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HUMAN SYSTEMS INTEGRATION CAPSTONE

CERTIFIED EJECTION SEAT WEIGHT RANGES AND THEIR EFFECTS ON PERSONNEL SELECTION

by

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September 2014

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ABSTRACT

Current ejection seat certified aircrew weight ranges (136 to 213 lbs.), such as for the F/A-18, prohibited over one third (38%) of women and (8%) of men from accessing the naval aviation strike pipeline (carrier-based aviation) between 2008 and 2013. This is deleterious to the Naval Aviation Enterprise to restrict access of otherwise qualified and talented applicants to the strike aviation pipeline due to an outdated anthropometric survey based specification. The acceptable level of risk that was utilized by the Naval Aviation Systems Command was overly conservative and needs to be updated to align with current operational risk management principles, actual ejection seat performance mishap data and the naval aviation anthropometric population. This research is a deep exploration of all aspects of this issue and makes recommendations that can be used by Commander of Naval Air Forces in establishing an operational weight limit for all ejection seat aircraft.

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I. INTRODUCTION

This capstone project aims to conduct an in-depth look at the Naval Aviation Enterprise Pipeline Selection Process (NAEPSP). Specifically, the intent is to identify current ejection seat restriction criteria, which limit the selectable population to those individuals weighing between 136 and 213 lbs. The consequence of these criteria is that they prohibit over one third (38%) of women and (8%) of men from accessing the naval aviation strike pipeline (carrier-based aviation). This is deleterious to the Navy to restrict access of otherwise qualified and talented applicants to the strike aviation pipeline due to an entirely arbitrarily assigned limitation based on anthropometric values that are overly conservative for ejection seat performance specifications and do not align with the current Naval Aviation population.

The methodology for the assessment is modeled after Hendricks's five steps of systematic approach for analyzing work systems, Table 1 (Hendrick and Kleiner, 2002). For the purpose of this assignment, the specific Area of Interest (AOI) that has been identified and analyzed is that of personnel selection, which is step one in Hendricks's model.

Table 1. Assessment and Intervention

Step	Hendrick's Steps (Hendrick & Kleiner, 2002, p. 19)	Intervention
1	Recommend the design modifications to the overall work system	Alter/eliminate the ejection seat criteria for the pipeline personnel assignment process.
2	Review existing job/system	Review and critique personnel subsystem; Discuss existing ejection seat weight limits, based on population trends from decades ago, fail to reflect changing demographics. Address organizational implications of failure to update the ejection seat weight ranges.

3	Review related human-system interfaces	Review ejection design specifications by aircraft, manpower, personnel, training, anthropometric surveys and studies, hazard risk assessments, mishap data, engineering investigation reports
4	Determine if steps 1, 2, 3 are congruent	Review available information and documentation (policy, test data, case studies, mishap data, etc); review literature/research and relate findings to intervention to support congruence assessment.
5	Recommend how to modify those that are not	Discuss data/findings that show weight limits can be broadened to include significantly more aviators, both female and male, without compromising ejection safety. Recommend changes to make carrier aviation more congruent with the psychosocial environment of the relevant external environment (an inclusive, egalitarian, 21st century America).

II. OVERVIEW OF THE NAVAL AVIATION ENTERPRISE PIPELINE SELECTION PROCESS

The NAEPSP is depicted in Figures 1 and 2. Reading the figure from right to left shows the impact of the current ejection seat limits on the personnel selection process. Start with the final fleet aircraft (F-18,) and then move left along the yellow path to the first selection point. The T-45 aircraft depicted next to the blue diamond has a set of weight limits (136 - 213 lbs). Continue to follow the path to the left until the next selection point (T-6),), which is where all naval aviation students begin flight training, and it also has a set of weight limits (103 - 245 lbs.). Currently, in order for a student to progress to the right along the yellow strike pipeline path, they must meet a minimum Navy Standard Score (NSS), otherwise known as your flight school g.p.a., of 50 during flight training, as well as be anthropometrically compatible (to include weight) with any and all training aircraft and at least one of the final fleet aircraft.

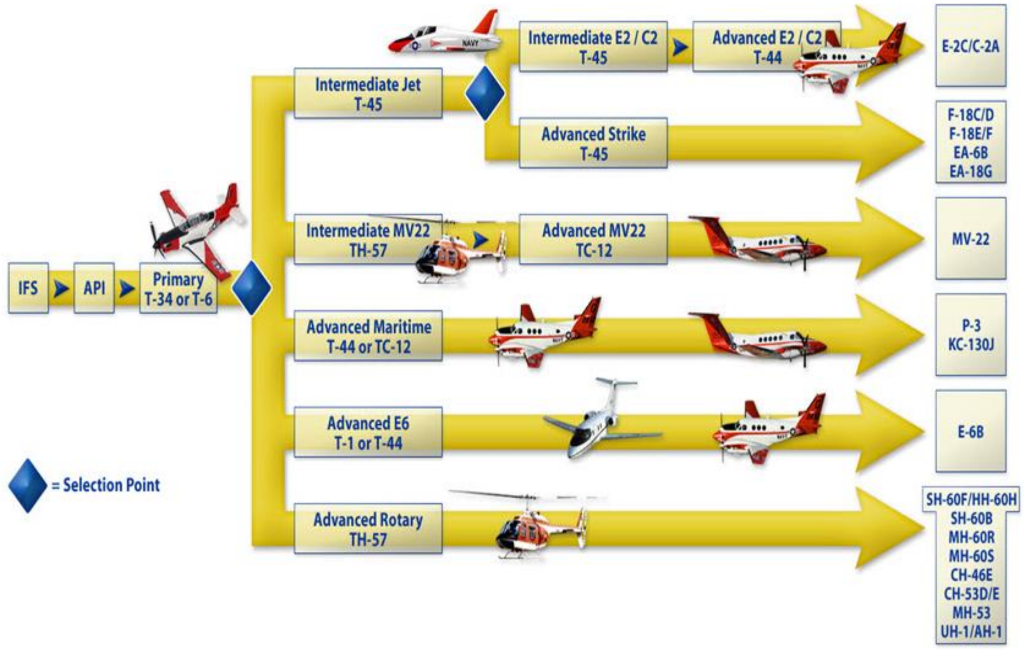

Figure 1. Naval Aviator Pipeline Diagram

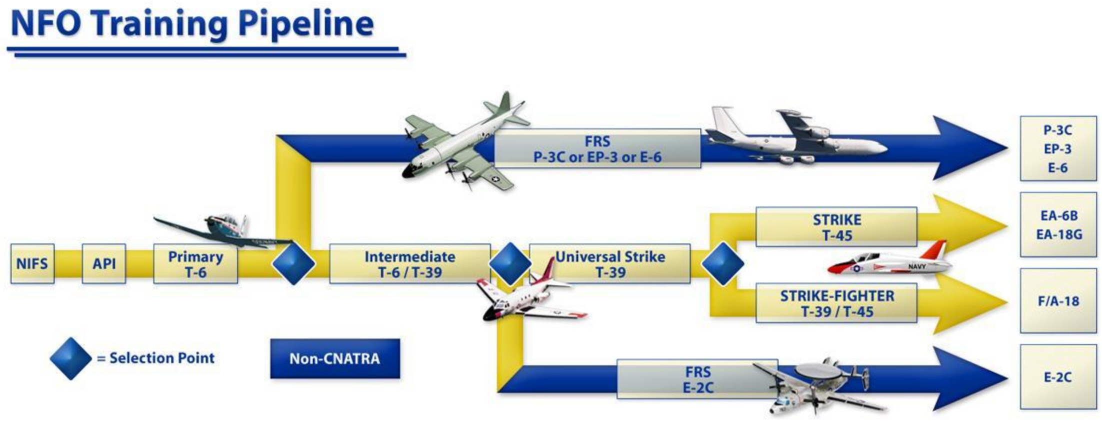

Figure 2. Naval Flight Officer Pipeline Diagram

Early in the accession process, naval recruitment/selection sources ensure that accurate anthropometric measurements of prospective Naval Aviators/Naval Flight Officers are determined and recorded. This early screening results in early identification of individuals with possible anthropometric incompatibilities with naval aircraft. NAVAVSCOLSCOM (API on Figures 1 and 2) is the Anthropometric Program Model Manager for anthropometric accommodation and the official source of and standard for all individual anthropometric measurements. The anthropometric measurements completed by NAVAVSCOLSCOM serve to determine if there are any functional aircraft restrictions for candidates. These measurements are then used by the Chief of Naval Air Training (CNATRA) for student pipeline selection and assignment.

Individuals who are anthropometrically incompatible with aircraft may submit a waiver request as early as practical during flight training to avoid delaying pipeline selection. The current Naval Aviation Anthropometric Compatibility Assessment (NAACA) report must be included with the request. Requests are submitted to the approving authority in writing via the chain of command with endorsement by CNATRA Chief of Staff as follows: (1) For Navy personnel: Submit request to Naval Personnel Command (PERS-43); (2) For Marine Corps personnel: Submit request to Commandant of the Marine Corps (CMC), Deputy Commandant for Aviation (ASM).

Since the consequences of assigning an anthropometrically incompatible crewmember to an aircraft can be both costly and potentially catastrophic, waivers are not granted to Naval Aviation/ Naval Flight Officer candidates. However, the focus of this capstone project is not functional disqualification; it is the use of ejection seat weight ranges alone as a restriction on the selection of candidates.

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III. FRONT END ANALYSIS

Certified aircrew weight ranges for strike aircraft were established in 1964 and arbitrarily set at 3rd through 98th percentile male as a basis for ejection seat design specifications. These weight limits were extracted from an anthropometric survey done by the U.S. Naval Air Engineering Center (NAEC-ACEL-533, 1965) shown in appendix A. The survey was intended to be used by aircraft and personal flight clothing designers to develop future cockpits and operational clothing. In that survey, 96 different body measurements were taken on each of the 1,549 naval aviators (roughly 10% of population) who participated. At the time of the survey, the naval aviation population was entirely male. Therefore, all early naval aviation anthropometric standards were based solely on the male anatomy and systems also were designed and built to those standards).

Modern ejection seats are required to provide the widest possible escape ‘envelope’ - that is the range of aircraft speed, height and attitude flight conditions under which it is possible to successfully eject. They must also operate within stringent and mandatory physiological limits (loads, accelerations, etc.) that ensure the crew comes through the ejection process without injury. It is an unfortunate fact of life that these two fundamental requirements tend to conflict, i.e. an enlarged escape envelope can be achieved with greater accelerations/forces, while lower injury risk implies lower accelerations/forces. The task of the seat designer is therefore to address this dichotomy to achieve the best possible balance between performance and safety. Seat ejection performance is heavily driven by the combined weight of the ejected seat and occupant, not simply the weight of the occupant. The ejected weight governs the fundamental design requirements, such as propulsive thrust, propulsive impulse and imposed acceleration levels on the seat occupant. To meet the seat performance needs over such a large weight range without resorting to complex and expensive control systems is an extremely difficult requirement. A number of design features have been incorporated into the seat specifically to meet these requirements. For example, the initial ejection gun phase of an ejection causes the seat to be accelerated at a high rate from the aircraft. The direction of this acceleration is approximately along the occupant’s spinal column, so control of the magnitude of the acceleration is extremely important if injury is to be avoided. The ejection seat recovery sequence is essentially the same for all flight conditions, with the recovery parachute deployment time delay being automatically adjusted as required for the prevailing flight conditions, i.e. a faster sequence for a low altitude ejection than for higher altitudes. Following self or command initiation of the seat the following on-seat actions occur immediatelyand the ejection gun delay cartridges (if fitted) are initiated. The shoulder harness retraction unit is operated to position the occupant for ejection. After the time delay, the ejection gun is fired, ejecting the seat. The seat separates from the ejection gun at 36 inches of travel, typically occurring 0.15 seconds after first seat movement. During the ejection gun stroke the aviator’s legs are actively restrained to protect against flailing when the seat is exposed to the air-stream. All seat / crew / aircraft interfaces, e.g. crew services, automatically disconnect as the seat ejects. The emergency oxygen supply is switched on. The under-seat rocket motor lights up as the seat separates from the ejection gun to continue the seat vertical acceleration. The drogue deployment unit initiator cable is dispensed as the seat ejects, becoming fully deployed and initiating the drogue deployment unit 0.03 seconds after ejection gun separation. The recovery parachute timer barostatic time release unit, (BTRU) is started as the seat nears the end of the ejection gun stroke. This timer runs for 0.70 seconds, minimum, extended with increasing sensed speed and altitude. At medium altitude, the deceleration under the drogue and automatically adjusts the recovery parachute deployment delay time, as required. After ejection gun separation the seat is free of the aircraft. Propulsion continues by means of the under-seat rocket motor. The rocket motor also rolls the seat and steers it towards the right (rear seat) or left (front seat) to aid post-ejection spatial separation of the two seat systems, thus eliminating post-ejection collision risk.

This rolling motion is also important for optimum zero/zero ejection performance. The drogue deployment unit is operated to forcibly deploy the stabilizing drogue into the air stream. The drogue is attached to the seat by a 4-point stabilizing bridle which holds the seat 'face into wind.'. The drogue both stabilizes the seat and aids aerodynamic retardation. At a time controlled by the BTRU the recovery parachute is deployed. Simultaneously, the drogue and bridle are disconnected from the seat. Finally, all crew restraint connections are released and the seat falls away. The occupant retains the survival kit, which is attached to the parachute harness. If fitted and armed, the distress radio beacon is automatically activated by seat-crew separation. While descending under the recovery parachute the crew may steer the parachute. The survival aids container lowers on its lanyard automatically, if so selected before or during flight. After landing the crew releases the parachute. The parachute is fitted with water pockets to prevent dragging after water entry if the crew does not, or cannot for any reason, release the parachute. Life raft inflation can be initiated either manually or automatically during descent or after water entry.

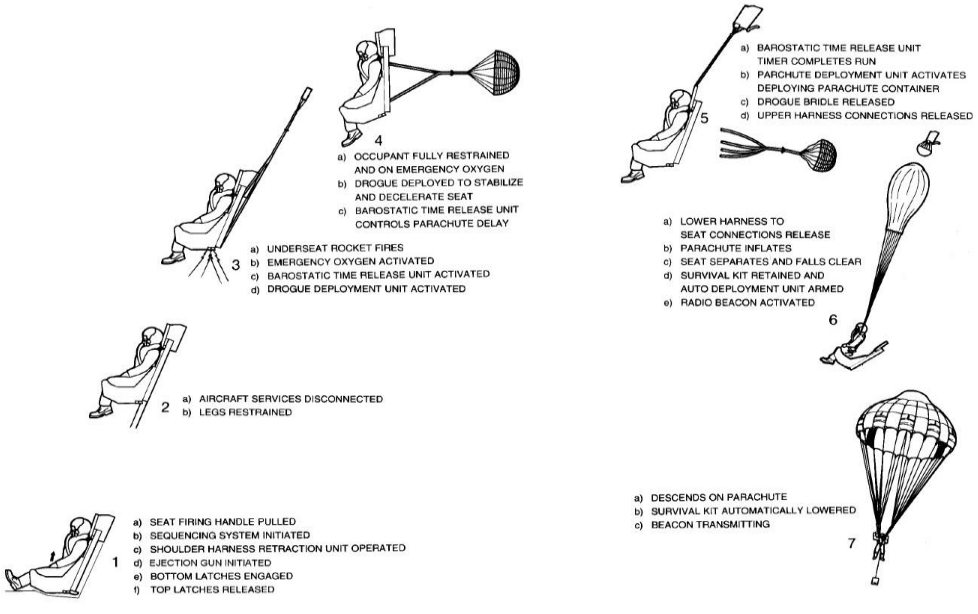

Figure 3. Ejection Sequence

The primary injury mechanism for light aircrew is the acceleration during the drogue stabilization phase that becomes progressively higher as airspeed increases (Figure 4). Smaller aircrew reduces the seat/occupant moment-of-inertia in all three axes. This allows the seat/occupant combination to yaw more prior to drogue bridle line stretch. The rapid yaw correction that occurs when the drogue chute becomes effective can result in injury since the body's ability to tolerate acceleration loads is weakest in the lateral axis. Lightweight aircrew will have a high risk of spinal injury during ejections above 300 KEAS.

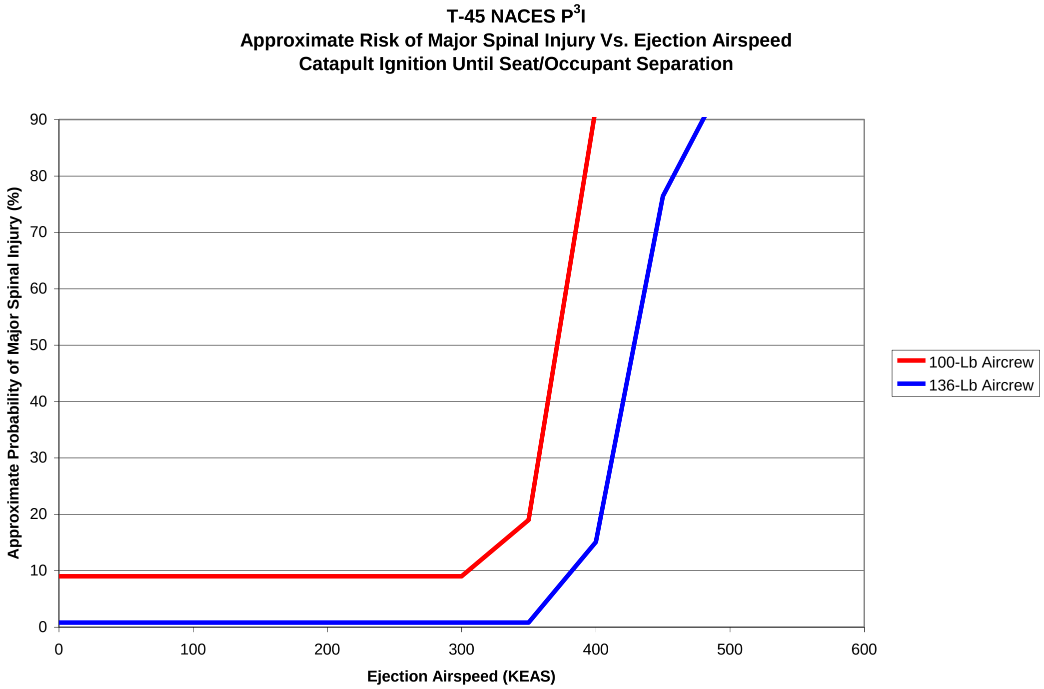

Figure 4. Approximate Risk of Major Spinal Injury versus Ejection Airspeed

The primary injury mechanism for heavier aircrew is the possibility of impacting the aircraft's vertical stabilizer(s) during the initial ejection phase (Figure 5), the seats inability to reach a sufficient height in order to deploy the parachute during a zero/zero ejection and the injuries sustained when impacting the ground during a parachute descent (Maximum suspended weight = aircrew nude weight + flight equipment + seat survival kit).

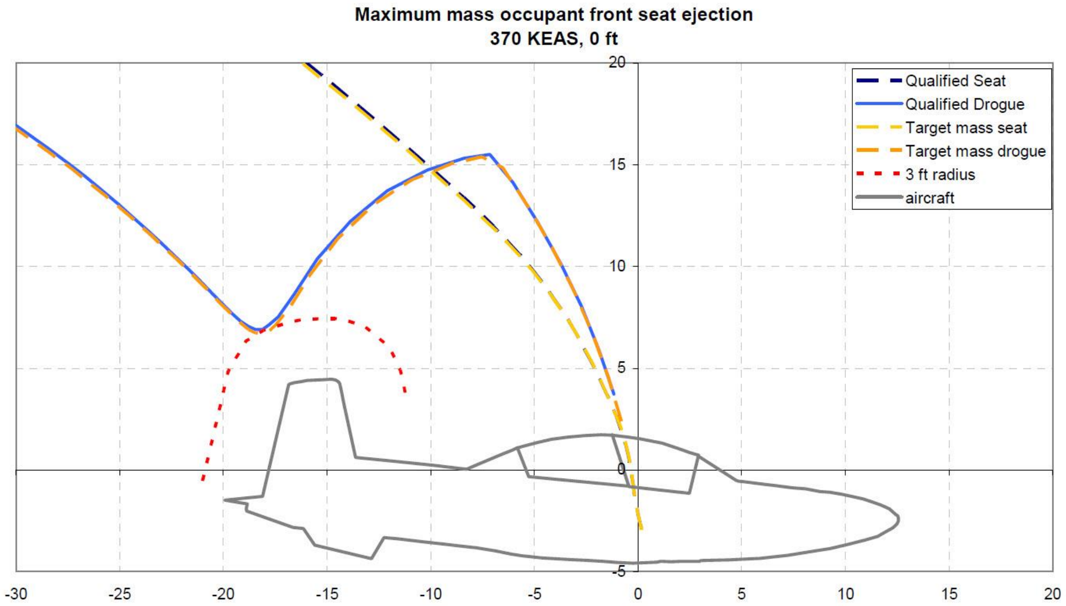

Figure 5. Vertical Tail Clearance for Maximum Mass Aircrew

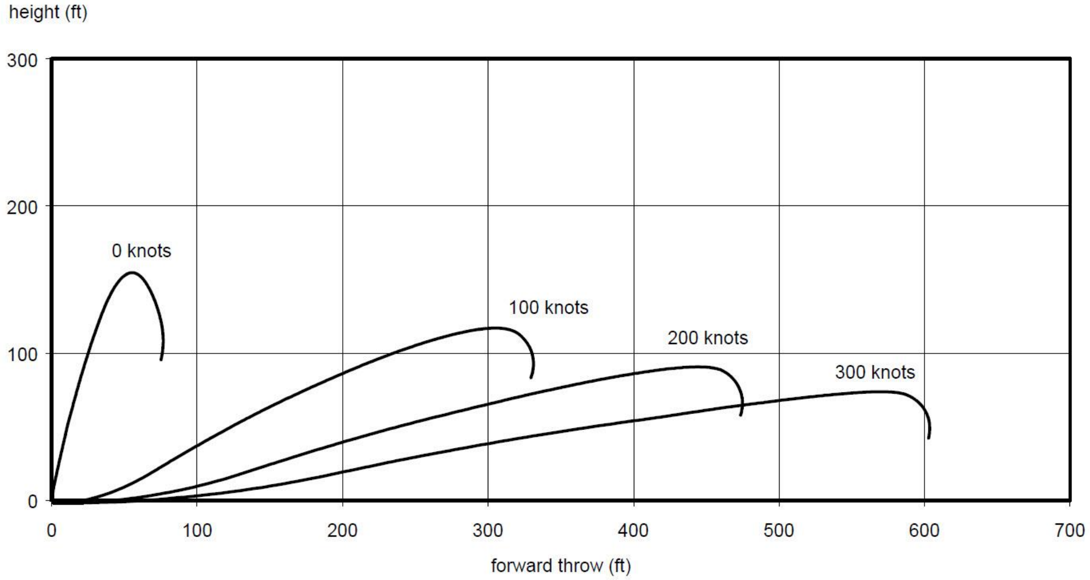

Figure 6. Vertical Height and Forward Throw of Maximum Mass Aircrew (achieve proper parachute inflation and descent rate)

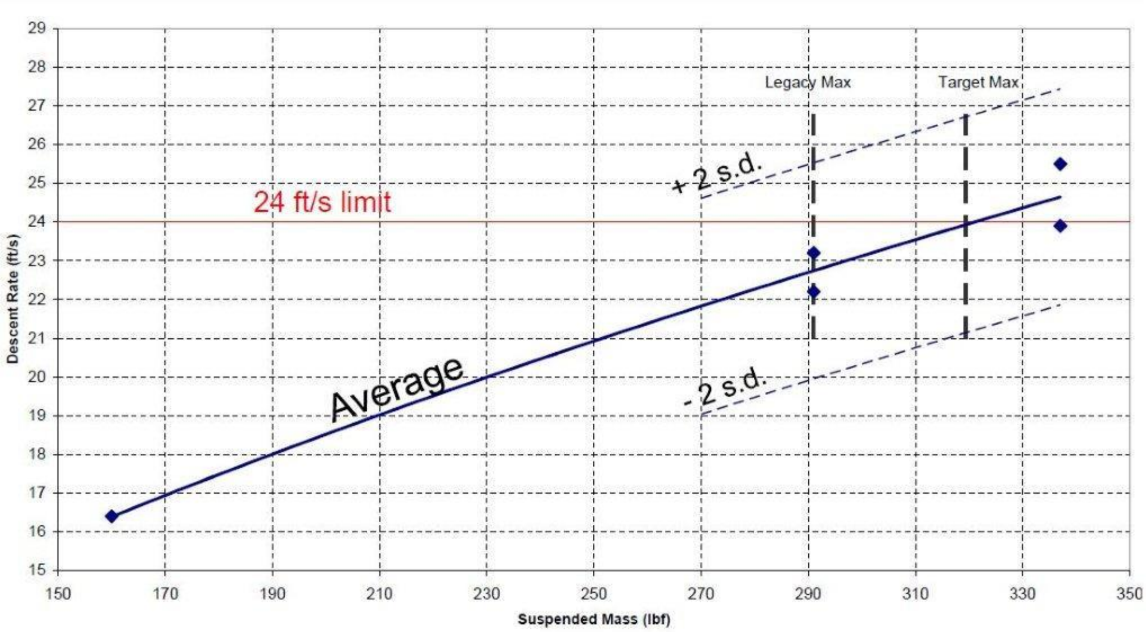

Figure 7. GQ-5000 Parachute Descent Rate

IV. DEFINING THE PROBLEM

A. CHANGING DEMOGRAPHICS

In 1973, the Secretary of the Navy announced the enrollment of women into Naval Aviation and the first female, LTJG Barbara Allen, earned her wings of gold. Over the years, the female aviation population increased. Finally, in 1993, the first female strike pilot climbed into the cockpit of the F-14 Tomcat. The USN currently has over 750 (500 pilots, 288 NFOs) qualified female aviators. The number of female pilots and NFOs has risen in recent years, albeit much more slowly than in the surface warfare community.

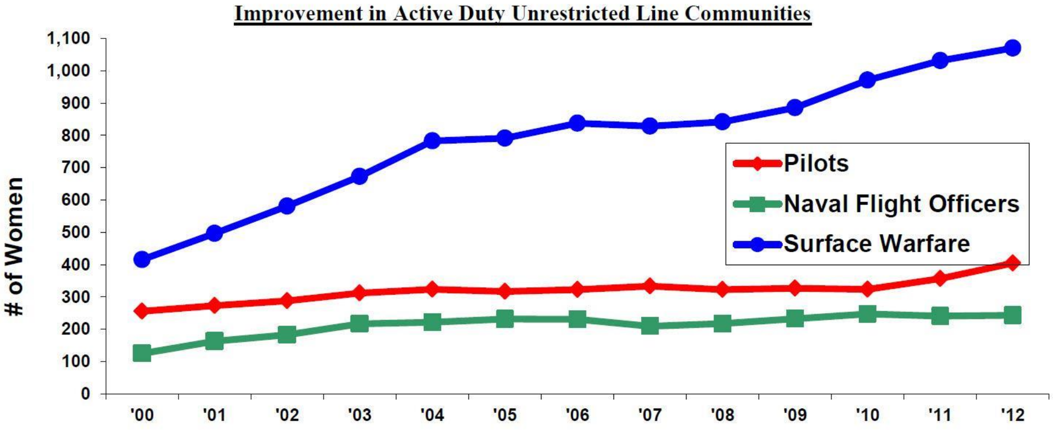

Figure 8. Women in Naval Aviation Since 2000

Not only has the number of female aviators in naval aviation increased in the past decades, so too have the overall dimensions of our male aviators. In a survey conducted by US Army NATICK Solder RD&E Center (Technical Report NATICK/TR-09/014) in 2009, anthropometric measurements of a sample from the current army aviation population (3,462 subjects) were compared to a nearly identical survey from 1988. It was determined that the 3rd percentile male weight measurement remained relatively the same, whereas the 98th percentile measurement increased by 26 lbs. The increase in the upper limit of the male range, in conjunction with the lower weight range due to the increase in the female population, has expanded the overall force demographics substantially (109 – 256 lbs.).

Even though no official USN aviation population survey has been conducted since 1964, it is reasonable to surmise that a similar expansion in the USN population has occurred just as it has in the USA population. Unfortunately, the pipeline selection process has not been revised accordingly, but is still constrained by the original certified weight ranges, meaning that individuals outside the range (less than 136 or greater than 213 pounds) cannot pursue the strike pipeline. Most notably, the limits for the majority of the USN's current strike aircraft still match the survey weight measurements from 1964.

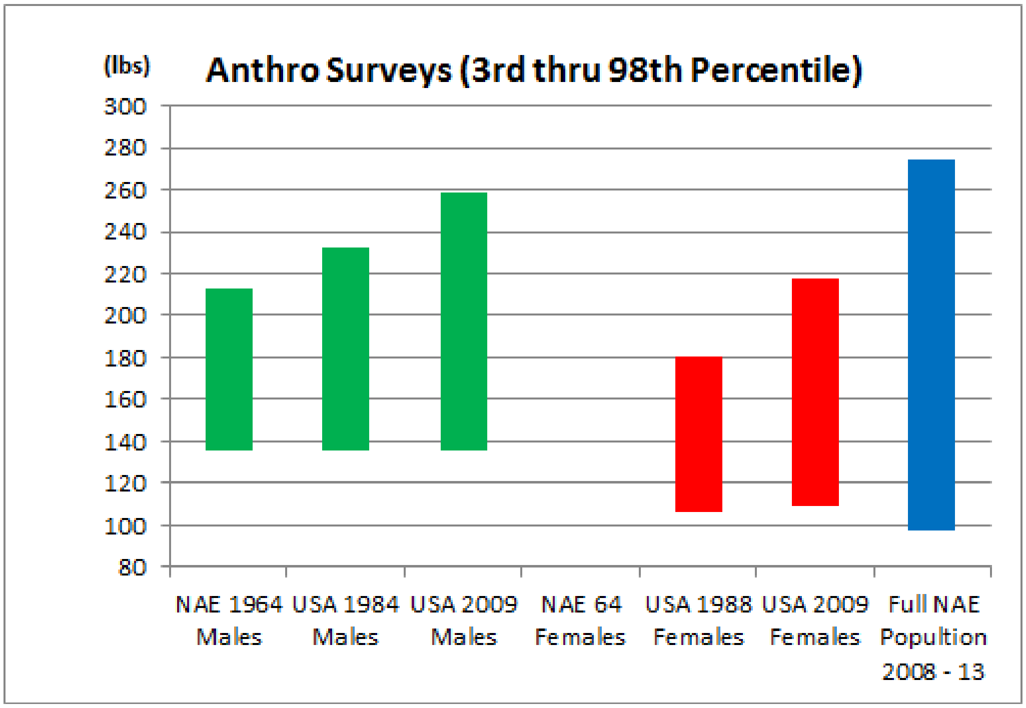

Figure 9. Various Military Anthropometric Surveys from 1964 to 2013, showing weight data of USN (1964) and overall USA males and females (various, 1984, 1988, 2009).

B. TECHNOLOGY

To address the expanding range of the body types and to satisfy the political desire to allow the greatest number of candidates, both male and female of all ethnicities, to be eligible, the US services re-defined the acceptable crew size/weight limitations for the Joint Primary Aircraft Training System (JPATS) in a way that is more representative of real crew. Seven ‘multi-variant’ body size cases have been defined that, as a group, encompass a much larger proportion of the population than the previous percentile method. Each of the 7 cases is given a descriptor, such as ‘Shortest reach with highest shoulders’ and ‘Longest limbs’.

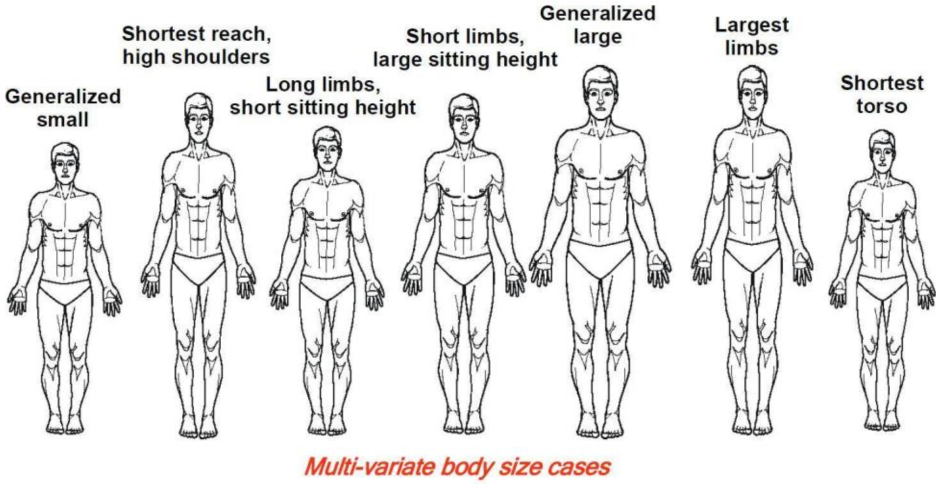

Figure 10. U.S. Military Anthropometric Cases

In addition to size, the required crew weight range was also substantially increased. For example, previously the required crew weight range was typically:

- 136 - 213 lbs. nude (boarding weight range was typically 174 - 259 lbs.).

For the JPATS program the range was originally set at:

- 116 - 245 lbs. nude (boarding weight range 137 - 271 lbs.)

This range was subsequently extended further for JPATS and also for the NASA T-38 crew escape upgrade program, to 103 - 245 lbs. nude (boarding weight range 123 - 271 lbs.).

Despite the fact that discrimination was not the original intent of the limitation, it is nonetheless a side effect of the current selection process that persists to this day. The lower limit of 136 lbs. effectively eliminates 38% of all females who enter naval aviation from ever selecting the strike pipeline. Further and equally important, 1.3 % (106 aviators) of males are also eliminated from the strike pipeline on the basis of their (relatively) underweight condition: six percent of male aviators are also disqualified for being over the upper limit of 213 lbs. That six percent is primarily made up of former athletes coming from the Naval Academy or other major universities across the country. Since 2008, that 6% translated to 749 males versus the 702 females who were excluded for being too light.

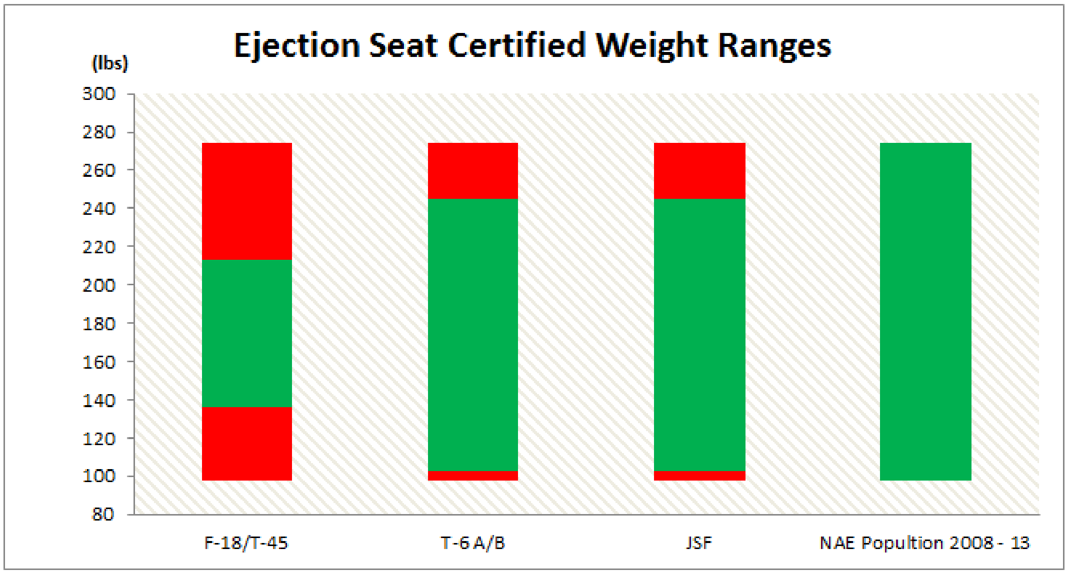

Figure 11. Ejection Seat Certified Weight Ranges, in green. Red shows the overall population and indicates the extent of restriction in aircraft assignment.

C. DIVERSITY

An area of concern for naval aviation and for USN senior leadership revolves around the point of diversity. It is possible to perceive the consequences of the weight limit restriction as gender and possibly ethnic discrimination; even though it was not the original intent when the specification/certification was applied. At the time the weight study was conducted the naval aviation population was predominantly Caucasian males.

The integration of women into the military has been met with a range of controversy and opinion, both historically and currently. Recent efforts, however, have attempted to highlight the range of benefits of including women at all levels and all branches of the military. Lau and Murnighan’s (1998) analysis of the literature showed that groups with low levels of diversity tend to form fault lines more readily compared to groups with comparatively high levels of diversity. Carnegie Mellon and the Massachusetts Institute of Technology (MIT) conducted research on collective intelligence and found that a group’s collective intelligence tends to increase as the percentage of women in the group increases. Their research also found that groups with more women tended to have a more even communication distribution pattern, suggesting that adding women can strengthen an organization (Haring, 2013, p. 27-28).

Other countries have been noted to view women in the military with less scrutiny than the USA. In a 2005 study of female combatants, Israeli commanders reported that women “exhibit superior skills” in 1) discipline and motivation, 2) maintaining alertness, 3) shooting, 4) managing tasks and organization, and 5) displaying knowledge and professionalism in weapons use. Similarly, the Canadians, who have been fully integrated since the 1980s, report there are no negative effects on operational performance or team cohesion due to the presence of women in combat units (Haring, 2013). Other work shows it is possible to form teams of more diverse composition that develop greater interdependence and engagement, which can in turn aid in the cultivation of ‘rapid trust’ amongst members; these could improve group processes and functioning, and by extension, overall effectiveness (Rousseau et al, 1998; Wageman, 1995).

A relative dearth of diversity amongst naval aviators selected in the strike pipeline can potentially affect team effectiveness. Cannon and Bowers (2011) assert that heterogeneity may be advantageous for high-difficulty tasks; since team composition is considered an important contributor to team effectiveness. An increase in women in the strike aviation pipeline will likely provide an instrumental contribution to both critical and creative thinking, collaboration, and decision making; skillsets that are currently underutilized and unrealized within the gender constraints imposed by the current ejection seat weight limits. In light of this perceived gender discrimination, the disqualification of a large percentage of women based on an arbitrary and outdated weight is incongruous, and this apparent incongruity needs to change to align better with the stated goals and values of the Navy.

D. HIGHER PERFORMANCE STANDARDS

In order to select the strike pipeline, students need to achieve and maintain a minimum Navy Standard Score (NSS),of 50 or greater for USN and 53 for USMC. The NSS is the equivalent of a GPA, but for flight training. It is comprised of classroom, simulator and flight event scores. NAE students who meet the minimum score may list strike as one of their pipeline selection choices. Students who do not reach the minimum score are not eligible and will not be considered for the strike pipeline. No other pipeline has this requirement. As long as a student completes primary flight training they are eligible for all other pipelines.

This NSS score requirement has never officially been validated. However, during interviews with a training specialist with over 20 years of experience it was revealed that it has been internally reviewed by several different CNATRA Aerospace Experimental Psychologists (AEPs) over the years. During every investigation, AEPs found that students who finished primary flight training with a score of 60 or higher completed the strike pipeline with zero percent attrition. However, when they looked at the average NSS of those students who failed to successfully complete the strike pipeline, they found that as score decreased from 60 towards 50, the attrition rate increased to well above acceptable levels.

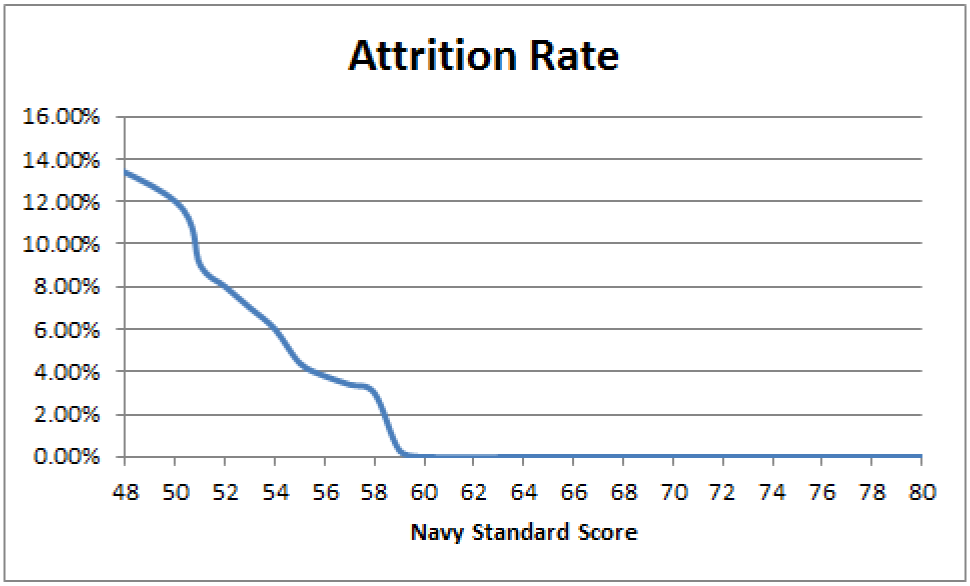

Figure 12. Strike Student Attrition Rates by Navy Standard Score

The USN strike pipeline is the longest flight training pipeline and therefore the most expensive. In order to maximize the taxpayers' dollar, the attrition rate is optimized to keep washout rates below 8%.

E. FOCUS

The purpose of this capstone project is to conduct an assessment of the NAEPSP system, focusing on the personnel selection issue. This effort is built upon inquiries to specific questions: a) Why are certified seat weight ranges out of alignment with the aviation population? and b) What needs to change in order to expand the operational ranges and make the system (personnel selection) congruent with its environment (the population)?

The goal is to find the root causes of the area of interest and recommend specific solutions to expand the operational weight range for ejection seats. To date, no one has raised the issue and presented the relevant information to the Chief of Naval Air Forces (Three-star, a.k.a. The Air Boss) in order to make a final operational decision. Although these areas of interest focus primarily on engineering, design, and testing, this document also focuses on identification of system features in need of correcting the relevant HSI domains (Manpower, Training, Occupational Health, Safety, Environment, Habitability, and Survivability) that can be applied to positively affect personnel selection.

This personnel selection process is intended to ensure that candidates selected for strike aviation training are best suited to the array of tasks they will face, and to address the flaws in the selection system that unnecessarily eliminate people on the basis of characteristics that truly do not pose as great of a safety risk as originally thought by the engineering community. The HSI approach for the NAEPSP is based upon the idea that organizational benefits are most likely to be achieved through focus on the people (Booher, 2003). I will also make strategic recommendations to improve and optimize the system to achieve operational efficiency without compromising the working environment for the NAE.

F. CONSTRAINTS

The applicability of HSI is subject to the sociotechnical system complexity, and external and internal NAE constraints will limit the options available. Only a few factors constrain this assessment. Mainly the collection of the historical documents associated with anthropometric surveys and mishap data. However, several constraints play a major role in whether or not this intervention will be successful in making a change in the selection process:

1. Inconsistent and outdated USN Anthropometric Policy.
2. Lack of anthropometric knowledge at commands with waiver authority.
3. Limited amount of test and live ejection data at weights outside the current certified limits

4. The defensive posture of the USN engineering community. (Department that tests and certifies ejection seats)

5. Properly addressing leaderships concerns for aircrew safety.

6. Aircrew misconceptions about certified ranges and the USN waiver policy.

7. The engineering communities understanding of fleet waiver authority.

8. Leadership’s understanding of seat design specifications and the probability and severity of injury associated with ejections.

9. Misconceptions of the probability of ejections per 100,000 flight hours.

10. Poor communication between Engineering and Engineering Safety communities with regard to Hazard Risk Assessments and Risk Acceptability Authority.

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V. BREAKDOWN OF THE NAEPSP WORK SYSTEM

The NAEPSP is a “work system” (Hendrick & Kleiner, 2002, pp. 1-2) and consists of the following commands:

1. Commander Naval Air Forces (CNAF)
2. Commandant of the Marine Corps (CMC)
3. Bureau of Naval Personnel (BUPERS)
4. Bureau of Medicine and Surgery (BUMED)
5. Chief of Naval Air Training (CNATRA)
6. Naval Air Systems Command (NAVAIRSYSCOM)
7. Naval Aviation Schools Command (NAVAVSCOLSCOM)
8. Squadron Commanding Officers

Commander Naval Air Forces (CNAF) serves as the anthropometric program policy coordinator and NAVAVSCOLSCOM is the program manager. Coordination with Commandant of the Marine Corps (CMC), Bureau of Naval Personnel (BUPERS), Bureau of Medicine and Surgery (BUMED), Chief of Naval Air Training (CNATRA) and Naval Air Systems Command (NAVAIRSYSCOM) is essential to the success, effectiveness, and applicability of the program. CMC supports program implementation within the Marine Corps to ensure anthropometric compatibility of Marine Corps Aeronautically Designated Personnel upon initial assignment after completion of instruction at the Naval Air Training Command and when considering individuals for transition/conversion training thereafter.

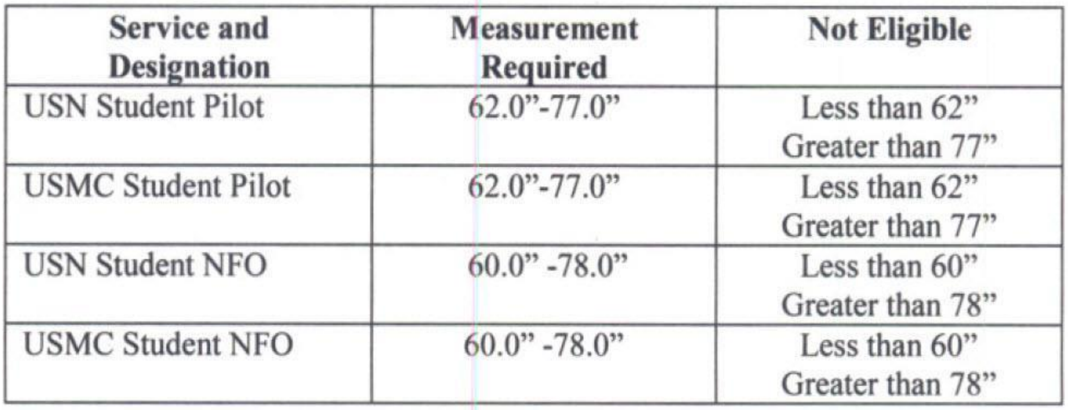
NAVAIRSYSCOM serves as an advisor to CNO and CNAF on anthropometric issues. They manage the overall Aircrew Anthropometric Engineering Program. This includes determining the scope of naval aircraft requiring anthropometric measurements, the resources required to measure aircraft crew stations, analyzing and developing anthropometric measuring procedures, identifying anthropometric restriction codes and crewmember weight restrictions, and developing and managing an anthropometric measurement certification program. NAVAIR is also responsible for keeping anthropometric restriction codes current by updating dimensional data as modifications to existing aircraft and/or aircrew clothing/equipment occur, or as new aircraft are introduced.

CNATRA ensures anthropometrically compatible pipeline assignments of student Naval Aviators/Naval Flight Officers to current inventory of training and pipeline aircraft. This command ensures anthropometric coding and copies of the student's Anthropometric Data Measurement Record are entered as part of the student's Aviation Training Jacket and Naval Air Training and Operating Procedures Standardization (NATOPS) jacket, respectively. The NATRACOM supports the entire accession decision process, through the use of technical guidance and provide assessment of anthropometric compatibility for prospective Naval Aviators/Naval Flight Officers. CNATRA refers to BUPERS(PERS-43) or CMC(ASM) respectively, for disposition prior to commencing any further aviation training, those Navy or Marine Corps students not capable of being assigned to two or more pipelines.

CMC(ASM)/BUPERS(PERS-43) ensure that prospective aviators meet aviation anthropometric entrance standards, coordinate with CNATRA to ensure compatible initial assignments of newly aeronautically designated personnel, and ensure Aeronautically Designated Personnel receive assignments to anthropometrically compatible aircraft.

BUMED trains/indoctrinates Aeromedical Safety Officers, Flight Surgeons and Enlisted Aeromedical technicians and contractors in the processes, procedures, and techniques for accurate anthropometric evaluations. They enforce policy set by NAVAVSCOLSCOM to ensure that anthropometric measurements taken at Navy Military Treatment Facilities (MTF) are accurately recorded for all prospective Naval Aviators/Naval Flight Officers seeking aeronautical designation. This information is recorded in the Naval Aviation Anthropometric Compatibility Assessment (NAACA) database as part of the prospective Naval Aviators/Naval Flight Officers medical examination and forwarded to NAVAVSCOLSCOM for review. The MTF is responsible for anthropometric measuring equipment. It should be available, standardized, properly maintained, and utilized. Accession sources refer all NAE candidates to qualified MTFs for full anthropometric measurement whose stature categorizes them as "measurement required".

Table 2. Accession Candidates' Stature "Measurement Required



Service and Designation	Measurement Required	Not Eligible
USN Student Pilot	62.0"-77.0"	Less than 62" Greater than 77"
USMC Student Pilot	62.0"-77.0"	Less than 62" Greater than 77"
USN Student NFO	60.0" -78.0"	Less than 60" Greater than 78"
USMC Student NFO	60.0" -78.0"	Less than 60" Greater than 78"

Individuals whose physical characteristics are anthropometrically compatible with requirements are eligible and can be offered contracts for selection to attend training as a student Naval Aviator or student Naval Flight Officer.

Student aviators must meet published anthropometric and weight requirements (103 - 245 lbs.) prior to commencing Aviation Preflight Indoctrination. Official anthropometric measurements are taken no more than two different times while assigned to NAVAVSCOLSCOM. Students may be afforded safe weight gain/loss training time to meet primary training aircraft (T-6) weight requirements of (103 - 245 lbs. Any student who remains outside of weight limits and/or body fat composition requirements per USN/USMC physical fitness standards are not permitted to transfer for follow-on flight duty and may be recommended for attrition. Foreign national students are also held to U.S. Navy anthropometric requirements and body fat composition requirements.

Unless a weight waiver was previously granted, Student Naval Aviators and/or Student Naval Flight Officers must meet weight restrictions on the day of selection to be eligible to select a specific pipeline. The Squadron Commanding Officer ensures the following are annotated in the CO's comments section of the Summary Selection Record:

- Student weight
- Aircraft restrictions based on student's current weight
- Any waivers for anthropometric/weight incompatibilities

At this point, any student who does not meet the weight ranges for the next aircraft in the training pipeline is restricted from pursuing that pipeline.

Upon reaching the fleet, Commanding Officers are responsible for ensuring that aviators suspected of an anthropometric incompatibility are referred to the squadron flight surgeon or local Aeromedical Safety Officer for anthropometric evaluation. However, the CO does so at the risk of losing an important asset and potentially ending that individual's aviation career as a strike pilot.

VI. STEP TWO: REVIEW OF EXISTING JOBS

The second step of the assessment is to review existing USN doctrine and policies to develop an understanding of the system’s selection process.

A. NAEPSP JOB DESCRIPTIONS

The job descriptions for each member of the NAEPSP system can be found below in Table 3.

Table 3. NAEPSP Job Descriptions

Position	Job Description	References
Naval Aviator	Found to be of no significance with regards to this assessment	(OPNAVINST 3710.7U)
Naval Flight Officer	Found to be of no significance with regards to this assessment	(OPNAVINST 3710.7U)
Aeromedical Professional	Found to be of no significance with regards to this assessment	(OPNAVINST 3710.7U)

B. NAEPSP TASKS

Routine tasks performed by naval aviators, naval flight officers, and aeromedical professionals were identified and found to be of no significance with regards to this assessment. The tasks performed by aircrew at 103 lbs. are no different than that of one at 136 lbs. As long as a minimum weight (103 lbs.) individual is anthropometrically compatible in all other areas (i.e. sitting height, thumb tip reach, sitting eye height, butt to knee length), then tasks remain the same. However, if individuals are not compatible in those functional areas, we do not propose allowing them to select the strike pipeline in order to meet a diversity shortfall.

C. NAEPSP KSAS

Knowledge, skills, and abilities for naval aviators, naval flight officers, and aeromedical professionals were identified and found to be of no significance with regards to this assessment. The KSAs for a 103 lbs. individual are no different than those for another at 136 lbs. Similarly, as long as the 103 lbs. individual is anthropometrically compatible in all other areas (i.e. sitting height, thumb tip reach, sitting eye height, buttock to knee length), the KSAs remain the same.

VII. STEP THREE: REVIEW HUMAN-SYSTEM INTERFACES

The third step of the assessment was to examine the system components that relate to personnel selection. The work system breakdown and the review of the anthropometric process, engineering documentation, operational policy and training command pipeline selection process were vital in order to understand the strengths and shortfalls of the selection process. This knowledge enabled insight to the three major sociotechnical system elements that interact and affect optimal work system functioning: (1) the technological subsystem, (2) personnel subsystem, and (3) relevant external environment (Hendrick & Kleiner, 2002, p. 45).

The human system interfaces that are most relevant to NAEPSP include the manpower and personnel domains, as these are the areas most affected by the proposed assessment. Training would be another consideration, to help improve performance of squadron teams that will be changed as a result of this intervention. Salas et al.'s review of teamwork research shows that teams who train together perform better (2008).

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VIII. STEP FOUR: CONGRUENCE

The fourth step in the assessment is to determine if the design modification is congruent with the selected personnel, the job, and tasks the personnel are required to do, and the human-system interfaces the personnel interact with. Human factors engineering and operational policy are the areas that have been identified within the constraints of the project that require a congruence validation. The order in which these congruence validations are conducted matters.

A thorough seat design and performance analysis to include USN mishap/ejection data is a critical first step that will provide an accurate picture of the ejection seat capabilities. A review of all efforts to improve seat performance should also be conducted. If performance improvements are found, then they should be converted into cost estimations and retrofit time impacts to training and operations. Once those are complete, then training and operational commanders need to determine if the money and time are worth spending. Two concurrent hazard risk assessments should be conducted: the first to determine the risk associated with low end weight (below 136 lbs.), and the second for high end weight (above 213 lbs.). Finally, all governing policy for anthropometrics and operational limitations regarding the physical attributes of aircrew must be reviewed thoroughly to identify shortfalls and inconsistencies.

A. HUMAN FACTORS ENGINEERING ANALYSIS

An in-depth review of human factors engineering documents found that the original design specification for the Navy Aircrew Common Ejection Seat (NACES) was based on a 1964 anthropometric survey, which was the best anthropometric data available at the time with which to aid in development and testing of ejection seats. The engineering test and certification process was followed properly with regard to the development, test, and certification of the NACES ejection seat. However, there were inconsistencies found in the rate of injury compared to the risk standard that is used by the USN engineering community (Figure 8) as compared to the risk predictions of the USAF engineering community (Figure 9).

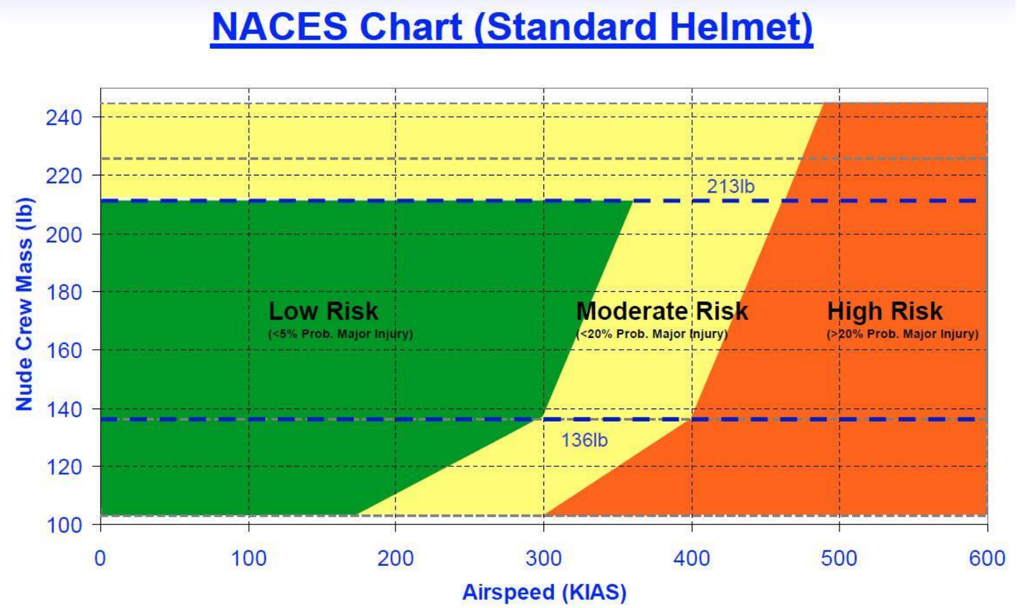

Figure 13. USN NACES Injury Risk Chart

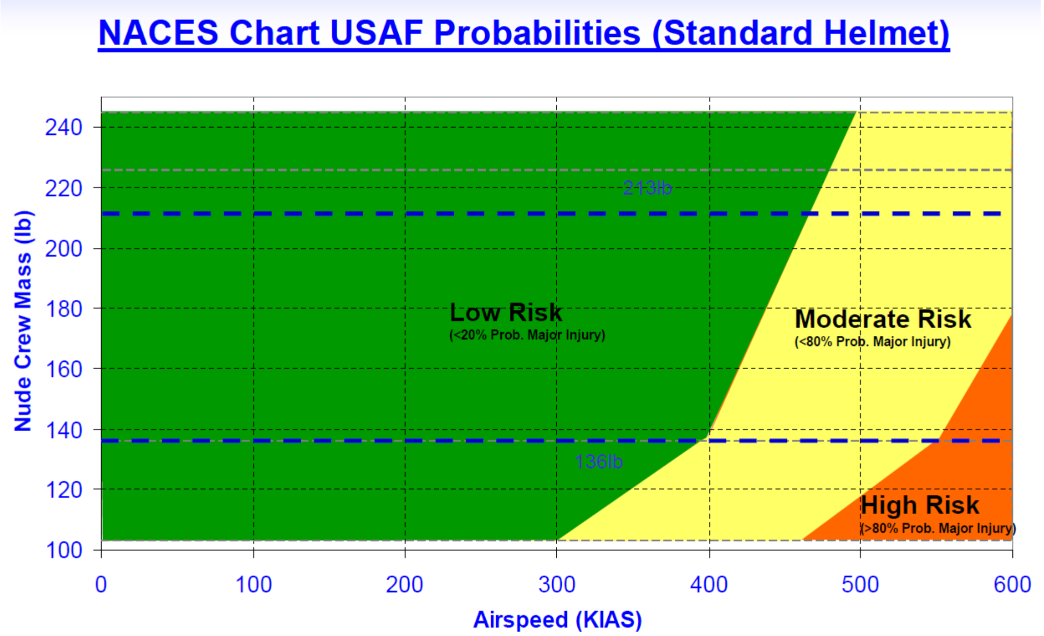

Figure 14. USAF NACES Injury Risk Chart

Upon review of the available ejection seat risk predictions and ejection event injury data for similar aircraft, it became clear that the USN standard for acceptable injury rates is more conservative compared to actual injuries sustained by mishap aircrew (Figure 10).

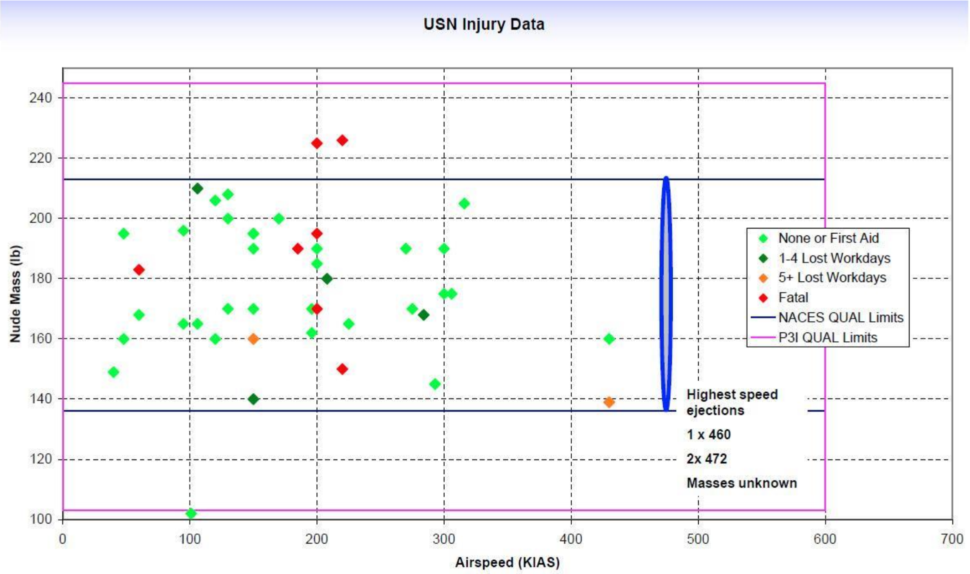

Figure 15. USN Injury Data, airspeed vs. nude mass.

Plotted USN mishap data more closely resembles USAF acceptable injury envelopes, which is to say that the available evidence does not support the USN’s stricter standard. This insight should help address leadership concern with regard to aircrew safety. Of particular note, the data includes a T-45 event in which a female who weighed very close to 100 lbs. ejected from the aircraft. The only injuries she sustained were scratches and abrasions from landing in a mesquite tree.

B. SYSTEMS IMPROVEMENT ANALYSIS

In the engineering community's defense, it is evident that NAVAIR realized fairly early in the seat development pathway that the seat weight range limit was far too narrow to address the expected future USN demographic; a two phase pre-planned product improvement (P3I) engineering proposal for larger parachutes to reduce parachute descent rates and delayed drogue shoots to help stabilize seats and reduce possible neck injuries (P3I Phase II) was created. A lumbar adjustment was also developed (P3I Phase I) and eventually funded and implemented in order to address proper knee position and rudder reach to prevent leg injuries during the initial ejection phase. Unfortunately, the most expensive improvements (P3I Phase II) for the seat that addressed the expansion of the weight range never received proper funding. In ensuing years, the issue was raised by the fleet at various Aircrew System Enabler requirements group meetings, but failed to receive an endorsement for funding due to the strong support and confidence in the current ejection seats capabilities, the low probability of an actual ejection taking place (Average = 2:100,000 flight hours) and the cost associated with the proposed engineering solution (nearly a $50M project). As a result, the fleet demanded that NAVAIR conduct hazard risk assessments for weights above and below the certified range for the NACES.

C. HAZARD RISK ASSESSMENT (HRA) ANALYSIS

Several HRAs were conducted in 2012 and 2013, and found that all necessary safety concerns were properly addressed for both lower weight (neck injuries due to reduced levels of muscle strength associated with smaller individuals) and higher weight (acceptable aircraft clearance during initial ejection phase and parachute descent rates) ranges. In both cases, NAVAIR systems safety experts rated the risk of ejection injuries as medium. Per DODI 5000.02, low to medium risks can be acknowledged by the appropriate fleet representative and accepted at the program manager level. The lower and upper weight ranges were acknowledged and accepted accordingly.

This risk acceptance effectively expanded the allowable ejection seat weight range but did not change the certified weight range, which is from 103 - 245 lbs. Unfortunately, this information has never been directly shared with the fleet, nor was it published. During the same time period, a similar HRA was performed to assess risk associated with lower weight aviators while wearing the

Joint Helmet Mounted Cueing System (JHMCS). Even though it is not a required piece of equipment to operate the T-45 or the F/A-18, it is widely used to support the strike mission as a lethal weapons delivery system. The certified weight range for that helmet matches the current certified seat range solely because an individual cannot utilize the helmet without flying in an aircraft that has the NACES.

D. ANTHROPOMETRIC AND OPERATIONAL POLICY ANALYSIS

Upon review of several USN Anthropometric and Operational policies, I have found numerous inconsistencies and fleet misinterpretation of published weight ranges, waiver policies, basic definition of terms, varying weight standards for applicants compared to students and winged aviators, lack of weight monitoring and enforcement programs. The most alarming was the published certified weight ranges in the OPNAVINST 3710.7 series that referenced the appropriate NAVAIR instruction, which is the only official list of certified ranges for all military aircraft, but included a table that contradicts the NAVAIR reference.

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IX. STEP FIVE: RECOMMENDATIONS

RECOMMENDATION 1: Conduct a review of anthropometric data and pipeline selection data.

- Compile all NAACA data, current measurement data and pipeline selection data
- Determine how many of the 38% of females who did not qualify for the strike pipeline because of weight did qualify based on performance.
- Determine how many of the 6% of males who did not qualify for the strike pipeline because of weight did qualify based on performance.

RECOMMENDATION 2: Conduct an anthropometric policy working group meeting.

- Gather all of the stakeholders listed in USN anthropometric compatibility document (OPNAVINST 3710.37A):

  OPNAV N98

  PERS-43

  CMC

  NAVAIRSYSCOM – 4.6 division

  CNAF

  CNATRA

  NASC

  BUMED

  All T/M/S Program Managers with ejection seats

- Modify and align all governing documents that concern ejection seat weight limitations. Policy needs to be made very clear to the fleet in order to prevent further confusion on weight limits and proper weight limit waiver guidance. Those documents include:

  OPNAVINST 3710.37A

OPNAVINST 3710.7U

NAVAIRINST 3710.9D

CNATRAINST 3710.37C

NAVAVSCOLSCOM INST 3710.37B

All T/M/S NATOPS Manuals – flight manuals

RECOMMENDATION 3: Conduct an anthropometric survey of the current naval aviation population. Data from this assessment will establish a range that better reflects the current naval aviation population.

- Have all naval aviation population measured during next annual flight physical.
- Gather Naval Aviation Anthropometric Compatibility Assessment (NAACA) Data from Naval Aviation Schools Command.

RECOMMENDATION 4: Conduct a pipeline selection survey to better characterize the existing selection system.

- Request all pipeline selection data from Chief of Naval Air Training.
- Break down the racial and gender demographic
- Determine how many flight students qualified for the strike pipeline but did not receive a strike pipeline assignment ??.
- Determine how many students were selected for strike but did not list strike as their number one choice.
- Determine how many students who qualified for the strike pipeline actually listed strike as their number one choice.

RECOMMENDATION 5: Survey the fleet.

- Survey female and male strike pilots/NFOs to determine satisfaction levels of pursuing that particular pipeline.
- Survey Commanding Officers to determine satisfaction levels with their junior officers.
- Determine if any gender-related anthropometric issues exist in aviation life support systems in modern carrier aviation squadrons(i.e. boots, gloves, helmets, flight suits, armor)

RECOMMENDATION 6: Request body composition information data

- Request body composition assessment information from the USN and USMC physical fitness assessment program office.
- Last five years' of weight data from all ejection seat squadrons
- Determine how much of the fleet is actually outside the 136 - 213 lbs. certified range to establish the impact on readiness and production if the weight limit as it exists were enforced.

RECOMMENDATION 7: Collectively gather all the information referenced in this paper. Develop a summary document consisting of all the material references and argument made here, including the information gathered from recommendations 1 through 6.

RECOMMENDATION 8: Investigate and the certified range of the Joint Helmet Mounting Cueing System. Based on similar findings in this intervention the same arguments can be made for the certified range for JHMCSs.

RECOMMENDATION 9: Request CNAF Safety to task NAVAIR systems safety with completing HRAs for all other platforms with seats (ejection and crashworthy) that have certified weight ranges.

RECOMMENDATION 10: Present this information and the results of the NAVAIR systems safety HRAs to the Chief of Naval Forces (CNAF). Request that CNAF establish an operational weight range (103 - 245 lbs.) for all platforms and seats, to include JHMCS, and publish an operational limit in the 3710.7 series.

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X. EXPECTED OUTCOMES

If the body of evidence gathered here is presented to Commander Naval Air Forces in a clear and unbiased manor, I am confident that an operational limit for the strike pipeline of 103 to 245 lbs. will be established. If so, this will allow for all individuals entering naval aviation the same opportunity to select any and all pipelines.

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XI. CONCLUSIONS

This assessment discussed reduced diversity as a possible unintended side effect of outdated personnel selection process applied to the population of strike aviators in the US Navy. The outdated weight-specific selection criteria eliminated a significant percentage of the female population from eligibility for duty as aviators on a carrier-based strike team. This investigation determined that this phenomenon is at odds with the broader goals of a 21st-century Navy, and arguably limits its effectiveness. Through review and analysis of available literature, documentation, and process/procedures related to the sociotechnical work system, support and recommended strategy for revision of the criteria was developed to bring the system into congruence. If these findings and recommendations are successfully translated and implemented, it will produce a change in operational policy that will assist in improving the selection process within NAEPSP system and will increase the quality and quantity of qualified personnel eligible for the strike pipeline. Opening the naval aviation strike community by making it accessible to greater numbers of qualified candidates will also increase the diversity of the Navy overall, and presumably enhance its ability to select, build, and develop carrier strike squadrons that are more capable, effective, and suitable for its changing missions.

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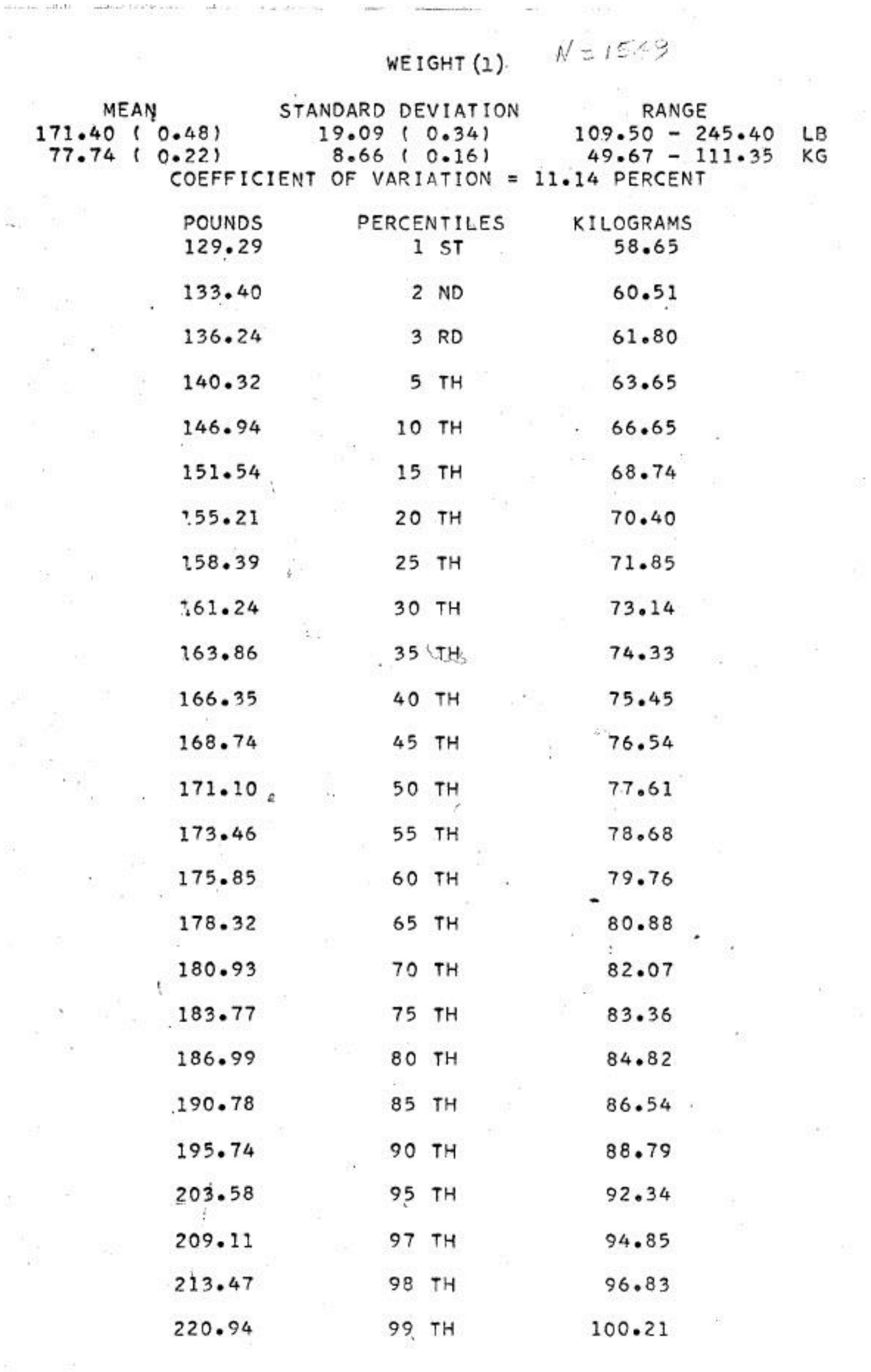
APPENDICES

A. U.S. NAVAL AIR ENGINEERING CENTER (NAEC-ACEL-533, 1965)



WEIGHT (1) N = 1549

MEAN	STANDARD DEVIATION	RANGE	
171.40 (0.48)	19.09 (0.34)	109.50 - 245.40	LB
77.74 (0.22)	8.66 (0.16)	49.67 - 111.35	KG

COEFFICIENT OF VARIATION = 11.14 PERCENT

POUNDS	PERCENTILES	KILOGRAMS
129.29	1 ST	58.65
133.40	2 ND	60.51
136.24	3 RD	61.80
140.32	5 TH	63.65
146.94	10 TH	66.65
151.54	15 TH	68.74
155.21	20 TH	70.40
158.39	25 TH	71.85
161.24	30 TH	73.14
163.86	35 TH	74.33
166.35	40 TH	75.45
168.74	45 TH	76.54
171.10	50 TH	77.61
173.46	55 TH	78.68
175.85	60 TH	79.76
178.32	65 TH	80.88
180.93	70 TH	82.07
183.77	75 TH	83.36
186.99	80 TH	84.82
190.78	85 TH	86.54
195.74	90 TH	88.79
203.58	95 TH	92.34
209.11	97 TH	94.85
213.47	98 TH	96.83
220.94	99 TH	100.21

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