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ANALYSIS OF FLIGHT CLOTHING EFFECTS ON AIRCREW STATION GEOMETRY--ETC(U)

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Technical Memorandum

ANALYSIS OF FLIGHT CLOTHING EFFECTS ON AIRCREW STATION GEOMETRY

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19 October 1977

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The purpose of this evaluation was to quantify the effect of flight clothing and equipment on pilot accommodation in ejection seat tactical aircraft. The data derived from this evaluation are applicable to any similarly dressed and equipped aircrewman in tactical or training aircraft. Subjects selected for the study represented the typical range of aircrewmen body sizes within the Naval aviation population. Comparative anthropometric measurements were made between three conditions: (a) unclad, (b) wearing summer flight gear, and (c) wearing winter flight gear. Volumetric quantifications of increased bulk, as well as angular quantifications of decreased mobility, were accomplished. The data →

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describe significant limitations in cockpit reach capability and torso movement as a function of summer and winter flight clothing and equipment. The most restrictive item worn was the CWU-33P anti-exposure garment. An all-encompassing reengineering of the total system of flight clothing and equipment should be undertaken to lighten the weight and reduce the mobility-restricting bulk of such items. When designing crew station geometry and locations of controls and displays, designers should incorporate the maximum available data describing reduction in anthropometric mobility and increase in anthropometric volume, resulting from flight clothing and equipment worn on the body.

PREFACE

NAVAIR Project Order N62269/76/PO/0067 tasked NAVAIRTESTCEN with the quantification of flight clothing equipment effects on pilot crew station accommodation. This analysis involves the measurements of increased bulk and decreased mobility attributable to those items of clothing and equipment worn by aviators. Comparative data were derived from summer and winter flight clothing. The data are applicable to computer based cockpit geometry models used to design and evaluate cockpit geometry. This paper was prepared for presentation at the Military Testing Association Meeting in San Antonio, Texas, on 17-21 October 1977.

APPROVED FOR RELEASE

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INTRODUCTION

BACKGROUND

1. Typically aircrew station geometry requirements have been based on nude male anthropometric data taken from measurements on a standard anthropometric chair, a flat seat with a 90 deg perpendicular back surface. Since aircrew persons do not fly nude, nor do they sit on a flat surface with a 90 deg perpendicular back, nor are they all male anymore, it is necessary to quantify the effect of those items worn in the aircrew station environment. The necessity to quantify the effects of personal flight clothing and equipment is particularly important in presently developing tactical aircraft since the anticipated higher g operational environments are more restrictive to anthropometric mobility than earlier models of tactical aircraft. Additionally, the primary flight instrument status of Heads-Up Displays and similar electro-optical devices may limit the design eye reference of the pilot's eye position to a greater degree than other similar aircraft models.

2. Many of the prior research efforts in the area of quantifyng the effects of flight clothing relative to anthropometric accommodation have generally been item specific; i.e., the effects of wearing a pressure suit or a helmet, etc. There has been little research, if any, on the anthropometric effects of an entire complement of flight clothing and equipment.

3. Military Standard 1472B, the Human Engineering Design Criteria for Military Systems, Equipment, and Facilities, specifies that suitable allowances must be made for the design-critical dimensions imposed by protective clothing or equipment. Providing "suitable allowances" for an unknown quantity can be difficult at best, if not impossible. The failure to use data concerning the effect of flight clothing and equipment on anthropometry in the design of aircrew stations has historically been costly in terms of aircrew safety, efficiency, mobility, and comfort.

4. The specific goal of this analysis was to provide data to quantify and describe the effect of increased bulk and decreased mobility resulting from the wearing of summer and winter flight clothing and equipment in a typical ejection seat environment.

5. The data derived from this evaluation can be used in the following applications: (1) as correction constants to be applied to current computer based simulation models which have as their goal the early (blueprint) detection of inconsistencies between planned cockpit geometry and anthropometric characteristics of the intended user population, (2) as a design aid to engineers tasked with providing the anthropometric accommodation in aircrew stations specified by military standards, and (3) as a reference aid to those organizations tasked with developing aircrew clothing and equipment possessing the minimum bulk, weight, and mobility restriction commensurate with the necessary protective characteristics.

DESCRIPTION OF TEST FACILITY

6. Comparative anthropometric measurements of subjects in unclad, summer flight gear and winter flight gear configurations were made using a Navy 64A105H1-1 Integrated Measuring Anthropometric Device and a standard medical weight scale.

7. The cockpit specific anthropometric range of motion measurements was made in a Douglas ESCAPAC IF-3 ejection seat and restraint system modified with adjustable point-of-reference protractors positioned at range-of-motion joints (i.e., neck, clavicle, elbow, wrist, lumbar, hip, and ankle areas). The ejection seat selected was typical of lap belt and inertia-reel torso restraint systems found in ejection-seat equipped tactical aircraft.

8. This evaluation investigated the flight clothing and equipment effects on volume and mobility for a sample of aircrewman representative of the entire spectrum of Naval aviator body sizes. The 1964 Anthropometry of Navy Aviators Survey, which listed body size data for 96 measurements of 1,549 aviators, was used for anthropometric percentile-rank criterion of the measurements evaluated except for buttock-leg dimensions. A 1976 data sample compiled on anthropometric variables for 969 aviators was used to define the buttock-leg percentile-rank criterion for this evaluation.

9. The anthropometric dimensions, joints, and respective range-of-motion measurements included:

a. Dimensions.

(1) Weight.

(2) Stature.

(3) Standing waist height.

(4) Functional arm reach.

(5) Shoulder-elbow length.

(6) Forearm-hand length.

(7) Hand length.

(8) Standing hip breadth.

(9) Sitting height.

(10) Bideltoid diameter.

(11) Buttock-knee length.

(12) Sitting hip breadth.

(13) Popliteal height.

(14) Buttock-leg length.

(15) Foot length.

b. Joints and respective ranges of motion.

(1) Neck - head/look angle.

(a) Elevation.

(b) Declination.

(c) Azimuth right.

(d) Azimuth left.

(2) Clavicle/humeral - extended arm movement.

(a) Elevation.

(b) Declination.

(c) Azimuth right.

(d) Azimuth left.

(3) Elbow - lower arm movement (measured with upper arm extended horizontally and vertically from clavicle joint).

(a) Elevation.

(b) Declination.

(c) Azimuth.

(4) Wrist - extended hand movement.

(a) Elevation.

(b) Declination.

(c) Azimuth right.

(d) Azimuth left.

(5) Lumbar - torso movement, sitting.

(a) Declination.

(b) Torsion right.

(c) Torsion left.

(6) Hip - upper leg movement, sitting.

(a) Elevation.

(b) Azimuth right.

(c) Azimuth left.

(7) Knee - tibial movement.

(a) Elevation.

(b) Declination.

(8) Ankle - foot movement.

(a) Elevation.

(b) Declination.

(c) Azimuth right.

(d) Azimuth left.

10. The parameters for both series of anthropometric dimensions and angular range-of-motion joints were selected from a crew station assessment of reach computer based simulation model. Over 2,300 measurements were taken for this evaluation.

11. The scope of the flight clothing and equipment evaluated included those current inventory items typically worn by those Navy crewmen who fly tactical and training aircraft equipped with ejection seats.

12. With the exception of those data directly affected by the torso harness and ejection seat restraint systems, other data can be applicable to nonejection seat aircraft.

METHOD OF TESTS

13. The subject crewmen were measured in three separate configurations: (1) unclad, (2) dressed and equipped for summer flight, and (3) dressed and equipped for winter flight. Each dimensional and angular measurement was made four times and averaged to reduce measurement error variability. The quantification procedures are listed below:

a. The subject was weighed.

b. Cockpit specific anthropometric measures were made using the Navy 64A105H1-1 Integrated Anthropometric Measuring Device. Data were recorded on an anthropometric data form.

c. The subject was seated in the ejection seat. Specially mounted transparent protractors were then adjusted horizontally or vertically with the protractor center of radius point aligned with the estimated locus of the joint center of mass. The protractor zero deg reference line was then adjusted vertically and horizontally forward from the subject's respective joint. The subject then moved his joint segment (e.g., arm around clavicle joint) to a point of maximum possible elevation, declination, or azimuth. The experimenter aligned an index marker line which originated in the protractor center of radius with the estimated midline of the respective segment and read the degrees of rotation from zero deg as indicated on the protractor by the index marker line. The maximum angles of motion about joints were recorded on a second anthropometric data form.

d. Additionally, while secured to the ejection seat lap belt and inertia-reel torso restraint system, each subject's reach distance was measured relative to three specified "reach zones." Zone 1 defines the subject relaxed in a locked harness reaching to controls without straining against the harness. In Zone 1, the lumbar, thoracic, interclavicular, and clavicular segments do not move. In Zone 2, the subject strains against the locked harness to obtain maximum reach. The lumbar, thoracic, and interclavicular segments do not move except for the stretch in torso restraint system. The clavicular segment does move since it is not securely held by the torso harness and restraint system. In Zone 3, the shoulder harness is unlocked and the subject is free to lean forward or to the side to obtain maximum reach within the limits of shoulder harness strap length. The lumbar and thoracic segments move within the limits of shoulder harness strap length. The reach distances were measured from the thumb and forefinger grasp to a point at the intersection of the seat back surface and top surface midpoint of the subject's shoulder.

RESULTS AND DISCUSSION

14. The subjects used in this evaluation were seven males, carefully selected to represent the range of anthropometric characteristics found in the Naval aviation population. Subjects representative of 5th, 25th, 50th, 75th, and 99th percentile population members relative to stature and weight were selected. For subjects 1 through 5, each of the 16 anthropometric variables was screened to be within one standard deviation of the population percentile equivalent being represented.

15. The primary purpose of the evaluation was to quantify the added bulk, displacement of posture, and restriction of mobility which results from the average effects of flight clothing and equipment. Therefore, population-wide representative sampling of pertinent anthropometric parameters was employed. The data are, therefore, presented as plus or minus correction factors relative to the dimensional and angle of motion differences quantified between unclad and summer gear and between unclad and winter gear configurations. The average increased bulk anthropometric dimensional correction factor data are presented in appendix A.

16. For angular quantification, a forward-facing seated posture was assumed by the subjects. All joint measurements were made on the right side of the body; left side mirror-image reciprocals were assumed. Vertical measurements were made from a line extending 90 deg to the right of the joint at zero deg elevation. All horizontal measurements were from a line extending forward of the joint at zero deg azimuth. The angular quantifications of average decreased mobility resulting from summer and winter flight gear with locked torso restraint systems are presented in appendix B. Appendix C presents reach data as a function of reach zone and flight gear worn.

RECOMMENDATIONS

17. A maximum effort redesign of the complete flight clothing and equipment system is necessary to reduce the bulk and weight effects of such clothing and equipment on mobility within an aircrew station.

18. When designing crew station geometry and locating controls and displays, designers should incorporate the maximum available data describing reduction in anthropometric mobility and increase in anthropometric volume resulting from flight clothing and equipment worn on the body.

19. The following comments are relative to bulk and mobility restrictions per item or per group of items comprising the flight clothing and equipment.

a. Helmet (APH 6-3)/Oxygen Mask (A13-A) - Five and one-half lb (2.5 kg); weight, bulk, and oxygen hose/regulator "drag" compromise vertical and horizontal head motion and look angle. The anti-exposure suit hampers horizontal mobility less than it does vertical mobility.

b. Flying coveralls (CSFRP-1), gloves (GS1FRP-1), torso harness (MA-2) - Six and six-tenths lb (3.0 kg); weight and bulk not oppressive. When secured to lap belt and shoulder restraint, mobility is naturally restricted. However, redesign of the lap belt to an inertia system such as the shoulder restraints and increasing shoulder inertia-reel strap length would ease mobility in Zone 3 conditions. The flight gloves were the least bulky and least restrictive item of wear.

c. Anti-G coveralls (MK-2A) - Two and two-tenths lb (1.0 kg); slightly restrictive due to necessary tight fit. As a result of interviewing operational pilots, it was determined that this item was generally not accepted to wear in conjunction with CWU-33P anti-exposure suit.

d. Survival vest (SV-2A) - Two and four-tenths lb (1.1 kg); weight and bulk interfere with torso and arm movements.

e. Boots (B 21408) - Four and five-tenths lb (2.0 kg); slight mobility restriction due to weight and length of vertical dimension.

f. Life preserver (LPA-2) - Four and five-tenths lb (2.0 kg); displaces posture slightly due to packaging. Occasional interference with inertia-reel shoulder straps.

g. Anti-exposure suit (CWU-33P) - Six lb (2.7 kg); this was by far the bulkiest, most restrictive item of equipment. The anti-exposure suit significantly reduced angle of motion in the arms, legs, and torso. The bulk was restrictive not only about the shoulders, elbows, and knees, but increased the effective retention of the torso system regardless of harness locked or unlocked condition. Reach to cross-cockpit, vertical, and side-console areas was considerably hampered, if not prevented, by the anti-exposure suit. Some subjects had difficulty reaching the overhead face-curtain ejection handle as a result of the anti-exposure suit bulk and mobility restrictions.

h. The total weight of either summer or winter gear was subjectively identified as one of the more objectional factors of the flight clothing and equipment by each of the subjects as well as numerous aircrewmen interviewed during the project.

i. All aircrewmen involved in the project expressed the need for an all-encompassing integrated redesign of the entire package of personal flight equipment which would reduce weight and increase mobility.

SUMMARY TABLE OF AVERAGE FLIGHT CLOTHING/EQUIPMENT DIMENSIONAL CORRECTION FACTORS

Anthropometric Measurements	Mean Differences Between Nude Dimensions and Summer Flight Gear	Mean Differences Between Nude Dimensions and Winter Flight Gear
1. Weight	+28.3 lb (+12.8 kg)	+32.0 lb (+14.5 kg)
2. Stature	+3.2 in. (+8.1 cm)	+3.2 in. (+8.1 cm)
3. Waist height	+1.2 in. (+3.1 cm)	+1.2 in. (+3.1 cm)
4. Arm reach(1)	+.3 in. (+.8 cm)	+.5 in. (+1.3 cm)
5. Shoulder-elbow length	+.1 in. (+.3 cm)	+.6 in. (+1.5 cm)
6. Forearm-hand length	+.1 in. (+.3 cm)	+.3 in. (+.8 cm)
7. Hand length	0	0
8. Hip breadth, standing	+1.1 in. (+2.8 cm)	+1.5 in. (+3.8 cm)
9. Sitting Height(2)	+2.2 in. (+5.6 cm)	+2.5 in. (+6.2 cm)
10. Eye height, sitting	+.3 in. (+.8 cm)	+.5 in. (+1.3 cm)
11. Bideltoid diameter	+.2 in. (+.5 cm)	+1.8 in. (+4.6 cm)
12. Buttock-knee length	+.2 in. (+.5 cm)	+.4 in. (+1.0 cm)
13. Hip breadth, sitting	+.9 in. (+2.3 cm)	+1.8 in. (+4.6 cm)
14. Popliteal height, sitting	+.2 in. (+.5 cm)	-.1 in. (-.3 cm)
15. Buttock-leg length(3)	+1.4 in. (+3.6 cm)	+1.7 in. (+4.3 cm)
16. Foot length	+1.4 in. (+3.6 cm)	+1.4 in. (+3.6 cm)

NOTES: (1) Clavicular joint, humeral, radial, hand finger-grip links.
(2) Lumbar, thoracic, vertical neck, lower head, upper head links.
(3) Femoral, Tibial foot links.

SUMMARY TABLE OF AVERAGE FLIGHT CLOTHING/EQUIPMENT CORRECTION FACTORS FOR JOINT-MOTION REDUCTION[1] ANGULAR DIFFERENCE DATA

Joint		No Flight Gear Average	Differences in Summer Flight Gear	Differences in Winter Flight Gear
Neck:	elevation	73	-22	-34
	declination	61	-12	-16
	azimuth-right	85	-8	-18
	azimuth-left	85	-8	-18
Arm:	elevation	105	-22	-47
	declination	152	-13	-26
	azimuth-right	132	-1	-12
	azimuth-left	55	-19	-38
Elbow:	elevation	116	-22	-33
	declination	72	-7	-13
	azimuth-left	63	-8	-14
Wrist:	elevation	61	-1	-3
	declination	75	-1	-11
	azimuth-right	44	0	0
	azimuth-left	26	0	0
Torso:	declination[2]	86	-55	-68
	torsion-right	45	-14	-32
	torsion-left	45	-14	-32
Leg:	elevation	46	-8	-20
(femur)	azimuth-right	7	-2	-3
	azimuth-left	28	-6	-11
Ankle:	elevation	23	-9	-9
	declination	15	-4	-5
	azimuth-right	45	-8	-8
	azimuth-left	40	-9	-10

NOTES: (1) Measured in degrees. Corrections are ± from right arm and leg extremities, left side mirror image is assumed.

(2) Average of lumbar and thoracic link harness unlocked.

SUMMARY TABLE OF AVERAGE FLIGHT CLOTHING/EQUIPMENT CORRECTION FACTORS REACH ZONE DATA FOR JOINT-MOTION REDUCTION

	Zone 1	Zone 2	Zone 3
Summer Gear	32.1 in. (81.5 cm)	36.8 in. (93.5 cm)	43.5 in. (110.5 cm)
Winter Gear	32.2 in. (81.8 cm)	35.3 in. (89.7 cm)	40.3 in. (102.4 cm)

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