

Anthropometrics Research to Develop Respirator Fit Test Panels

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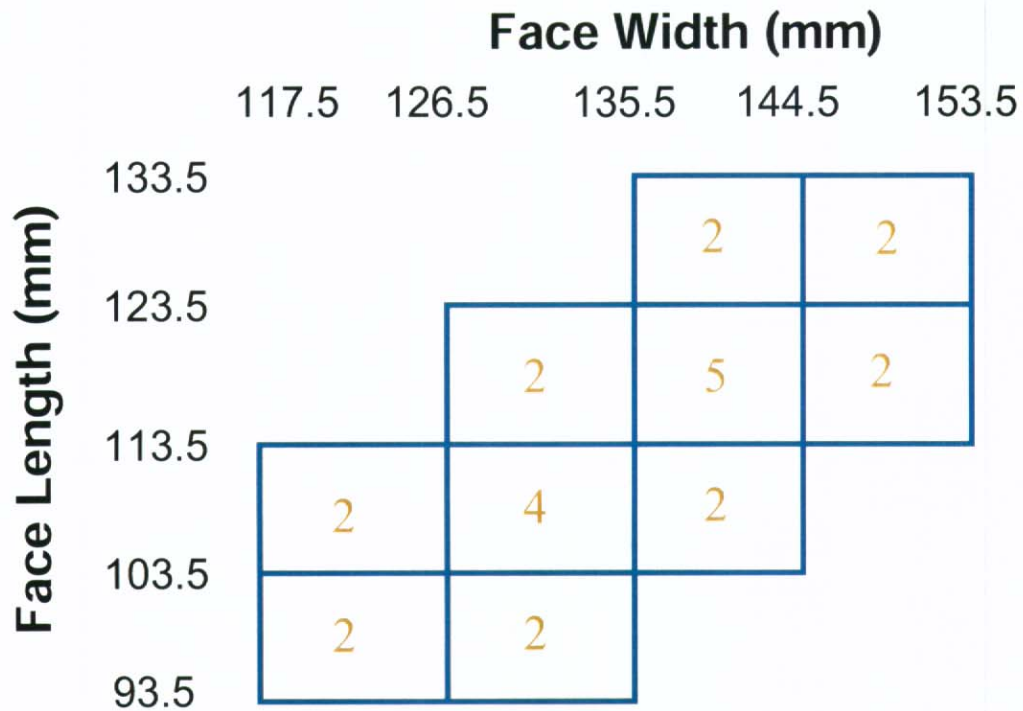
Importance of Test Panels

- Anthropometric panels of facial dimensions are relied upon to provide sizing reference for respirators in many applications
 - APF establishment
 - Respirator design and development
 - TIL certification and standards
 - Research standards

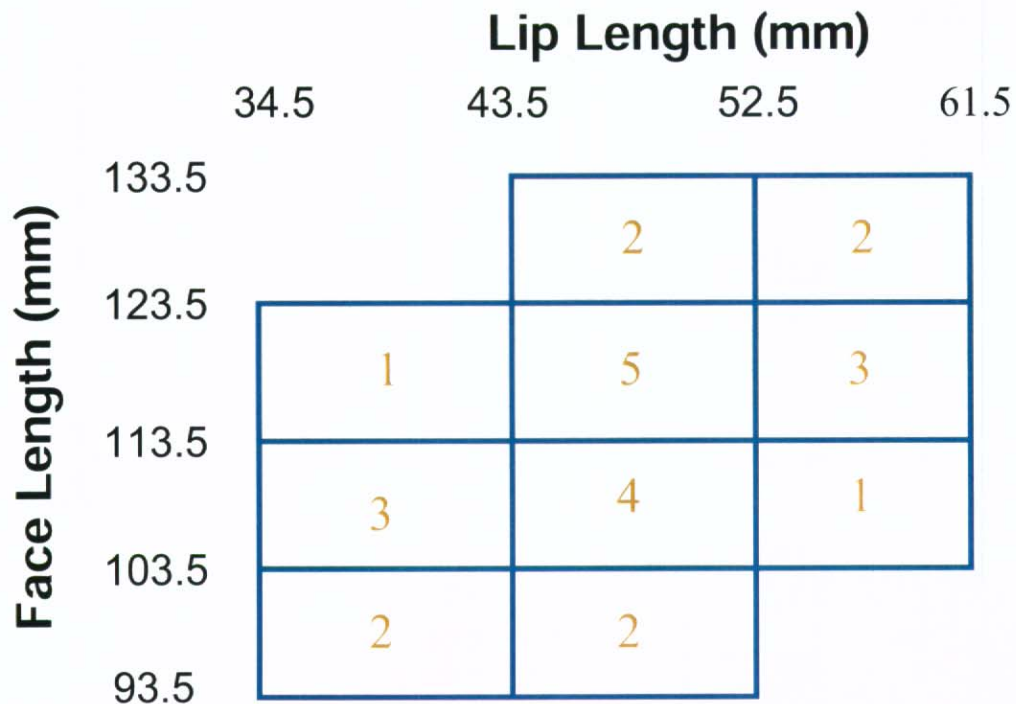
History of LANL Panels

- No survey of facial dimensions of the U.S. civilian workers
- The 1967 and 1968 US Air Force anthropometric survey
- The facial anthropometry was assumed to be representative of U.S. adults
- Face length, face width, and lip length

LANL 25-Member Panel for Full-Facepiece Respirators



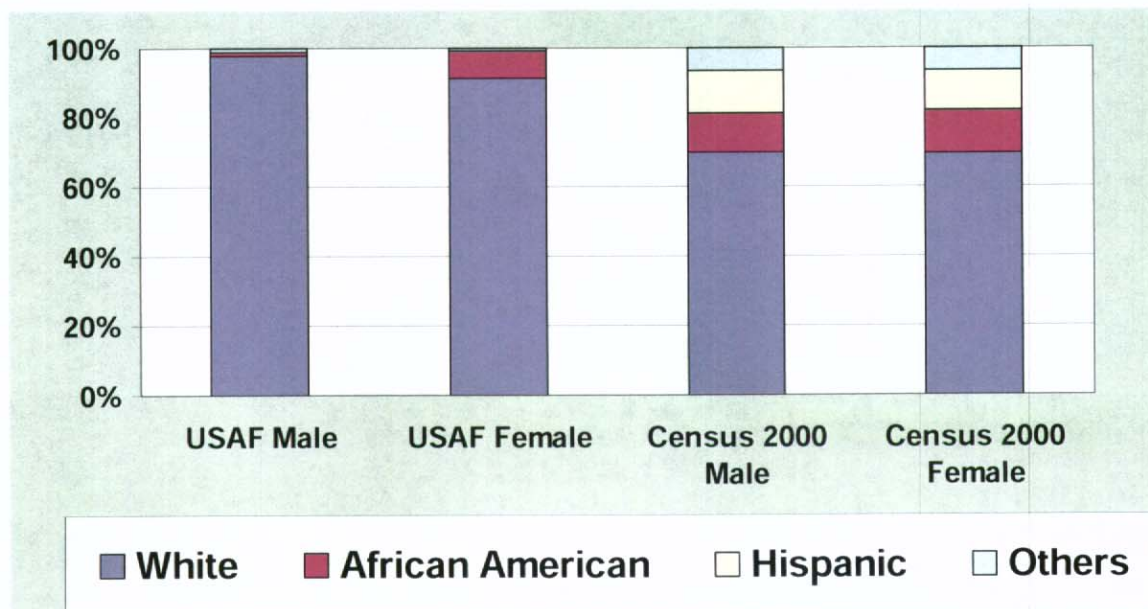
LANL 25-Member Panel for Half-Mask Respirators



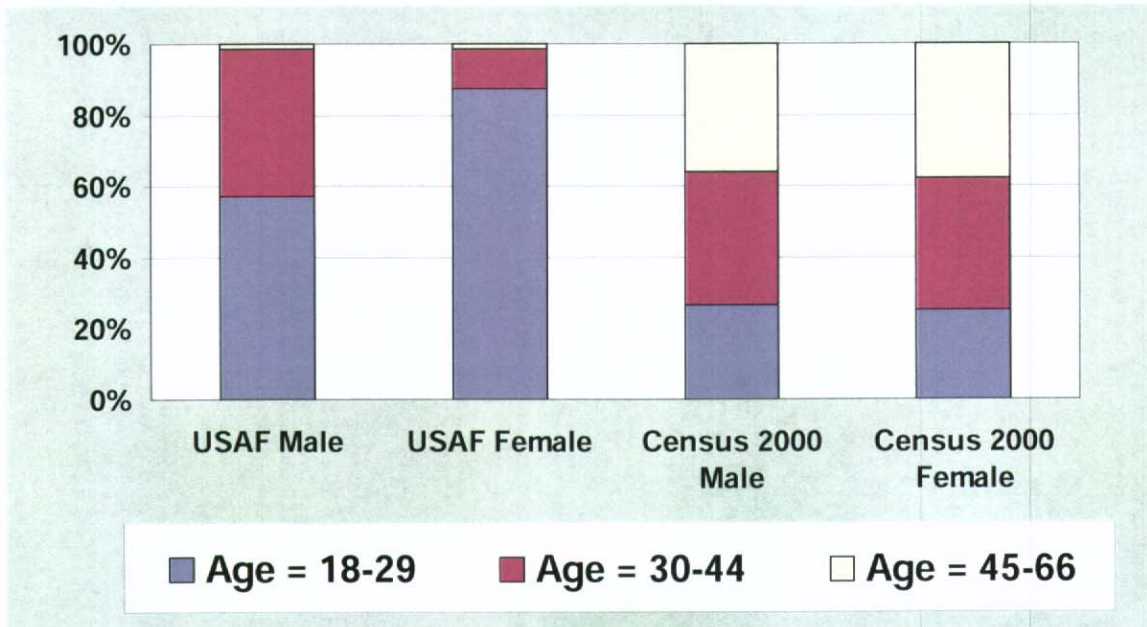
Panel Applicability Problem

- Concern raised:
 - Demographics of the U.S. population has changed over the last 30 years
 - Military data may not fairly represent the diversity of face sizes

Race Distribution of 1967–1968 Air Force Survey Subjects and 2000 Census Data



Age Distribution of 1967–1968 Air Force Survey Subjects and 2000 Census Data



Panel Applicability Problem

▪ Scientific Evidence:

- Leigh measured 1,467 employees (1975)
- Bureau of Mines surveyed 48 male mine rescue workers (1978)
- NIOSH found that 16% of Civilian American and European Surface Anthropometry Resources (CAESAR) subjects were outside the limits of the LANL panel for full-facepiece respirators (2002)
- Lip length is not appropriate for half-masks (Oestenstad, 1990, 1992)

NIOSH Research

- Develop an anthropometric database detailing the face-size distributions of respirator users
- Evaluate the applicability of the LANL respirator fit test panels
- Investigate correlation between facial dimensions and respirator fit
- Develop new respirator fit test panels

Panel Development Timeline

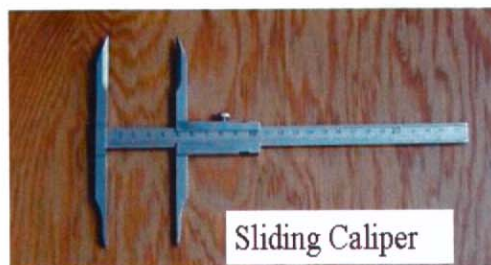
- **Protocol development and review**
 - November 2002
- **Data collection**
 - September 2003
- **Data analyses & report preparation**
 - May 2004
- **First Proposed NIOSH panel**
 - August 2004
- **Peer-review**
 - January 2007

Anthropometric Survey

- A stratified sampling plan was used
 - Two-gender strata: male and female
 - Four race/ethnic groups:
White, African American, Hispanics, and others
 - Three age groups:
18–29, 30–44, and 45–66

- Sample size: 3,997

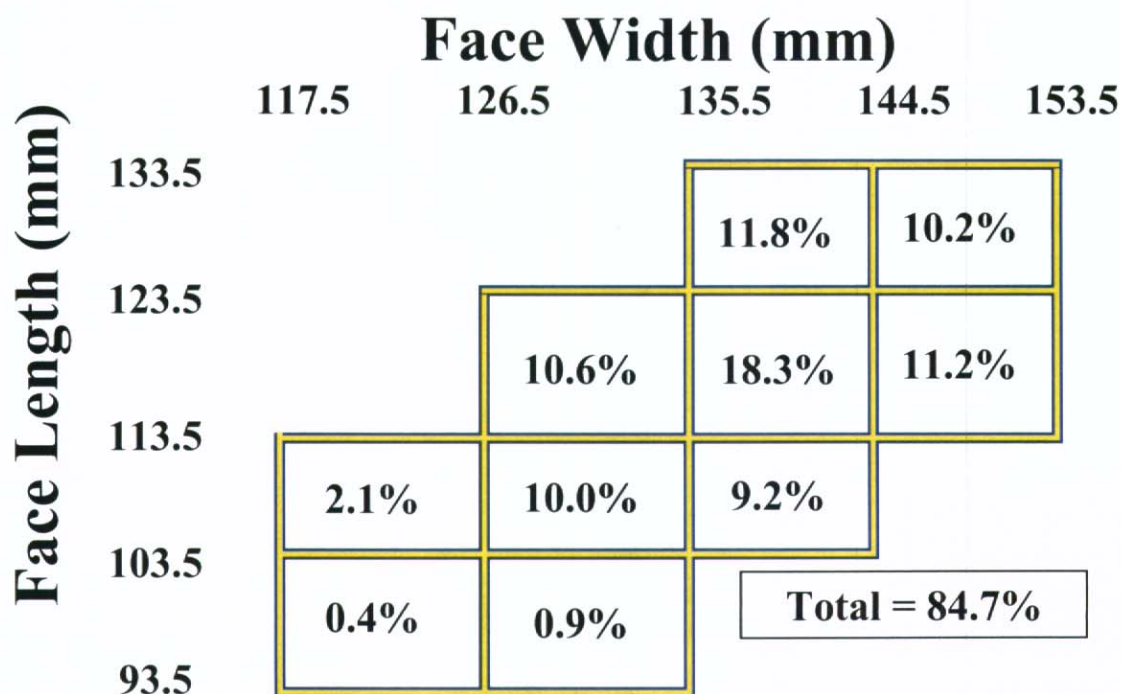
Traditional Measurements



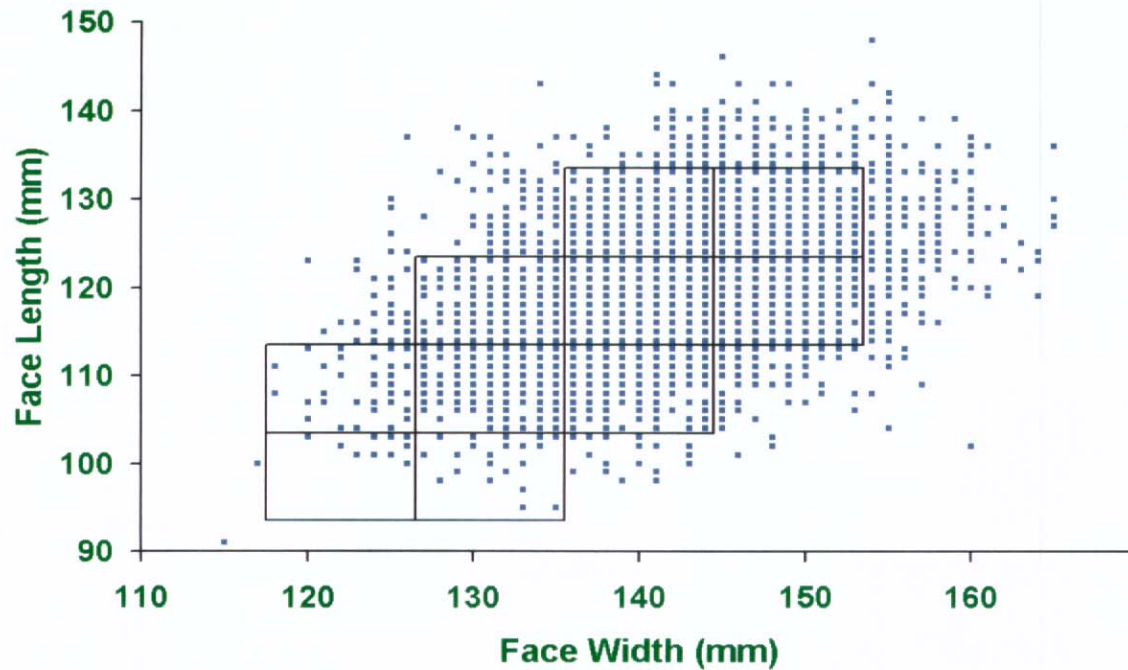
Anthropometric Data Base

Race	Male				Female			
	Age group			Total	Age group			Total
	18-29	30-44	45-65		18-29	30-44	45-66	
White	271	611	485	1,367	151	194	174	519
African American	101	255	278	634	51	213	325	589
Hispanic	155	182	75	412	53	36	37	126
Other	24	47	59	130	52	65	103	220
Total	551	1095	897	2,543	307	508	639	1,454

Fitting NIOSH Data into LANL Panel



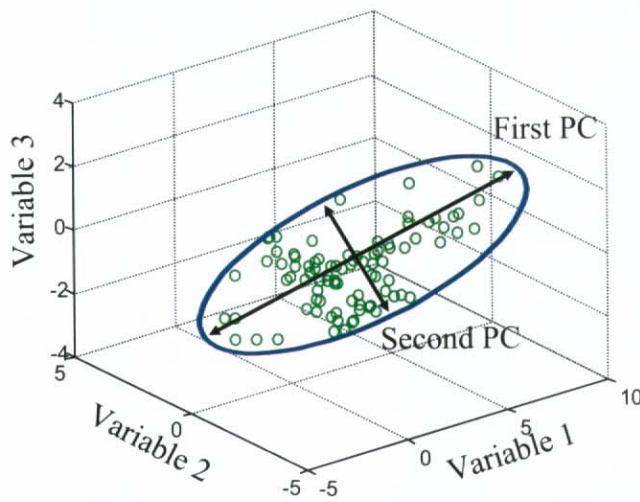
Bivariate Distribution against LANL Panel



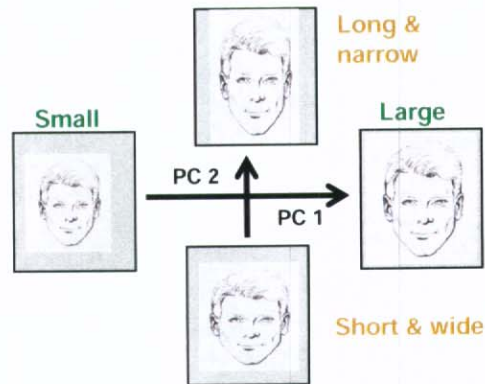
Development of New Panels

- Two approaches:
 - Bivariate
 - Principal component analysis

Principal Component Analysis: Theory



PCA defines a new coordinate system using linear combinations of the original variables to describe trends in the data



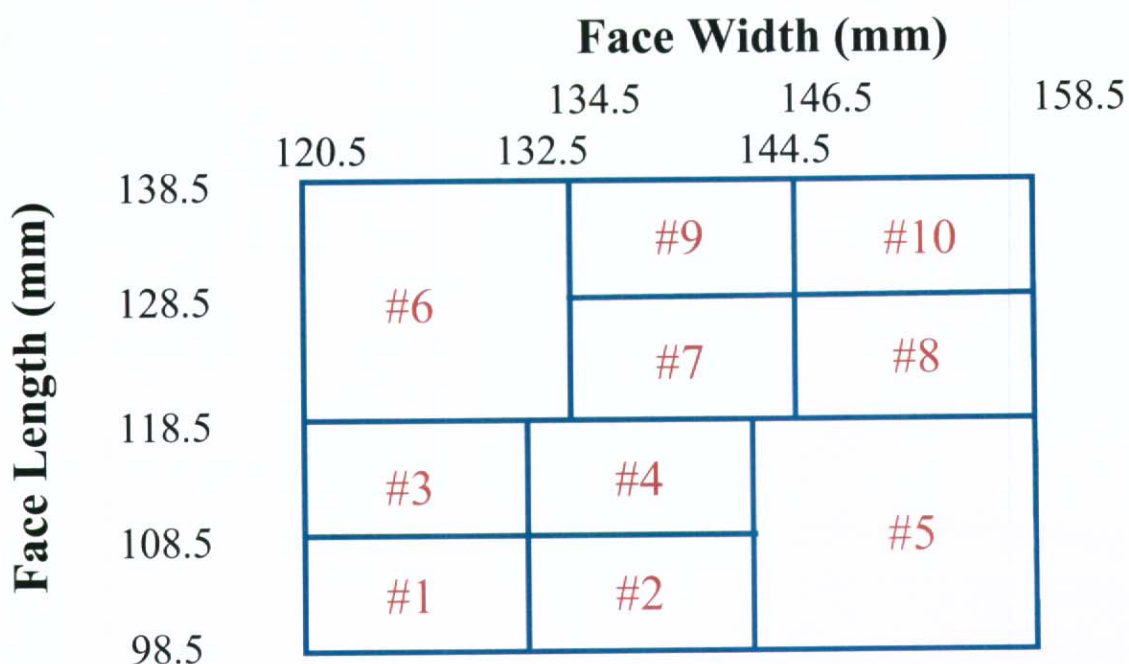
Criteria for Selecting Dimensions

- The dimensions are relevant to respirator fit
 - Literature review
 - Expert opinion
- The dimensions excluded can be predicted by the dimensions included in the PCA
- The number of dimensions is reasonable
- Dimensions that are difficult to measure and/or highly variable are excluded

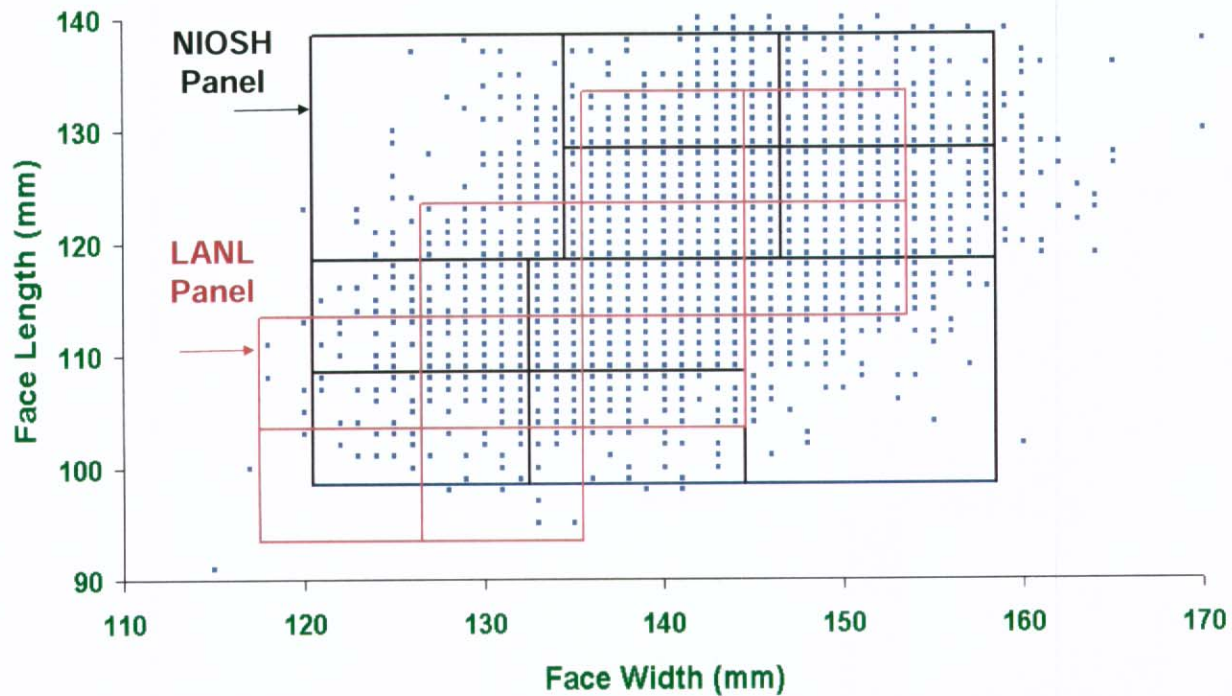
NIOSH Bivariate Panel

- 10-cell panel
- 25 subjects
- The number of subjects can be adjusted
- At least two subjects for each cell
- Matching the distribution of the population
- Face length and face width were selected to define the bivariate panel for both half-masks and full-facepiece respirators

NIOSH Bivariate Panel



Scatter Plot against NIOSH & LANL Panels



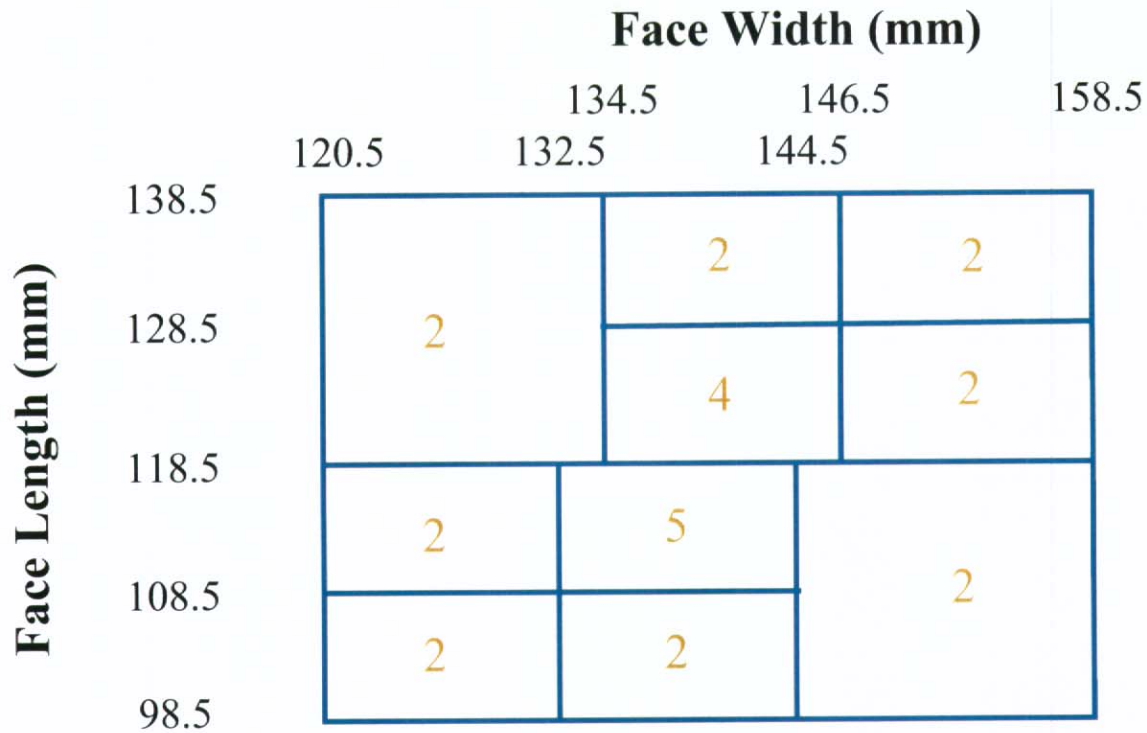
Distribution of US Workers by NIOSH Panel

Total = 97.7%

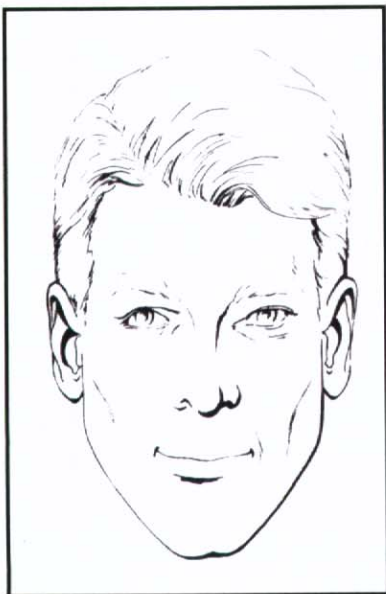
Face Width (mm)

Face Length (mm)	Face Width (mm)		
	120.5	132.5	144.5
138.5		5.2%	3.5%
128.5	5.7%	21.3%	8.7%
118.5	10.5%	25.0%	7.1%
108.5	5.5%	5.3%	
98.5			

25-Member Panel



Dimensions Used in the PCA Panel



Minimum Frontal Breadth

Face Width

Bigonial Breadth

Face Length

Interpupillary Breadth

Head Breadth

Nose Protrusion

Nose Breadth

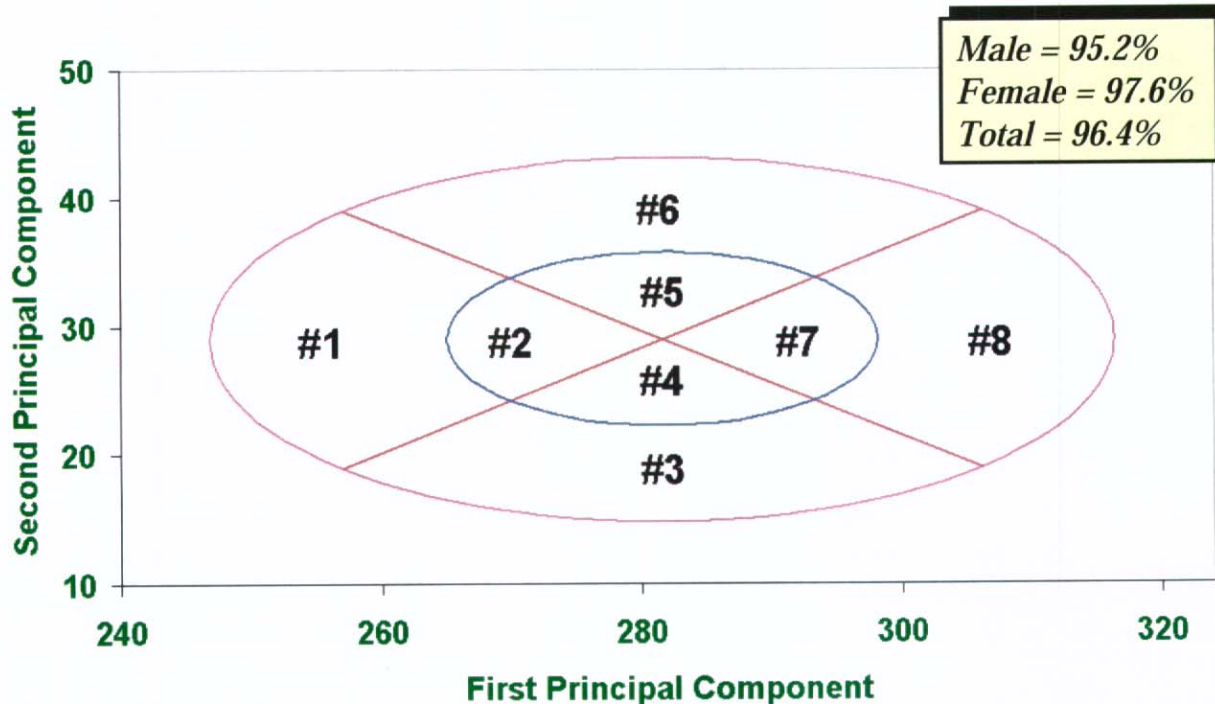
Nasal Root Breadth

Subnasale-Sellion Length

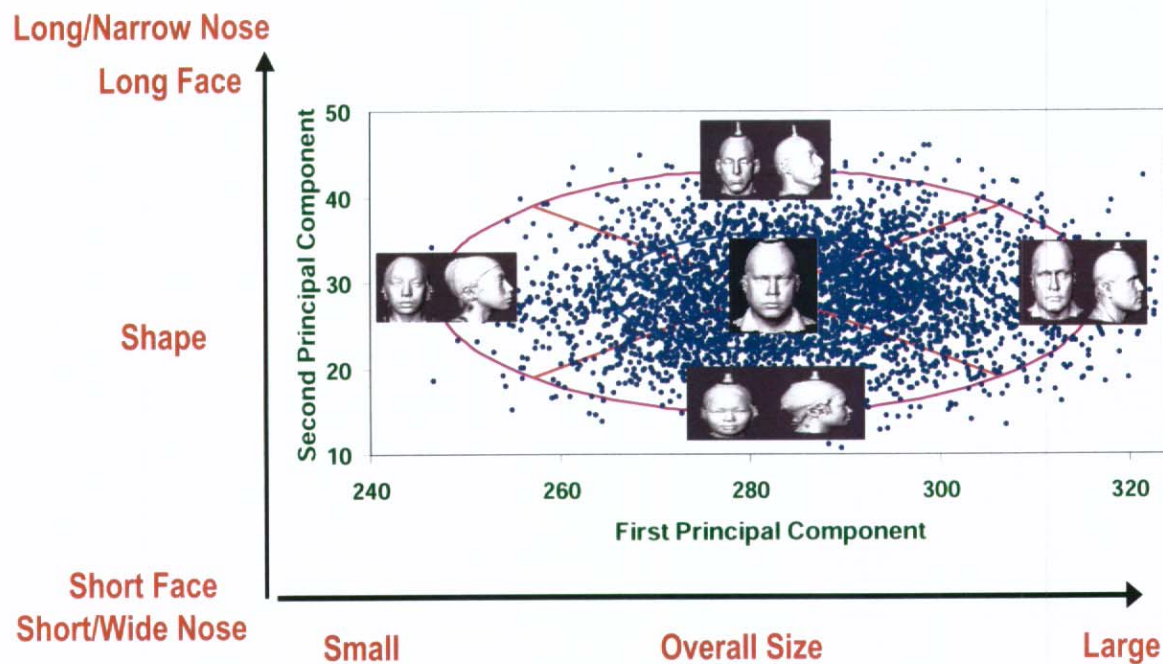
Principal Component Analysis (Males and Females)

<u>Variables</u>	Eigenvectors	
	<u>PC 1 (42%)</u>	<u>PC 2 (16%)</u>
Minimum Frontal Breadth	0.3433	-0.1530
Face Width	0.4265	-0.0391
Bigonial Breadth	0.3727	-0.0933
Face Length	0.3296	0.3598
Interpupillary Breadth	0.3635	-0.1731
Head Breadth	0.3722	0.0133
Nose Protrusion	0.1136	0.5518
Nose Breadth	0.3011	-0.2108
Nasal Root Breadth	0.2023	-0.3412
Subnasale-Sellion Length	0.1937	0.5843

NIOSH PCA Panel



Facial Shape Trends



Distribution of U.S. Workers by the PCA Panel

Cell	Male (%)	Female (%)	Total (%)
1	1.1	22.0	11.6
2	5.7	21.6	13.7
3	5.6	17.8	11.7
4	9.1	15.5	12.3
5	16.7	8.1	12.4
6	17.9	6.6	12.2
7	18.4	5.1	11.7
8	20.8	1.0	10.8
Total	95.2	97.6	96.4

25-Member PCA Panel

Cell	Male	Female	Total
1	0	3	3
2	1	3	4
3	1	2	3
4	1	2	3
5	2	1	3
6	2	1	3
7	2	1	3
8	3	0	3
Total	13	12	25

Conclusions

- Two panels were developed
- Respirators designed to fit these panels are expected to accommodate more than 95% of the current U.S. civilian workforce
- Both panels represent an improvement over the LANL panels used today
- Training video on facial measurement and computer program are available upon request

Journal Publications

1. Zhuang Z, Guan J, Hsiao H, and Bradtmiller B [2004]. Evaluating the Representativeness of the LANL Respirator Fit Test Panels for the Current U.S. Civilian Workers. *Journal of the International Society for Respiratory Protection*, 21(III-IV):83-93.
2. Zhuang Z and Bradtmiller B [2005]. Head-and-Face Anthropometric Survey of U.S. Respirator Users. *J Occup. Environ. Hyg.*, 2, 567-577.
3. Zhuang Z, Coffey CC, and Berry Ann R [2005]. The effect of subject characteristics and respirator features on respirator fit. *J Occup. Environ. Hyg.* 2, 641-649.
4. Roberge R, Zhuang Z, Stein, L [2006] Association of Body Mass Index with Facial Dimensions for Defining Respirator Fit Panels. *Journal of the International Society for Respiratory Protection*, 23(I-II):44-52.
5. Zhuang Z, Bradtmiller B, and Shaffer RE [2007]. New Respirator Fit Test Panels Representing the Current U.S. Civilian Workforce. *Journal of Occupational and Environmental Hygiene* (In press).
6. Zhuang Z, Roberge R, Landsittel D, Stein L, Viscusi DJ and Shaffer RE [2007]. Facial anthropometric differences among race/age groups. In preparation to submit to the *Annals of Occupational Hygiene*.

New Respirator Fit Test Panels Representing the Current U.S. Civilian Work Force

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The fit test panels currently used for respirator research, design, and certification are 25-subject panels developed by Los Alamos National Laboratory (LANL) and are based on data from the 1967 and 1968 anthropometric surveys of U.S. Air Force personnel. Military data do not represent the great diversity in face size and shape seen in civilian populations. In addition, the demographics of the U.S. population have changed over the last 30 years. Thus, it is necessary to assess and refine the LANL fit test panels. This paper presents the development of new respirator fit test panels representative of current U.S. civilian workers based on an anthropometric survey of 3997 respirator users conducted in 2003. One panel was developed using face length and face width (bivariate approach) and weighting subjects to match the age and race distribution of the U.S. population as determined from the

INTRODUCTION

In the early 1970s, the Respirator Research and Development Section of the Los Alamos National Laboratory (LANL) was asked by the National Institute for Occupational Safety and Health (NIOSH) to develop anthropometric specifications for fit testing full- and half-facepiece respirators. Because no survey of face dimensions of the U.S. workers was available at that time, the LANL team decided to develop these specifications based on the 1967 and 1968 U.S. Air Force (USAF) anthropometric surveys.⁽¹⁻²⁾

Prompted by concerns over the possible inapplicability of military data to civilian workers, the Los Alamos team cur

Presentations

1. Zhuang Z, Coffey C, BerryAnn R, Lawrence RB, Viscusi D, The effect of subject characteristics and respirator features on respirator fit, American Industrial Hygiene Association Conference & Expo, Dallas, TX May 10-15, 2003.
2. Zhuang, et al. "Anthropometric Survey of Respirator Users" at the 2004 American Industrial Hygiene Conference and Exposition (AIHCE), Atlanta, Georgia, May 10, 2004.
3. Zhuang, et al. "Evaluating the Representativeness of the LANL Respirator Fit Test Panels for the Current U.S. Civilian Workers" at the ISRP 12th International Conference, Yokohama, Japan, November 9-12, 2004.
4. Zhuang, et al. "New Respirator Fit Test Panels Representing the Current U.S. Civilian Workforce" at the ISRP 12th International Conference, Yokohama, Japan, November 9-12, 2004.
5. Zhuang Z, Williams LM, Viscusi DJ and Shaffer RE. Facial anthropometric differences among race/age groups. American Industrial Hygiene Conference and Exposition, Anaheim, CA, May 18-26, 2005.
6. Roberge, R., Zhuang Z., Stein, L., Association of Body Mass Index with Facial Dimensions for Defining Respirator Fit Panels. American Industrial Hygiene Conference and Exposition, Chicago, IL, May 14-16, 2006.
7. Z. Zhuang, B. Bradtmiller, and R.E. Shaffer, New Respirator Fit Test Panel Based on Principal Component Analysis. American Industrial Hygiene Conference and Exposition, Chicago, IL, May 14-16, 2006.
8. Zhuang Z, Viscusi D, and Reddington A. "Anthropometrics for developing headforms for testing respiratory and eye protective devices" at the ISRP 13th International Conference, Toronto, Canada, Aug 27- Sep 1, 2006.
9. Chen W, Zhuang Z, et al. "Head-and-face Anthropometric Survey of Chinese Respirator Users" at the 2007 American Industrial Hygiene Conference and Exposition (AIHCE), Philadelphia, PA, June 7, 2007.

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Thank You

Any questions?

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