U D SD 5. The design of current aircraft controls (e.g. rudders, yoke, throttles) does not allow safe aircraft operation by a female aircrew

SA A U D SD 6. Current cockpit design inhibits optimum female aircrew performance

SA A U D SD 7. The full operation of rudder pedals is a problem for female aircrew

SA A U D SD 8. The strength required to operate cockpit control (e.g. throttles) inhibits the efficient and timely operation of these controls

SA A U D SD 9. Current aircraft controls design (e.g. rudders, yoke, throttles) allows for safe aircraft control by female aircrew

SA A U D SD 10. Optimum female aircrew performance can be achieved with current cockpit design

SA A U D SD 11. Cockpit seat adjustments allow for a sufficient range of operation to accommodate female aircrew

SA A U D SD 12. Current cockpit design adequately accommodates female aircrew

OPEN-ENDED QUESTIONS

Please answer as completely as possible and include aircraft type when able. Feel free to use both sides of the paper.

1. Describe any problems you have had physically managing aircraft controls

2 Describe any problems you have had with the range of adjustments of the cockpit seat

3. Do you feel that current aircraft cockpit designs allow for your optimum and safe performance? Please explain

4. Please feel free to add any comments that you feel are relevant to the design of aircraft cockpits when considering optimum female aircrew performance.

APPENDIX B

COCKPIT DESIGN QUESTIONNAIRE/OPINIONNAIRE - VERSION 2

PERSONAL INFORMATION (please print)

Name: ____
(Surname) (First)

Mailing Address: ____
(Street)

____
(City) (State) (Zip)

Telephone # (Daytime): ____

(Evening): ____

Do you wish to receive a copy of the results of this study: Yes___ No___

NOTICE OF CONFIDENTIALITY

All personal information on this form will be stored separately from the rest of the questionnaire. Personal information will only be utilized to track data collection and remind those people who have not responded. Upon completion of the data collection, all personal information will be destroyed. In order to assure the anonymity of your responses, you may even mail this sheet separately from the data sheets. If you send them both in the same envelope, personal information will immediately be separated from the remainder of the data.

FLIGHT EXPERIENCE:

Your age: (years)		Your height: (inches)		Body type:	
<20	___	<50	___	petit	___
21-30	___	51-55	___	small	___
31-40	___	56-60	___	medium	___
41-50	___	61-65	___	large	___
51-60	___	66-70	___	x-large	___
>61	___	71-75	___		
		>76	___		

Years Flying: _____

Total Flight Time (approx.): __________

Current Pilot Certificates Held: ______________________________

____

Types of Aircraft Flown: ______________________________

____

____

Type of Aircraft Flown Most: ______________________________
(most flight hours)

Type(s) of Aircraft Currently Flying:
For Hire: ______________________________

Personal Use: ______________________________

COCKPIT DESIGN QUESTIONNAIRE:

SA = Strongly Agree
A = Agree
U = Undecided
D = Disagree
SD = Strongly Disagree

Please circle the letter on the left which best indicates your experience as relating to each statement. **Refer all statements below to the aircraft which you are currently flying for hire.**

SA A U D SD 1. Even when adjusted to its upmost position the cockpit seat does not allow an adequate outside visual reference.

SA A U D SD 2. Strength required to operate aircraft controls (e.g. control wheel, reverse thrust levers) can be easily exerted.

SA A U D SD 3. The full range of rudder pedal operation can be easily accomplished.

SA A U D SD 4. The back pressure required to operate the control wheel during takeoff does not allow one hand manipulation.

SA A U D SD 5. Current cockpit design adequately accommodates female aircrew.

SA A U D SD 6. The position of overhead controls inhibits the efficient and timely operation of these controls.

SA A U D SD 7. The full operation of rudder pedals is a problem for female aircrew.

SA A U D SD 8. Current aircraft controls design (e.g. rudders, yoke, throttles) allow for safe aircraft control.

SA A U D SD 9. Current cockpit design inhibit optimum female aircrew performance.

SA A U D SD 10. The strength required to operate aircraft controls during an emergency situation (e.g. aborted takeoff, engine failure) is too excessive to allow safe aircraft control.

SA A U D SD 11. Cockpit seat adjustments allow for a sufficient range of operation to accommodate female aircrew.

SA A U D SD 12. Optimum female aircrew performance can be achieved with current cockpit design.

OPEN-ENDED QUESTIONS:

Please answer the following questions as completely as possible and include aircraft type whenever able. Please feel free to use both sides of the paper.

1. Describe any problems you have had physically managing aircraft controls.

2. Describe any problems you have had with the range of adjustments of any cockpit design item.

3. Describe any problems you have had with the position or reach of any cockpit control.

4. Describe any situation in which you feel that your safety or efficiency has been reduced due to aircraft cockpit design.

5. Do you feel that current aircraft cockpit designs allow for your optimum and safe performance? Please explain.

6. Please feel free to add any comments that you feel are relevant to the design of aircraft cockpits when considering optimum female aircrew performance.

APPENDIX C

COCKPIT DESIGN QUESTIONNAIRE/OPINIONNAIRE - VERSION 3

PERSONAL INFORMATION (please print)

Name: ________________________________ . ________________
(Surname) (First)

Mailing Address: ________________________________
(Street)

____
(City) (State) (Zip)

Telephone # (Daytime): ________________________________

(Evening): ________________________________

Do you wish to receive a copy of the results of this study: Yes___ No___

NOTICE OF CONFIDENTIALITY

All personal information on this form will be stored separately from the rest of the questionnaire. Personal information will only be utilized to track data collection and remind those people who have not responded. Upon completion of the data collection, all personal information will be destroyed. In order to assure the anonymity of your responses, you may even mail this sheet separately from the data sheets. If you send them both in the same envelope, personal information will immediately be separated from the remainder of the data.

FLIGHT EXPERIENCE:

Your age: (years)
- <20 ___
- 20-30 ___
- 31-40 ___
- 41-50 ___
- 51-60 ___
- >61 ___

Your height: (inches)
- <50 ___
- 50-55 ___
- 56-60 ___
- 61-65 ___
- 66-70 ___
- 71-75 ___
- >76 ___

Body type:
- petit ___
- small ___
- medium ___
- large ___
- x-large ___

Years Flying: _____

Total Flight Time (approx.): __________

Current Pilot Certificates Held: ______________________________

____

Types of Aircraft Flown: ______________________________

____

____

Type of Aircraft Flown Most: ______________________________
(most flight hours)

Type(s) of Aircraft Currently Flying:
For Hire: ______________________________

Personal Use: ______________________________

COCKPIT DESIGN QUESTIONNAIRE:

SA = Strongly Agree
A = Agree
U = Undecided
D = Disagree
SD = Strongly Disagree

Please circle the letter on the left which best indicates your experience as relating to each statement. **Refer all statements below to the aircraft which you are currently flying for hire.**

SA A U D SD 1. Even when adjusted to its upmost position, the cockpit seat does **not** allow you an adequate/safe outside visual reference.

SA A U D SD 2. Strength required to operate aircraft controls (e.g., control wheel, reverse thrust levers) is within your capabilities.

SA A U D SD 3. It is physically possible for you to operate the rudder pedals through their full range.

SA A U D SD 4. The back pressure required to operate the control wheel during takeoff does **not** allow you to manipulate it with one hand.

SA A U D SD 5. The hand width required for the satisfactory operation of the throttle levers is within your physical capabilities.

SA A U D SD 6. The position of overhead controls **inhibits** your efficient and timely operation of these controls.

SA A U D SD 7. Your foot size presents a physical **problem** in manipulating rudder pedals.

SA A U D SD 8. Current aircraft control designs (e.g., rudders, yoke, throttles) allow you to safely control the aircraft.

SA A U D SD 9. Cockpit seat adjustments allow for a sufficient range of operation to accommodate your sitting height.

SA A U D SD 10. The strength required to operate aircraft controls during an emergency situation (e.g., aborted takeoff, engine failure) is **too excessive** to allow you to safely control the aircraft.

SA A U D SD 11. Your optimum performance can be achieved with current cockpit design.

OPEN-ENDED QUESTIONS:

Please answer the following questions as completely as possible and include aircraft type whenever able. Please feel free to use both sides of the paper.

1. Describe any problems you have had physically managing aircraft controls.

2. Describe any problems you have had with the range of adjustments of any cockpit item.

3. Describe any problems you have had reaching or manipulating any cockpit control.

4. Describe any situation in which you feel that your safety or efficiency had been reduced due to aircraft cockpit design.

5. Do you feel that current aircraft cockpit designs allow for your optimum performance? Please explain.

6. If you could change one item of current cockpit design, which do you feel would be the most important.

APPENDIX D

QUESTIONNAIRE/OPINIONNAIRE COVER LETTER - VERSION 1

March 3, 1993

Toni Dylewska
ERAU # 5917
600 S. Clyde Morris Blvd
Daytona Beach, FL 32114

Dear fellow female aircrew member:

I am a certified flight instructor and graduate student at Embry-Riddle Aeronautical University I am writing to you in order to ask your help in a research study that I am currently conducting. This study addresses the effect of cockpit design on female aircrew performance I don't know if you re aware of this, but most airplanes are designed with only the male in mind With the increasing number of females entering the aviation field, it is important to determine if current cockpit designs still allow safe and efficient operations

The valuable information required for this study can only be gathered from females already in the field of aviation, such as yourself. Please take a moment to answer the enclosed questionnaire A self-addressed, stamped envelope is included for your convenience A response by April 30, 1993 is greatly appreciated The results of this study will be published as a graduate thesis, offered to the Embry-Riddle Flight Department, and presented to the Federal Aviation Administration Human Factors Division. This study is am important step in the incorporation of females into the world of aviation

I thank you for your much valued cooperation

Sincerely,

Toni Dylewska

APPENDIX E

QUESTIONNAIRE/OPINIONNAIRE COVER LETTER - VERSION 2

September 1, 1993

Toni Dylewska
ERAU #5917
600 S. Clyde Morris Blvd.
Daytona Beach, FL 32114

Dear fellow female aircrew member:

I am a certified flight instructor and graduate student at Embry-Riddle Aeronautical University. I am writing to you in order to ask your help in a research study that I am conducting.

This study addresses the effects of male-oriented cockpit design on female aircrew performance. I don't know if you are aware of this, but most airplanes are designed with only the male in mind. With the increasing number of females entering the aviation field, it is imperative to determine if current cockpit designs allow safe and efficient operations.

The valuable information required for this study can only be gathered from females already in the field of aviation, such as yourself. This questionnaire is only being sent to select female pilots who hold ATP certificates. This study is an important step in the incorporation of females into the world of aviation. Please take a moment to answer the enclosed questionnaire. A self-addressed, stamped envelope is included for your convenience. A response by **September 30, 1993** will be greatly appreciated.

The results of this study will be published as a graduate thesis, offered to the Embry-Riddle Flight Department, and presented to the Federal Aviation Administration Human Factors Division. If you wish to receive a copy of the results, please indicate so on the questionnaire and include your name and address.

I thank you for your much valued cooperation.

Sincerely,

Toni Dylewska

APPENDIX F

QUESTIONNAIRE/OPINIONNAIRE COVER LETTER - VERSION 3

September 1, 1993

Toni Dylewska
E-RAU #5917
600 S. Clyde Morris Blvd.
Daytona Beach, FL 32114

Dear fellow female aircrew member:

I am writing you to ask for your help in an important research study that is being conducted at Embry-Riddle Aeronautical University. I am presently a certified flight instructor and graduate student in the Masters of Aeronautical Science program here at Embry-Riddle.

This study addresses the effects of male-oriented cockpit design on female aircrew performance. I am sure you are aware that most airplanes are designed with only the male in mind. With the increasing number of females entering the aviation field, it is imperative to determine if current cockpit designs allow safe and efficient operations.

The valuable information required for this study can only be gathered from females already in the field of aviation, such as yourself. This questionnaire is only being sent to selected female pilots who hold ATP certificates. The study is an important step in the further incorporation of females into the world of aviation.

Please take a moment to answer the enclosed questionnaire. A self-addressed, stamped envelope is included for your convenience. A response by **September 30, 1993** will be greatly appreciated.

The results of this study will be published as a graduate thesis, offered to the Embry-Riddle Flight Department, and presented to the Federal Aviation Administration. If you wish to receive a copy of the results, please indicate so on the questionnaire and include your name and address.

I thank you for your much valued cooperation.

Sincerely,

Toni Dylewska

APPENDIX G

SUBJECT DATA - FAA REGION

SUBJECT #	REGION								
	ALASKAN=AL	CENTRAL=CE	EASTERN=EA	GREAT LAKES=GL	NEW ENGLAND=NE	NORHTWEST MOUNTAIN=NM	SOUTHERN=SO	SOUTHWEST=SW	WESTERN/PACIFIC=WP
	YELLOW	RED	LT PINK	PURPLE	ORANGE	DARK PINK	BEIGE	GRAY	BLUE
1			1						
2			1						
3			1						
4			1						
5			1						
6			1						
7			1						
8				1					
9				1					
10				1					
11				1					
12				1					
13				1					
14				1					
15				1					
16					1				
17					1				
18						1			
19						1			
20						1			
21						1			
22						1			
23						1			
24							1		
25							1		
26							1		
27							1		
28							1		
29							1		
30							1		
31							1		
32							1		
33							1		
34							1		
35							1		
36							1		
37							1		
38							1		
39								1	
40								1	
41								1	
42								1	
43								1	
44								1	
45									1
46									1
47									1
48									1
49									1
50									1
51									1
52									1
53									1
54									1
55									1
56									1
57									1
58									1
	REGION								
	ALASKAN=AL	CENTRAL=CE	EASTERN=EA	GREAT LAKES=GL	NEW ENGLAND=NE	NORHTWEST MOUNTAIN=NM	SOUTHERN=SO	SOUTHWEST=SW	WESTERN/PACIFIC=WP
	YELLOW	RED	LT PINK	PURPLE	ORANGE	DARK PINK	BEIGE	GRAY	BLUE
TOTALS	0	0	7	8	2	6	15	6	14

APPENDIX H

SUBJECT DATA - AGE

	AGE (YEARS)					
	<20	*20-30*	*31-40*	*41-50*	*51-60*	*>61*
1			1			
2		1				
3			1			
4			1			
5			1			
6		1				
7				1		
8			1			
9			1			
10			1			
11			1			
12				1		
13			1			
14			1			
15			1			
16				1		
17				1		
18					1	
19			1			
20			1			
21				1		
22			1			
23		1				
24			1			
25				1		
26		1				
27				1		
28			1			
29			1			
30			1			
31			1			
32			1			
33			1			
34			1			
35			1			
36			1			
37				1		
38			1			
39				1		
40				1		
41						1
42			1			
43			1			
44			1			
45			1			
46			1			
47		1				
48			1			
49		1				
50				1		
51			1			
52				1		
53			1			
54			1			
55				1		
56				1		
57			1			
58		1				

	AGE (YEARS)					
	<20	*20-30*	*31-40*	*41-50*	*51-60*	*>61*
	0	7	35	14	1	1

APPENDIX I

SUBLECT DATA - HEIGHT

			HEIGHT (INCHES)				
	<50	*50-55*	*56-60*	*61-65*	*66-70*	*71-75*	*>76*
1					1		
2					1		
3					1		
4				1			
5					1		
6							1
7			1				
8					1		
9				1			
10					1		
11					1		
12				1			
13		1					
14				1			
15					1		
16						1	
17				1			
18			1				
19				1			
20					1		
21				1			
22				1			
23						1	
24					1		
25					1		
26				1			
27					1		
28					1		
29		1					
30					1		
31				1			
32			1				
33				1			
34			1				
35			1				
36			1				
37					1		
38					1		
39					1		
40						1	
41				1			
42				1			
43			1				
44			1				
45					1		
46					1		
47					1		
48			1				
49			1				
50				1			
51		1					
52					1		
53				1			
54					1		
55				1			
56					1		
57				1			
58				1			
			HEIGHT (INCHES)				
	<50	*50-55*	*56-60*	*61-65*	*66-70*	*71-75*	*>76*
	0	3	10	18	23	3	1

APPENDIX J

SUBJECT DATA - BODY TYPE

			BODY TYPE		
	PETIT	*SMALL*	*MEDIUM*	*LARGE*	*X-LARGE*
1			1		
2		1			
3			1		
4			1		
5			1		
6				1	
7			1		
8			1		
9			1		
10			1		
11				1	
12		1			
13			1		
14			1		
15				1	
16			1		
17		1			
18	1				
19			1		
20			1		
21			1		
22		1			
23			1		
24			1		
25			1		
26			1		
27			1		
28			1		
29		1			
30		1			
31			1		
32				1	
33			1		
34		1			
35			1		
36			1		
37			1		
38			1		
39		1			
40			1		
41	1				
42			1		
43			1		
44		1			
45			1		
46				1	
47		1			
48			1		
49			1		
50	1				
51			1		
52				1	
53	1				
54		1			
55			1		
56			1		
57	1				
58		1			
			BODY TYPE		
	PETIT	*SMALL*	*MEDIUM*	*LARGE*	*X-LARGE*
	5	12	35	6	0

APPENDIX K

SUBJECT DAT - TOTAL YEARS FLYING

YEARS FLYING	
1	17
2	7
3	12
4	15
5	7
6	9
7	6
8	10
9	18
10	15
11	14
12	23
13	20
14	11
15	12
16	9
17	32
18	20
19	15
20	10
21	9
22	15
23	4
24	16
25	14
26	9
27	15
28	16
29	10
30	15
31	15
32	15
33	6
34	16
35	16
36	10
37	20
38	10
39	15
40	19
41	35
42	7
43	13
44	16
45	10
46	14
47	11
48	20
49	13
50	21
51	18
52	30
53	16
54	11
55	15
56	25
57	13
58	13
YEARS FLYING	
	AVERAGE
	15

APPENDIX L

SUBEJCT DATA - TOTAL FLIGHT TIME

TOTAL FLIGHT TIME	
	(HOURS)
1	3,000
2	2,800
3	2,500
4	5,000
5	3,000
6	4,500
7	3,000
8	4,800
9	7,000
10	6,000
11	6,300
12	8,000
13	7,700
14	3,600
15	6,000
16	2,000
17	6,400
18	5,000
19	10,000
20	2,500
21	2,850
22	5,000
23	3,000
24	10,000
25	8,000
26	4,000
27	3,200
28	10,000
29	4,500
30	4,000
31	9,000
32	6,000
33	3,100
34	5,000
35	8,800
36	3,500
37	12,000
38	7,000
39	4,500
40	11,000
41	11,000
42	2,500
43	5,000
44	7,000
45	7,000
46	4,000
47	3,000
48	9,000
49	5,000
50	7,000
51	9,000
52	26,000
53	7,600
54	5,000
55	7,500
56	2,815
57	4,300
58	7,500
TOTAL FLIGHT TIME	
	(HOURS)(AVG)
	6,099

APPENDIX M

SUBJECT DATA - AIRCRAFT TYPE FLOWN FOR HIRE

TYPE AIRCRAFT CURRENTLY	
	FLYING FOR HIRE
1	SK76
2	SM/SE
3	B727
4	BE-200,HS25-800
5	G-159
6	BAC 3100
7	SD3-SHORT 360
8	B727
9	DC8
10	B757,A320
11	F20,F10,G159
12	CITATION VII,CONVAIR 580
13	FALCON 50/20
14	PA31/34,C414
15	MD80
16	PA31-350
17	BEECH BARON/BONANZA,C172/182
18	BONANZA,C182
19	B757,B767
20	B727
21	BE80,C411
22	B737-300/200
23	BAe-3101
24	B747-400
25	DC9
26	C172,C152,PA28,C182RG
27	PA31
28	DC9,MD80
29	B727
30	BE-C90
31	DC9
32	CITATION V-560
33	PIPER NAVAJO,SENECA,LANCE,C206
34	CHEYENNE III, PIPER NAVAJO
35	A320
36	B727
37	B737-300
38	B737-400/200
39	LR55, AGUSTA 109A-ROTOR
40	B727
41	PIPER CUB, STEARMAN,B707
42	G159
43	B727
44	B737
45	F100
46	B737-300/500
47	B737
48	B737-300/400
49	B737,DASH8
50	B737
51	B747
52	ALL PISTON
53	MD S80,DC9
54	B737-300
55	B757,B767
56	C172
57	B727
58	B737-400

APPENDIX N

COMPLETE DATA - COCKPIT DESIGN QUESTION 1

		QUESTION #1			
	SA	*A*	*U*	*D*	*SD*
1					1
2		1			
3				1	
4				1	
5				1	
6					1
7					1
8				1	
9		1			
10					1
11					1
12					1
13	1				
14				1	
15				1	
16					1
17	1				
18	1				
19				1	
20					1
21				1	
22				1	
23					1
24					1
25				1	
26		1			
27				1	
28				1	
29					1
30				1	
31					1
32					1
33					1
34					1
35					1
36				1	
37				1	
38					1
39				1	
40					1
41		1			
42				1	
43					1
44					1
45					1
46				1	
47				1	
48					1
49					1
50					1
51				1	
52					1
53				1	
54				1	
55					1
56				1	
57				1	
58				1	
		QUESTION #1			
	SA	*A*	*U*	*D*	*SD*
	3	4	0	25	26

APPENDIX O

COMPLETE DATA - COCKPIT DESIGN QUESTION 2

	QUESTION #2				
	SA	*A*	*U*	*D*	*SD*
1	1				
2	1				
3		1			
4			1		
5			1		
6	1				
7				1	
8		1			
9		1			
10	1				
11	1				
12		1			
13	1				
14	1				
15	1				
16	1				
17		1			
18		1			
19	1				
20	1				
21	1				
22	1				
23	1				
24		1			
25	1				
26		1			
27		1			
28		1			
29	1				
30		1			
31	1				
32	1				
33		1			
34	1				
35	1				
36	1				
37		1			
38		1			
39		1			
40	1				
41		1			
42		1			
43		1			
44		1			
45	1				
46		1			
47	1				
48	1				
49	1				
50		1			
51	1				
52	1				
53		1			
54		1			
55	1				
56			1		
57	1				
58			1		

	QUESTION #2				
	SA	*A*	*U*	*D*	*SD*
	30	23	4	1	0

APPENDIX P

COMPLETE DATA - COCKPIT DESIGN QUESTION 3

		QUESTION #3			
	SA	*A*	*U*	*D*	*SD*
1	1				
2	1				
3		1			
4		1			
5			1		
6	1				
7		1			
8		1			
9		1			
10	1				
11	1				
12					1
13	1				
14		1			
15				1	
16	1				
17				1	
18				1	
19	1				
20	1				
21	1				
22	1				
23	1				
24	1				
25	1				
26		1			
27		1			
28	1				
29	1				
30		1			
31	1				
32	1				
33	1				
34	1				
35	1				
36	1				
37		1			
38	1				
39		1			
40	1				
41				1	
42		1			
43		1			
44		1			
45	1				
46	1				
47	1				
48	1				
49	1				
50		1			
51	1				
52					1
53		1			
54		1			
55	1				
56		1			
57	1				
58	1				

		QUESTION #3			
	SA	*A*	*U*	*D*	*SD*
	33	18	1	4	2

APPENDIX Q

COMPLETE DATA - COCKPIT DESIGN QUESTION 4

		QUESTION #4			
	SA	*A*	*U*	*D*	*SD*
1					
2					1
3				1	
4				1	
5				1	
6					1
7		1			
8				1	
9		1			
10					1
11					1
12			1		
13					1
14				1	
15				1	
16					1
17					1
18		1			
19					1
20				1	
21					1
22					1
23					1
24				1	
25					1
26				1	
27				1	
28		1			
29					1
30				1	
31					1
32		1			
33					1
34					1
35					1
36					1
37					1
38				1	
39		1			
40					1
41				1	
42				1	
43				1	
44				1	
45					1
46				1	
47				1	
48					1
49					1
50				1	
51					1
52					1
53				1	
54				1	
55					1
56					1
57		1			
58				1	

		QUESTION #4			
	SA	*A*	*U*	*D*	*SD*
	0	7	1	22	27

APPENDIX R

COMPLETE DATA - COCKPIT DESIGN QUESTION 5

		QUESTION #5			
	SA	*A*	*U*	*D*	*SD*
1	1				
2	1				
3		1			
4			1		
5		1			
6	1				
7		1			
8		1			
9					1
10	1				
11		1			
12		1			
13	1				
14		1			
15		1			
16	1				
17		1			
18				1	
19	1				
20	1				
21	1				
22	1				
23	1				
24		1			
25	1				
26		1			
27		1			
28		1			
29		1			
30			1		
31	1				
32		1			
33	1				
34	1				
35	1				
36	1				
37		1			
38	1				
39		1			
40	1				
41				1	
42		1			
43		1			
44		1			
45	1				
46		1			
47	1				
48	1				
49	1				
50		1			
51		1			
52		1			
53		1			
54		1			
55		1			
56		1			
57		1			
58		1			
		QUESTION #5			
	SA	*A*	*U*	*D*	*SD*
	23	30	2	2	1

APPENDIX S

COMPLETE DATA - COCKPIT DESIGN QUESTION 6

			QUESTION #6		
	SA	A	U	D	SD
1					1
2					1
3			1		
4			1		
5				1	
6					1
7				1	
8			1		
9		1			
10					1
11					1
12		1			
13					1
14				1	
15			1		
16					1
17		1			
18			1		
19					1
20				1	
21			1		
22					1
23				1	
24					1
25				1	
26				1	
27				1	
28				1	
29				1	
30				1	
31					1
32					
33					1
34					1
35					1
36					1
37				1	
38		1			
39				1	
40					1
41		1			
42			1		
43				1	
44				1	
45					1
46					1
47				1	
48					1
49					1
50		1			
51				1	
52				1	
53				1	
54					
55					1
56				1	
57				1	
58					1
			QUESTION #6		
	SA	A	U	D	SD
	0	6	7	21	22

APPENDIX T

COMPLETE DATA - COCKPIT DESIGN QUESTION 7

		QUESTION #7			
	SA	*A*	*U*	*D*	*SD*
1					1
2					1
3				1	
4		1			
5				1	
6					1
7				1	
8				1	
9		1			
10				1	
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14				1	
15				1	
16					1
17				1	
18	1				
19					1
20					1
21				1	
22					1
23					1
24					1
25					1
26				1	
27				1	
28				1	
29					1
30				1	
31					1
32					1
33					1
34					1
35					1
36					1
37					1
38					1
39				1	
40					1
41					
42					1
43				1	
44	1				
45					1
46					1
47				1	
48					1
49					1
50				1	
51					1
52					1
53				1	
54		1			
55		1			
56					1
57				1	
58					1
		QUESTION #7			
	SA	*A*	*U*	*D*	*SD*
	2	4	0	21	30

APPENDIX U

COMPLETE DATA - COCKPIT DESIGN QUESTION 8

		QUESTION #8			
	SA	*A*	*U*	*D*	*SD*
1	1				
2	1				
3		1			
4			1		
5			1		
6	1				
7		1			
8	1				
9				1	
10	1				
11		1			
12		1			
13	1				
14		1			
15		1			
16	1				
17		1			
18		1			
19	1				
20	1				
21		1			
22	1				
23	1				
24	1				
25	1				
26		1			
27		1			
28		1			
29	1				
30		1			
31	1				
32		1			
33		1			
34	1				
35	1				
36	1				
37			1		
38	1				
39		1			
40	1				
41				1	
42		1			
43		1			
44		1			
45	1				
46	1				
47	1				
48	1				
49	1				
50		1			
51	1				
52	1				
53		1			
54		1			
55		1			
56	1				
57	1				
58		1			
		QUESTION #8			
	SA	*A*	*U*	*D*	*SD*
	29	24	3	2	0

APPENDIX V

COMPLETE DATA - COCKPIT DESIGN QUESTION 9

		QUESTION #9			
	SA	*A*	*U*	*D*	*SD*
1	1				
2				1	
3		1			
4				1	
5				1	
6	1				
7		1			
8		1			
9					1
10	1				
11		1			
12		1			
13	1				
14		1			
15		1			
16	1				
17				1	
18					1
19	1				
20	1				
21				1	
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32	1				
33	1				
34	1				
35	1				
36		1			
37				1	
38	1				
39		1			
40	1				
41					1
42	1				
43	1				
44				1	
45	1				
46	1				
47	1				
48	1				
49	1				
50		1			
51	1				
52		1			
53		1			
54		1			
55	1				
56		1			
57			1		
58				1	
		QUESTION #9			
	SA	*A*	*U*	*D*	*SD*
	25	20	1	9	3

APPENDIX W

COMPLETE DATA - COCKPIT DESIGN QUESTION 10

		QUESTION #10			
	SA	*A*	*U*	*D*	*SD*
1					1
2					1
3				1	
4					1
5			1		
6					1
7				1	
8					1
9				1	
10					1
11				1	
12				1	
13					1
14				1	
15				1	
16					1
17				1	
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48					1
49					1
50				1	
51					1
52					1
53				1	
54				1	
55					1
56				1	
57				1	
58				1	
		QUESTION #10			
	SA	*A*	*U*	*D*	*SD*
	0	0	2	25	30

APPENDIX X

COMPLETE DATA - COCKPIT DESIGN QUESTION 11

		QUESTION #11			
	SA	A	U	D	SD
1	1				
2				1	
3			1		
4					1
5			1		
6	1				
7				1	
8				1	
9				1	
10	1				
11		1			
12				1	
13				1	
14			1		
15			1		
16		1			
17					1
18				1	
19		1			
20		1			
21		1			
22	1				
23	1				
24		1			
25	1				
26			1		
27		1			
28				1	
29		1			
30			1		
31	1				
32		1			
33		1			
34	1				
35	1				
36				1	
37				1	
38		1			
39		1			
40	1				
41				1	
42		1			
43		1			
44				1	
45	1				
46	1				
47	1				
48	1				
49	1				
50				1	
51	1				
52	1				
53				1	
54				1	
55				1	
56		1			
57				1	
58				1	
		QUESTION #11			
	SA	A	U	D	SD
	17	15	6	18	2

APPENDIX Y

ADDITIONAL REMARKS MADE REGARDING COCKPIT DESIGN QUESTIONS 1-11

Question #1

The seat was modified (013).

Question #2

- Depends on the airplane   King Air   yes, G159 - difficult (005).

Question #3

- If cushion used (004).

- Just barely, would be better if seat moved forward another inch (G159) (005).

All of our a/c rudder pedals are adjustable (011).

Question #4

- N/A to rotary (001).

- Takeoff is ok, the landing flare is more difficult (G159) (005).

Question #5

- Barely (053).

Question #6

- Occasionally, more poor design for <u>all</u> than just awkward for women, poorly placed ergonomically (003).

- N/A (032).

- Some are behind me I sit so close to the window (050).

- N/A (054).

Question #7

Size 6 - cannot reach rudder pedals with heels on floor (054).

Question #8

- King Air agree, G159 disagree. The G159 in not a current design (005).

- Could be better (037).

I have to lean slightly to completely "get behind" the throttles (053).

Question #9

Seat height ok, but seat needs to move forward another inch to better manipulate rudder + throttles (005).

Question #10

Although I have demonstrated that I can safely handle all emergencies in the simulator at Flight Safety Intl., there is doubt in my mind as to how well I would handle an actual engine failure at rotation due to excessive control forces (G159) (005).

Only when mechanical/electrical/computerized assists fail (041).

- Assuming simulator control pressures are accurate (053).

Question #11

- B727 is not particularly well designed, in several ways, for pilots in general. It seems to have pre-dated concern for pilot ease during the design process (003).

- Depends on the airplane. The King Airs were not a problem at all, easy + comfortable to fly. The G159 which was built in the '60's is heavy + difficult (005).

- Not without modification (013).

Width of control wheel in my hand combined with effort to use electric trim is excessive for my hand width. Many things are "barely" within acceptable limits (053).

General

These are very difficult to answer. The answers change with each aircraft, and each aircraft presents different design problems. It is hard to make a judgment on an overall compilation of all aircraft flown (004).

- The King Airs (C90, F90, B200) were very comfortable, seat, rudder + throttle positions were good, I felt like I had good control + would also during an emergency (005).

- I hope this doesn't skew your data, but... I'm 6'6" tall and while I'm not overweight, I weight 200 pounds. Size is not a problem except maybe things are too small (006).

- Currently not funded for flight time - answers reflect aircraft flown in past few years (017).

- I am not currently flying for hire - statements refer to plane flown for personal use (018).

- Note: These answers would be opposite if I were currently flying DC3 and/or BE-18 (021).

- Most cockpits are rather cramped for space. In many cases I have found it an advantage to be of smaller stature. The only problem I have encountered is a seat position that will move forward enough to reach rudder pedals. This is true in General Aviation types as much as in commercial or air carrier type aircraft (041).

- This does not apply since I am retired from commercial flight. FYI from previous experience (041).

APPENDIX Z

RESPONSES GIVEN TO OPEN-ENDED QUESTION 1

"Describe any problems you have had physically managing aircraft controls."

- None (001).

Manipulating gear handle from left seat in a Navajo Chieftan (002).

As an engineer in the 727, immediately after takeoff we were required to reset power to a "quiet" setting. Usually had to unlock shoulder harness in order to reach them. Can't remember anything else (003).

Even small aircraft such as the C172 quite often requires me to use a cushion to adjust myself forward to fully manipulate the rudders. The Citabria is the same way and the C310. In the Gulfstream I use two hands to rotate. In the HS25-800 I find it difficult to go to lift/dump. The reverses are difficult to lift up. (I have weak hands) (004).

G159 parking brake has to be pulled out approx. 5" + then turned 90o to set I can't do it with one hand. G159 crosswind landings difficult to do with one hand (005).

None (006).

For x-wind lndgs in the Shorts [SD3-Shorts 360], I cannot handle the yoke + throttles at the same time (007).

The only aircraft I had problems physically managing was a C172XP. The controls were very difficult for me to reach. And, I felt unsafe without the use of extra cushions etc. (008).

- Yoke on the jets is too big + uncomfortable for my size hand. Even the BE-99 was a little wide at the grip. Also I can not reach across all four throttles (DC-8) (009).

- The only problems that arise are because of the seats or rudders not being placed in the proper position but this is easily corrected by vertical & horizontal adjustments as the F20, F10 & G159 all have fully adjustable positions (011).

- The Convair 580 is an old aircraft with unboosted controls and was not designed when women were active in aviation. It takes a great deal of strength -- even for a male pilot (012).

- The seat on the Falcon 50 had to be cut to allow full fwd and aft movement of the yoke (013).

- The only problem I have had is pushing an aircraft back into a slot after flying. But I have noticed that the men I work with are not any better at it.

There are many things I would change in the cockpit. But none that the guys wouldn't change also. I have had to deal with many problems flying. EX: Engine failures, run away trim, electrical loss, emer. gear ext., etc. I handled them just as well as any male could have. Lets all remember it doesn't take physical strength to fly a aircraft it takes mental strength (014).

During single engine work, I must use rudder trim as quickly as possible to avoid fatigue. However, I don't think that this is gender unique (015).

None (016).

- None that I can recall. However, I've had to work at it harder than men I've flown with because of the "length of travel" of control response. Because I must move the seat full forward + sometimes use extra cushions on the seat, it is much more difficult to get proper leverage to use in manipulating the controls. This was true in all cases except Lear Jets. Small single + multiengine aircraft were the worst (017).

- The throttles on most multi engine aircraft are too big to grasp easily (018).

- None (019).

- KC-135: w/ strong crosswinds need both hands on yoke for control during landing - but - male pilots do too (020).

- DC3: Unable to get full rudder, even with seat full forward. Both feet on 'good' rudder with engine out until trimmed. BE18: With 2 pillows behind back and one under butt, still unable to see 1 o'clock on taxi or get full rudder (021).

- In most cases - none - flew CV580 + in an engine out, ie V1 cut it becomes very heavy for anyone, man or woman (022).

- None (023).

- Convair 580 was a very heavy aircraft to fly w/ one hand on yoke - particularly in a x-wind - but the difficulties were encountered by both sexes (024)!

- C-140, C-150, Ercoupe - pull starter required too much force. PA-28 series - requires booster seat (026).

- As long as I have trim control I have no problem with controls on aircraft I have flown. Without trim I have problems (027).

- Cockpit seat is such that short (women's) arms do not reach ailerons comfortably with rudders set for legs length - thrust reverses on power-backs is difficult at times w/ wide, stiff controls (028).

None (029).

- None (030).

- Only on Short 330-360 models at max x-wind. It took both hands to control the ailerons. But the men couldn't do it alone either. One pilot would work the ailerons - the other pilot would work the rudders and throttles (031).

Control yoke switches - electric trim, control wheel steering, AP disconnect are sometimes hard to reach because my hand is smaller - there are grooves in the yoke for fingers can't do both (032).

- On CE-441, felt like I needed a little more upper body strength to move thrust reverses quickly + easily, although I didn't feel it was a safety issue (033).

None (034).

As I now fly an a/c that is fly-by-wire there is really very little pressure needed to control the aircraft. But in previous planes I found no physical problems in managing the aircraft controls (035).

- I think myself and most women pilots have learned to compensate for strong control forces by trimming more often and better. A better trimmed aircraft is easier to fly more smoothly. During emergencies such as no trim available (in the simulator) rudder or aileron, it was very difficult to fly and I could have done better (smoother) if I was stronger but I certainly could always operate the aircraft safely (036).

The throttles will go to wall - with effort, however if seat is at comfortable position (not so far forward that on rotation it (the yoke) is being pulled into my chest) the throttle is at end of my finger tips (037).

- None - even in B727 manual reversion (simulator) I have been able to control aircraft (038).

In practice of emergency procedures it is physically more demanding but certainly not impossible and I have always stayed in control (039).

- None (040).

- Flying G-1 in crosswinds was a hand full. This is due to the heavy controls. It was not a big problem (042).

- On a couple 727's, it has been difficult getting the controls into reverse (2 out of 50) (043).

- Must lean far forward to push thrust levers to takeoff - limits fine control - hands too small to grasp for fine control. Full rudder throw gets tiresome. Armrests not high enough to use for using yoke. Rudder pedals too far off floor (heel to toe). Rudders don't come close enough if pull seat forward (though you can't anyway) would be banged at full aft travel (044).

- N/A (045).

None. During all normal and abnormal operations I have felt totally in control in civil a/c, military a/c, and air transport a/c (046).

- After spending 4 hours flying approaches in the C-141, my left arm (the one holding the yoke) would get a little stiff. (But the same was true for the group) (047).

None (048).

- N/A (049).

- A manual reversion in a 737 requires <u>extreme</u> physical strength. (No hydraulics) Southwest allowed me to use a male crew member to assist. The 737 normally is no problem to handle, but occasionally I will tell myself I need to lift weights. After a hardful approach - x wind, etc. (050).

None (051).

None (052).

- With full nose up trim in the King Air models without T-tail configuration during landing then go-around required, forward pressure on control wheel is excessive (053).

- Piper Apache (?) - needed both feet on one rudder during engine out (054).

- I am 5'4" + size 8 shoe. The rudder pedals are such that in order to move them close, I must bend my feet well back towards me from the ankle to position my feet on the pedals + heels on the floor. This is uncomfortable + I tend to take feet off pedals a few thousand feet in the air (055).

- I had some problems to get adjusting to fly the low wing aircraft, but after a few hours that was piece of cake (056).

- I refer to meet all aircraft I have flown. Boeing seat adjustments are much better however they still should have a better range of adjustments. Control sizes 727 awkward. In some aircraft had to use pillows behind my back in order to use full movement of throttles or power levers and also to get better visibility and full rudder control. Some airplanes seemed particularly heavy in steep turns where I would prefer to use both hands instead of trimming. Power levers feel awkwardly large (057).

- <u>Some</u> reverse levers are stiff + takes more strength than usual to lift them over the gate + into reverse (058).

APPENDIX AA

RESPONSES GIVEN TO OPEN-ENDED QUESTION 2

"Describe any problems you have had with the range of adjustments of any cockpit item."

- None (001).

Seats in Navajo don't move forward far enough for optimum comfort level (002).

F/O seat must be fully up in order to see out properly. Some of them are stiff. Engineer's chairs are very stiff, some of them. Mechanics are fussy about fixing them. With seat all the way up (as I had to use it) the longer moment arm made fore-and-aft motion even harder. I gave myself a hernia shoving it (a bad one) once (003).

- Seat adjustments in the HS25-800 don't allow me to see out and comfortably use the rudders/brakes. The same with the King Air. A lot of aircraft do not allow you to adjust the seat forward enough. I quite often use a cushion behind my back (004).

- Seat (G159) needs to move forward another inch for better application of full rudder. Can't reach all switches that need to be reached with shoulder harness fastened. The cockpit of the G159 is very roomy - which means everything is spread out (005).

- Would like the seat to go lower - I'm 7'7" tall (006).

None (007).

- Minimal (008).

- The seats on the DC-8 + 727 are manual adjust + never very comfortable. (I need the seat full up on the 8 + my feet don't touch the floor.) The L-1011 are electric + easier to control. On the non-jet a/c it would have been nice to have a vertical adjustment because so much of that kind of flying relies on using the nose-to-horizon as a visual cue (009).

None (011).

The Convair 580 seats/rudder pedals do not accommodate an individual with a height less than 5'5" (012).

- Even with "long legs" at 5'8", my seat must always be close to "full forward" in order to have full rudder travel (MD-80) (015).

- None (016).

- Rudders sometimes do not extend far enough towards the seat or not at all. Seats sit too low + too far back. When seats are pulled full forward, you sometimes have the yoke nearly under your chin making it difficult to manipulate - particular for stalls, cross-wind landings, etc. Comments apply to virtually all makes/models aircraft I've flown (017).

In the single engine and small multi-engine airplanes the seats do not have adequate adjustment. I always have to use a cushion. The larger multi-engine airplanes have seats which can be adjusted to be comfortable (018).

None (019).

None (020).

BE18: Too low seat, no rudder pedal adj. C411: No vertical adj. on seat. C172/182: Seat doesn't go far enough forward, need pillow behind back (021).

Some seats are not as adjustable as others because of the seat design (022).

- None (023).

- None (024).

Seat height is only problem (026).

- None. I am quite long-limbed (027).

- None - with my current company, anyone (male or female) under 5'6" is required to undergo a "strength and reach" test. This entailed sitting in different simulators and reaching all switches. Then flying single engine, loss of hydraulics, engine failure at takeoff, use of thrust reverses, etc. (029).

- Some seat belts do not adjust tight enough, built for much larger people. Recently noticed this in a Cessna Citation II (030).

- Seats on smaller General Aviation airplanes are terrible. In my early days of flying I always had to use cushions under my rear + behind my back just to reach the controls (031).

- Seats don't go back far enough a problem for men too (032).

None other than #1, 3 + 4 as noted (no problems with Navajo or any other aircraft I can think of) (033).

- None (034).

- Because of my height & weight I have had no problem with being able to reach any circuit breaker or light switches in any of the a/c I have flown (035).

My sitting height is shortest allowed by Air Force. I often wished for a higher seat in the T-38 but that was the only aircraft I've flown where I wished I could adjust the seat higher. (It wasn't a safety consideration - just comfort.) The big aircraft I've flown 707, E-3, 727 I didn't even have to put the seat to its highest position (036).

- See above (037).

- B737 - Overhead cockpit panel difficult to reach and see, unless adjustment from normal seat position is changed. Seat - vertical motion up or down is often difficult for seat, due to my light body wt. Seat does not always respond unless I actually bounce on seat - B737-200 (038).

- None (039).

None (040).

None on Hawker 800 (042).

I use rudder pedals in full aft position which is adequate (043).

- See previous (044).

N/A (045).

- None (046).

None (047).

None (048).

N/A (049).

Sometimes I have to get out of my seat to reach things over the captain's head - realign the IRS - but nothing safety related - I can reach those (050).

747 - certain engineer seats adjust to different positions requiring more of a stretch when adjusting throttles (051).

- None (052).

Single engine Cessna's seats do not adjust for enough forward requiring me to carry a pillow (053).

- Swearnjen Metro - sometimes needed seat cushion for optimum height

(054).

- None what so ever (056).

- Some seats did not move up high enough (pillows under) for adequate visibility, other seats did not move up far enough (pillows behind). Some rudder pedals did not move forward enough (057).

- Cockpit seat is not designed for my size. I use pillows for lumbar support etc. The range is not complete (058).

APPENDIX AB

RESPONSES GIVEN TO OPEN-ENDED QUESTION 3

"Describe any problems you have had reaching or manipulating any cockpit control."

- None (001).

- Fuel selectors in Navajo impossible to pull up & move quickly (002).

This is fine (003).

- In the Gulfstream I have to lift up out of the seat in order to reach the far upper corners of the overhead panel. The Hawkers arrangements of lift/dump and reverse are awkward and difficult to use (004).

I have to stretch to push throttle full forward (G159) + to apply full rudder. Throttle levers would be more comfortable if they were closer to the L seat (005).

No problems (006).

- Without hydraulic controls it is difficult to land with windy conditions. I usually adjust throttle over threshold + both hands on yoke for the flare (007).

Minimal (008).

- I usually stand on a seat to reach the top row of circuit breakers. Some rudder pedals are too big for my feet (009).

- None (011).

- Overhead panels require a long reach and often moving seat rearward in the Convair 580 (012).

- See item 1 (013).

- See item #2 (015).

See 4 (016).

- See #2. Basically, I've used my body in some cases of where I've needed to use full travel of controls; i.e. I've "scrunched" down in my seat in order to get full travel on rudders. Result is much more difficulty with full travel of yoke/throttles, etc. than what anyone should have. Also means my seat belt isn't as tight as it should be so I can change position in the seat to get needed leverage (017).

- In the Beech airplanes that require the use of a hand crank for emergency gear extension, it is almost impossible to reach the crank handle, and turn it with the seat in the forward position (018).

- None (019).

- None (020).

- BE80: unable to reach circuit breakers with shoulder harness on. DC3: unable to reach feather button on opposite side. (All other overhead switches, too) (021).

In general, none (022).

None (023).

- None (024).

- None (026).

- None (027).

- I recall a Cessna Conquest II, CE-441 having throttle levers that were extremely difficult to move into reverse (030).

- See above (031).

- See #1 (032).

- On PA-34 (Seneca II), have difficulty moving manual flap lever to "full flap" position. Also, in the event of a go around w/ full flaps it would be almost impossible to retract the flaps from the "40o" or "full" position, creating a safety hazard. Even the guys I fly with admit it takes a lot of strength. Therefore, I just don't use 40o flaps in the Seneca on landing, so no danger will exist. (I believe the males don't usually use 40o flaps either) (033).

- None (034).

- Due to the size involved for most cockpits, between either two or three people, everything that I can think of can be reached. As I have mostly flown in two person a/c, it works that one or the other person has been able to manipulate or reach the required item (035).

- None (036).

- Only length of arm as in question 1 (037).

- Overhead panel - neck breaking (038).

- None (039).

- None (040).

None (042).

- None (043).

- Aft overhead panel - must get out of seat to reach. Cannot reach cross cockpit. In DHC-8, couldn't reach emergency gear stuff (044).

(F100-Fokker) Not a problem, throttles on center console are not at a comfortable distance. My arm is slightly more extended than I would prefer (045).

None (046).

The C-141 has four throttles that must all be lifted over a detent prior to using reverse thrust. They are about 7-8" wide & it can be difficult to lift them all at the same time. But it's also hard for men to do this, so I'm not sure if it applies. The C-141 was designed in the 1950's & I don't think Lockheed was very aware/or concerned with ergonomics (047).

- None (048).

- N/A (049).

- I have always used a pillow to push myself forward to better reach the rudders, <u>until</u> the 737 - it has best seat - no pillow required! I used pillows in the 152 + the Beech 1900 (050).

- 747 engine anti ice hard to reach but not impossible (from engineer seat) (051).

- None (052).

- Rudder pedal adjustment seems to solve most problems. Couldn't reach right hand circuit breaker panel in King Air with seatbelt on (053).

- Rudder pedals commonly too high off floor. Distance between position needed to steer on ground and position needed to brake too great (054).

- The circuit breakers on the right hand side on some aircrafts (056).

- Through the years I have learned to compensate in many aircraft such as using pillows behind my back in order to reach the rudder pedals to get full control movement. In the Boeing aircraft the rudder pedals do move forward but I feel ridiculous having to always adjust the seat to max forward position + rudders max forward + seat height. My height is 5'3" and I am by no means the shortest female (057).

- N/A (058).

APPENDIX AC

RESPONSES GIVEN TO OPEN-ENDED QUESTION 4

"Describe any situation in which you feel that your safety or efficiency had been reduced due to aircraft cockpit design."

- None (001).

- General discomfort with takeoff & landing in Navajo due to seat too far aft. In an emergency would have difficulty opening aft cabin door (002).

- None that I can recall (003).

- In aircraft where I could not reach the rudders (C172, C310, Citabria) without a cushion presented a problem especially when instructing when it is vital to be able to reach the controls promptly but you don't want to make the student nervous by looking as if you are always in a position to grab them. During aborts the design of lift/dump and reverse in the HS25 make it difficult to smoothly execute an abort. In the HS25 and the King Air and GIV the rudder/brake pedals are very large. In order for me to use the brakes and rudders concurrently I have to take my feet off then move them up with my heels off the floor. Since I have to have my seat far forward my ankles have to bend at an uncomfortable angle to accomplish this (004).

- Excessive torque situations such as an engine failure at rotation (G159) may be difficult to deal with due to heavy, difficult to manipulate controls + seat position not being as far forward as I would like (005).

- None (006).

- See #1 (008).

- I set T.O. power on both the 8 + 1011. I have had to slip out of the shoulder harness on some a/c's to reach the throttles (009).

None (011).

- None in the newer designed aircraft (012).

- None (015).

- Switches and circuit breakers on the outboard wall are not reachable from the opposite seat. This is a design problem which has nothing to do with gender (016).

- Virtually every flight for reasons cited above, but especially in training situations, cross-wind landings, etc. (017).

- N/A (019).

- None (020).

Strong crosswinds in DC3 + BE18 needed differential power in part because of rudder pressure and/or distance. Instructor needed to take landing roll out from me in C185 once in crosswind, with no pillow, I couldn't get enough rudder (021).

The only one, is the one I describe below (022).

- The seats in the BAe-3101 are uncomfortable. After occupying the seat for several hours many pilots complain of severe backaches (023).

- None (024).

- Visibility could be improved. Raising seat height may be inadequate. Providing more windshield, lower panel, less blind spots may be helpful (026).

- Especially on older aircraft the panel is sometimes set up so that it is difficult to see engine gauges (027).

- No (029).

- Not relating to cockpit but safety is an issue. Many business turbo jet aircraft doors are nearly impossible to open & close, most recent experience was with a Falcon 20 and a Sabreliner-65 (030).

Only the seat problems on the Cessnas + Pipers. The bigger aircraft (Shorts + DC9) the seats adjust more than enough in all directions (031).

- See #1 - if on single engine or a situation where I need to keep a firm grip on the yoke this could be a problem - disconnecting trim, autopilot, etc. (032).

- I do not like the manual flap lever on the Piper aircraft. I don't like having to duck below the windscreen to manipulate the control, both when lowering or retracting. (This is not because I'm female + smaller I don't feel.) i.e. I think a male would agree (033).

- None (034).

- I would say that a lot of a/c that I have flown have problems with the side windows in which we would use in case of an emergency. But I would not classify this as a problem of being male or female rather more of a manufacture problem (035).

None (036).

- It's a real twist to the spine to reach over the seat with that large heavy flt.

kit to get it placed in cockpit for use (037).

- Poor sun visor design and slider bar for visor. The supplied visors and their size (small) never block as much sun as necessary (038).

In the Aerospatiale helicopter I could not lower the collective enough to descend and still see over the instrument panel. The collective is located on the floor. This is the only aircraft with which I have not been able to fly because of a physical limitation (039).

None (040).

None (042).

- None (043).

- See #1 (044).

- The pedestal of the yoke is too high. I would like to sit back further and lower but can't because pedestal blocks sight of PFD/ND screens (glass cockpit) (045).

None (046).

None (047).

- None (048).

- N/A (049).

- I did a sim ride in the DC10 for United (I was offered a job but didn't go) and could barely get my hand across the throttles. I would like throttles to be smaller and closer together (but not too small) (050).

No (051).

- None (052).

- So far no serious problem has been encountered but compensation has often been made (053).

- Engine out many aircraft require excessive rudder pressure for 1 foot/leg (054).

- None (056).

I never had a situation where safety has been reduced since I had learned to compensate. For example where large forces need be applied such as a Vmc demo in some of the light twins I made sure that I had something behind me where I could really push my back hard against the seat (leverage) instead of trying to use leg power. In some aircraft that were just shy of adjusting forward enough I would not use pillows, but would merely reach for one in the event it was needed for full range movements or control pressures. This may however have restricted some vision over the panel (057).

N/A (058).

APPENDIX AD

RESPONSES GIVEN TO OPEN-ENDED QUESTION 5

"Do you feel that current aircraft cockpit designs allow for your optimum performance?"

- Yes (001).

- No. All captains at company are men. They have no difficulty with aircraft. It's difficult enough being a woman in aviation, without having to ask for help in the cockpit (002).

- Yes. I am taller than many women, however, and seem to correspond to the shortest/smallest acceptable size. (Delta, e.g., won't hire folks shorter than 5'6". Which is invariably a subtle way to reduce # of women, some think. I think they're just absurd about "Image". I fear your study will be fuel for their fire rather than a redesign! Fire but...so be it) (003).

- No. Everything is too large and spread out. Seats don't adjust to allow you to comfortably reach everything (004).

- King Air - yes. The G159 which I fly now was built 30 yrs ago + it does <u>not</u> allow for my optimum performance. I don't really know what current aircraft design is, so it is hard to answer this question. The next aircraft I will be typed in, the Hawker BAe 800, the cockpit is much more compact (I haven't flown it yet) so I think it will be easier to reach all controls + be easier to fly (005).

- Yes (006).

- Seat adjustment, rudder pedals, + throttles are fine no problem (007)!

Some cockpit designs could be improved for "an easier reach." I think the older airplanes have the longest reaches. For example - sitting in the flight engineer seat in the 727, I must slide my seat to the forward most position + lean forward to touch the throttles with shoulder harness on (as required) (008).

- Some DC-8 seats are too big. I can't fasten the crotch strap or shoulder harness + still get full range of motion. Circuit breakers should be more clearly marked + easier to find. Overhead panels should be kept to a minimum as it's inconvenient to look up + search sometimes (009).

- Yes (011).

- Yes, the flow patterns and switch positions in the aircraft I fly (with the exception of the Convair) have improved significantly over the past 3-5 years (012).

- No, not without mods (013).

The current cockpit design does not inhibit me (015).

- Subject to item 4 above, and the fact that for the over-40 age group (male or female) it is difficult to see markings on overhead controls without specially designed glasses, I think design is acceptable (016).

- No. Explained in #1-3 (017).

- Overall performance would be improved by a comfortable cockpit (018).

- Yes I'm flexible (019).

- I've had no problems, but I'm above average height and very active physically. I can envision smaller women having problems reaching or seeing out (020).

- 1. Most of my problems have been with old airplanes (DC3 + BE18). 2. The men who fly the BE80 can't reach some things, too. 3. In the newer (relatively) equipment (BE80 + C411) the controls seem ok mostly (021).

- Yes, in most instances this is true, there are some design problems with certain switches for example in the B737 200. The engine anti ice switches are just above the B hydr switches and I + other F/O's have inadvertently turned off the B pumps instead of the engine anti ice switches because of their location. But has nothing to do with gender (022).

- It would be nice to have a tiller (steering) on the right side of the flight deck also (023).

- Yes - there are <u>always</u> certain things you'd change "if you could design the cockpit," but for the most part, the design on the 747-400 is good. Rudder pedals are large, which makes for a little clumsiness in normal ops, but is great for max braking, eng. failure, etc. (024).

Hard to answer. Visibility is my primary problem, but increasing visibility might result in unwanted trade-offs (026).

Yes (027).

- Yes (029).

- To date, I have not encountered an aircraft where the cockpit design inhibited performance (030).

- Yes (031).

- I am not sure one design can cover all the ranges of people flying it. The CV cockpit is smaller than most and could be better (032).

Overall, yes. But there is always room for improvement. Aerospatiale (spelling?) has a very pilot friendly (female or not) cockpit (033).

- Yes. Every airplane that I have flown without exception, has been no problem. This includes the Jetstar, which with four throttles, took a little getting used to, but was no problem (034).

- Again, because of my size I seem to have no problems. Maybe for someone who was very large or very small and couldn't reach pedals etc. (035).

Not as well as it could be - however this would apply to males I fly with also - see above (037).

- Yes (038).

- Yes except the aerospatiale helicopter (039).

- Yes no explanation needed (040).

Yes (042).

- In the sim my leg starts to get fatigued after more than five minutes of engine out work without rudder trim. If I was in a real emergency with prolonged muscle stain, it may be too much (043).

No (044).

Yes, in particular, military + air transport a/c. Having been trained in naval flight training, an early prerequisite was to be able to reach + manipulate all controls in a mock cockpit. One had to fit to go on with flight training (046).

- Yes. Especially newer cockpits, they are much more compact & efficiently designed. If you compare the huge, poorly designed cockpit of a C-141 to something like a MD-80/DC-9 I think you'll see a huge improvement (047).

- Yes (048).

- Yes. I am an average size girl, 5'7 1/2" and slender. I really have never had any problem operating an aircraft. The aircraft that was heaviest on required control input was the Fairchild Metro III. I had no trouble operating this aircraft & in fact I grew very used to "the feel" of the metro that I actually prefer to have heavier control inputs required in flying an airplane. My friend Maura flies a DC-8 for UPS. This is supposed to be "a handful" as claimed by male pilots, but she has no trouble operating this aircraft (049).

- I would put more in front of the pilot and less above + behind. Especially with my sitting as close as I do. But it's hard to imagine having spent 20 yrs flying with the current cockpits. I will say the 737 is designed as well as <u>any</u> of the planes I've flown as far as a women is concerned (050).

- If I felt unsafe in an aircraft, I wouldn't fly it, therefore all a/c cockpits have been adequate (051).

- Yes (052).

- Most times it's ok. With rudder pedal adjustment capabilities it helps a lot but still find myself too close to the control wheel when I am close enough to achieve full rudder travel (053).

- Reduction of force required for control, particularly during engine out <u>or</u> loss of hydraulic fluid would aid performance But these items are a factor for men too. I work out with weights and am stronger than some men (054).

- Yes, I have checked the new designs on Dakotas cockpit which very well designed for optimum performance looking outside (056).

- No. While I have learned to compensate I feel my performance would be better if all aircraft seats moved forward enough, high enough to where I could be closer & see higher over the panel without compensating. Lesser control pressures would not be required but definitely helpful instead of <u>having</u> to be in great shape. Power levers such as Boeing are awkward in size & I usually would have to compensate to bring all power levers forward equally. I also feel the yoke and rudder sizes are overly large (Boeing) (057).

Aircraft seats are not comfortable or supportive for my body (058).

APPENDIX AE

RESPONSES GIVEN TO OPEN-ENDED QUESTION 6

"If you could change one item of current cockpit design, which do you feel would be the most important."

- Undecided (001).

- Most important would be seat adjustments; a better range is required (002).

Make the yoke a stick - a much easier control (003)!!

- 1. Seat adjustment. 2. Size of everything. 3. Bring switches, etc. in closer (004).

Controls + switches close to pilot, or easily adjustable, controls shouldn't require tremendous force to operate/manipulate (005).

A little more room would be nice (006).

Need hydraulic controls + autopilot. During turbulent conditions I have a hard time with controls. I have developed tendinotus in the rgt. elbow. Autopilot would alleviate some of the problem (007).

Shape of the yoke (009).

Cockpit seats with lumbar supports for back support and increased comfort on long trips - also would help decrease fatigue (011).

- Redesign of pedestal/console to allow easier entry and exit from the cockpit (012).

- Design the seats in such a way to reduce fatigue i.e. lumbar support, and to allow full range of motion of the controls (013).

- Enlarge markings on overhead panels (016).

Rudders would be more adjustable. I would adjust them to be closer to the seat, higher so that I can raise the seat while still having the rudder @ the correct angle + they would have a built in heel rest. The latter is important because frequently I cannot rest my heels on the floor while flying - my feet are too small. Because I rest them (my feet) solely on the rudder to compensate this means my legs and feet are in am unnatural position resulting in discomfort (017).

- Coordinate the range of seat adjustment with the position of the rudder pedals, so that with the seat in the forward position, and raised to the highest position, it is still possible to push the rudder pedals at an angle that allows full movement - Also, the knees should not hit the instrument panel or parking brake (018).

- The poorly designed window sun shades on B757+767 (019).

Make to seat/rudder adjustments to allow broader range of heights (020).

Wider range of adjustments on seats and pedals. Not size related: 1. BE80 subpanel looks like randomly placed switches, indicators and handles. Needs a plan, organization. 2. Consistency of layout across aircraft would help those of us who fly multiple machines. E.g. in the BE80 and C411 that I fly, the gear and flap handles are reversed (021).

- The one I described above would be the one. I would have Boeing change the switch design for the engine anti ice so they wouldn't be mistaken for B pump switches. This problem is a hazard usually at night with the cockpit lights turned down (022).

- No item immediately comes to mind except adding effective humidifiers and more noise reduction (024).

- Increase visibility, as suggested in #4 (026).

How about vanity mirrors in the sun visors (027)?

Design a cockpit where one would not need to pick up a skirt and climb into the seat (030).

On the airplane I'm currently flying, it would be more cooling ventilation in the cockpit (031).

- Yoke design (032).

- Make all Piper aircraft with manual flaps change to electric (or redesign the lever so it's easier to reach and not difficult to move in + out of 40o range) (033).

More use of the heads up display. Have fewer or no items overhead, beyond a "glance up" range. In other words, not having to tilt your head back to physically look at an item (034).

I believe the seats in most a/c are poorly designed. As I now fly legs that are 5 hrs or less I believe there is poor support. Most pilots spend long hrs in the seat and usually one will find pillows around to try and compensate for this problem (035).

- Nothing having to do with being female but lots of ideas as a pilot. Sorry (036).

- Length of forward advancement of throttle in combination of aft travel of yoke for rotation. Also, though it has nothing to do with safety, the seats are very uncomfortable as they were made for folks with much longer backs than most females (037).

- B737 - Flight kit storage area difficult access, and retrieval (awkward to lift out, esp when bag is heavy). Storage area for manuals very difficult to access and slide - (weight) (038).

- Only in Aerospatiale helicopter - raise collective (039).

- No changes needed (040).

- I can not think of any one design I would change. I adapt to each cockpit. It has not been a problem (042).

- Ease of throttles to reverse (043).

- Rudder pedals, armrests, flight bag arrangements so a weak woman doesn't break her back, range of seat back adjustment should be continuous not only for comfort but also to balance comfort, visibility, + control (044).

- Above (045).

- I feel that it will be impossible to design a cockpit that will accommodate people as short as 5' and as tall as 6'7" or greater all in the same seat. In my profession, I definitely feel that my height at 69 1/2" has been a great asset (046).

- I think I might recommend enlarging cockpit windows to permit more visibility (047).

- None (048).

- The most important concern to me at this time is the amount of solar radiation that comes through the cockpit windows. I think this a major concern to all pilots, men & women. I understand that some of the newer airliners have them, but I would like to see them installed in all aircraft (049).

- The best way to do this would be to get into a simulator w/ a video camera and do engine outs and no hydraulics approaches, etc. and freeze the video and study it while it happens. It's so hard to know what you are doing that could be easier. You might be able to get America West to let you use their sims to do something like that (050).

- 1. Back support in seats. 2. Humidifiers in cockpit. Equally important (051).

None (052).

- Width or thickness of control wheel. More travel on rudder pedal adjustment (053).

- Round edges & corners on center console of B737 so I don't keep hitting my shins on it. Allow for rudder pedal adjustment that lowers them nearer the floor (054).

- I would like to see rudder pedals designed such that the lower edge is closer to the cockpit floor (055).

Communication + navigation radios, they could be placed in console area between the seats (056).

I cannot select just one item. The airplanes need to accommodate a larger height range. It would be nice to feel like I was closer to the panel (057).

- Aircraft cockpit seats (058)!