Paper No.

THE APPROACH TO AIRCREW ANTHROPOMETRY AND CREW STATION SIZE LIMITATIONS IN THE CANADIAN FORCES *

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The Canadian Forces (CF) operates twenty-three different aircraft types, ranging in design date from the early 1950s to 1980. In almost every case, the aircraft were designed for a user population other than the CF. The cockpit types range from large transport aircraft through to light helicopters.

It is CF policy that, once selected, aircrew can be assigned to any aircraft type. Thus any physical size selection standards should ensure that aircrew are compatible with all aircraft types. In recent years, the justification for the current aircrew size selection standards has been questioned. As a result, DCIEM has been tasked to review CF aircrew anthropometry and aircraft cockpit geometry, and to make appropriate recommendations to ensure that CF aircrew selection standards are compatible with current and future cockpits.

The key aspect of the tasking is seen as being the proposal of a process for determining physical incompatibility between each CF aircraft type and potential aircrew. Following a review of the methods for assessing aircrew/cockpit compatibility currently used in the ASCC member services, an approach based on man-modelling computer aided design (CAD) has been adopted. This paper reviews progress made on the tasking thus far, and discusses the rationale for the selection of the CAD approach.

INTRODUCTION

The Canadian Forces have some 2200 officers within the aircrew classifications. Of those officers, some 1250 pilots and 350 navigators are assigned to 23 different aircraft types, ranging from the DC-3 Dakota through the Kiowa helicopter to the CF-18. In almost every case the aircraft were designed for a user population other than the CF.

It is CF policy that, once selected, aircrew can be assigned to any aircraft type. Thus any physical size selection standards should ensure that aircrew are compatible with all aircraft types. The implications of this policy for aircrew size selection standards have been of concern for some years. In 1966 the issue of aircrew/cockpit compatibility lead to the adoption of aircrew size selection standards based on the 1st to 99th percentiles of an anthropometric survey of CF aircrew conducted in 1962 [1]. The resulting selection standards were not dissimilar to those of other nations (Figures 1 and 2).

In the early 1970s a survey of aircrew/cockpit compatibility problems

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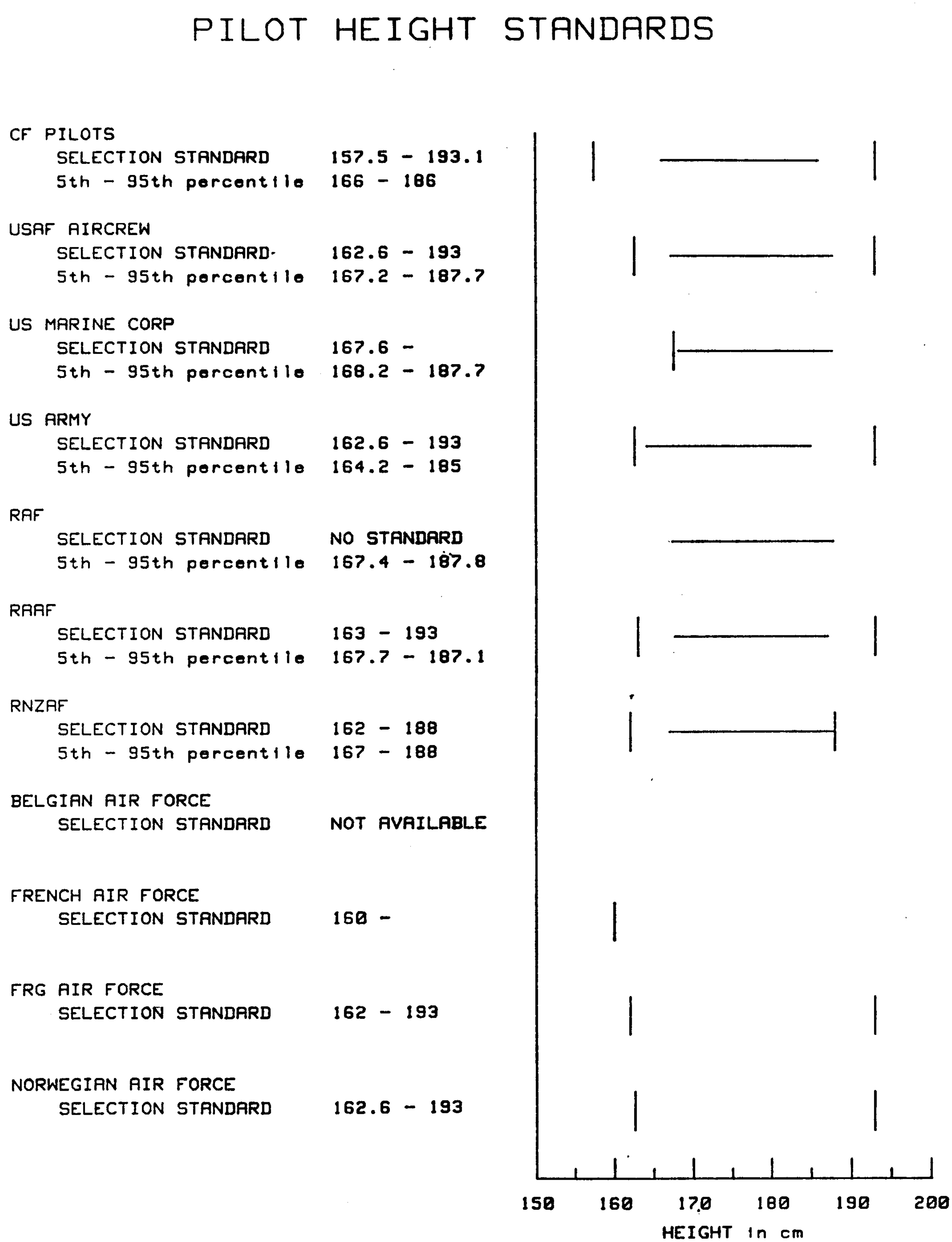

Figure 1. Pilot Height Standards (cm).

PILOT WEIGHT STANDARDS

CF PILOTS		
	SELECTION STANDARD	59 - 95
	5th - 95th percentile	NOT AVAILABLE
USAF AIRCREW		
	SELECTION STANDARD	47.6 - 102.5
	5th - 95th percentile	63.6 - 95.6
US NAVY PILOTS		
	SELECTION STANDARD	47.2 - 105.7
	5th - 95th percentile	63.7 - 92.3
US ARMY		
	SELECTION STANDARD	47.6 -
	5th - 95th percentile	60.4 - 95.9
RAF		
	SELECTION STANDARD	NO STANDARD
	5th - 95th percentile	61.3 - 90.3
RAAF		
	SELECTION STANDARD	51.9 - 94.1
	5th - 95th percentile	62.9 - 92.8
RNZAF		
	SELECTION STANDARD	55 - 85.9
	5th - 95th percentile	62.5 - 91.3
BELGIAN AIR FORCE		
	SELECTION STANDARD	- 95
FRENCH AIR FORCE		
	SELECTION STANDARD	NO STANDARD
FRG AIR FORCE		
	SELECTION STANDARD	56.6 - 97.3
NORWEGIAN AIR FORCE		
	SELECTION STANDARD	47.6 - 102.5

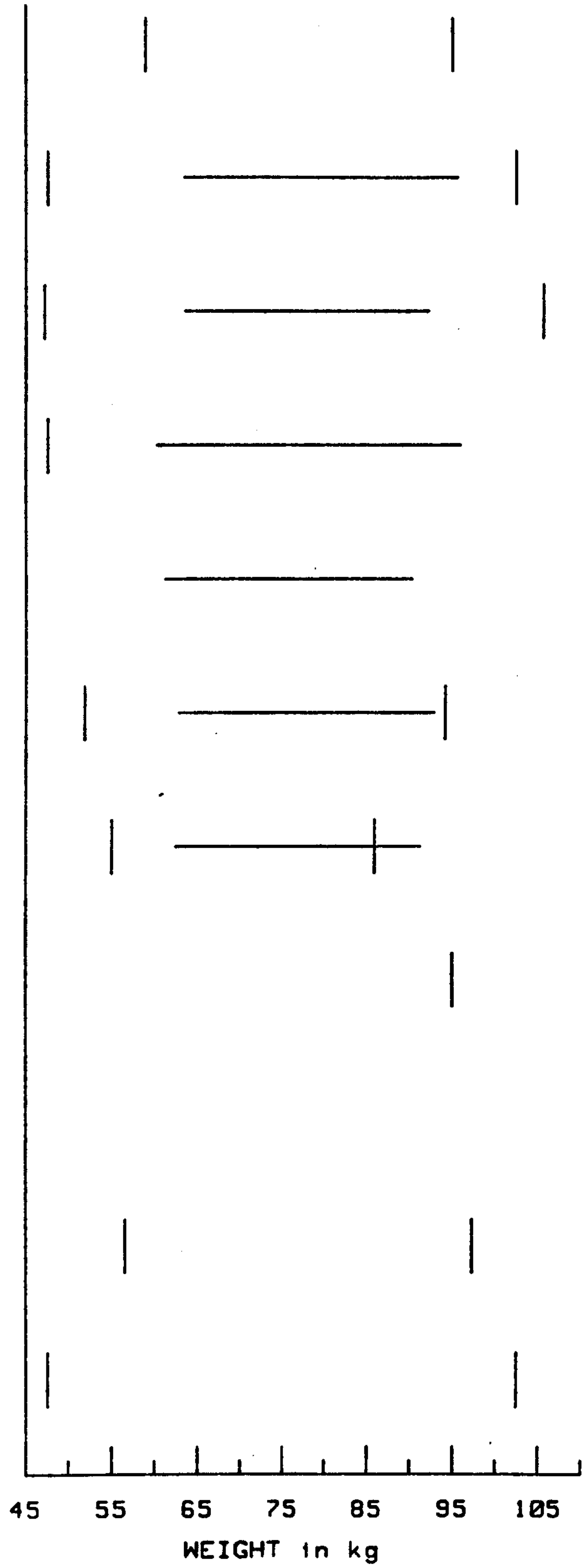

Figure 2. Pilot Weight Standards (kg).

In the mid 1970s, three basic concerns were raised by the Directorate of Air Requirements (DAR):

a) the numbers of aircrew experiencing compatibility problems were not known in detail, but believed to be significant;

b) many aircraft cockpits were designed to a more restrictive range than the current 5th to 95th percentile design limits;

c) the stature of the general population is increasing, and the effect of this increase on personnel selection was not known.

A subsequent review of the size selection standards [2] showed that they were well outside the 5th to 95th percentile design limits in use in the USA. The review also indicated, but was unable to prove, that secular increases in body size were occurring in the CF aircrew population. There was some suggestion that those increases were resulting in an increasing number of aircrew applicants being rejected, especially for buttock to heel length. Coincidentally, the justification for the current aircrew size selection standards has been questioned, particularly by some rejected applicants.

As a result of these developments, DCIEM was tasked by DAR to review CF aircrew anthropometry and aircraft cockpit geometry, and to make recommendations to ensure that CF aircrew selection standards are compatible with current and future cockpits [3].

APPROACH TO THE PROBLEM

Several obstacles prevented an immediate solution to the problem. First, anthropometric data on CF pilots and navigators were outdated and incomplete, and it was not known if the physical characteristics of CF aircrew could be represented using data from other populations. Secondly, there were no data available which accurately described the physical dimensions of CF aircraft. As a result, it was not possible to determine the relationships between CF aircrew selections standards [4] and the geometry of CF aircraft, or to estimate the percentage of CF aircrew that were not physically compatible with CF aircraft crew stations. Therefore, DCIEM had to review both CF aircrew anthropometry and cockpit geometry.

In accordance with the tasking, DCIEM began the Aircrew/Cockpit Compatibility Evaluation (ACCE) in October 1983, addressing the following aims:

a) propose a process for determining physical incompatibility between each CF aircraft type and potential CF aircrew;

b) determine the critical cockpit dimensions of current CF aircraft;

c) determine corresponding anthropometric dimensions of current CF aircrew;

d) identify which current CF aircrew are physically incompatible with each CF aircraft type;

e) review the anthropometric data for aviators given in MIL-STD-1472 and determine if it adequately reflects CF aircrew anthropometric requirements; for example, will CF aircrew be compatible with a cockpit designed around the 5th to 95th percentile aviator's dimensions, as given in the Standard?

f) review Canadian Forces Publication (CFP) 154 standards and recommend required changes.

Since only officers are selected using CFP 154, only pilot and navigator aircrew classifications are to be assessed for compatibility with their respective aircraft workplaces (i.e. the pilot, co-pilot and navigator crew stations).

To approach the aims of the tasking, DCIEM is using the following seven-phase work plan:

Phase 1 - Examine methods used by countries participating in ASCC to determine crew station geometry, aircrew anthropometry and aircrew/cockpit physical compatibility;

Phase 2 - Determine a process for evaluating aircrew/cockpit compatibility in the CF;

Phase 3 - Determine critical physical tasks performed in each CF aircraft crew station;

Phase 4 - Determine the geometric characteristics of all CF aircraft crew stations;

Phase 5 - Determine the anthropometric characteristics of CF aircrew;

Phase 6 - Evaluate CF aircrew/cockpit compatibility using the information obtained in Phases 3, 4 and 5 according to the process determined in Phase 2;

Phase 7 - Recommend required changes to the current CF aircrew selection standards.

PROGRESS

PHASE 1

Phase 1, to review methods of assessing aircrew/cockpit compatibility, was completed in April, 1984. Originally, methods used by NATO and The Technical Cooperation Program (TTCP) countries were to be examined. From discussions with the task sponsor and representatives of the Surgeon General's Office, it was concluded that a review of the methods used by military services of the Air Standardization Coordinating Committee (ASCC) would be sufficient. Therefore, the methods were drawn from a review of known aircraft evaluation techniques employed by countries participating in the ASCC, and traditional human engineering methods to assess work spaces. The various methods included:

a) cockpit fitting trials using live subjects;

b) mock-up fitting trials;

c) cockpit fitting trials using dummies or manikins;

d) stick-figure manikin measurements;

e) comparing existing cockpit specifications with published anthropometric data;

f) 2-dimensional drawing board manikin analysis;

g) 3-dimensional computer man-modelling.

Each method was appraised for its capability to represent the anthropometric characteristics of the user population, input data requirements, ease of use, etc [5]. Three-dimensional computer man-modelling appeared to offer the most advantages. It permits the representation of the anthropometry of individuals or of whole user populations, using data that are expressed as absolute values or percentile equivalents. As well, its analytical capabilities to assess the operation of controls (reach), vision inside and outside the aircraft, body clearances, and ingress and egress seem to be superior to other techniques. Three-dimensional computer man-modelling was determined to be the most appropriate technique to satisfy the CF tasking requirements and it was recommended that an appropriate program be acquired to address the ACCE problem [5].

PHASE 2

Phase 2, to determine the CF process for evaluating aircrew/cockpit compatibility, addresses three issues: a) selection of a man-modelling computer aided design (CAD) program, b) determination of a method to measure crew station geometry, and c) establishment of the criteria and process to be used to evaluate CF aircrew/cockpit compatibility. Issues a) and b) have been resolved, while issue c) is currently undergoing a final appraisal. Each of these issues is discussed separately.

<u>Selection of a Man-Modelling CAD Program</u>

Before selecting an appropriate man-modelling CAD program, desirable features to address the ACCE tasking had to be determined. Generally, they were the capabilities to model man and model aircraft crew stations, and to analyse reach, vision and body clearance using interactive graphics techniques.

The computer systems identified as having effective man-modelling programs were: BUBBLEMAN, BUFORD, CAR, COMBIMAN, CYBERMAN and SAMMIE [6]. ERGOMAN, ADAM and EVE have been referred to in the literature [7,8] but no details regarding their derivations or applications are available. Of the computer programs identified, only SAMMIE is commercially available. CAR and COMBIMAN, which are the property of the US Department of Defense, may be obtained through cooperation within the ASCC. Therefore, CAR, COMBIMAN and SAMMIE were considered for use in the ACCE tasking, and were assessed for that application.

CAR was rejected as the primary CAD tool for the ACCE tasking for several reasons [9]. Primarily, its analytical capabilities are limited (e.g. it has no capability to address body clearances and provides no indication that the man-model is reaching through something). Furthermore, CAR has no graphical capabilities, so visual examination of the analyses is not possible and illustrations for presentation purposes cannot be generated.

CAR does show potential as a supplementary tool for the tasking since it is useful for generating populations of varying anthropometric proportions and for converting individual body segment lengths to percentile equivalents. Other advantages have also been identified [6]. Therefore, CAR has been retained for further study and a contract has been let to determine the validity of its reach, vision and head clearance predictions for the CF aircrew population.

To determine which of COMBIMAN and SAMMIE is the more appropriate man-modelling CAD program for the ACCE tasking, multi-criteria decision analysis was employed. The criteria used to evaluate the programs were based on the features considered to be important for man-modelling and workspace-modelling. Of equal importance were the capabilities to address the problems of reach, clearance and vision in aircraft crew stations. On the basis of the comparative analysis using the Electre multi-criteria decision technique [10], SAMMIE was judged to be the more reasonable means by which to address the tasking. On that basis, SAMMIE was recommended for purchase.

Determination of a Method to Measure Crew Station Geometry:

In the determination of a method to measure crew station geometry, personnel representing ASCC military services and aircraft manufactures were consulted. All those questioned or interviewed indicated that they currently use manual measurement techniques, if in fact they measure aircraft cockpits at all. Therefore, the reliabilities of three manual techniques were examined in measurement trials conducted on Kiowa and F-18 aircraft. Briefly, the three techniques employed the use of; a) levels, plumb-bobs and rulers, b) a modified version of the US Navy's stick-figure anthropometer [11], and c) a measurement probe (developed for the measurement trials) that defines workplace locations according to angular and linear displacements from an arbitrary origin. No method was found to be satisfactory in terms of repeatability of measurement.

The search for an automated measurement technique revealed that sonic digitization may be a viable method. Since it previously has not been used for this application, The de Havilland Aircraft of Canada assisted DCIEM in a preliminary evaluation of the method. It was determined that sonic digitization does indeed seem to be a good method, so the technique will be evaluated more rigorously through the activities of Phase 4.

Establishment of the Evaluation Process:

A proposal for the specific step-by-step process of evaluating of aircrew/cockpit compatibility was prepared in April, 1985. The process, which is based on traditional anthropometric and workspace evaluation criteria, is currently under review.

In general terms, the process focuses on the manipulation of anthropometric variables that effect body clearances, capabilities of vision in and around the workspace, and arm and leg reaches. While it would be ideal to use one process to analyse aircrew in all CF aircraft, it is necessary to vary the process according to the type of seat adjustment available in the individual aircraft types (i.e. non-adjustable, fully adjustable, or ejection seat).

The majority of the compatibility analysis will be conducted using SAMMIE. CAR may be used in the later stages of the analysis, to provide randomly-generated man-models for input to SAMMIE, based on the CF aircrew anthropometric survey data (Phase 5).

The product obtained using the process will include a range of acceptable limb lengths or combination of limb lengths, which indicate compatibility with each aircraft. The process is being validated in Phase 2, but will be employed for assessment in Phase 6.

PHASE 3

Phase 3 commenced in October 1984 with two specific objectives; to become familiar with each CF aircraft, and to determine the critical (physical) tasks performed by pilots and navigators in those environments.

For each CF aircraft, the principal investigator participates in three activities. First, a briefing is conducted, in the aircraft, by one pilot or navigator. In the briefing, standard seating practices, control positions, clothing ensembles and personal equipment uses are discussed for each crew station. As well, the functions of all controls and displays are outlined and emergency procedures discussed.

Structured interviews are then conducted with separate groups of pilots and navigators. The personnel selected include 4-6 aircrew (preferably Captain rank) currently assigned to the aircraft and having two or more years of relevant experience. Representation of female aircrew is requested where applicable, and representation of left-handers is desired. In the interviews, general physical requirements of aircrew are discussed and specific physical tasks (related to reach, vision or clearance) are identified.

To complete the appraisal of aircrew tasks in each aircraft, a familiarization flight is arranged. In that way, physical activities in the aircraft are observed and contrasted with verbal descriptions of physical tasks that aircrew perform. Furthermore, some of the constraints imposed by the physical environment are experienced first-hand.

To date, 17 of the 23 CF aircraft types have been reviewed in this manner. It is expected that the remaining aircraft will be reviewed during the first quarter of 1986.

PHASE 4

As discussed earlier, sonic digitization has been identified as a potential means of obtaining the crew station geometry data. The determination of each CF aircraft's geometric characteristics is to be carried out under contract with industry.

It is proposed that the contract be let in two stages. In Stage 1, the contractor will develop a method to determine (x,y,z) crew station geometric information (including required software), using sonic digitization. In Stage 2, the contractor will measure the crew stations of each type of CF aircraft, employing the method outlined in Stage 1. He will determine the general physical layout of each crew station, the locations of specific critical controls and displays, ranges of movement of controls and the characteristics of the aircrew seat. The geometric data will be presented in formats that satisfy the input requirements of the CAD programs CAR and SAMMIE.

PHASE 5

Phase 5, to determine the anthropometric characteristics of CF aircrew, is concerned with aims (c) and (e) of the ACCE tasking. As with Phase 4, it was an activity to be completed under contract with industry.

Work on Phase 5 was completed in October 1985, and addressed three work areas. The first work area was to conduct an anthropometric survey on CF aircrew. The data were prepared in formats that satisfy the input requirements of the CAD programs CAR and SAMMIE. The second work area was to compare the CF survey data with US Military Standard 1472C, in order to determine the relevance of US aircraft design specifications to the CF. The third work area was to summarise the anthropometric survey results according to current CF aircrew selection criteria outlined in CFP 154 and Canadian Forces Administration Order (CFAO) 34-44 [4,12] and the draft proposal of ASCC guidelines for common practices in the conduct of anthropometric surveys [13].

A total of 398 pilots and 132 navigators were surveyed at nine CF bases, representing a total of 17 CF aircraft types. Specific results of Phase 5 cannot be given until the final report has been examined.

PHASE 6 and PHASE 7

Phases 6 and 7 cannot be initiated until Phases 3, 4 and 5 are completed. Once the necessary data have been put into the SAMMIE and CAR programs, the evaluation of aircrew/cockpit compatibility will be conducted according to the procedure determined in Phase 2. Recommendations for future aircrew selection standards can be made only when the results of that evaluation are completed.

CONCLUSIONS

To the outsider, perhaps it is surprising that so much effort is necessary to address what many consider to be an elementary problem in man/machine integration. Our experience has been that the issues involved are more complex than they initially appear to be.

The process which has been outlined is a logical development of work being undertaken in several other ASCC member services. It appears to be the most rational approach to the problem of revising aircrew selection criteria for the CF. Due to differences in size, organization, logistics and geography, however, it may not be the most appropriate approach for all services.

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