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# Current USN/USMC Aircraft Anthropometric Compatibility Issues and the "Street to Fleet" Proposal

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## ABSTRACT

Shortcomings of the USN/USMC anthropometric compatibility process have driven a requirement for an improved process, "Street to Fleet." During the course of the NAVAIRSYSCOM (PMA-202) Aircrew Accommodation Expansion Program (reference 1), where AIR 4.6, Patuxent River was tasked to perform accommodation evaluations on in-service USN/USMC inventory, the increased costs associated with safely assigning aviators to an appropriate training curriculum through to their fleet aircraft have been identified. Both the shortcomings and increased costs are due in part to the lack of solid legacy guidance. Currently, four anthropometric measurements receive a "code" that indicates whether a particular candidate is compatible, incompatible, or requires a "fit check."

Under current official guidance, a short sitting height is the only anthropometric measurement that receives an incompatible Anthropometric Restriction Code (ARC) with a given aircraft, primarily due to inadequate over the nose visibility. Newer aircraft are designed with the intent of accommodating an increased proportion of anthropometric extremes and these anthropometric parameters are considered simultaneously vice one dimension at a time. Therefore, the process used to screen aviators needs to more closely relate to the specification guidance used to develop the aircraft. This paper discusses the USN/USMC "Street to Fleet" proposal for dealing with these issues in the long term, including:

- validation of recent military population anthropometric surveys with respect to current USN/USMC candidate and fleet aviators
- the statistical precision of the predicted accommodation envelope

- software model development and decision process
- advanced and automated anthropometric measurements

## INTRODUCTION

The US Navy and US Marine Corps have been using for the past 15 or more years a screening system to better assure the safety of assigning aviators to their aircraft pipelines based on their personal anthropometry. The system that the USN employs for this screening process crosses several USN commands, including the OPNAV sponsorship, NAVAIR, BUMED, and BUPERS. Each of these commands has a stake and a task in the process. The Anthropometric Restriction Codes (ARC's) that were generated at NAVAIR in 1987 (references 2, 3, and 4) were recorded solely in an official instruction without benefit of archiving the methods for corporate preservation. Additionally, the codes have not been updated or reviewed until recently.

The chosen arrangement of cockpit critical parameters was limited to four because that was the number of available slots remaining on the FORTRAN card used in the late 1980's to carry the aviators' personal information. One of the major shortcomings caused by this limitation was the lack of relationships between anthropometric parameters, which affect determining the appropriate seat location for a given individual's anthropometry. Other shortcomings of the system that developed over time were the outdated coding intervals. The vast majority of inventory aircraft were designed to meet either a 5<sup>th</sup> to 95<sup>th</sup> or 3<sup>rd</sup> to 98<sup>th</sup> percentile with the intent of accommodating either 90 or 95% of a population of USN aviators. The percentiles came from a predominantly white, exclusively male aviator database in 1964 (reference 5). The aviator population has changed substantially in the past 35 years, and dramatically in the time frame since the ARC's

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were developed. It is no great surprise that some assignment process costs have recently started to rise.

#### **THE COST OF REASSIGNMENTS AND FIT CHECKS**

Anecdotal information that AIR 4.6 has suggests that there may be as many as 10 USN or USMC aviator pipeline reassignments this year. The reported tax payer costs to train a jet aviator are estimated at over 1 million dollars. When a trained aviator is reassigned, 3 million dollars may have been spent by training the aviator in the original unsuitable pipeline, reassigning and training the aviator to a different pipeline, and replacing the lost aviator within the original pipeline.

Some of these expenses may result from another limitation of the current guidance. This limitation is the lack of fit check procedures at the Fleet Replacement Squadrons (FRS). The only aircraft with fit check procedures are those used in the training commands. Many of the reassignments result from assuming aviators can fit in the fleet aircraft on the basis of their training aircraft fit checks and performing only a quick screen through the ARC's for compatible fleet aircraft. Sometimes this assignment process is successful; however, at times two anthropometric parameters may cause conflicting seat location requirements that would be noticed in a fleet aircraft fit check, but may not be evident through the ARC's.

#### **JSSG DATABASE AND VALIDATION**

The current population that is now driving aircraft design is the Joint Service Specification Guide (JSSG) database. This database, derived from the 1988 Anthropometric Survey of Army Personnel (reference 6), was developed to meet a tri-service agreement to satisfy a Congressional mandate to accommodate 80 percent of females in military aircraft, striving for 95 percent as a goal. This reference population does not correspond with current operational USN/USMC realities.

According to reference 7, the projected population was based on three elements: matching the racial mix of the 1992 Department of Education college graduates, at least 22 years of age, and within the USN/USAF height and weight standards. The current proportion of

females in USN/USMC aviation billets is only 3 percent of the total USN/USMC flying population; however, the JSSG database is comprised of 40% females. The issue of body weight is also incorrectly represented in the database with respect to the current population of aviators. The database contains no personnel in the population possessing body weights greater than 235 pounds. However, during a survey at Training Wing 2 (March 1998), several of the student naval aviators and instructors participating in the study weighed in excess of 213 (the weight limit for the applicable ejection seat) and a few were above 235 pounds.

When percentages of the population that are successfully accommodated are reported, the estimated results may be biased. In order to minimize any biasing of the results, a validation of the JSSG population is needed. A statistical analysis of the population demographics reveals that for the four dimensions used (sitting height, sitting eye height, buttock knee length, and thumb tip reach), approximately 100 males and 100 female aviators would need to be measured in order to estimate confidence at the tails and to validate the JSSG database. Because of the variability of body weight, it would be necessary to measure 588 men and 692 women to validate weight.

#### **NEW CODING SYSTEM PROPOSAL**

As the USN aviator population continues to change and potentially causes high costs due to reassignments and questions regarding database validity, it is becoming necessary to change the current ARC's. The old ARC system relied upon four anthropometric measurements that did not interact with one another. It would only express if there was at least one position where an individual could place the seat and operate critical controls; it would not determine whether at this same seat location the individual also attained Design Eye Point (DEP) and possessed over the nose external field of view. This one interaction of sitting eye height and thumb tip reach is often the most limiting factor in safely assigning an aviator to a particular aircraft. A clear relationship of these two anthropometric parameters is not included in the current ARC system.

The first step performed by AIR 4.6 was to simply update the existing codes as an interim

solution. Revised codes for all of the trainer aircraft were published, along with new codes for the T-45 and H-60 because none previously existed (reference 8). Therefore, a new ARC system is being proposed (reference 9) that takes into consideration both the expanding population size (by extending the ARC ranges on each end) and also the important interactions between various anthropometric parameters. In addition to being accommodated in each of four anthropometric parameters individually, a candidate must also show correct accommodation in combination.

The individual codes are added together to determine the level of full accommodation. This summation deals with both extreme ends of the spectrum. Smaller statured individuals must meet a certain sum of sitting eye height and thumb tip reach codes to ensure simultaneous over the nose visibility and operation of critical controls. Similarly, larger statured individuals must meet a certain sum of sitting eye height (or sitting height) and buttock knee length codes to ensure that there is a seat location where the individual has overhead clearance and also knee clearance both to the instrument panel and any other areas that could become obstructions during an ejection.

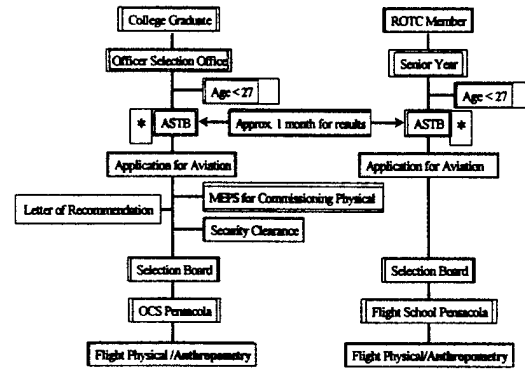
The revised ARC's are based on previous guidance and regression equations resulting from USN/USMC cockpit accommodation evaluations. These equations, which generally have a coefficient of determination ( $R^2$ ) of 0.7 or above, and a standard error of measurement of 0.5 inches (except for reach to controls where the error is less than 1.0 inches), are used to help determine the accommodated and excluded from flight ranges for specific aircraft crew stations. Safety of flight for the aircraft and occupants is paramount, followed by mission effectiveness.

Thus, with the proposal of the new ARC's, a true multivariate analysis is being performed vice a univariate analysis that only examines one measurement at a time. This ensures that an individual is not being incorrectly assessed in either the operation/vision issue or in the area of cockpit clearances.

## REFINEMENT OF THE MEASUREMENT PROCESS

The current measurement process, Figure 1, places anthropometry with the flight physical that is performed in Pensacola, Florida, after the individual has completed Officer Candidate School (OCS).

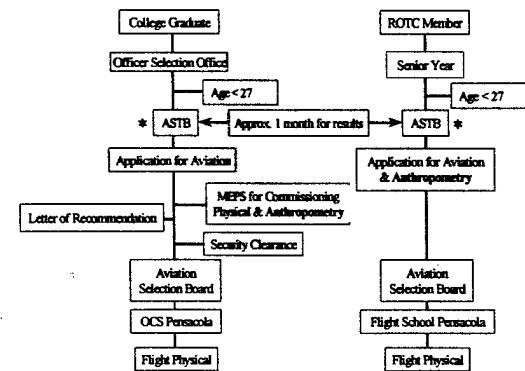
Figure 1



However, this is often too late in the cycle; the likely promise of training the candidate for aviation duty has already been made. It then may become known that the candidate's anthropometry is incompatible with many or all of the aircraft platforms, or he/she may be screened into a less desired platform.

If the anthropometric measurements were taken earlier at the individual Military Entrance Processing Stations (MEPS) (Figure 2), there could potentially be great cost savings as the candidates are advised much earlier what pipeline choice(s) they have.

Figure 2



The early determination of pipeline(s) would also immediately exclude those who are not compatible with any aircraft and save the cost of their training, billeting, and moving expenses. With this proposed system in place, the individual could be measured as early as the recruitment physical and shown a list of aircraft with which his/her personal anthropometry is compatible. The candidate could then have the up front knowledge and go "Street to Fleet."

The tools rapidly being developed to allow the anthropometry block to be moved to the recruiting physical include development of a Digital Anthropometric Video Imaging Device (DAVID) and the complementary Automated Anthropometric Evaluation Program (AAEP). These two components have been prototyped and await a phase II, demonstration/validation process.

#### THE INTRODUCTION OF AUTOMATED ANTHROPOMETRIC SOFTWARE

The next application of the regression equations used for ARC refinement is in the newly developed Automated Anthropometric Evaluation Program (AAEP). The AAEP is a software package that requires an individual's anthropometric measurements as inputs and expresses their overall pipeline accommodation as outputs. Simultaneously using all the regression equations for a particular aircraft, along with any other pertinent guidance, it determines whether the individual is accommodated in that aircraft.

The individual is accommodated if he/she can achieve over the nose visibility, activate critical hand and foot operated controls, and fit within the confines of the cockpit, all occurring in at least one seat position. A margin of error is being incorporated into the AAEP software that will account for the stacking of standard errors from each of the regression equations. A conservative approach is utilized, i.e., type I errors are acceptable but type II are excluded.

Once this accommodation determination is made, the software presents the answer in one of two ways. If the individual is accommodated, the software will output the specific seat adjustment range that is safe. If the individual is not accommodated, the software will present the anthropometric measurements and interactions

that limit the individual from the particular aircraft, such as a "G" in Figure 3 representing the sitting eye height/thumb tip reach interaction.

Figure 3

Weight:	142.86 lb
Height:	68.90 in
Sitting Height:	35.04 in
Sitting Eye Height:	30.63 in
Sitting Acromial Height:	21.65 in
Thumb Tip Reach:	31.30 in
Buttock Knee Length:	24.49 in
Functional Leg Length:	45.67 in

Aircraft	Results	Seat Range
T-34 FWD		0 - 5.12
T-34 AFT		1.84 - 5.12
T-2 FWD		3.29 - 4.65
T-2 AFT		3.05 - 4.65
TH-57 LT	B F G J K	none
TH-57 RT	B F G J K	none

#### Legend:

A = SH too large	G = SEH vs. TTR
B = SEH too small	H = BKL vs. FLL
C = FLL too short	I = BKL vs. TTR
D = BKL too long	J = BKL vs. SEH
E = TTR too short	K = SH vs. SEH
F = SEH vs. FLL	

At its completion, this software will be able to assess an individual's accommodation levels among all USN platforms and correctly assign the individual to the most suitable pipeline at the earliest possible stage. This system, as well as the interim proposed ARC's, will lower the occurrence of aviator reassignments by providing essential pipeline information before an incorrect assignment has been made.

#### Validation of the AAEP

The AAEP will first be validated prior to its introduction. Several methods will be used to ensure its validity. Anthropometric measurements of a population of subjects will be processed through the AAEP software and its results will then be compared to the results achieved in using the new proposed ARC's. Additionally, software comparisons will be made with AMSO fit checks to determine a percentage of agreement between the various methods. Again, safety of flight will be used as a first

criterion in determining the correct handling of error. Only after these validations have been performed and subsequent software refinements occur, will the software be released for use.

#### **THE INTRODUCTION OF DAVID**

This method of measuring at the MEPS stations would be easily facilitated by the introduction of DAVID, a Digital Anthropometric Video Imaging Device, a system that could greatly increase both the reliability and ease of performing anthropometric measurements. It is a quick process of capturing digital images of an individual in various anthropometric postures and then dimensioning the measurements through a software package. It allows for reliability checks and preserves the images for any subsequent measurements that may be desired. DAVID was developed and currently resides at the Naval Aerospace Medical Research Laboratory (NAMRL) in Pensacola. It is expected to become the standard measurement procedure at all MEPS stations, where the digital images would be captured and then sent to a central processing center in Pensacola to perform and record the measurements.

The DAVID is a system that is intended to provide individual anthropometric measurements as inputs to the AAEP software, where the regression equations will be accessed and aircraft compatibilities determined. The compatibility output from the AAEP will then serve as input back into the DAVID. Resident within the DAVID is a file that will combine the individual digital photos along with the aircraft compatibility information from the AAEP to produce a report format detailing the end results of both systems used to determine pipeline suitability.

#### **THE DAVID COMPARISON STUDY**

NAMRL will conduct the DAVID comparison study during the first half of 2000. The study will provide correlation values for sitting height, shoulder breadth, functional reach, leg length, and buttock knee length measurements acquired using both the current method and the DAVID. Since previous evaluations of the current method revealed inconsistencies and the current method does not use accepted, standard anthropometric landmarks, direct comparison between the DAVID and the current method is difficult.

In addition to this comparison study, a previous study, to be published as a NAMRL Technical Report, shows no significant difference between the DAVID method and the accepted standard manual (anthropometer) method for nine anthropometric measurements. A sitting height comparison study where the same person was measured by 15 different people using the DAVID, manual, and current NOMI method was also completed. No significant differences were found between the methods.

The second sitting height study has been accepted for publication in Aviation, Space, and Environmental Medicine as a technical note entitled "Comparison of Sitting Height Measurement Using Three Anthropometric Measuring Techniques" by JL Saxton and FR Patterson.

#### **CONCLUSIONS**

Anthropometry has greatly progressed from the days of rulers and tape measures to digital imaging and software prediction packages. Due to the expanding population of today's Naval and Marine Corps aviators, it is necessary both to ensure that a representative database is in use and that accommodation issues are investigated up front and early for this new population.

An examination of the current ARC's reveal that the important combination of tasks that must be performed in an aircraft have been inadvertently overlooked and led to the need for costly fit checks; thus, a new ARC system is being proposed that looks closely at all aspects of flight that must occur dynamically.

The future application of this knowledge is in software packages and their ability to interact with one another. To truly make this move to newer technologies from the present, the current and upcoming aviator population must correctly be identified, understood, and assessed. Only then can the candidate make the transition from "Street to Fleet."

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#### **BIOGRAPHIES**

Heather D. Tucker has been employed by the Naval Air Warfare Center in Patuxent River, Maryland, since 1996. She is a project engineer active on the Aircrew Accommodation Expansion Program. She is responsible for data collection and analysis of anthropometric assessments of Navy aircraft. She has also developed a software program to analyze aviator accommodation in all existing aircraft and predict aviator candidate pipeline assignments. In addition, she is involved with the ANGEL (Active Network Guidance in Emergency Logic) program, which is planning to integrate new and upcoming technologies to help increase survivability of the aircrew and aircraft and improve mission effectiveness. Heather received a Bachelor of Science in Industrial Engineering

from West Virginia University, and is currently pursuing a Master of Science in Systems Management/Operations Research from Florida Institute of Technology.

Lori L. Brattin has been with Crew Systems for one year, and also supported Crew Systems for the prior 5 years as contract support on the Aircrew Accommodation Expansion Program. She has more than 5 years of experience with the FARO-Arm™ for aircraft cockpit geometry data collection and development of ANTHRO-CAM data collection routines. Prior to government/contract support roles, Lori has 7 years in aviation maintenance with the US Army. Her unique blend of anthropometric knowledge, hands on experience with maintainer issues, and mechanical engineering has placed her in high regard for development of a Design for Maintainer presence in next generation aircraft design. Lori is a graduate of Embry Riddle with both associates and bachelor degrees in Professional Aeronautics and Management of Technical Operations respectively. She is enrolled as Master of Science candidate in Aeronautical Science.