Ergonomic Flight Suit Design

- Sizing System & Pattern -

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Agenda

- Introduction
- Objective of the Study
- Method: Ergonomic Design
- Results
  - Sizing System Design
  - Pattern Design
- Discussion

Importance of Flight Suit

Combat Flight Suit

Flight Operations

≥ 6 hours/day

Ground Operations

Complex cockpit environment

Ejection

Importance of Flight Suit

Combat Flight Suit

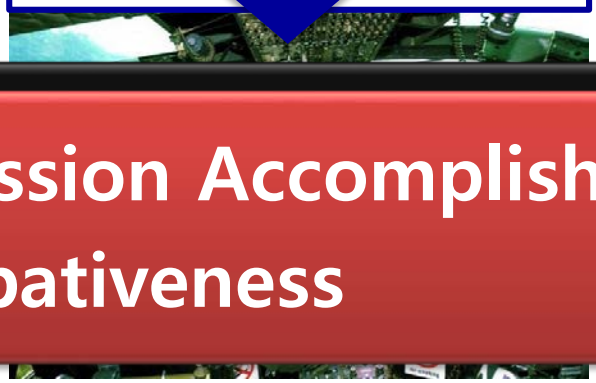
Flight Operations

Ground Operations

≥ 6 hours/day

Fit, Mobility, Convenience

Complex [illegible] **nvironment**



Ejection

Efficient Mission Accomplishment
Flight Combativeness

Problem Statement

❖ Usability survey by the ROK Air Force Headquarters in 2009

Sizing System

- **Difficult to find a right size**

<= 18 sizes based on stature & chest circumference by using the anthropometric data of 3,973 Army soldiers measured in 2002

Pattern

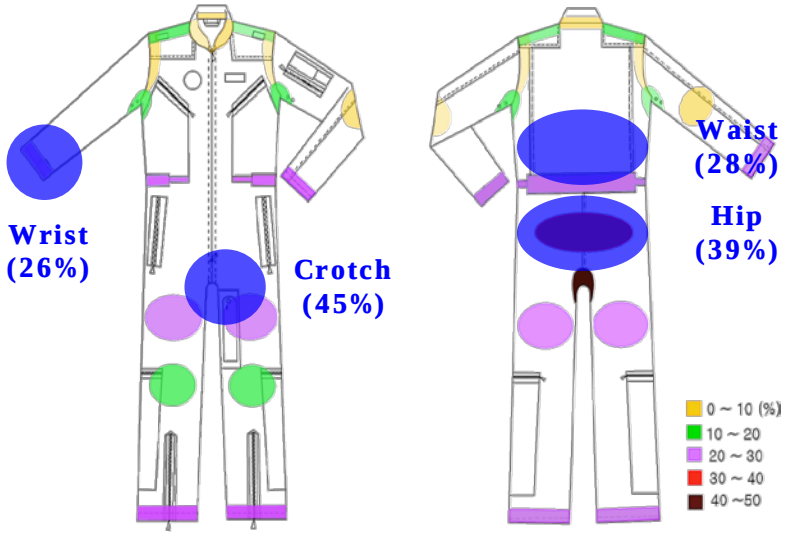
- **Lack of fit, discomfort in motion**

<= inappropriate application of anthropometric data

<= use of improper allowance

Chest circumference \ Stature	Special small < 163	Small < 168	Medium < 173	Large < 178	Special < 183	Special large < 190	Total
85 (82.5~87.4)							7.1 (115)
90 (87.5~92.4)		1.55	7.19	8.06			19.8 (320)
95 (92.5~97.4)			10.11	12.15	5.52		30.8 (497)
100 (97.5~102.4)			5.27	10.79	6.76		25.7 (415)
105 (102.5~107.4)			2.17	4.22	3.53		11.4 (184)
110 (107.5~112.4)			0.68		1.18		3.8 (64)
115 (112.5~117.4)			0.19		0.37		1.1 (17)
120 (117.5~122.4)					0.06		0.1 (1)
125 (122.5~127.4)					0.00		0.0 (0)
Total	0.18	5.64	28.83	39.00	21.14	5.21	100(1,613)

Existing sizing system



Problematic areas

Objective of the Study

Sizing System

New sizing system design for Korean pilots

↓

Target accommodation percentage: 95%

Korean pilot anthropometric data

Pattern

Improvement of the existing pattern designs

↓

Fit, mobility, convenience ↑

Contribution to combativeness through improvement of flight suit design

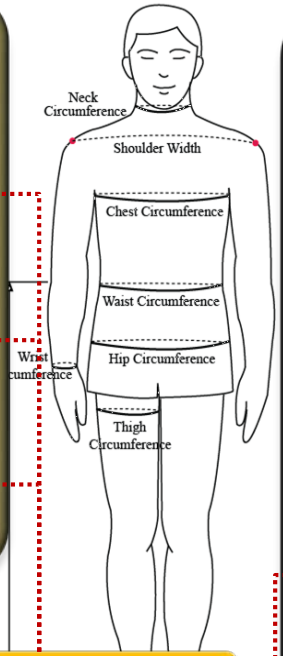
Research Framework

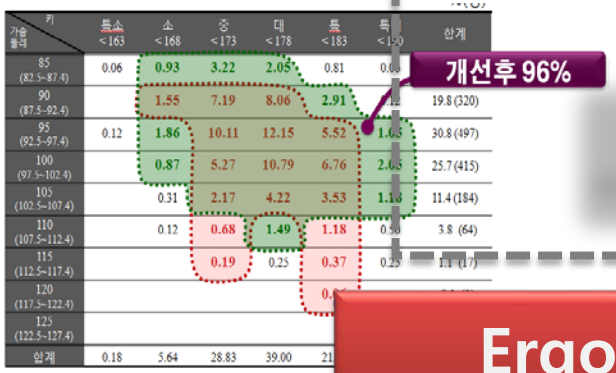
Sizing System

1) Analysis of Korean pilot anthropometric data

2) Improvement of the existing sizing system

3) Analysis of the accommodation percentage





Korean pilot anthropometric data

Pattern

1) Analysis of the characteristics of flight suit wearing and pattern

2) Survey the usability problems

3) Determination of improvement directions

4) Development of design equations:
design var. = f{anthropometric var. + allowance}

5) Application of the design equations to pattern design

Ergonomic Flight Suit Design

Evaluation of the Improved Design

Sizing System Design

- **ROK pilot anthropometric data:** 1,613 pilots (KBS8415-1022)
- **17% accommodation percentage ↑**

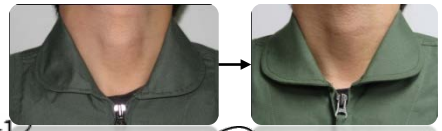
Size interval = 5 cm (1.97 inch)

Chest circumference \ Stature	Special small < 163	Small < 168	Medium < 173	Large < 178	Special < 183	Special large < 190	Total
85 (82.5~87.4)		0.93	3.22	2.05	New 23 sizes		7.1 (115)
90 (87.5~92.4)		1.55	7.19	8.06	2.91		19.8 (320)
95 (92.5~97.4)		1.86	10.11	12.15	5.52	1.05	30.8 (497)
100 (97.5~102.4)		0.87	5.27	10.79	6.76	2.05	25.7 (415)
105 (102.5~107.4)			2.17	4.22	3.53	1.18	11.4 (184)
110 (107.5~112.4)			0.68	1.49	1.18		
115 (112.5~117.4)	Existing 18 sizes		0.19		0.37		1.1 (17)
120 (117.5~122.4)		Before 80%			0.06		0.1 (1)
125 (122.5~127.4)					0.00		0.0 (0)
Total	0.18	5.64	28.83	39.00	21.14	5.21	100(1,613)

After 97%

Pattern Improvement

Design criteria	Part		Problem
Mobility	A	Neck	tight & tense
	B	Sleeve	excessive allowance (wrist, sleeve width)
	C	Collar	tight, unnatural
Fit	D	Waist	excessive allowance
	E	Crotch	tight & tense
	F	Hip	circumference: excessive allowance length: tight in sitting
	G	Slacks	circumference: excessive allowance length: short
Conve-nience	H	Pocket	inconvenient



Design Equations

	Anthropometric Variables	Design equation = *f*(anthropometric variable + allowance)	
		Existing	Improved
A	Chest circumference	Front: B/4+3.25 Back: B/4+3.75	Front: B/4+3.6 Back: B/4+3.6
B	Neck back breadth	B/12	B/12
C	Back breadth	B/5+6.37	B/5+5.4
D	Axilla breadth	Front : breast width/2+3.5 Back : shoulder width/2+4	Front: breast width/2+3 Back: shoulder width/2+3
E	Chest breadth	B/5+5.37	B/5+4.9
F	Shoulder breadth	Front: shoulder breath/2+5.05 Back: shoulder/2+5.85	Front: shoulder breath/2+4.6 Back: shoulder/2+5.6
G	Wrist circumference	Wrist circumference+18.6	Wrist circumference+14.9
H	Waist circumference	Front: waist circumference/4+5.85 Back: waist circumference/4+6.85	Front: waist circumference/4+4 Back: waist circumference/4+4
I	Hip circumference	Front: H/4+8.3 Back: H/4+7.3	Front: H/4+8 Back : H/4+7
J	Slack circumference	Front : ankle circumference/2+11.3 Back : ankle circumference/2+16.3	Front : ankle circumference/2+9.8 Back : ankle circumference/2+13.8
K	Hip front breadth	Hip circumference /4+2.3	Hip circumference /4+2.8
L	Crotch front	H/20+1.26	H/20+1.26
M	Hip back breadth	H/4+4.3	H/4+4.3
N	Crotch back	H/20+10.26	H/20+10.26
O	Hip line height	H/20+7.26	H/20+7.26
P	Sleeve length	Arm-hole circumference/2+23.4	Arm-hole circumference/2+23.4
Q	Sleeve circumference	AH/6+3	AH/6+3
R	Slacks length	Leg length + 1	Leg length + 1
S	Waist back	Crotch circumference + 0.5	Crotch circumference + 0.5
T	Neck front circumference	Neck front circumference + 1	Neck front circumference + 1

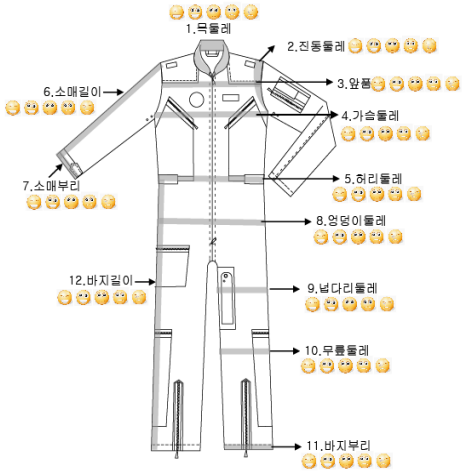
※ Existing design equations: Kim & Park (2004) etc. 13 references

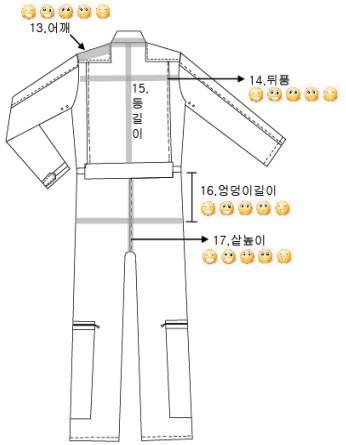
※ B: breast / AH: arm-hole

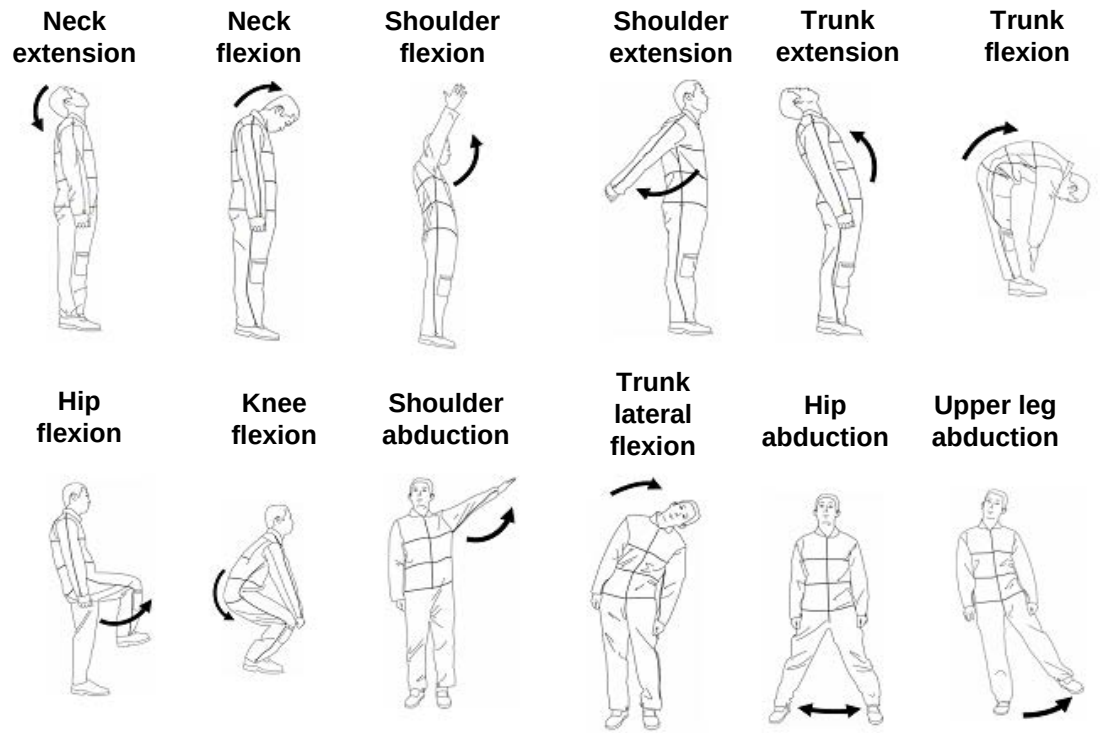
Survey existing design equations → 1st usability test → 1st adjustment of allowances → 2nd usability test → 2nd adjustment of allowances

Evaluation of Improved Design

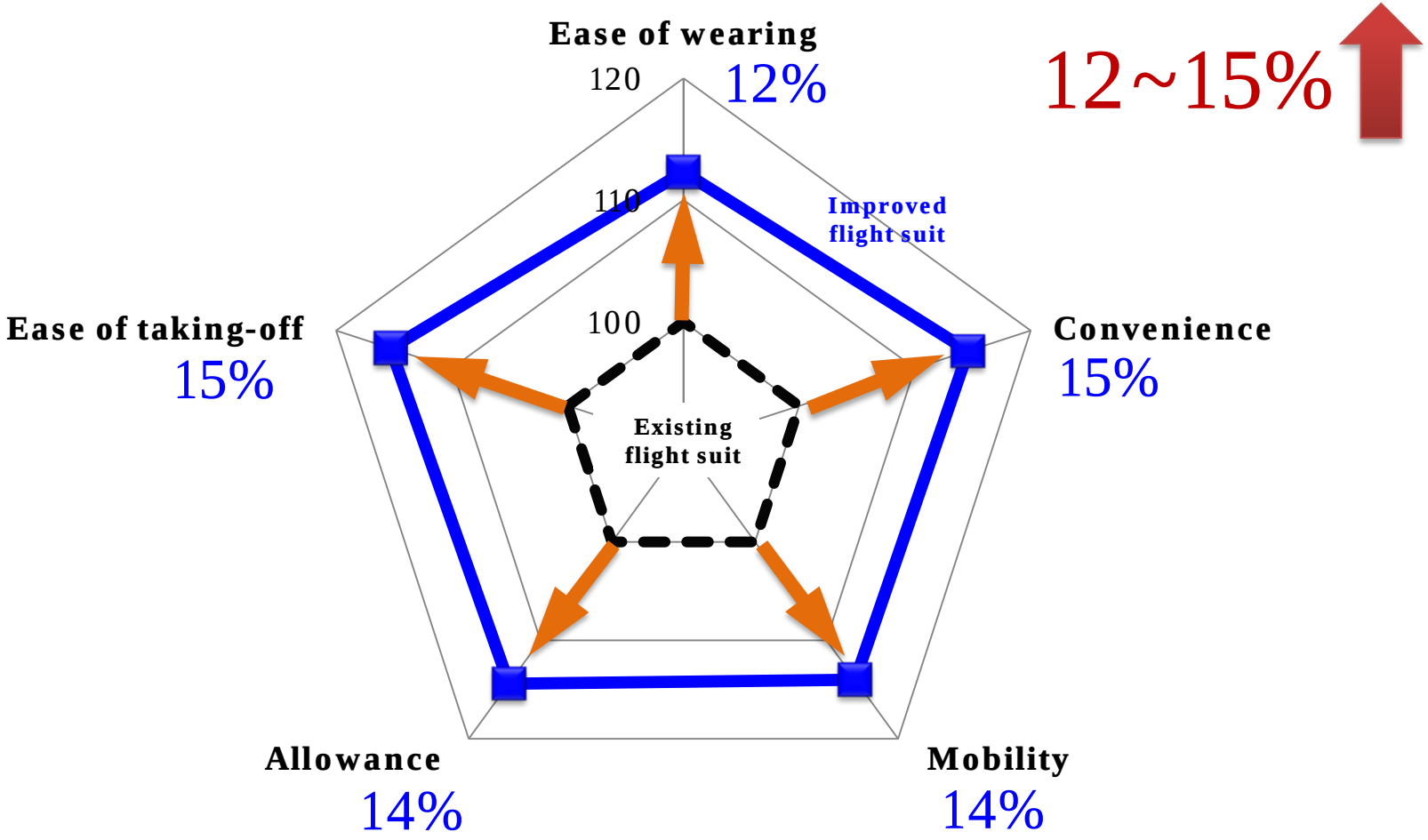
- Participants: 38 pilots (4 to 5 pilots for 8 sizes showing a higher accommodation percentage)
  - Subjective satisfaction (5-point Likert scale)
    - Ease of wearing/taking-off, allowance, mobility, convenience
  - Range of motion (ROM): 12 body motions





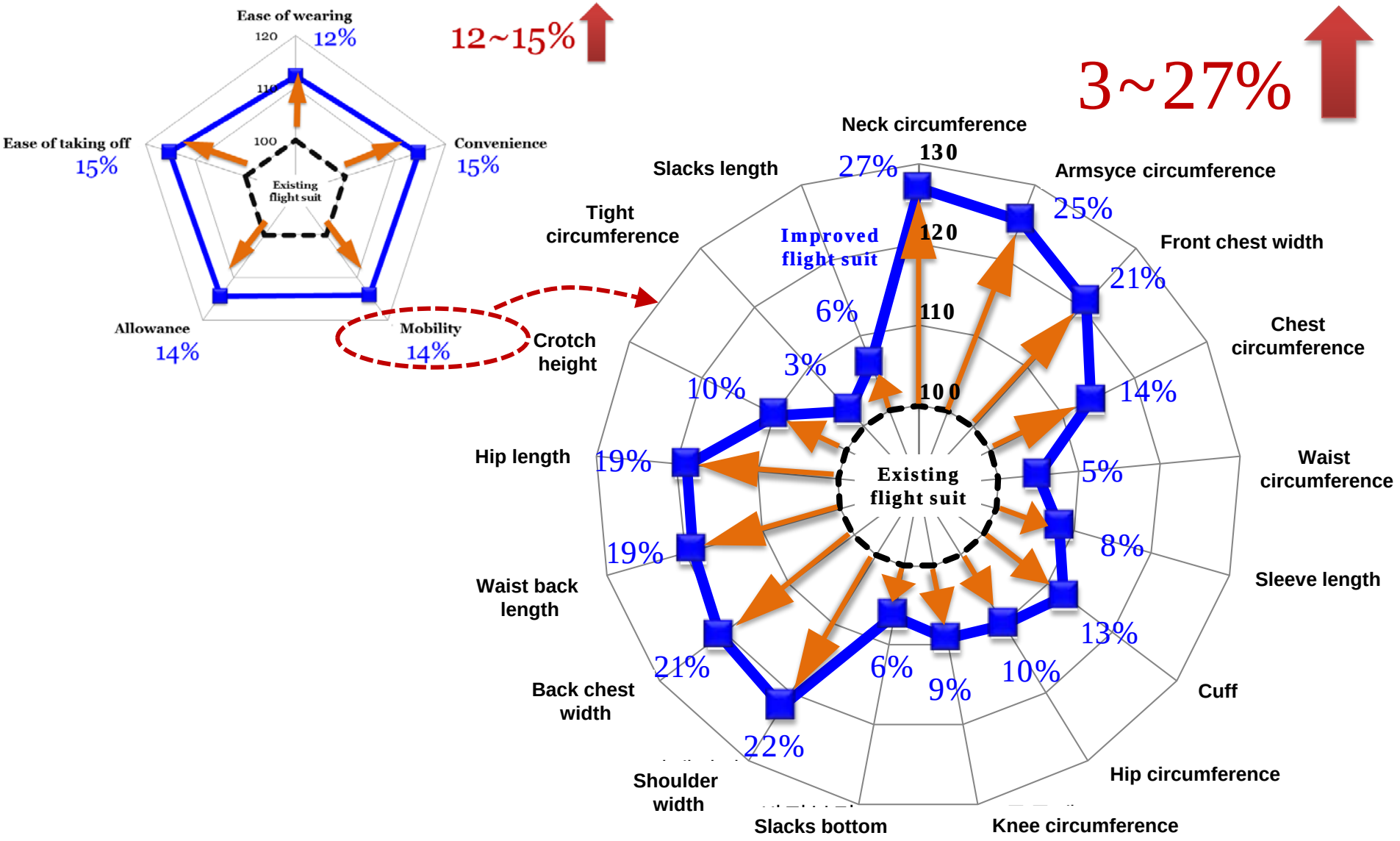


Result: Subjective Satisfaction



12~15%

Result: Mobility



Result: ROM

4~13%

Discussion

- **Accommodation percentage** of the **new sizing system**: **97%** (17% ↑)
  - Used Korean pilot anthropometric data
  - Eliminated 5 unnecessary size categories and added 10 necessary size categories
- **Improvement** of the **existing pattern design**
  - 8 parts: neck, sleeve, collar, waist, crotch, hip, slacks, and pocket

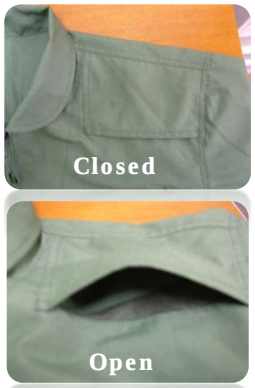
    ⇒ **Fit, mobility, convenience ↑**
  - Subjective satisfaction: 12 ~ 15% ↑; ROM: 4 ~ 13% ↑
- **Development** of the **design equations**
  - Pattern design variables = *f*{anthropometric variables, allowances)

    ⇒ **Applicable for a flight suit customized to an individual**
- Limitation: Evaluated on the ground => need to evaluate in flight operations

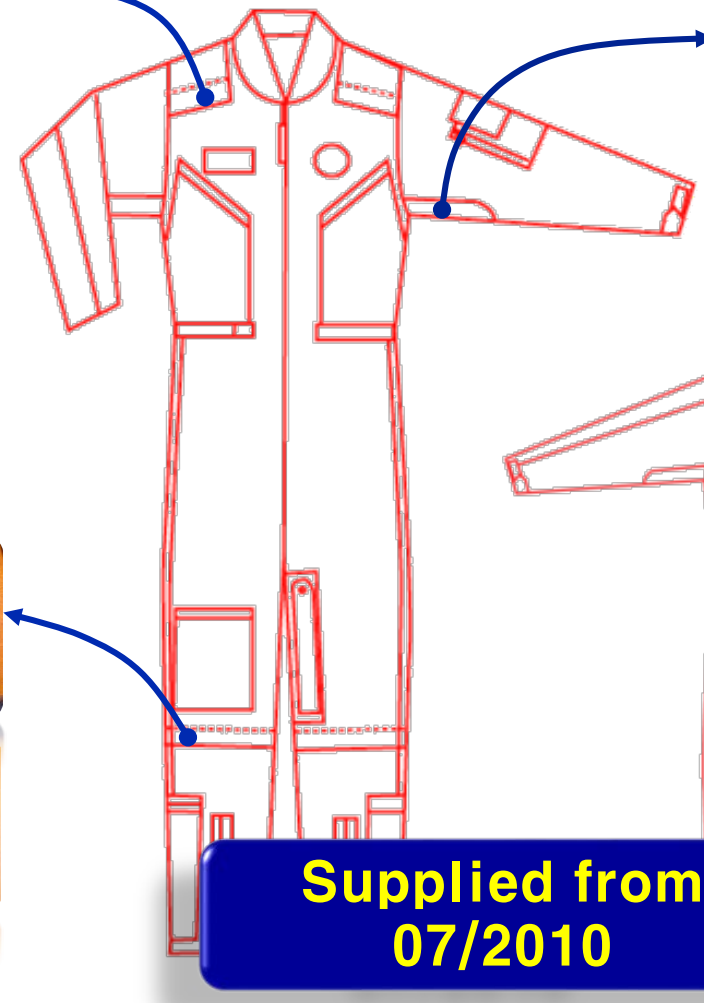
Summer Flight Suit

❖ Addition of 5 vent-holes for better ventilation in flight suit

1. Yoke front



2. Armpit



4. Yoke back

3. Knee front

5. Back wrinkle

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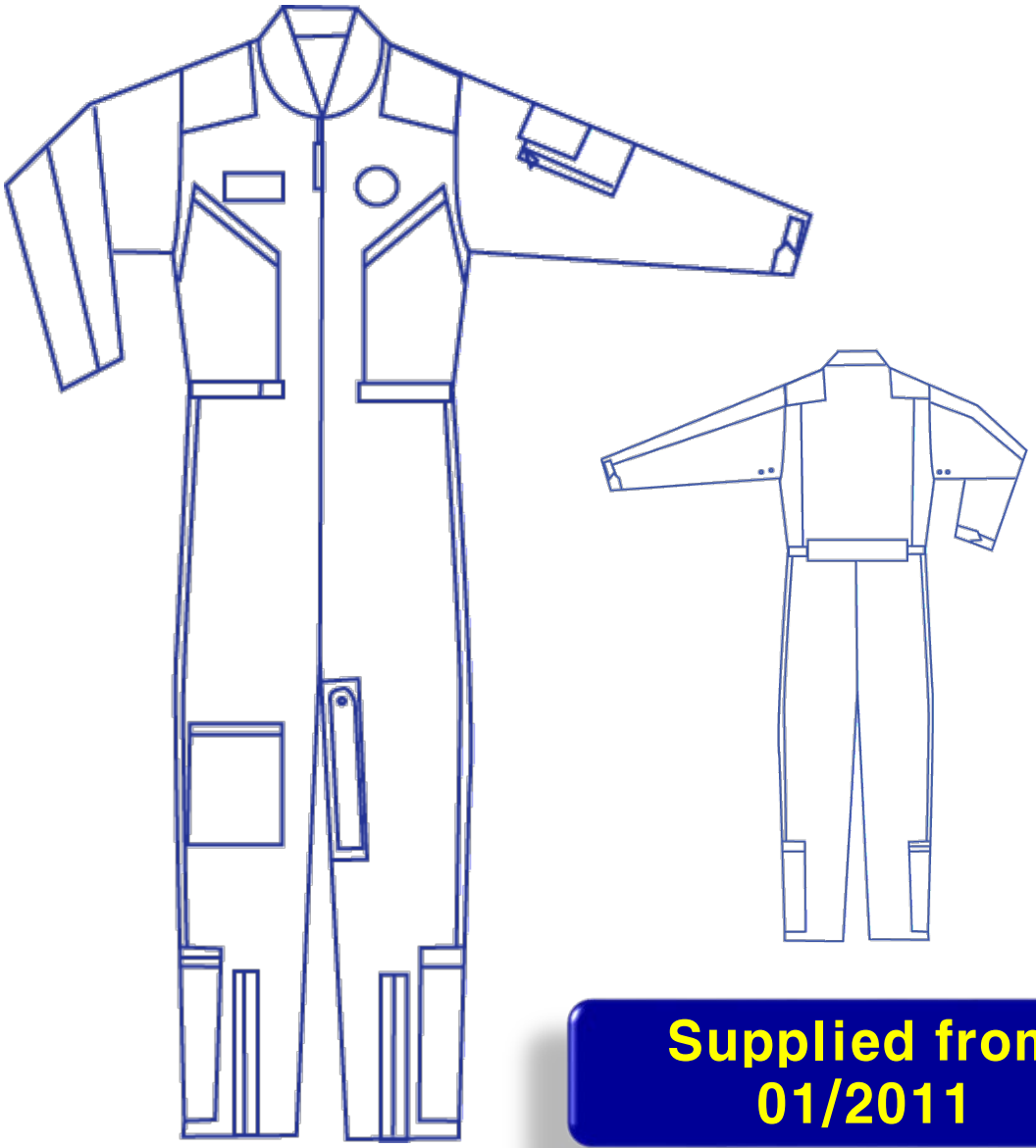
Winter Flight Suit



Pattern improvement

Sizing system improvement

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Q & A

Thank You for Your Attention ☺