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**ANTHROPOMETRY OF A FIT TEST SAMPLE USED IN EVALUATING
THE CURRENT AND IMPROVED MCU-2/P MASKS (U)**

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CAVERVING

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER


CHARLES BATES, JR.
Director, Human Engineering Division
Armstrong Aerospace Medical Research Laboratory

REPORT DOCUMENTATION PAGE

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PREFACE

This study was conducted by Anthropology Research Project, Inc. under Air Force Contract F33615-85-C-0531 (Project 718408) with the Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. It was initiated by Captain Catherine Sanchez of ASD/AESE.

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TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION.....	5
TESTING OF THE MCU-2/P.....	5
THE SAMPLE.....	7
METHOD.....	8
RESULTS.....	9
THE NEWPORT SAMPLE.....	9
THE NEWPORT SAMPLE AND THE USAF POPULATION.....	9
EVALUATION OF MCU-2/P SIZING.....	16
DISCUSSION AND RECOMMENDATIONS.....	20
APPENDIX A: MEASUREMENT DESCRIPTIONS.....	23
APPENDIX B: LANDMARK DESCRIPTIONS.....	35
REFERENCES.....	37

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Current (left) and improved (right) MCU-2/P masks: (a) exterior view, (b) interior view.....	6
2	A bivariate frequency table for Face Breadth and Face Length for the 1968 Air Force women and the 1967 Air Force men, with the Newport sample superimposed.....	14
3	Distribution of ARP and MSA Menton-Sellion Length by size for the current mask.....	18
6	Distribution of ARP and MSA Menton-Sellion Length by size for the improved mask.....	19

LIST OF TABLES

<u>No.</u>		<u>Page</u>
1	Race and Sex Composition of the MCU-2/P Test Subjects	7
2	Age Structure by Sex of the MCU-2/P Test Subjects Compared to USAF 1967 and 1968 Survey Sample	8
3	Comparison of Summary Statistics for the Male Sample to 1967 Air Force	10
4	Comparison of Summary Statistics for the Female Sample to 1968 Air Force	11
5	Summary Statistics by Sex and Race/Ethnic Origin (Males).	12
6	Summary Statistics by Sex and Race/Ethnic Origin (Females).	13
7	MANOVA Results Showing Overall Sex, Race, and Interaction Effects for the Standard and Headboard Data Sets	15
8	Menton-Sellion Length (Face Length) Used in Determining Mask Size	16
9	Comparison of MSA and ARP Menton-Sellion Lengths	17
10	Tariffing of Both MCU-2/P Configurations According to MSA and ARP Dimensions	20

ANTHROPOMETRY OF A FIT TEST SAMPLE USED IN EVALUATING THE CURRENT AND IMPROVED MCU-2/P MASKS

INTRODUCTION

This report summarizes the results of an anthropometric study of a fit-test sample employed by Mine Safety Appliances (MSA) to evaluate two models of the MCU-2/P full face protective mask for use by the U.S. Air Force. The study was performed from August 10 through August 19, 1987 at the Naval War College, Newport, Rhode Island.

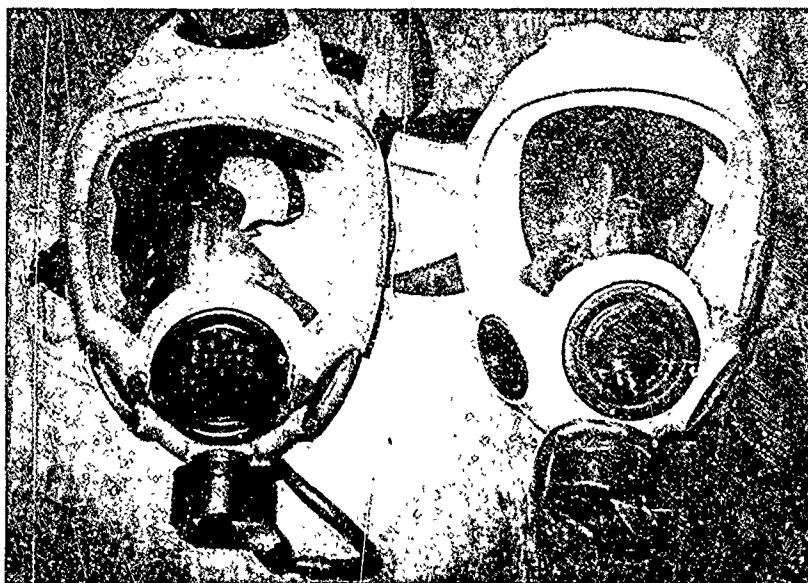
The work performed by Anthropology Research Project (ARP) was part of the larger MSA study. In March 1986, MSA was awarded a contract by the United States Air Force to improve the MCU-2/P full face protective mask. The MCU-2/P, originally designed by the Army as the XM-30, has been repeatedly evaluated in the past 10 years; the percentage of masks achieving the required protection factors of 10,000 or more has ranged from 77% to 95%. Changes in the improved MSA mask include a more pronounced in-turn of the seal in the forehead region, a deeper, narrower chin cup, and modifications of the voice emitter/microphone and the lens. The sizing of the masks was also modified. The object of the MSA study was to compare and evaluate the current MCU-2/P and the newer improved mask. The current and improved models are both pictured in Figure 1.

The role of ARP was to provide anthropometric support. Since specifications required that the improved mask accommodate 90 percent of the total male and female population of the United States Air Force, ARP's principal tasks were to collect head and face dimensions to determine whether MSA's test sample was anthropometrically representative of the larger USAF population and to determine, if necessary, the facial characteristics related to seal breakage. The fitting criteria currently in use for both masks were also evaluated.

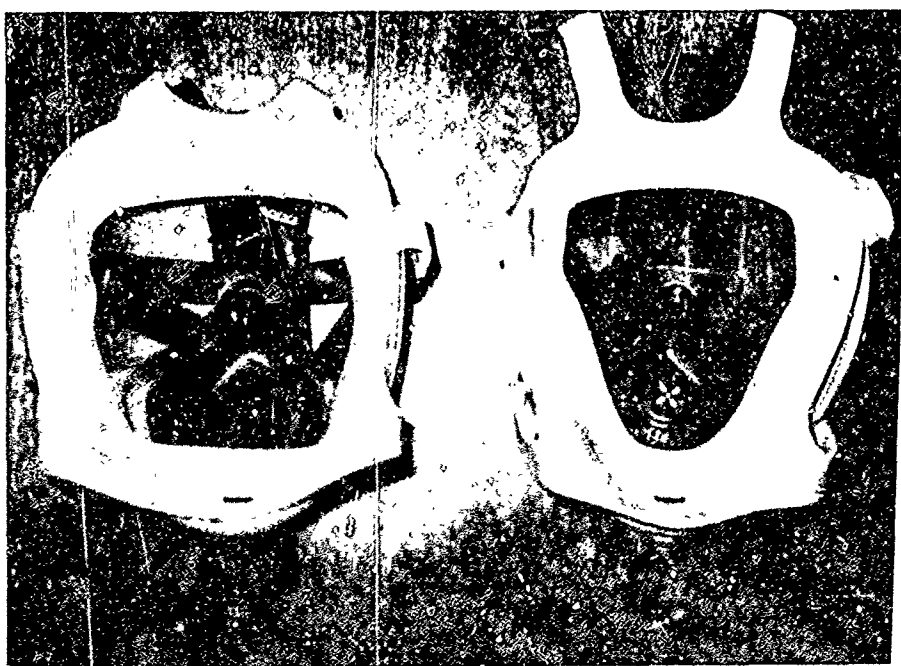
TESTING OF THE MCU-2/P

After subjects were briefed on the testing procedures, each subject was assigned a mask size based on Menton-Sellion Length as measured by an MSA staff member. Subjects then viewed a video tape which instructed them on how to don the masks, and demonstrated specific exercises to be performed in the test chamber. The exercises were done for 15 seconds each and were performed in the following order: normal breathing; deep breathing; walking in place; looking up, left and right, while on hands and knees; stepping up and down; touching toes; twisting at the waist; rapid side-to-side head movements; talking; shallow knee bends; and, assuming various facial expressions (yawning, smiling, frowning, rotating the chin).

To test the protection capability of the mask, the exercises were performed inside a Dynatech Frontier Portable Fit Testing System 1000 which measured the amount of challenge agent (corn oil mist) that leaked into the masks. Each subject was tested in both masks, worn in random order. Twenty-five of the subjects repeated the testing while wearing spectacles.



(a)



(b)

Figure 1. Current (left) and improved (right) MCU-2/P masks:
(a) exterior view, (b) interior view.

THE SAMPLE

The test subjects, consisting mainly of Navy personnel, also included six civilians and one individual from each of the following services: Air Force, Army, and Coast Guard. Most male subjects were officers, whereas most female subjects came from the enlisted ranks. The sample provided a wide range of racial and sexual diversity as shown in Table 1. Racial classification was based on each individual's classification of him/herself. The category "Other" included individuals not classified in any of the other three categories; it was a highly diverse group and, in this sample, consisted of individuals who classified themselves as Filipino, American Indian, Jamaican, and Chinese. The proposed sampling strategy was to have 50 males and 50 females, each sex to include 15 Whites, 15 Blacks, 15 Hispanics, and 5 Other. It is evident from Table 1 that the number of Hispanic females was far from realized.

TABLE 1

RACE AND SEX COMPOSITION OF THE MCU-2/P TEST SUBJECTS

<u>Race</u>	<u>Male</u>	<u>Female</u>	<u>Total</u>
White	22	17	39
Black	14	22	36
Hispanic	13	5	18
Other	<u>6</u>	<u>5</u>	<u>11</u>
TOTAL	55	49*	104

* One of the 50 female subjects dropped out midway through the testing program.

A breakdown of the sample by age and sex and a comparison with larger Air Force populations are shown in Table 2. It was a generally young group. Ages ranged from 19-57 years, with only ten individuals aged 35 and over. For both sexes, close to half the subjects fell within the 20-24 year age group. Beyond 45 years there was a complete absence of females, and males were only sparsely represented. There were no males under 20 in either the Air Force or Newport samples, but the Air Force sample had a much greater proportion of women under 20 than did the Newport sample.

TABLE 2

AGE STRUCTURE BY SEX OF THE MCU-2/P TEST SUBJECTS
COMPARED TO USAF 1967 AND 1968 SURVEY SAMPLES

Age	Males		1967 AF %	Females		1968 AF %
	Newport n	%		Newport n	%	
<20	0	0	0	1	2.1	36.8
20-24	30	55.6	29.0	23	47.9	40.3
25-29	12	22.2	28.0	10	20.8	10.2
30-34	5	9.3	20.4	11	22.9	4.6
35-39	3	5.5	13.6	2	4.2	3.8
40-44	1	1.9	7.7	1	2.1	2.9
45-49	1	1.9	1.3	0	0	.9
>50	2	3.7	0	0	0	.5
Unknown	<u>1</u>			<u>1</u>		
TOTAL	55			49		

METHOD

Forty-two head and face measurements were taken on each subject after he/she had completed MSA's series of fit tests. Of these, 15 were measured with standard instruments (spreading and sliding calipers, and tape) and 27 were measured with subjects in a headboard (Hertzberg, et al., 1963). All measurements were taken to the nearest millimeter. They are listed and described in Appendix A.

Measurements of the head and face are taken between well-defined points known as landmarks. These are determined visually or by palpating recognizable features of the underlying skull which are then marked with a grease pencil for easy determination during the measuring process. Landmarks used in this study are defined in Appendix B.

Several stages were involved in the statistical analysis of the data. In the first, descriptive statistics showing sexual, racial, and age breakdowns of the sample were derived. Multivariate analysis of variance (MANOVA) was then used to test for overall sex, race, and interaction effects. For the multivariate tests, the standard anthropometric dimensions and the headboard dimensions were treated as two different data sets, and each was analyzed separately. This was done because standard measurements are usually more reliable; the potential for error is much greater among headboard dimensions since these measurements are extremely sensitive to movement by the subject.

In the second stage, the Newport sample was compared with the 1967 Air Force men's and the 1968 Air Force women's anthropometric survey samples (Churchill, et al., 1977; Clauser, et al., 1972) to determine whether it can be considered representative of the larger military population. This was done by comparing bivariate plots generated from the test sample with those obtained from the Air Force surveys. Finally, the fitting dimensions were evaluated.

RESULTS

THE NEWPORT SAMPLE

Summary statistics for the males and females from the Newport and Air Force samples are shown in Tables 3 and 4, respectively. As expected, the male dimensions are generally larger than those of the females. Females exceeded males in only two measurements, Nasal Root Breadth, and Wall-Left Tragon. The male-female discrepancy for the former probably reflects the slightly higher proportion of Blacks in the female sample. The larger Wall-Left Tragon value for females appears to be an error caused by subject placement. The Right Tragon measurement is smaller for women.

Along with sex, racial differences account for much of the observable variability in cranial and facial dimensions. Tables 5 and 6 show racial breakdowns of all dimensions for the respective sexes. Generally, the racial variations shown here bear out findings from previous studies (Long and Churchill, 1968; McConville and Churchill, 1976). Characteristic differences include longer faces for Whites and Blacks, broader faces for Orientals, greater cranial vault lengths for Whites and Blacks, narrower and more projecting noses for Whites, and broader noses and more pronounced midfacial prognathism for Blacks.

As expected, the MANOVA results included in Table 7 show significant race and sex differences at the 95 percent or better probability level for both the standard and headboard data sets. These differences serve to emphasize the obvious need for seeking a wide range of sexual and racial diversity in selecting subjects used to test critically important products.

For the headboard dimensions the interaction effects (race x sex) observed in the MANOVA results are also statistically significant, indicating that the degree of sexual dimorphism varies among races. This shows the complexity of sexual and racial variability and hence the difficulty of evaluating the distributions of poorly sampled groups. In the present analysis this applies in particular to Hispanic females and Others of both sexes.

THE NEWPORT SAMPLE AND THE USAF POPULATION

Anthropometry was used during the MCU-2/P testing to determine whether the test sample adequately represented USAF personnel. Figure 2 shows the face lengths (Menton-Sellion Length) and face breadths (Bizygomatic Breadth) of the Newport sample superimposed on a bivariate plot derived from the combined data of the Air Force 1967 men's and 1968 women's surveys. The numbers of individuals in each cell are listed, females to the left of the slash and males to the right. The 5th to 95th percentiles for females and males from the surveys in the 1960's are outlined by the left and right boxes respectively.

TABLE 3

COMPARISON OF SUMMARY STATISTICS FOR THE MALE SAMPLE TO 1967 AIR FORCE
(n=55; values in cm)

<u>Standard Measurements</u>	<u>Newport</u>		<u>USAF 1967</u>	
	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>
Bigonial Breadth	11.2	0.70	11.7	.69
Bitragion Breadth	14.2	0.49	14.3	.56
Bitragion-Crinion Arc	32.2	0.99		
Bitragion-Frontal Arc	30.7	0.87	30.8	1.00
Bitragion-Menton Arc	32.5	1.38	32.7	1.24
Bitragion-Submandibular Arc	30.3	1.40	31.0	1.58
Bitragion-Subnasale Arc	29.5	1.30	29.3	1.02
Bizygomatic Breadth	14.1	0.64	14.2	.52
Lip Length	5.2	0.37	5.2	.37
Maximum Frontal Breadth	11.3	0.47	11.6	.46
Menton-Sellion Length	12.0	0.56	12.0	.61
Minimum Frontal Breadth	10.8	0.50		
Nasal Breadth	3.6	0.40	3.6	.29
Nasal Root Breadth	1.8	0.22		
Temporal Depression Breadth	12.1	0.57		
<u>Headboard Measurements</u>				
Vertex-Crinion	4.7	1.05		
Vertex-Glabella	10.1	0.69	9.27	.97
Vertex-Gonion	19.8	0.86		
Vertex-Infraorbitale	13.1	0.62		
Vertex-Lateral Ala	15.5	0.68		
Vertex-Left Tragion	13.3	0.61		
Vertex-Menton	23.1	0.77	22.8	1.02
Vertex-Minimum Frontal	9.1	0.69		
Vertex-Promenton	21.3	0.82		
Vertex-Pronasale	15.0	0.79	14.7	1.10
Vertex-Right Tragion	13.2	0.59	13.5	.61
Vertex-Sellion	11.2	0.64	10.8	.94
Vertex-Stomion	18.5	0.71	18.4	1.00
Vertex-Subnasale	16.3	0.70	16.1	1.02
Wall-Crinion	18.9	0.67		
Wall-Glabella	20.3	0.50	20.4	.67
Wall-Gonion	12.0	0.81		
Wall-Lateral Ala	19.6	0.54		
Wall-Left Tragion	10.2	0.63		
Wall-Lip Protrusion	21.2	0.69	21.2	.86
Wall-Menton	19.0	0.92		
Wall-Minimum Frontal	17.1	0.59		
Wall-Promenton	20.2	0.77		
Wall-Pronasale	22.4	0.63	22.7	.75
Wall-Right Tragion	10.2	0.59	10.3	.65
Wall-Sellion	20.1	0.49	20.2	.66
Wall-Subnasale	20.9	0.57	21.0	.79

TABLE 4

COMPARISON OF SUMMARY STATISTICS FOR THE FEMALE SAMPLE TO 1968 AIR FORCE
(n=49; values in cm)

<u>Standard Measurements</u>	<u>Newport</u>		<u>USAF 1968</u>	
	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>
Bigonial Breadth	10.5	0.64	10.2	.56
Bitracion Breadth	13.3	0.49	12.9	.50
Bitracion-Crinion Arc	30.8	1.08		
Bitracion-Frontal Arc	29.1	1.08		
Bitracion-Menton Arc	30.7	1.32		
Bitracion-Submandibular Arc	27.7	1.27		
Bitracion-Subnasale Arc	27.8	1.21		
Bizygomatic Breadth	13.5	0.47	12.9	.58
Lip Length	4.7	0.43	4.4	.42
Maximum Frontal Breadth	10.8	0.48		
Menton-Sellion Length	11.3	0.70	10.6	.61
Minimum Frontal Breadth	10.4	0.49		
Nasal Breadth	3.5	0.41		
Nasal Root Breadth	1.9	0.23		
Tempora ¹ Depression Br	11.6	0.48		
<u>Headboard Measurements</u>				
Vertex-Crinion	4.2	1.11		
Vertex-Glabella	9.7	0.88		
Vertex-Gonion	18.7	0.91		
Vertex-Infraorbitale	12.7	0.90		
Vertex-Lateral Ala	14.9	0.97		
Vertex-Left Tracion	12.9	0.72		
Vertex-Menton	22.3	1.10	21.9	1.14
Vertex-Minimum Frontal	8.9	0.90		
Vertex-Promenton	20.5	1.08		
Vertex-Pronasale	14.3	0.91	14.8	1.17
Vertex-Right Tracion	12.8	0.75	12.7	.76
Vertex-Sellion	10.9	0.84		
Vertex-Stomion	17.8	1.04	17.6	1.12
Vertex-Subnasale	15.7	0.92	15.9	1.10
Wall-Crinion	18.3	1.21		
Wall-Glabella	19.5	1.09		
Wall-Gonion	11.8	1.08		
Wall-Lateral Ala	19.0	1.05		
Wall-Left Tracion	10.3	1.07		
Wall-Lip Protrusion	20.5	1.32	19.3	1.06
Wall-Menton	18.2	1.29	18.2	1.14
Wall-Minimum Frontal	16.5	1.02		
Wall-Promenton	19.6	1.22		
Wall-Pronasale	21.5	1.10	21.2	.96
Wall-Right Tracion	10.1	0.87	10.2	.90
Wall-Sellion	19.4	1.05		
Wall-Subnasale	20.1	1.17	19.7	.98

TABLE 5
SUMMARY STATISTICS BY SEX AND RACE/ETHNIC ORIGIN (MALES)
(values in cm)

Measurements	Hispanic (n=13)					White (n=22)					Black (n=14)					Other (n=6)				
	Mean	SD	MIN	MAX		Mean	SD	MIN	MAX		Mean	SD	MIN	MAX		Mean	SD	MIN	MAX	
Bigonial Breadth	11.1	0.54	10.4	12.2		11.3	0.82	10.3	13.0		11.1	0.72	10.0	12.1		11.6	0.31	11.1	11.9	
Bitragion Breadth	14.2	0.50	13.6	14.7		14.1	0.43	13.5	15.0		13.9	0.42	13.0	14.5		14.7	0.83	13.6	15.7	
Bitragion-Crinion Arc	32.2	0.86	30.9	33.5		32.4	1.16	30.4	34.7		31.8	0.84	30.7	33.6		32.5	0.59	32.0	33.8	
Bitragion-Frontal Arc	30.4	0.55	29.7	31.5		30.8	1.14	29.0	33.5		30.6	0.74	29.8	32.5		31.2	0.54	30.5	31.8	
Bitragion-Menton Arc	32.1	1.15	29.5	33.5		32.5	1.41	30.2	35.7		32.7	1.30	30.5	34.8		33.4	1.83	20.5	35.8	
Bitragion-Subman Arc	30.1	1.11	28.8	32.3		30.3	1.58	27.3	33.5		30.1	1.48	28.4	33.3		30.8	1.26	29.2	32.3	
Bitragion-Subnasale Arc	29.0	0.49	28.3	29.9		29.4	1.69	27.2	35.6		29.6	0.90	28.0	31.0		30.4	1.40	28.8	32.0	
Bizygomatic Breadth	14.1	0.36	13.6	14.6		14.0	0.64	13.2	15.1		14.0	0.61	13.1	15.0		14.9	0.90	13.9	16.3	
Lip Length	5.1	0.33	4.6	5.7		5.1	0.37	4.3	5.8		5.4	0.38	4.9	5.9		5.1	0.32	4.7	5.4	
Maximum Frontal Breadth	11.2	0.30	10.8	11.8		11.1	0.54	10.3	12.3		11.4	0.39	10.9	12.2		11.7	0.35	11.2	12.2	
Menton-Sellion Length	11.9	0.54	10.6	12.8		12.1	0.56	11.2	13.4		12.1	0.61	11.2	13.1		11.7	0.50	11.2	12.4	
Minimum Frontal Breadth	10.7	0.48	9.9	11.6		10.8	0.59	9.5	11.8		10.8	0.41	10.1	11.6		11.0	0.39	10.4	11.5	
Nasal Breadth	3.4	0.32	3.1	4.2		3.4	0.24	3.1	4.0		4.0	0.23	3.7	4.4		3.9	0.42	3.4	4.6	
Nasal Root Breadth	1.7	0.15	1.5	2.0		1.8	0.20	1.5	2.3		1.9	0.25	1.6	2.3		1.9	0.21	1.7	2.2	
Temporal Depression Br	12.0	0.31	11.5	12.6		11.8	0.61	10.6	13.0		12.2	0.49	11.5	13.0		12.8	0.38	12.4	13.5	
Vertex-Crinion	7.8	1.38	3.5	8.6		4.8	1.00	3.4	7.2		4.3	0.77	2.5	5.3		5.3	0.81	4.3	6.4	
Vertex-Glabella	10.2	0.76	9.2	11.5		10.2	0.56	9.4	11.2		9.6	0.48	8.8	10.1		10.5	0.83	9.3	11.6	
Vertex-Gonion	19.8	0.90	18.2	21.5		20.0	0.91	18.2	21.5		19.3	0.55	18.5	20.4		20.4	0.79	19.3	21.5	
Vertex-Infrorbitale	13.1	0.72	12.1	14.2		13.1	0.60	12.2	14.2		12.9	0.50	12.1	13.7		13.5	0.66	12.3	14.2	
Vertex-Lateral Ala	15.6	0.68	14.6	16.9		15.7	0.74	14.5	18.0		15.1	0.50	14.4	15.9		15.8	0.35	15.3	16.2	
Vertex-Left Tragon	13.3	0.67	12.3	14.4		13.3	0.59	12.5	14.9		13.2	0.53	12.2	14.2		13.7	0.77	12.9	14.8	
Vertex-Menton	23.0	0.72	22.0	24.4		23.2	0.82	21.6	25.2		22.9	0.82	21.4	24.4		23.4	0.61	22.6	24.1	
Vertex-Minimum Frontal	9.1	0.61	8.2	10.3		9.3	0.58	8.0	10.0		8.6	0.47	8.0	9.5		9.5	1.10	7.8	10.8	
Vertex-Promenton	21.2	0.70	20.4	22.4		21.5	0.99	19.5	23.6		21.0	0.65	20.0	22.2		21.4	0.71	20.4	22.2	
Vertex-Pronasale	15.0	0.85	13.8	16.5		15.2	0.83	14.0	16.8		14.6	0.51	13.6	15.4		15.4	0.69	14.4	16.4	
Vertex-Right Tragon	13.2	0.53	12.4	14.3		13.3	0.62	12.0	14.4		13.0	0.54	12.2	14.3		13.6	0.66	12.8	14.5	
Vertex-Sellion	11.3	0.69	10.4	12.4		11.3	0.55	10.2	12.2		10.9	0.48	10.2	11.6		11.7	0.84	10.5	13.0	
Vertex-Stomion	18.5	0.70	17.3	19.6		18.7	0.73	17.4	20.2		18.2	0.55	17.2	19.2		18.8	0.79	17.7	19.8	
Vertex-Subnasale	16.4	0.69	15.3	17.7		16.6	0.68	15.5	18.0		15.8	0.51	14.9	16.7		16.7	0.60	15.7	17.4	
Wall-Crinion	18.7	0.54	17.5	19.6		19.2	0.67	17.8	20.3		18.7	0.69	16.7	19.8		19.1	0.66	18.1	20.0	
Wall-Glabella	20.1	0.38	19.0	20.4		20.4	0.59	19.2	21.5		20.3	0.53	19.3	21.1		20.3	0.38	19.6	20.7	
Wall-Gonion	11.8	0.61	10.9	13.3		12.3	0.87	10.5	13.8		11.9	0.86	10.7	13.4		12.2	0.73	11.2	13.1	
Wall-Lateral Ala	19.3	0.38	18.5	20.2		19.6	0.60	18.0	20.7		19.8	0.57	18.6	20.7		19.4	0.29	19.0	19.9	
Wall-Left Tragon	10.0	0.53	9.3	11.0		10.3	0.67	8.6	11.6		10.4	0.65	9.2	11.6		10.2	0.56	9.3	11.0	
Wall-Lip Protrusion	20.8	0.51	19.9	21.9		21.0	0.61	19.8	21.9		21.3	0.75	20.5	22.9		21.1	0.42	20.6	21.7	
Wall-Menton	18.6	0.87	17.4	20.2		19.2	0.81	17.0	20.5		19.0	1.12	17.7	21.7		19.2	0.77	18.6	20.7	
Wall-Minimum Frontal	17.0	0.22	16.6	17.4		17.2	0.74	15.6	18.4		17.0	0.62	16.0	17.8		17.0	0.46	16.4	17.5	
Wall-Promenton	19.8	0.65	19.1	21.2		20.2	0.76	18.2	21.4		20.4	0.90	19.2	22.5		20.3	0.56	19.8	21.3	
Wall-Pronasale	22.2	0.36	21.6	22.8		22.5	0.74	20.8	23.6		22.5	0.64	21.6	23.5		22.1	0.66	21.2	23.1	
Wall-Right Tragon	10.1	0.39	9.6	11.1		10.3	0.71	8.9	11.8		10.3	0.55	9.4	11.3		9.9	0.59	8.9	10.5	
Wall-Sellion	20.0	0.36	19.0	20.4		20.3	0.52	19.1	21.2		20.0	0.52	19.1	20.9		19.9	0.48	19.2	20.5	
Wall-Subnasale	20.6	0.43	19.8	21.4		21.0	0.59	19.7	21.8		21.0	0.65	19.9	22.0		20.7	0.42	20.2	21.4	

TABLE 6

SUMMARY STATISTICS BY SEX AND RACE/ETHNIC ORIGIN (FEMALES)
(values in cm)

Measurements	Hispanic (n=5)					White (n=17)					Black (n=22)					Other (n=5)				
	Mean	SD	MIN	MAX		Mean	SD	MIN	MAX		Mean	SD	MIN	MAX		Mean	SD	MIN	MAX	
Bigonial Breadth	10.1	0.33	9.7	10.6		10.4	0.63	9.5	11.4		10.6	0.70	9.5	12.1		10.3	0.66	9.6	11.4	
Bitragion Breadth	13.5	0.79	12.1	14.1		13.2	0.54	12.2	14.0		13.3	0.31	12.6	13.8		13.3	0.67	12.4	14.1	
Bitragion-Crionion Arc	30.5	1.32	28.7	32.3		31.1	1.24	28.5	33.3		30.7	0.98	29.2	33.0		30.3	0.59	29.5	30.9	
Bitragion-Frontal Arc	29.0	1.03	27.8	30.5		29.2	1.12	27.0	31.2		29.4	1.02	27.8	31.4		28.1	0.82	27.0	29.0	
Bitragion-Menton Arc	30.2	1.35	28.9	32.3		30.1	1.09	27.8	31.8		31.5	1.10	29.3	34.1		29.5	1.03	27.9	30.5	
Bitragion-Subman Arc	26.8	0.86	25.5	27.5		27.7	1.30	24.5	29.8		28.1	1.21	25.9	30.6		26.7	0.66	25.9	27.6	
Bitragion-Subnasale Arc	27.7	1.03	26.4	29.2		27.3	1.03	25.4	29.0		28.5	0.97	26.2	30.5		26.5	1.16	25.1	28.0	
Bitragion-Subnasale Arc	13.5	0.50	12.7	14.0		13.3	0.55	12.4	14.2		13.6	0.37	13.0	14.4		13.5	0.55	12.9	14.2	
Bizygomatic Breadth	4.8	0.12	4.6	4.9		4.5	0.31	3.9	5.0		5.0	0.39	3.9	5.7		4.3	0.32	3.9	4.7	
Lip Length	10.8	0.41	10.3	11.4		10.7	0.54	10.0	11.8		11.0	0.40	10.3	12.2		10.6	0.50	10.0	11.1	
Maximum Frontal Breadth	11.2	0.43	10.4	11.4		11.2	0.51	10.6	12.2		11.5	0.81	10.3	13.4		10.7	0.59	9.9	11.3	
Menton-Sellion Length	10.2	0.38	10.0	10.9		10.4	0.61	9.5	11.6		10.5	0.38	9.8	11.1		10.1	0.57	9.5	11.0	
Minimum Frontal Breadth	3.3	0.27	3.0	3.6		3.1	0.27	2.6	3.6		3.8	0.20	3.4	4.2		3.5	0.41	3.0	4.0	
Nasal Breadth	1.7	0.21	1.5	2.0		1.8	0.22	1.4	2.1		2.1	0.20	1.5	2.3		1.8	0.15	1.6	2.0	
Nasal Root Breadth	11.5	0.43	11.0	12.0		11.4	0.53	10.7	12.6		11.8	0.40	11.0	12.7		11.5	0.54	11.1	12.4	
Temporal Depression Br	4.7	1.89	2.8	7.8		4.0	0.86	2.2	5.7		4.2	1.14	2.2	6.9		3.9	0.92	2.8	4.9	
Vertex-Crionion	9.8	1.14	8.9	11.7		9.6	0.69	7.8	10.5		9.7	1.06	8.6	12.5		10.0	0.15	9.8	10.1	
Vertex-Glabella	18.7	0.95	17.7	19.5		18.3	0.69	17.2	19.4		19.0	1.03	17.2	21.3		18.6	0.53	17.9	19.2	
Vertex-Gonion	12.7	0.98	11.7	14.1		12.2	0.67	10.8	13.2		13.2	1.01	11.5	15.3		12.7	0.50	12.2	13.4	
Vertex-Infraorbitale	15.0	1.02	13.8	16.1		14.5	0.74	12.7	15.7		15.2	1.10	13.7	17.7		15.0	0.63	14.4	15.9	
Vertex-Lateral Ala	13.3	0.63	12.5	14.1		12.7	0.50	11.9	13.8		12.9	0.92	11.6	15.1		12.8	0.29	12.4	13.2	
Vertex-Left Tragon	22.2	1.14	20.8	23.8		21.7	0.81	23.3	19.6		22.8	1.15	20.8	24.7		22.0	0.53	21.4	22.8	
Vertex-Menton	9.0	0.91	8.3	10.5		8.9	0.84	6.6	10.6		8.8	1.03	7.4	12.0		9.0	0.72	8.3	10.0	
Vertex-Minimum Frontal	20.7	1.21	19.0	22		20.5	0.82	18.1	22.4		21.0	1.16	19.2	23.2		20.1	0.51	19.5	20.9	
Vertex-Pronepton	14.5	1.01	13.4	17		14.1	0.71	12.5	15.1		14.4	1.08	13.1	16.8		14.6	0.55	14.1	15.4	
Vertex-Pronasale	11.1	0.87	10.3	12.7		10.5	0.54	9.2	11.2		11.2	1.01	9.9	13.8		11.2	0.35	10.8	11.7	
Vertex-Sellion	18.0	1.11	16.6	19.4		17.3	0.74	15.8	18.6		18.2	1.18	15.9	20.5		17.5	0.57	17.0	18.3	
Vertex-Stomion	15.9	0.88	14.8	17.1		15.4	0.67	13.8	16.6		15.8	1.13	14.2	18.1		15.9	0.57	15.2	16.5	
Vertex-Subnasale	13.1	0.77	12.3	14.2		12.6	0.44	11.6	13.2		12.9	0.95	11.8	15.7		13.0	0.49	12.4	13.6	
Vertex-Tragon	18.0	0.80	17.3	19.3		18.2	0.83	17.0	19.6		18.7	1.29	16.6	21.4		16.8	1.23	14.9	18.0	
Wall-Crionion	19.3	0.56	18.6	20.1		19.2	0.70	18.4	21.2		20.2	1.12	18.8	23.5		18.2	0.71	17.2	19.0	
Wall-Glabella	11.6	0.38	11.1	12.1		11.9	1.51	10.5	16.6		11.8	0.80	10.6	14.7		11.2	0.89	10.2	12.1	
Wall-Gonion	18.7	0.52	18.2	19.5		18.6	0.73	17.5	20.0		19.7	1.00	18.4	22.9		17.8	0.68	18.5	16.7	
Wall-Lateral Ala	10.2	0.46	9.8	11.0		10.0	0.95	11.5	7.5		10.8	1.16	9.5	14.9		9.4	0.36	9.7	8.8	
Wall-Left Tragon	20.3	0.77	19.4	21.4		19.8	0.95	18.6	21.8		21.5	1.10	19.6	24.8		19.1	0.74	17.8	19.6	
Wall-Lip Protrusion	18.3	1.08	17.3	19.7		18.1	1.32	15.8	20.9		18.6	1.30	16.9	22.1		17.1	0.72	16.0	18.0	
Wall-Menton	16.3	0.48	15.5	16.8		16.1	0.73	14.9	17.3		17.1	1.01	16.2	20.5		15.7	0.92	14.5	17.0	
Wall-Minimum Frontal	19.5	1.05	18.3	20.8		19.2	1.16	17.5	21.9		20.2	1.12	18.6	23.4		18.5	0.69	17.3	19.1	
Wall-Promenton	21.4	0.39	21.0	22.0		21.3	0.77	20.3	22.9		22.0	1.10	20.9	25.3		19.8	0.76	18.6	20.5	
Wall-Pronasale	9.8	0.29	9.5	10.3		9.7	0.67	8.7	11.2		10.6	0.92	9.6	14.0		9.8	0.69	8.8	10.7	
Wall-Right Tragon	19.1	0.37	18.6	19.6		19.2	0.70	18.3	21.0		19.9	1.08	18.6	23.1		17.9	0.77	16.9	18.7	
Wall-Sellion	20.1	0.63	19.3	21.0		19.7	0.93	17.7	21.4		20.7	1.10	19.5	24.0		18.6	0.74	17.5	19.4	

FACE BREADTH (mm)																															
105.0	111.0	117.0	123.0	129.0	135.0	141.0	147.0	153.0	159.0	165.0	171.0	177.0	183.0	189.0	195.0	201.0	TOTAL														
144.0																	2														
146.0																	4														
148.0																	3														
150.0																	11														
152.0																	21														
154.0																	45														
156.0																	70														
158.0																	1125														
160.0																	2182														
162.0																	3250														
164.0																	7308														
166.0																	19735														
168.0																	40726														
170.0																	67720														
172.0																	147131														
174.0																	191101														
176.0																	218712														
178.0																	248712														
180.0																	318712														
182.0																	318712														
184.0																	318712														
186.0																	318712														
188.0																	318712														
190.0																	318712														
192.0																	318712														
194.0																	318712														
196.0																	318712														
198.0																	318712														
200.0																	318712														
TOTAL	1	10	8	31	19	78	107	100	282	2	233	6	317	210	161	76	2271	380	29	303	374	5	311	1	1123	81	40	173	5	1305	2420

● = Males
 ☆ = Females

Figure 2. A bivariate frequency table for Face Breadth and Face Length for the 1968 Air Force women and the 1967 Air Force men, with the Newport sample superimposed. (The male subject shown to the far right and beyond the Face Breadth range has an actual value of 163 mm for that dimension.)

TABLE 7

MANOVA RESULTS SHOWING OVERALL SEX, RACE, AND
INTERACTION EFFECTS FOR THE STANDARD AND
HEADBOARD DATA SETS

	<u>DF</u>	<u>Wilks' L*</u>	<u>F</u>	<u>Prob</u>
Standard Data				
Sex	16,61	0.28800	9.43	0.0001
Race	48,189	0.16886	3.11	0.0001
Interaction (sex x race)	48,182	0.56430	0.81	0.8097
Headboard Data				
Sex	27,70	0.33565	5.13	0.00001
Race	81,210	0.09587	3.09	0.0001
Interaction (sex x race)	81,210	0.23361	1.63	0.0031

* Det SSCP within
Det (SSCP between + SSCP within)

In the Newport sample, stars designate females and circles show males. The area within the 5th-95th percentile male range is well represented in the Newport sample. Beyond the percentile brackets, sampling is moderate. A number of individuals fell below the male fifth percentile range for face breadth and one individual fell well beyond the upper Air Force range.

The women's sample did not fare as well. Relative to the Air Force women, the Newport female sample was shifted toward the upper end for both face length and breadth. Few of the Newport women fell within the lower female ranges for either dimension. Several factors were explored in an effort to determine the cause of the difference between the two groups. The fact that the standard deviations of the Newport group are equal to or larger than the Air Force indicates that the Newport sampling was as diverse, if not more so, as the sampling for the Air Force. Though the Newport sample was older than the Air Force 1968 sample, this factor does not seem to be related to the differences between the groups. This was determined by extracting the younger individuals (under 20) from the AF 1968 sample with the object of comparing the anthropometry of this "older" Air Force group with the Newport group. However, when anthropometry of the whole 1968 Air Force and the "older" Air Force 1968 group was compared, virtually no differences were detected, so further comparisons were abandoned.

The possibility of racial makeup as a source of differences between the groups was also examined; the Newport group was much more racially diverse than the Air Force 1968 group. However, a comparison of Whites and Blacks in the Newport group revealed few differences. Another explanation under consideration was differences in measuring techniques. Though measuring techniques are virtually impossible to duplicate exactly and usually contribute to variance to some extent, the fact that the Newport sample is consistently larger than the Air Force group makes the possibility of such an explanation unlikely.

A final unexplored factor is that of secular change -- the slow growth of populations over time. While there is some evidence that for well-nourished middle-class Americans this growth has slowed or stopped in the last decade, it is not clear that such growth has stopped for specific groups of Americans.

In short, though some differences are noted between the Newport females and Air Force 1968 personnel, the sources of these differences are unclear. It should be noted, however, that every attempt was made to get sufficient representation at the testing site. It may well be that this more up-to-date sample, though considerably smaller, is, in fact, more representative of the more racially diverse, current Air Force than is the Air Force sample of 20 years ago.

EVALUATION OF MCU-2/P SIZING

Both models of the MCU-2/P masks were tested on a wide range of facial sizes and shapes with excellent results. Subjects who failed to achieve a protection factor of 10,000 or more on any exercise during evaluation were resized. A total of five individuals, three in the current mask and two in the improved model required resizing. All of the former were downsized from medium to small, and the latter from large to medium. The initial failure of three subjects to maintain a seal can probably be attributed to the presence of beards for two individuals and excessive hair in the temporal region for the third. All subjects were successfully fitted in the improved mask. One subject failed to maintain a seal with the current mask which was probably caused by the presence of a beard rather than by the size or shape of the face.

Size parameters used in assigning mask sizes for the subjects are shown in Table 8 for both the current and improved models. Sizes for the current mask are those developed by Scott Aviation for the earlier version of the MCU-2/P, the Army's XM-30 mask. The English equivalent of these metric dimensions is presently used by the Air Force for the current MCU-2/P (Technical Order [T.O.] 14P4-15-2). Both Menton-Sellion Length and Bizygomatic Breadth were used to assign size during fit-testing the XM-30 mask. However, only the former is now used to assign size according to the present T.O. While Bizygomatic Breadth was measured by the MSA staff during the fitting procedure, it was not used in fitting the MCU-2/P masks. The fitting parameters for the improved mask were developed by MSA.

TABLE 8
MENTON-SELLION LENGTH (FACE LENGTH) USED IN
DETERMINING MASK SIZE
(values in cm)

<u>Current MCU-2/P</u>	<u>Size</u>	<u>Improved MCU-2/P</u>
<11.4	Small	<10.8
11.4-12.5	Medium	10.8-12.05
>12.5	Large	>12.05

The Menton-Sellion dimensions measured by MSA differ markedly from those measured by ARP. These differences are shown in Table 9. Eighty-five subjects (81.7 percent) differ from 1 to 13 mm between the two sets of measurements, with an absolute average difference of 2.77 mm. As can be seen, most measurements (73 or 70.2 percent) taken by ARP yielded higher values than MSA ones, though the magnitude of the differences showed little consistency. This degree of variation can be expected among measuring teams who have not practiced together with the expressed purpose of reducing interobserver error. Variation of this magnitude can probably also be expected among individuals who assign mask sizes in the field.

TABLE 9
COMPARISON OF MSA* AND ARP MENTON-SELLION LENGTHS
(n=104)

<u>Difference (mm)</u>	<u>MSA >ARP</u>	<u>MSA = ARP</u>	<u>MSA <ARP</u>
0		19	
1	6		13
2	1		15
3	1		6
4	3		20
5	1		6
6			9
7			2
8			1
9			
10			
11			
12			
13			1
TOTAL	12	19	73

* MSA dimensions were rounded to the nearest millimeter.

Given the likelihood that size assignment will vary in the field depending on the measurer, it is informative to compare the MSA assignments with those ARP dimensions. Histograms showing the distributions of subjects by Menton-Sellion Length according to assigned mask size are given in Figures 3 and 4 for the current and improved models. Values are given for both the ARP and MSA measurements. Resized individuals appear as a solid black bar. As expected, the MSA dimensions show fairly distinct breaks between sizes since these are the measurements used in fitting. The only areas of overlap between MSA sizes involve the five individuals who were resized and two who were erroneously assigned the wrong mask size based on their measurements (shown by heavy cross-hatched bars). As can also be seen on the histograms for both masks, a considerable number of subjects would have been assigned to larger masks (and a few to smaller ones) on the basis of ARP measurements -- some 21 individuals (20.2%) for the current mask and 28 (26.9%) for the improved.

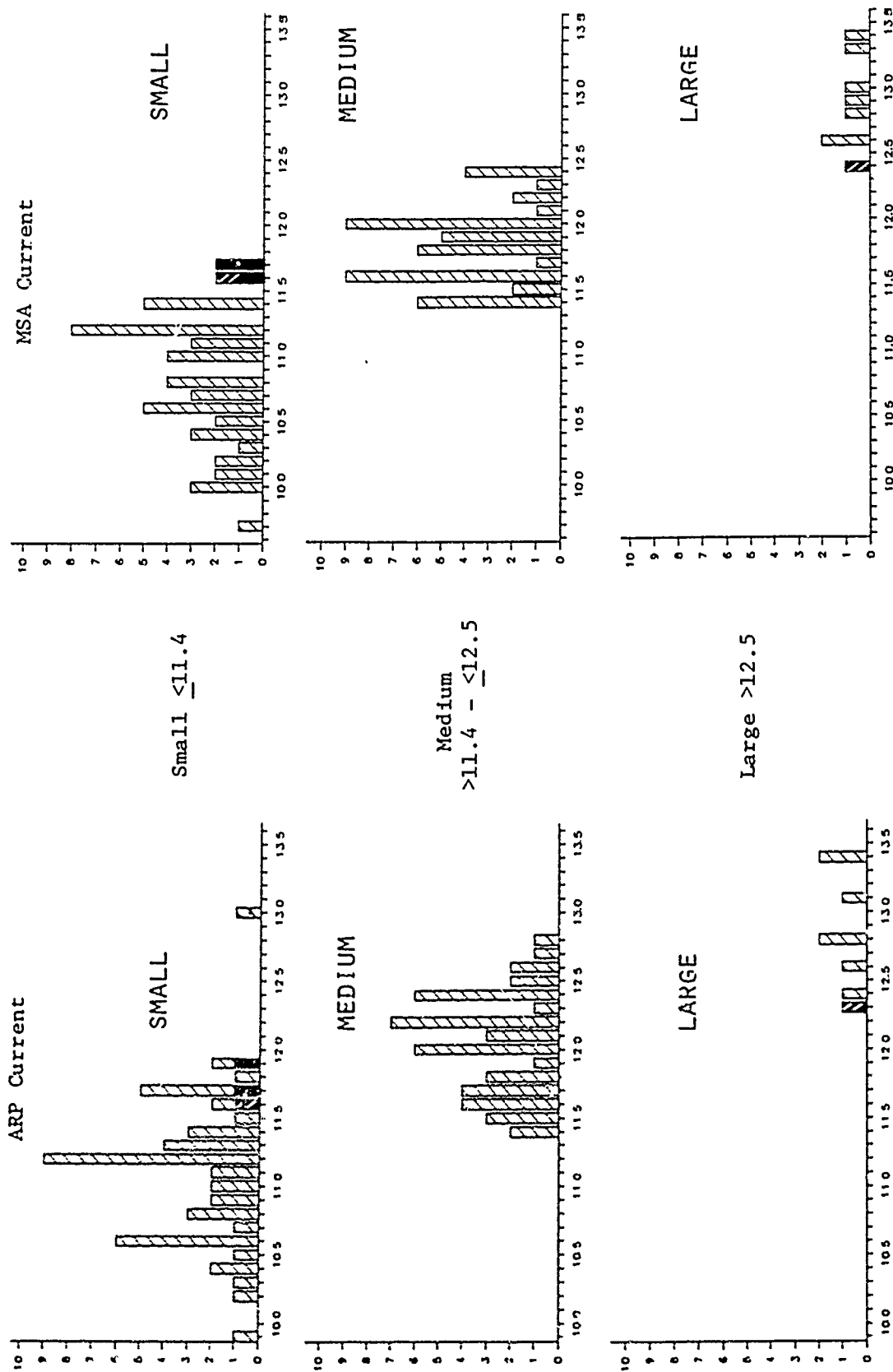


Figure 3. Distribution of ARP and MSA Menton-Sellion Length by size for the current mask.

The numbers on the left vertical axis of the graphs represent the number of subjects; Menton-Sellion Length (in cm) is shown on the horizontal axis. MSA dimensions were rounded to the nearest millimeter, and the value of 11.4 shown for the Small mask was measured as 11.35.

resized = mis-sized according to Menton-Sellion Length (MSA measurements)

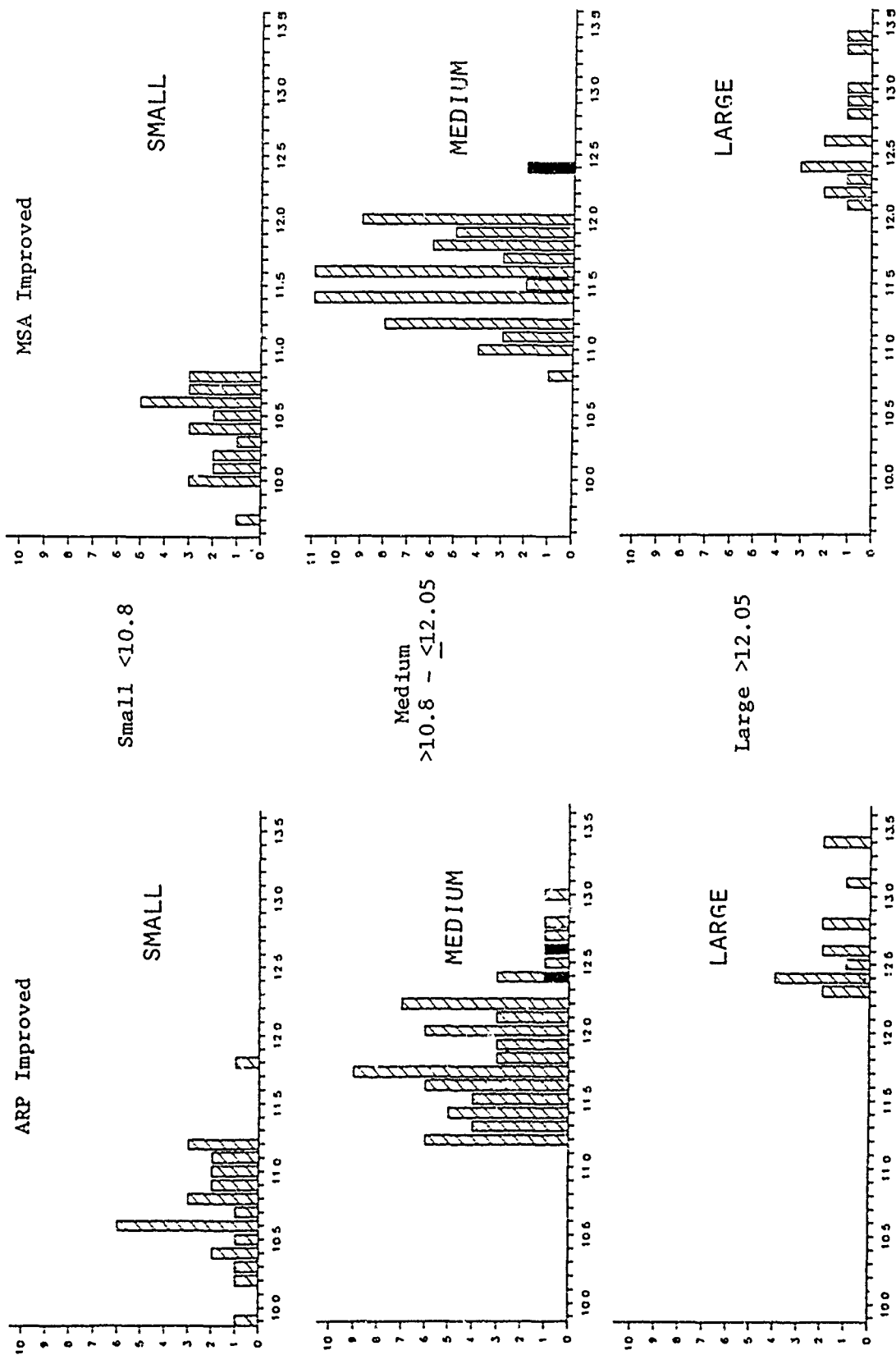


Figure 4. Distribution of ARP and MSA Menton-Sellion Length by size for the improved mask. The numbers on the left vertical axis of the graphs represent the number of subjects; Menton-Sellion Length (in cm) is shown on the horizontal axis. MSA dimensions were rounded to the nearest millimeter, and the value of 10.8 shown for the Small mask was measured as 10.75.

▨ = resized

Using the present size categories, the improved and current MCU-2/P mask sizes issued for the Newport sample by MSA are compared in Table 10 with the sizes which would have been issued using the ARP measurements. The principal difference between MSA and ARP sizing is that the former emphasizes the smaller sizes while the latter classifies more individuals as large.

TABLE 10

ISSUING OF BOTH MCU-2/P CONFIGURATIONS ACCORDING
TO MSA AND ARP MENTON-SELLION LENGTHS
(n=104)

		Improved		
	Size Categories	MSA	ARP	Differences
Small	<10.8 cm	25 (24%)	16 (15%)	9 (9%)
Medium	10.8 - 12.05 cm	63 (61%)	56 (54%)	7 (7%)
Large	>12.05 cm	16 (15%)	32 (31%)	16 (15%)

		Current		
Small	<11.4 cm	46 (44%)	35 (34%)	11 (10%)
Medium	11.4 - 12.5 cm	51 (49%)	58 (56%)	7 (7%)
Large	>12.5 cm	7 (7%)	11 (10%)	4 (4%)

DISCUSSION AND RECOMMENDATIONS

Both the current and improved models of the MCU-2/P mask were fit-tested on subjects representing a broad range of racial and sexual diversity. Results of the testing procedures indicate that there is little doubt about the ability of both models to accommodate this diversity. However, the high rate of accommodation can be reduced if problems exist in the fitting and issue of masks. Based on a bivariate distribution of Air Force males and females (see Figure 2), the MSA fitting categories for the improved mask seem reasonable for the accommodation of both sexes. However, showing that the mask fits properly and provides adequate protection, and determining how best to issue and tariff it are not the same thing. Furthermore, differences encountered in measuring Menton-Sellion Length call into question the consistency of issuing procedures for the different mask sizes, and the accuracy of a tariff derived from these data. Presently, the range of face sizes that can be accommodated in each mask size is unknown. Since each person was not tested in all sizes, it is possible that the overlap between sizes is large and that numerous individuals may be accommodated in more than one mask size. If the size overlap is large, considerable measurement error during size issue can be tolerated. On the other hand, a narrow overlap between sizes leaves little room for interobserver measurement error, and

increases the probability of misfitting individuals in the field. In addition, interobserver error increases the probability of insufficient supplies in the proper sizes at a give issue point.

Because of these problems a more in-depth fit-test study is recommended, one whose objective is to define the facial variability that can be fitted into each mask size and, conversely, the range of mask sizes that will fit any given face size. Since the range of facial sizes that can be accommodated in each size is unknown, it is uncertain whether all three sizes are actually needed. It is conceivable that the number of sizes can be reduced. If true, this could result in a large savings in manufacturing costs, and simplify the problem of tariffing and distribution. To accomplish these ends, subjects will need to be quantitatively fit-tested in all three mask sizes to determine which size will fit and protect a subject and which sizes will not. Several facial measurements should be taken to help define the facial variability as it relates to mask size. Menton-Sellion Length measurements should be repeated by several measurers, preferably including some military personnel whose responsibilities include fitting masks, to assess the amount of interobserver variability in this dimension, and consequently mask size assignment. To obtain reliable results, a large sample size would be needed.

Benefits to be gained from conducting such a study are numerous. The first is to obtain a sound basis for evaluating whether sizing intervals need to be revised from those currently in use. This is important for both future fitting and tariffing of the masks. Secondly, the consistency with which properly fitting masks are issued to Air Force personnel can be determined with some confidence. Third, given the measuring problems discussed above and the uncertainty over whether existing sizing categories are the optimum ones, establishment of tariffs at this time is questionable. More reliable tariffs could be established with information gained by the proposed study.

Finally, although interobserver measuring error can never be eliminated, it is desirable to reduce it as much as possible. One way is to provide written directions which complement the pictorial ones provided in T.O. 14P4-15-1. These would be tested in the proposed study by having military personnel measure individuals according to their normal procedure, and again with the addition of written instructions. The current sizing instrument also should be evaluated for ease and accuracy of use. If necessary, new instruments may have to be designed, manufactured and incorporated into the above testing procedures. The amount of interobserver variability between the different sets of measurements would be compared to determine whether they resulted in reduced interobserver differences.

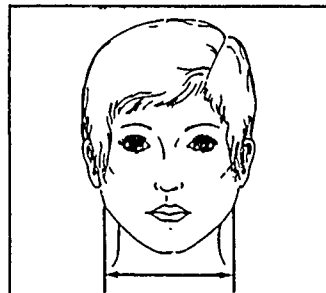
The above recommendations offer the only means of arriving at reliable fitting criteria and tariffing based on facial dimensions. Fit testing and tariffing based on prior assumptions concerning the facial dimensions that can be fitted in small, medium, and large sizes gives an inadequate understanding of the actual range of accommodation for the sizes. Tariffing based upon interpolation of the present sizing categories to the current Air Force population is the best approach for tariffing both models of the MCU-2/P given only these test data and it may serve well enough for the initial acquisitions.

APPENDIX A
MEASUREMENT DESCRIPTIONS

For all dimensions the subject is seated with mouth closed and teeth occluded. The head is positioned in the Frankfort plane.

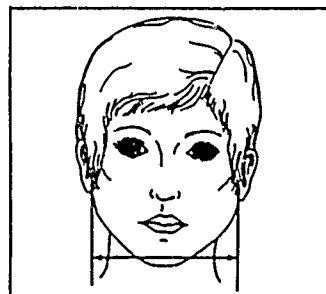
1. BIGONION BREADTH

Using a spreading caliper, the horizontal distance of the face at the gonion landmarks.



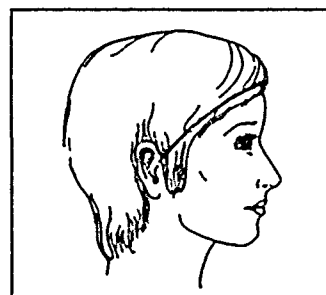
2. BITRAGION BREADTH

Using a spreading caliper, the horizontal breadth of the face between the tragions.



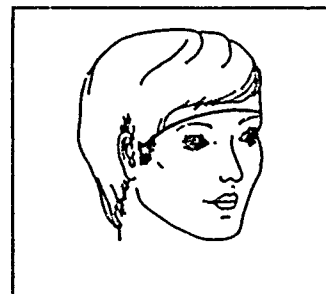
3. BITRAGION-CRINION ARC

Using a tape, the surface distance between the tragions when passing over the crinion landmark.



4. BITRAGION-FRONTAL ARC

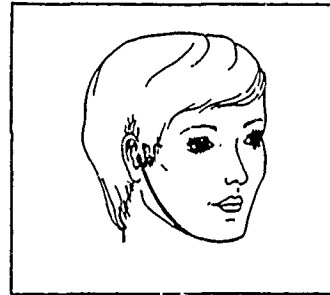
Using a tape, the surface distance between tragions when passing over the minimum frontal landmark.



MEASUREMENT DESCRIPTIONS (cont'd)

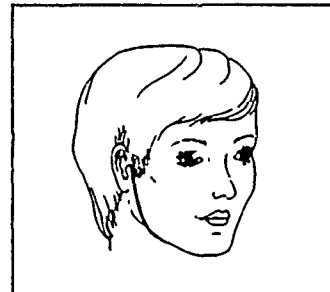
5. BITRAGION-MENTON ARC

Using a tape, the surface distance between tragions when passing over the menton landmark.



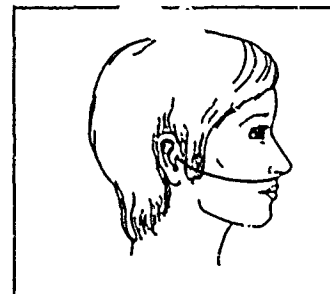
6. BITRAGION-SUBMANDIBULAR ARC

Using a tape, the surface distance between tragions when passing over the submandibular landmark.



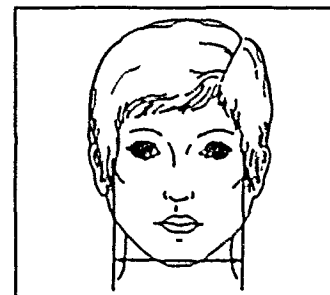
7. BITRAGION-SUBNASALE ARC

Using a tape, the surface distance between tragions when passing over the subnasale landmark.



8. BIZYGOMATIC BREADTH

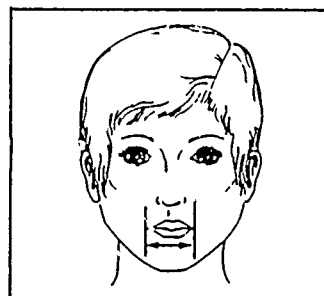
Using a spreading caliper, the maximum horizontal breadth of the face between the zygion landmarks.



MEASUREMENT DESCRIPTIONS (cont'd)

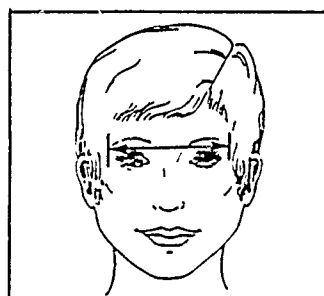
9. LIP LENGTH

Using a sliding caliper, the horizontal distance between the cheilions.



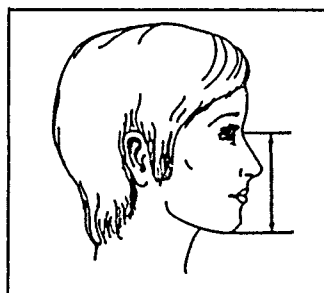
10. MAXIMUM FRONTAL BREADTH

Using spreading calipers, the horizontal distance between the zygo-frontale landmarks.



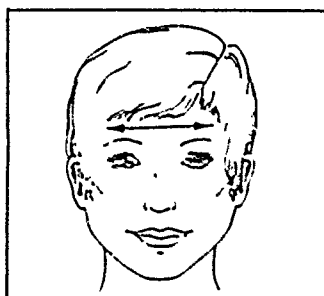
11. MENTON-SELLION LENGTH

Using a sliding caliper, the distance from the menton to the sellion landmark.



12. MINIMUM FRONTAL BREADTH

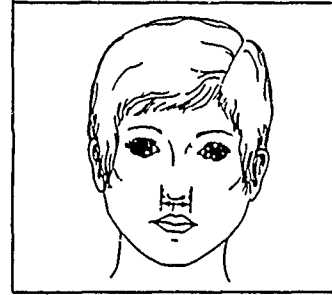
Using spreading calipers, the horizontal distance between the fronto-temporale landmarks.



MEASUREMENT DESCRIPTIONS (cont'd)

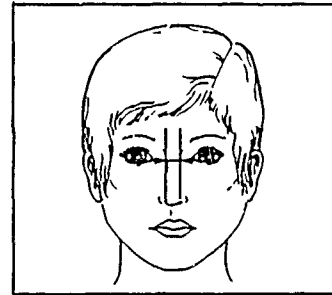
13. NASAL BREADTH

Using a sliding caliper, the maximum horizontal breadth of the nose at the junction with the face.



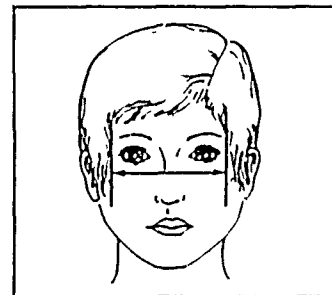
14. NASAL ROOT BREADTH

Using a sliding caliper, the horizontal width of the nasal root at the narrowest point.



15. TEMPORAL DEPRESSION BREADTH

Using a spreading caliper, the minimum horizontal breadth of the face between the temporal depressions.

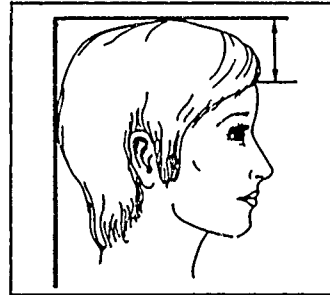


Headboard Measurements

For dimensions 16 through 42, the subject sits under the headboard looking straight ahead. The headboard is adjusted so that the horizontal and vertical planes are in direct contact with the top and back of the subject's head. The head is positioned in the Frankfort plane. All measurements are taken from the right side of the head, unless otherwise indicated.

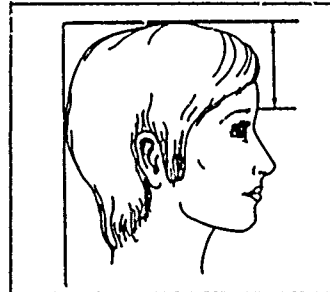
16. VERTEX TO CRINION

Vertical distance between the horizontal plane of the headboard and the crinion landmark.



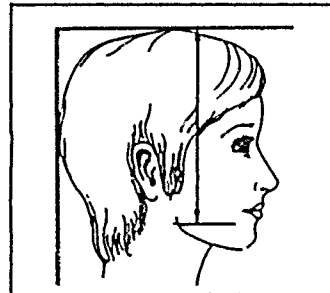
17. VERTEX TO GLABELLA

Vertical distance between the horizontal plane of the headboard and the glabella landmark.



18. VERTEX TO GONION

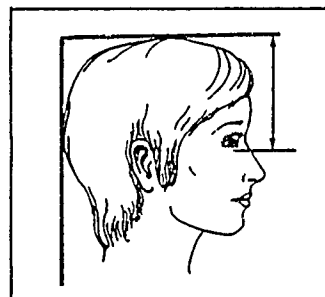
Vertical distance between the horizontal plane of the headboard and the gonion landmark.



MEASUREMENT DESCRIPTIONS, Headboard (cont'd)

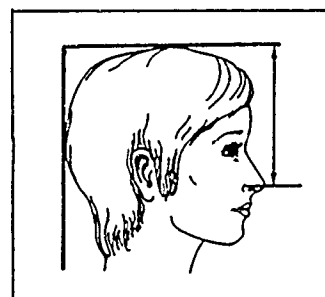
19. VERTEX TO INFRAORBITALE

Vertical distance between the horizontal plane of the headboard and the infraorbitale landmark.



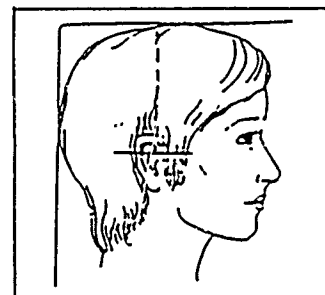
20. VERTEX TO LATERAL ALA

Vertical distance between the horizontal plane of the headboard and the lateral ala landmark.



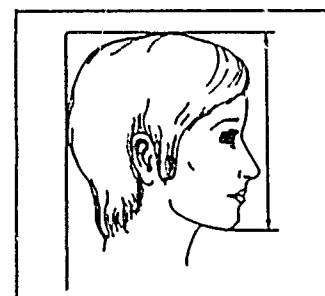
21. VERTEX TO LEFT TRAGION

Vertical distance between the horizontal plane of the headboard and the left tragon.



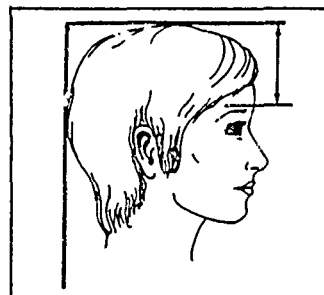
22. VERTEX TO MENTON

Vertical distance between the horizontal plane of the headboard and the menton landmark.



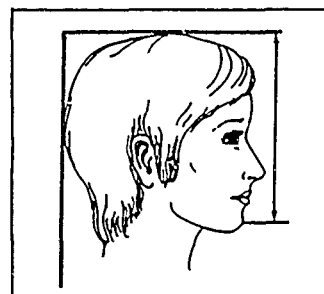
23. VERTEX TO MINIMUM FRONTAL

Vertical distance between the horizontal plane of the headboard and the frontotemporale landmark.



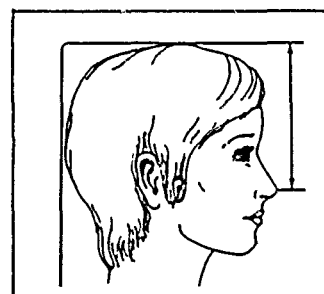
24. VERTEX TO PROMENTON

Vertical distance between the horizontal plane of the headboard and the promenton landmark.



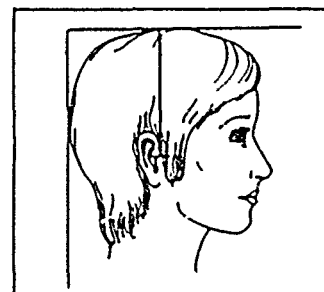
25. VERTEX TO PRONASALE

Vertical distance between the horizontal plane of the headboard and the pronasale landmark.



26. VERTEX TO RIGHT TRAGION

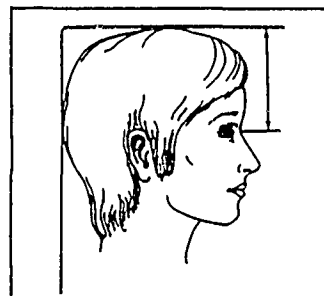
Vertical distance between the horizontal plane of the headboard and the right tracion landmark.



MEASUREMENT DESCRIPTIONS, Headboard (cont'd)

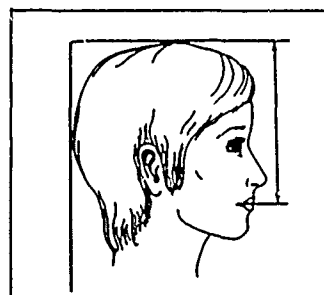
27. VERTEX TO SELLION

Vertical distance between the horizontal plane of the headboard and the sellion landmark.



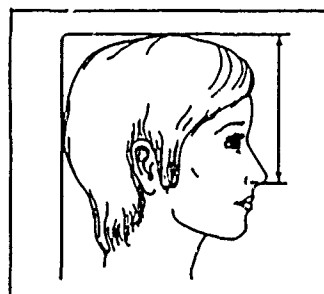
28. VERTEX TO STOMION

Vertical distance between the horizontal plane of the headboard and the stomion landmark.



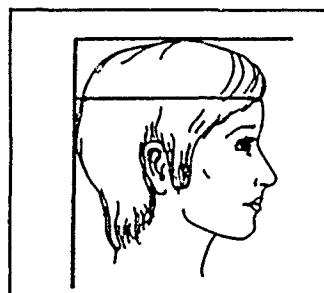
29. VERTEX TO SUBNASALE

Vertical distance between the horizontal plane of the headboard and the subnasale landmark.



30. WALL TO CRINION

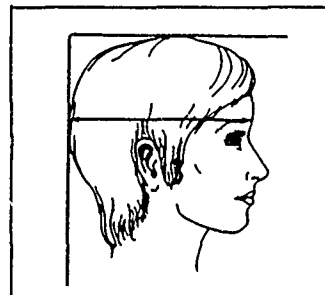
Horizontal distance between the vertical plane of the headboard and the crinion landmark.



MEASUREMENT DESCRIPTIONS, Headboard (cont'd)

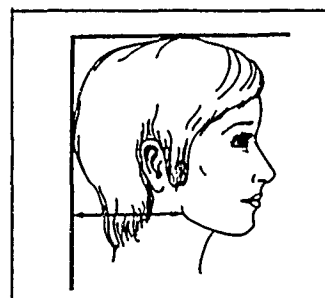
31. WALL TO GLABELLA

Horizontal distance between the vertical plane of the headboard and the glabella landmark.



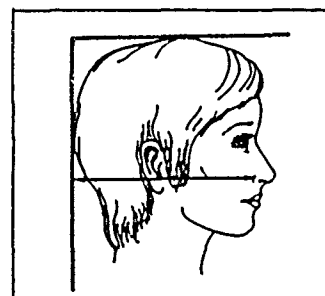
32. WALL TO GONION

Horizontal distance between the vertical plane of the headboard and the gonion landmark.



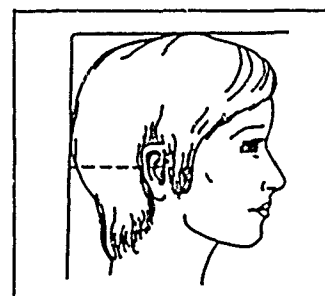
33. WALL TO LATERAL ALA

Horizontal distance between the vertical plane of the headboard and the lateral ala landmark.



34. WALL TO LEFT TRAGION

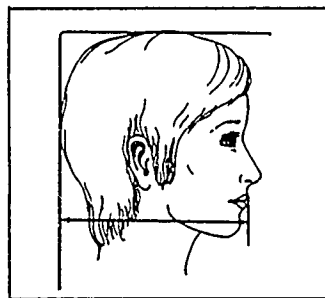
Horizontal distance between the vertical plane of the headboard and the left tragon landmark.



MEASUREMENT DESCRIPTIONS, Headboard (cont'd)

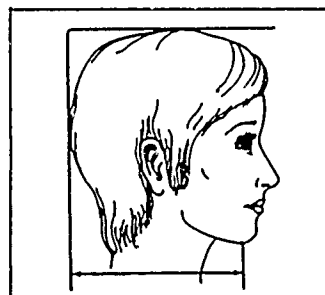
35. WALL TO LIP PROTRUSION

Horizontal distance between the vertical plane of the headboard and the point of maximum protrusion of the lips.



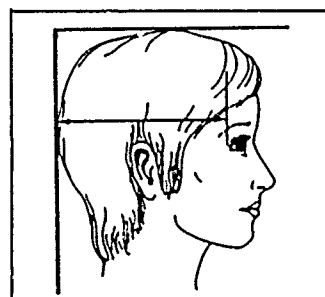
36. WALL TO MENTON

Horizontal distance between the vertical plane of the headboard and the menton landmark.



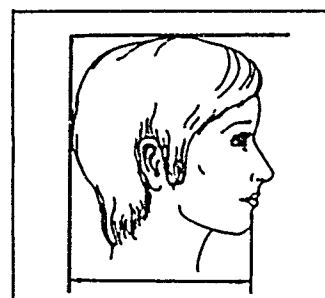
37. WALL TO MINIMUM FRONTAL

Horizontal distance between the vertical plane of the headboard and the frontotemporale landmark.



38. WALL TO PROMENTON

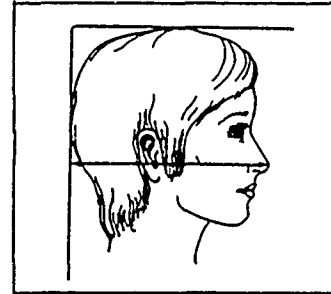
Horizontal distance between the vertical plane of the headboard and the promenton landmark.



MEASUREMENT DESCRIPTIONS, Headboard (cont'd)

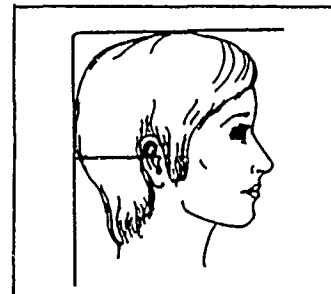
39. WALL TO PRONASALE

Horizontal distance between the vertical plane of the headboard and the pronasale landmark.



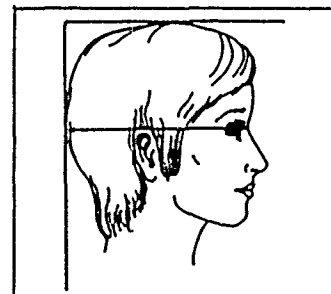
40. WALL TO RIGHT TRAGION

Horizontal distance between the vertical plane of the headboard and the right tragon landmark.



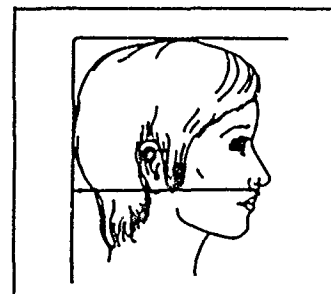
41. WALL TO SELLION

Horizontal distance between the vertical plane of the headboard and the sellion landmark.



42. WALL TO SUBNASALE

Horizontal distance between the vertical plane of the headboard and the subnasale landmark.



APPENDIX B

LANDMARK DESCRIPTIONS

Cheilion -	The most lateral point of the juncture of the lips with the facial skin at the corner of the mouth, determined by visual inspection.
Crinion -	The lowest point of the hairline in the midsagittal plane on the top of the forehead, determined by visual inspection.
Frontotemporale -	The deepest point of indentation of the temporal crest of the frontal bone above the browridges, determined by palpation.
Glabella -	The most anterior point in the midsagittal plane on the forehead between the browridges, determined by palpation and visual inspection.
Gonion -	The most lateral point on the posterior angle of the jaw, determined by palpation.
Infraorbitale -	The lowest point on the inferior border of the right orbit, determined by palpation.
Lateral Ala -	The most lateral point of the flare of the nose, determined by visual inspection.
Menton -	A point in the midsagittal plane on the curvature of the lower jaw, on a line approximating 45 degrees from vertical and perpendicular to a tangent of the curvature, determined by palpation.
Promenton -	The most anterior point of the chin, in the midsagittal plane, determined by visual inspection.
Pronasale -	The most anterior point of the nose, in the midsagittal plane, determined by visual inspection.
Sellion -	The point of deepest depression at the top of the nose, determined by visual inspection.
Stomion -	The point at which the lips touch in the midsagittal plane, determined by visual inspection.
Submandibular -	The juncture of the jaw and the neck in the midsagittal plane, determined by visual inspection.
Subnasale -	The point of intersection of the groove of the upper lip (philtrum) with the nose, on the midsagittal plane, determined by visual inspection.

Temporal Depression -	The point of deepest depression at the temples, determined by visual inspection and palpation.
Tragion -	The deepest point of the notch just above the tragus of the ear, determined by visual inspection.
Zygion -	The most lateral point of the zygomatic arch, determined by visual inspection and palpation.
Zygofrontale -	The most lateral point of the frontal bone where it forms the upper margin of the eye socket, determined by palpation.

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Clauser, Charles E., Pearl Tucker, John T. McConville, Edmund Churchill, Lloyd L. Laubach and Joan Reardon. 1972. Anthropometry of Air Force Women, AMRL-TR-70-5 (AD 743 113), Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Hertzberg, H.T.E., Edmund Churchill, C.W. Dupertius, Robert M. White and A. Damon. 1963. Anthropometric Survey of Turkey, Greece and Italy. MacMillan Company, New York.

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