smart & safe work wear

Virtual Garment Design and Fitting for Chemical Protective Costume for Rescue Teams and Firefighters

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First response teams against chemical accident are responsible for:

1) event recognition,
2) incident medical command and control,
3) safety and personal protection,
4) decontamination,
5) **isolation of the incident area,**
6) sampling and detection,
7) communication and coordination,
8) **triage,**
9) treatment,
10) **transportation,**
11) recovery activities,
12) fatality management.

Evacuation, i.e. incident site isolation and zone establishment together with triage and transportation is always a priority, because survival depends on the speed. People on one side of clearly demarcated ”hot line” are “dirty” (contaminated), and people on the other side are “clean”.

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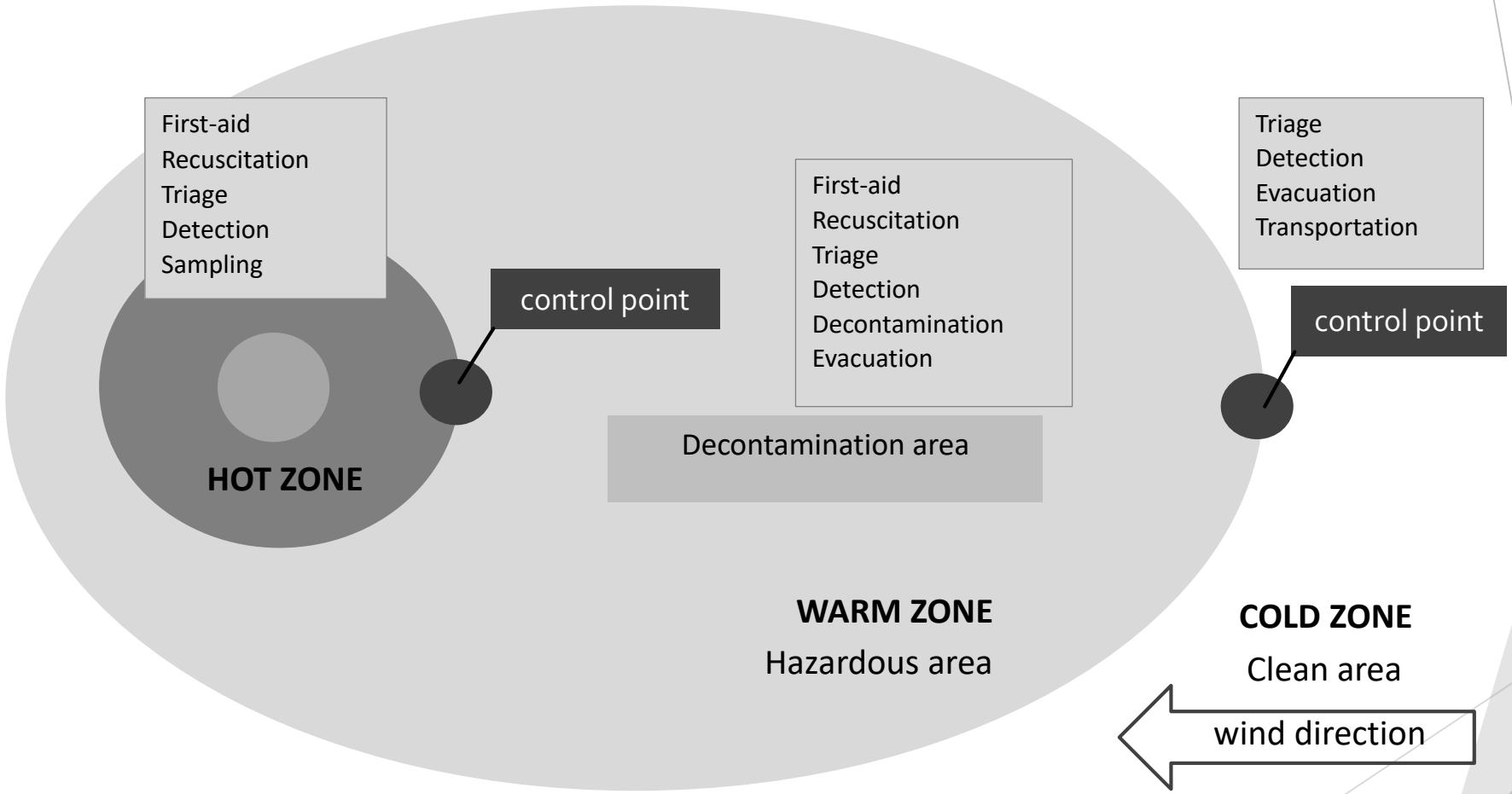
Rescue activities in chemical accident area



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There are four possible interactions between chemical environment and chemical protective textile:

1. the most common way by which chemicals flow through a protective clothing is ***penetration***, i.e. through pinholes, stitched seams, etc. The simplest way to determine imperfections affecting barrier properties is to inflate the garment with air and to check where the air passes out the garment.

2. the other way is ***degradation***, which is the breakdown of clothing material structure and change of its physical properties. Signs of degradation are: discoloration, swelling, occurrence of cracks, hardening and flaking or even decomposition.

3. the most research in the world has been reported on the third way – ***permeation***, which is a complex process and described by chemical diffusion through the protective clothing in a molecular level. The stages of the process are: a) absorption of the chemical by the barrier material, b) saturation of the barrier material, c) desorption of the material from the unexposed surface with the increase of chemical concentration.

4. in the fourth way the chemicals may not interact, but ***evaporate*** and the vapor will either go into the atmosphere or enter the garment.

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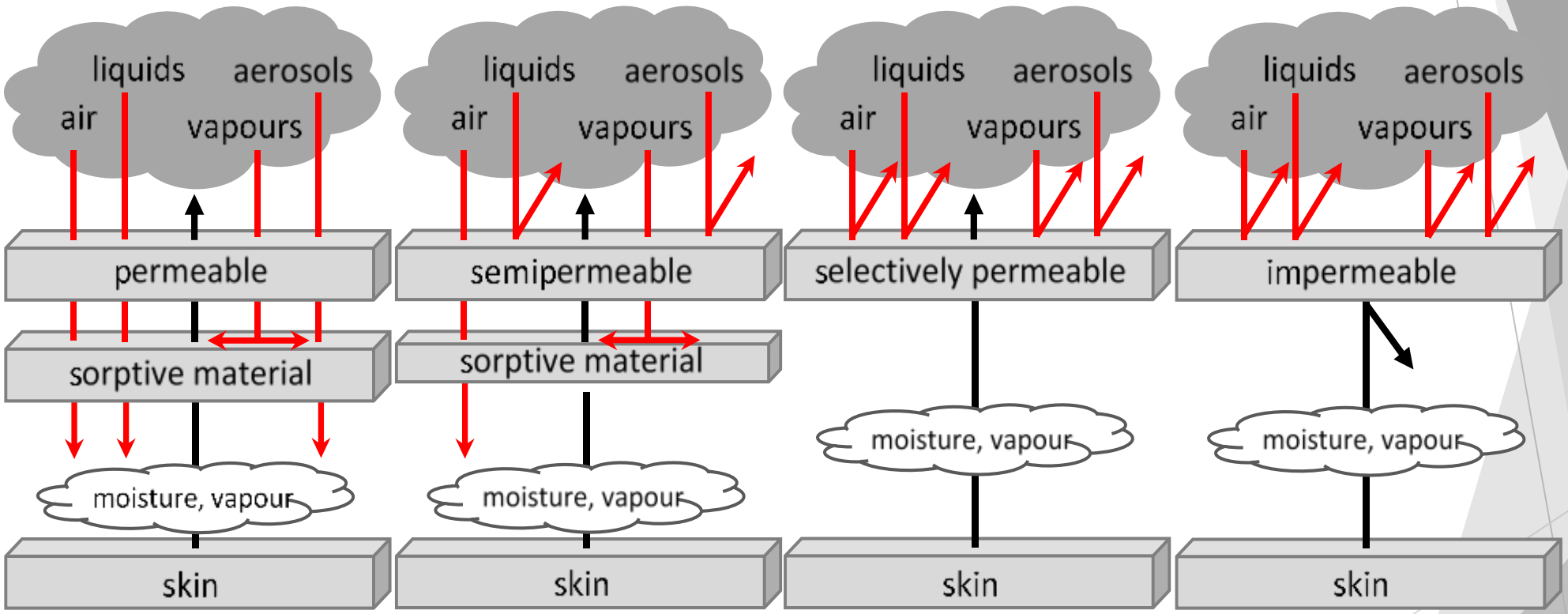
Performance of different types of protective materials: permeable, semipermeable, selectively permeable and impermeable



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Requirements for European types of chemical protective clothing (CPC)

Technical report **CEN/TR 15149** “Protective clothing – Guidelines for selection, use, care, and maintenance of chemical protective clothing”

Standard **ISO 16602** “Protective clothing for protection against chemicals – classification, labelling, and performance requirements”

Type 1 vapor-protective suits ***against hazardous gases, liquids, aerosols and solid particles***: 1a with a breathable air supply inside, e.g. self-contained open-circuit compressed air breathing apparatus; 1b with breathable air supply worn outside the CPC; 1c with positive pressure of breathable air provided via air hose.

The chemicals may be: dimethyl sulphate, ammonia, chlorine, cyanogen chloride, hydrogen cyanide, sulphur mustard and sarin.

Type 2 is not gas-tight and positive pressure of breathable air is provided into the suit via air hose. It can be used against aerosols, sprays, or gasses, e.g., in the ***manufacture of drugs*** where the task does not require to move around a lot.

Type 3 has liquid-tight connections between different parts of the suit and is used where the contaminants are not air-borne, ***chemicals may splash with pressure*** and the employee has to lean on contaminated surfaces.

Type 4 has spray-tight connections between different parts of the suit and is used where the contaminants are not air-borne, splashes of chemicals may exist, but the ***splashes are not pressurized***.

Type 5 is for protection from ***air-born solid particles*** such as asbestos, lead dust, and other hazardous dusts.

Type 6 is for tasks where ***limited protection*** against liquid chemicals is needed [14].

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Risk phrases and codes are defined by
"European Commission Directive 2001/59/EC – classification, packaging, and labelling of dangerous substances"

R21	harmful in contact with skin
R24	toxic in contact with skin
R27	very toxic in contact with skin
R34	causes burns
R35	causes severe burns
R38	irritating to skin
R43	may cause sensitization by skin contact
R45	may cause cancer
R46	may cause heritable genetic damage

Risk code	Description of hazard	EU classification abbreviations
Tx	very toxic	T+
T	toxic	T
Cx	highly corrosive, causes severe burns	C
C	corrosive, causes burns	C
X	harmful	Xn
Xi	irritant	Xi

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Pictogram *Skin and less serious hazards* refers to harmful in contact with skin and less serious hazards such as skin irritancy/sensitization
(risk code Xi and X; risk phrases 21, 38, 43.

Pictogram *Damage to organs* refers to damage to organs and reflects serious longer term health hazards such as carcinogenicity
(risk codes Tx and T; risk phrases 45 and 46)

Pictogram *Fatal in contact with skin* refers to fatal in contact with skin
(risk codes Tx and T; risk phrases 24, 27)

Pictogram *Skin burns and eye damage* refers to skin burns and eye damage
(risk codes Cx and C; risk phrases 34 and 35)

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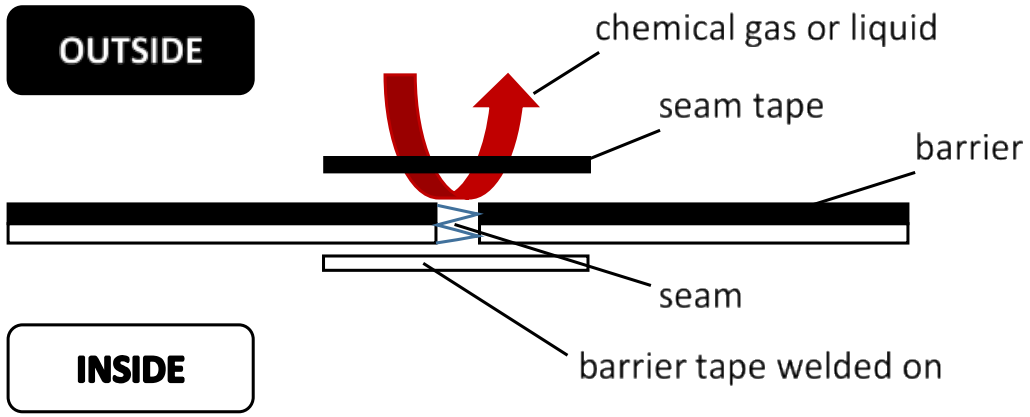
The view of encapsulating CPC clothing (type 1a) and the scheme of its welded seams



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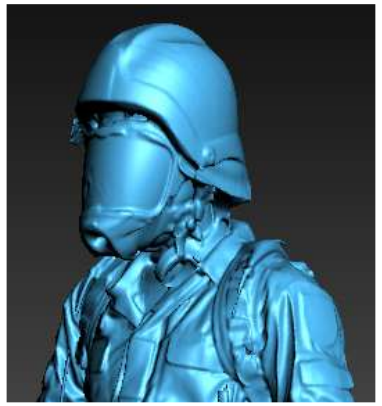
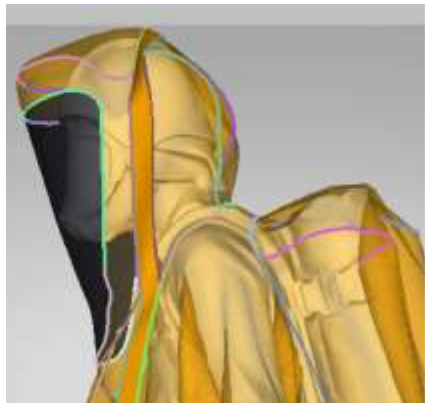
1st type of mask



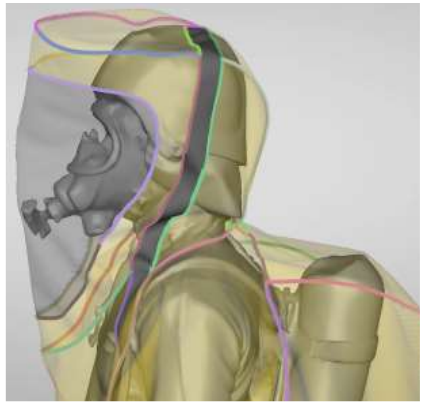
a)



b)

2nd type of mask

d)



e)

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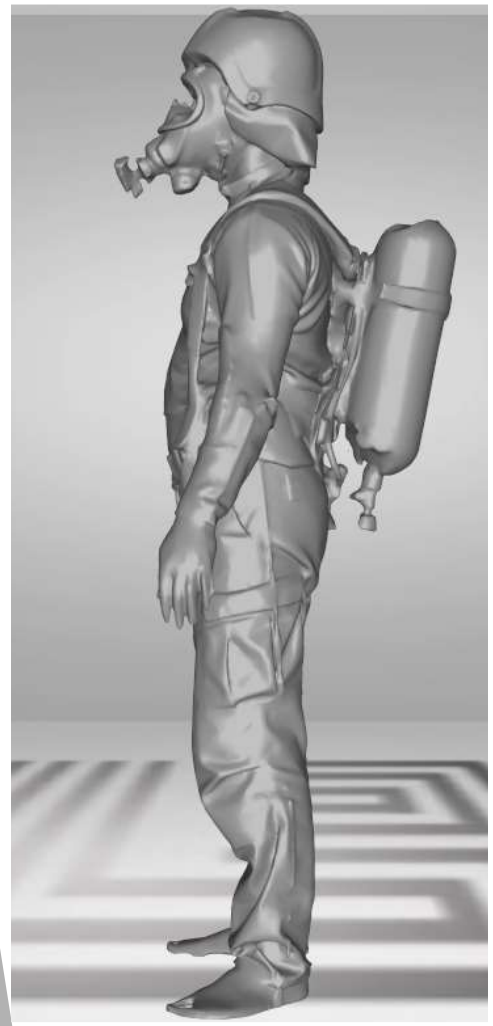

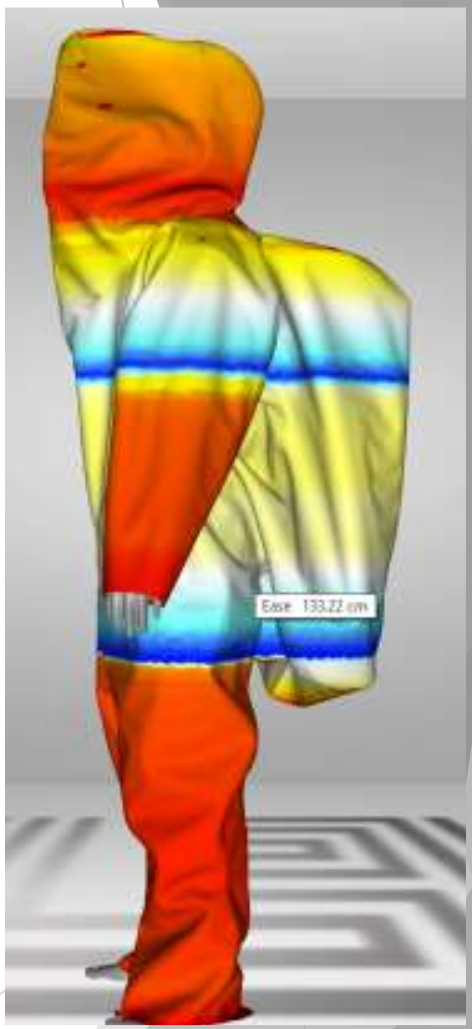

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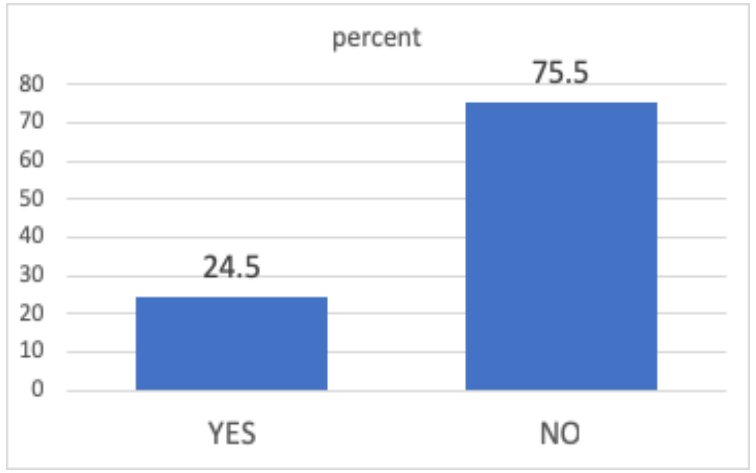
Do you feel comfortable while performing tasks in CPC suit? Please comment briefly.

- Yes ***13 from 53 (24,5 percent)***
- No ***40 from 53 (75,5 percent)***
- Comments: glass dew; restricted movements; uncomfortable to use communication tools; difficult to talk to partner; limited visibility; impossible to dress up without the help from outside; difficult to communicate through communication means; not possible to self-open the suit in the face of danger that air ends up in the balloon; inconvenient to move; glove rubber could be softer, because its limits hand movements.



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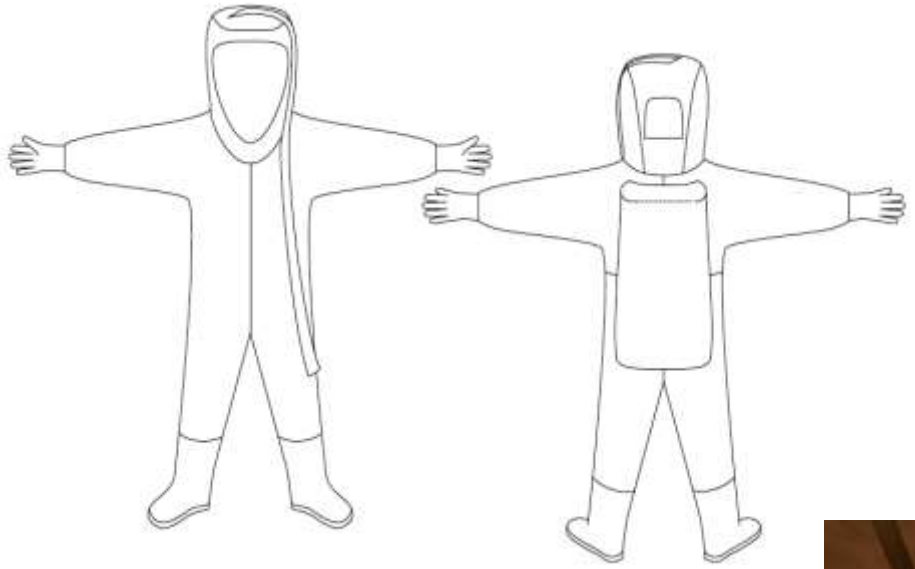
Three Stages of Comfortable CPC suit Development



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1st stage

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1st prototype, variant I

1st prototype, variant II

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2nd prototype, variant I



2nd prototype, variant II

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3rd prototype, variant I

3rd prototype, variant II

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Size of CPC suit **XL**;
Original marker: width **1.47 m**; length **4.90 m**; efficiency **78.62 %**

	Parameter	Prototype 1		Prototype 2		Prototype 3	
		Variant I	Variant II	Variant I	Variant II	Variant I	Variant II
1.	Cutting perimeter, m	**45.57**	**45.57**	48.24	46.98	48.24	48.06
2.	Area, m2	4.92	5.09	4.95	5.23	4.89	4.98
3.	Marker length, m	4.63	4.70	**4.46**	4.88	**4.46**	**4.47**
4.	Efficiency, %	72.33	73.60	75.60	79.98	74.56	75.82

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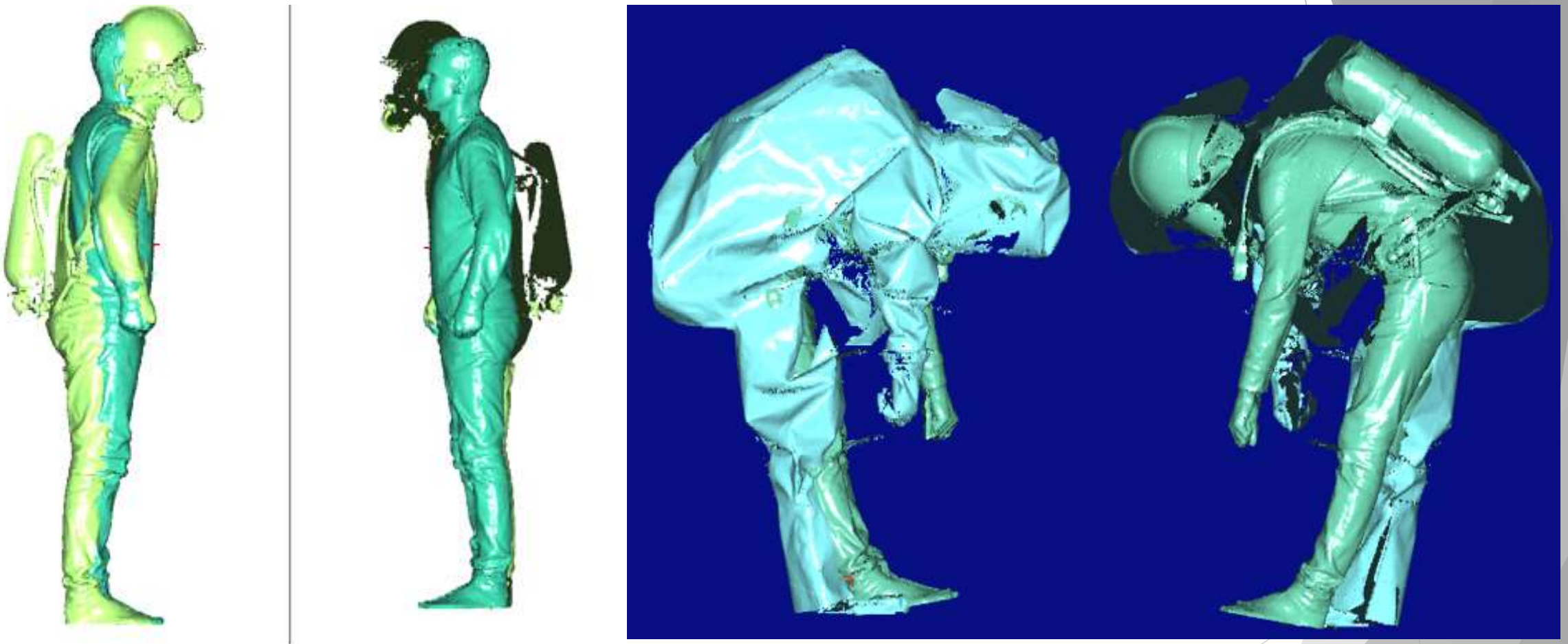

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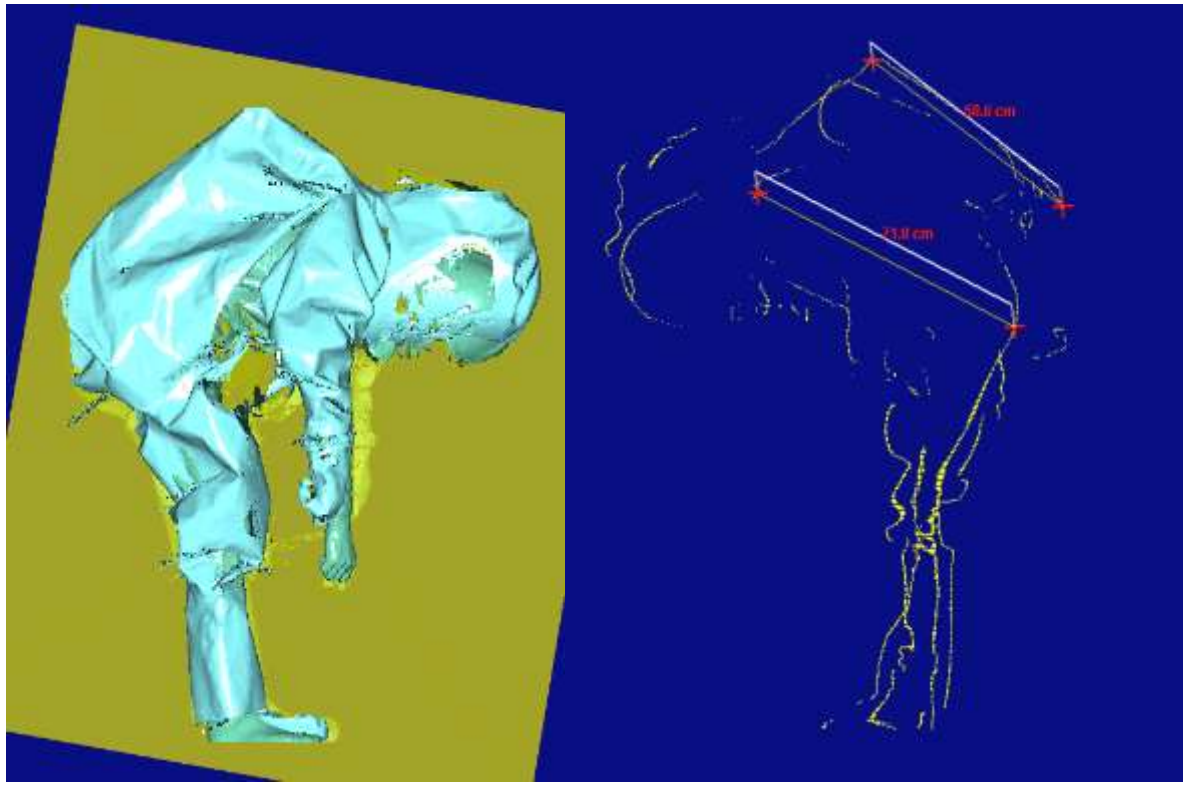

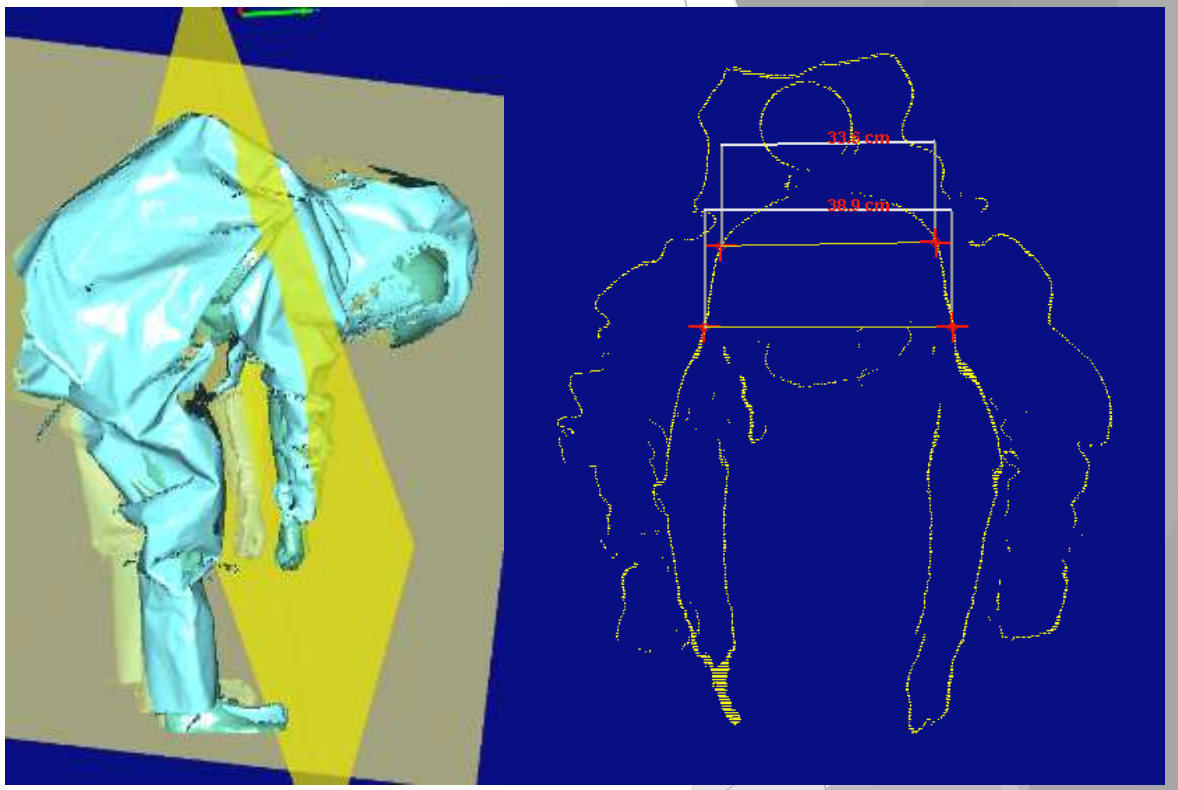

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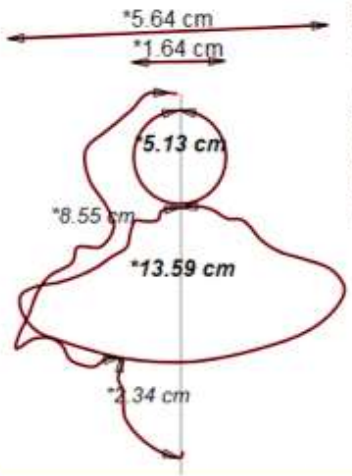
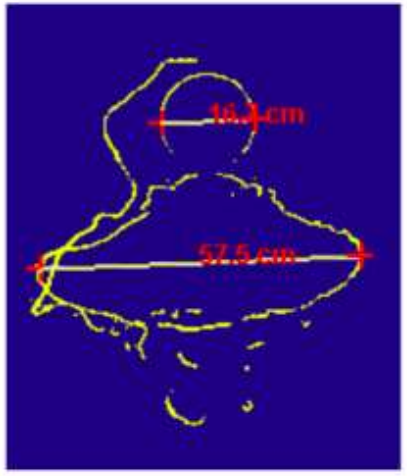
1st prototype, variant I



buvo:
57.5 cm; (mastelis = 10.20 cm)
16.1 cm; (mastelis 1cm = 9.82 cm)
*1cm = **10.00 cm***

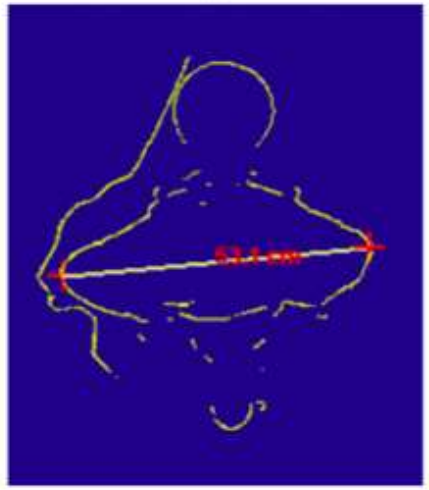
yra perimetrai:
balionas - 5.13 x 10 = 51.3 cm
kunas - 13.59 x 10 = 135.9 cm
kostiumas - (8.55 + 2.34) x 10 = 108.9 cm
visas kostiumas - 108.9 x 2 = 217.8 cm



1st prototype, variant II

buvo:
53.1 cm; (mastelis = 10.20 cm)
*1cm = **10.20 cm***

yra perimetrai:
balionas - 5.10 x 10.20 = 52.02 cm
kunas - 12.33 x 10.20 = 125.8 cm
kostiumas - (4.98 + 5.05) x 10 = 100.30 cm
visas kostiumas - 100.30 x 2 = 200.60 cm



Robertas
Cross section at the shoulder line

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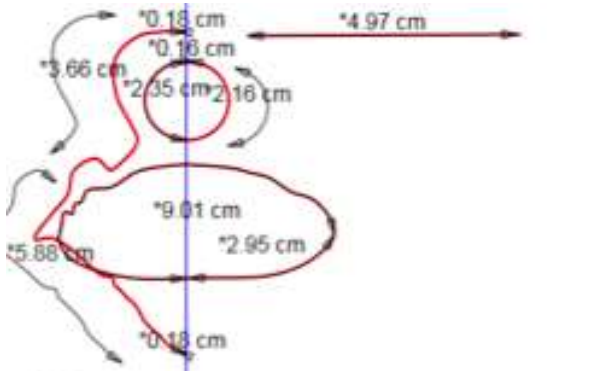
1st prototype, variant I



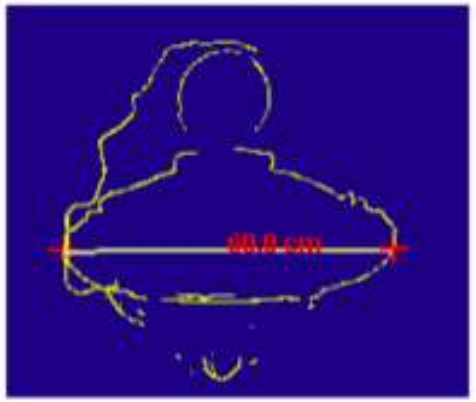
buvo:
55.8 cm; (mastelis = 11.23 cm)
fcm = **11.23 cm**

yra perimetrai:
balionas - (0.16 + 2.16 + 2.35) x 11.23 = 52.44 cm
kunas - (9.01 + 2.95) x 11.23 = 134.31 cm
kostiumas - (0.18 + 3.66 + 5.88 + 0.18) x 11.23 = 111.18 cm
visas kostiumas - 111.18 x 2 = 222.35 cm

1st prototype, variant II

buvo:
60.0 cm; (mastelis = 11.51 cm)
fcm = **10.51 cm**

yra perimetrai:
balionas - 4.98 x 10.51 = 52.34 cm
kunas - (14.04 + 0.15) x 10.51 = 149.14 cm
kostiumas - (0.20 + 6.64 + 2.48 + 0.37) x 10.51 = 101.84 cm
visas kostiumas - 101.84 x 2 = 203.68 cm



Antoni
Cross section at the shoulder line

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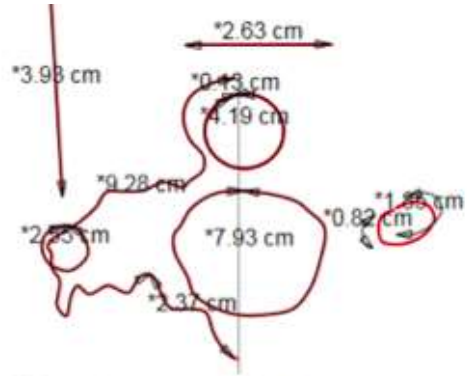
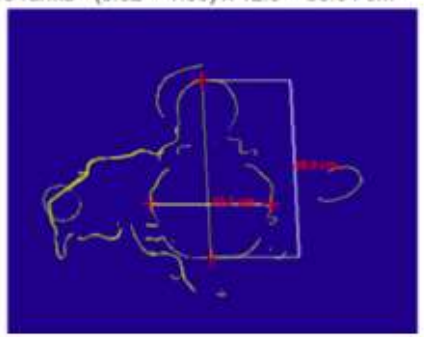
1st prototype, variant I

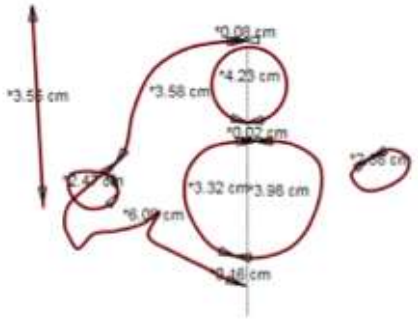


33.2 cm; (mastelis = 12.62 cm)
48.9 cm; (mastelis 1cm = 12.44 cm)
*1cm = **12.50 cm***

yra perimetrai:
balionas - (4.19 + 0.13) x 12.5 = 54.0 cm
kunas - 7.93 x 12.5 = 99.13 cm
kostiumas - (9.28 + 2.37) x 12.5 = 145.63 cm
visas kostiumas - 145.63 x 2 = 291.26 cm
desine ranka - 2.55 x 12.5 = 31.88 cm
kaire ranka - (0.82 + 1.85) x 12.5 = 33.34 cm

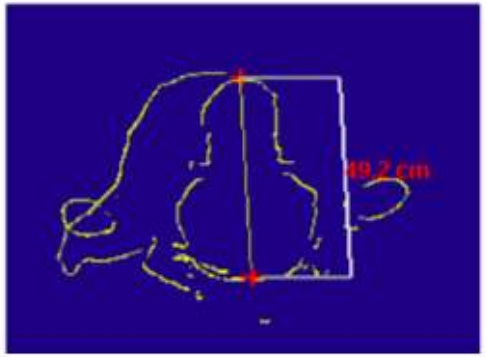


1st prototype, variant II



buvo:
49.2 cm; (mastelis = 13.86 cm)
*1cm = **13.60 cm***

yra perimetrai:
balionas - 4.23 x 13.6 = 57.53 cm
kunas - (0.02 + 3.32 + 3.98) x 13.6 = 99.55 cm
kostiumas - (0.16 + 6.09 + 3.58 + 0.08) x 13.86 = 134.78 cm
visas kostiumas - 134.78 x 2 = 269.56 cm
desine ranka - 2.47 x 13.6 = 33.59 cm
kaire ranka - 2.68 x 13.6 = 36.45 cm



Robertas
Cross section at the bust line

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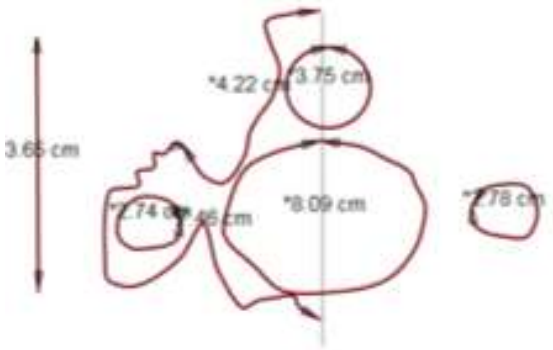
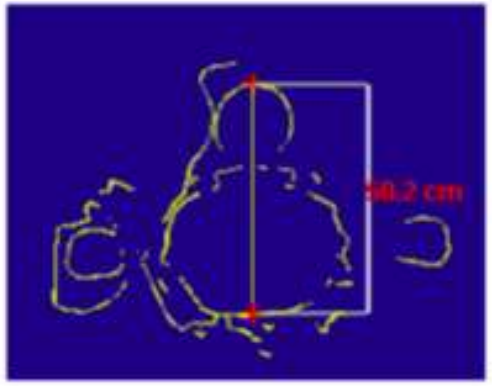
1st prototype, variant I

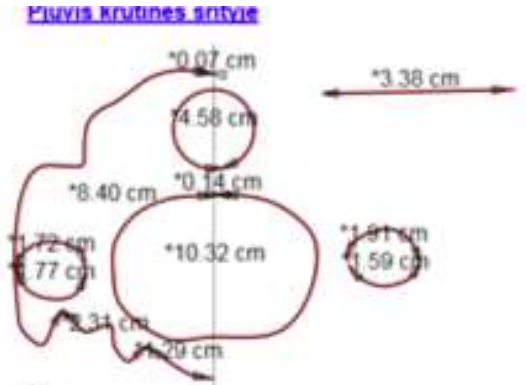


buvo:
50.2 cm; (mastelis = 13.57 cm)
1cm = **13.57 cm**

yra perimetrai:
balionas - 3.75 x 13.57 = 50.89 cm
kunas - 8.09 x 13.57 = 109.78 cm
kostiumas - (7.46 + 4.22) x 13.57 = 158.50 cm
visas kostiumas - 158.5 x 2 = 317.00 cm
desine ranka - 2.74 x 13.57 = 37.18 cm
kaire ranka - 2.78 x 13.57 = 37.72 cm



1st prototype, variant II



buvo:
39.1 cm; (mastelis = 11.50 cm)
1cm = **11.50 cm**

yra perimetrai:
balionas - 4.58 x 11.50 = 52.67 cm
kunas - (10.32+0.14) x 11.5 = 120.29 cm
kostiumas - (0.07 + 8.40 + 2.31 + 1.29) x 11.5 = 138.81 cm
visas kostiumas - 138.81 x 2 = 277.61 cm
desine ranka - (1.72 + 1.77) x 11.5 = 40.14 cm
kaire ranka - (1.91 + 1.59) x 11.5 = 40.25 cm

Antoni
Cross section at the bust line

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2nd stage

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1st prototype, variant III

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2nd prototype A, variant III
Accepted for production

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2nd prototype B, variant III

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Vilnius Universityof Applied Science

3rd prototype, variant III
Accepted for production

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Vilnius Universityof Applied Science

Size of CPC suit **XL**;
Original marker: width **1.47 m**; length **4.90 m**; efficiency **78.62 %**

	Parameter	Prototype 1			Prototype 2				Prototype 3		
		I	II	III	I	II	IIIA	IIIB	I	II	III
1.	Cutting perimeter, m	45.57	45.57	47,93	48.24	46.98	48.04	44.69	48.24	48.06	48.74
3.	Marker length, m	4.63	4.70	4.61	4.46	4.88	4.53	4.67	4.46	4.47	4.58
4.	Efficiency, %	72.33	73.60	75.03	75.60	72.98	75.95	71.84	74.56	75.82	74.23

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	Parameter	Prototype 2		Prototype 3	
		IIIA	FINAL	III	FINAL
1.	Cutting perimeter, m		47.82		45.57
3.	Marker length, m	4.59	4.52	4.72	4.76
4.	Efficiency, %	75.79	78.48	73.56	73.31

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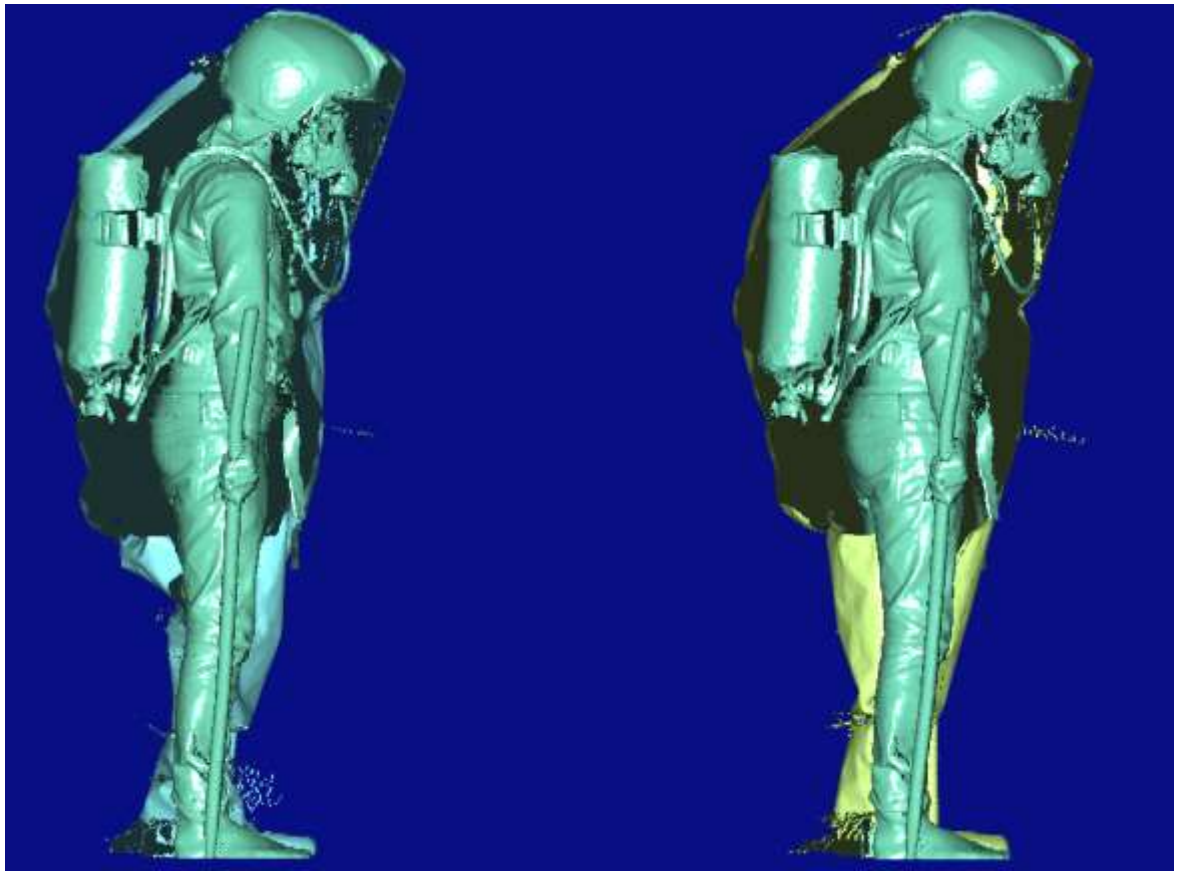

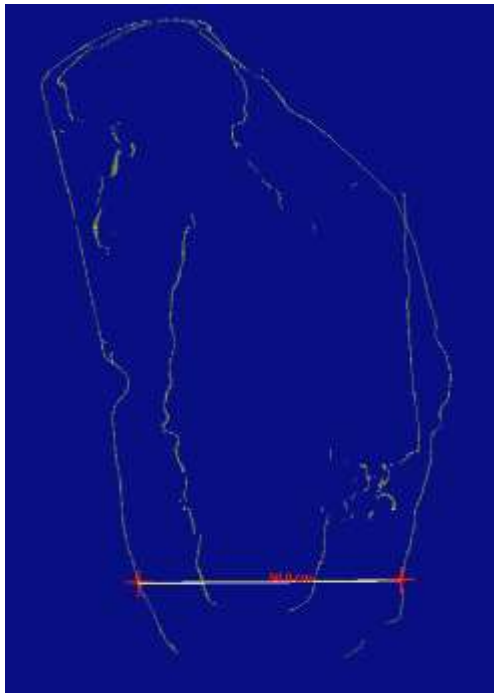

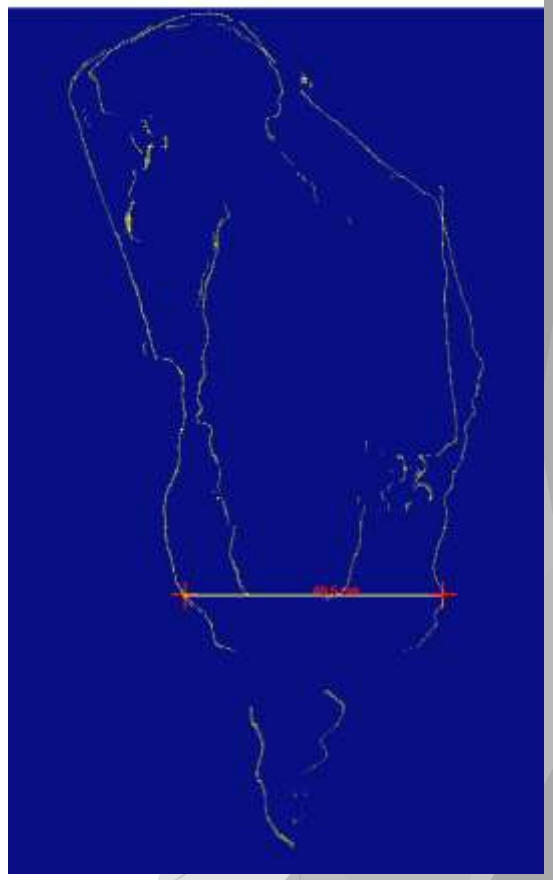

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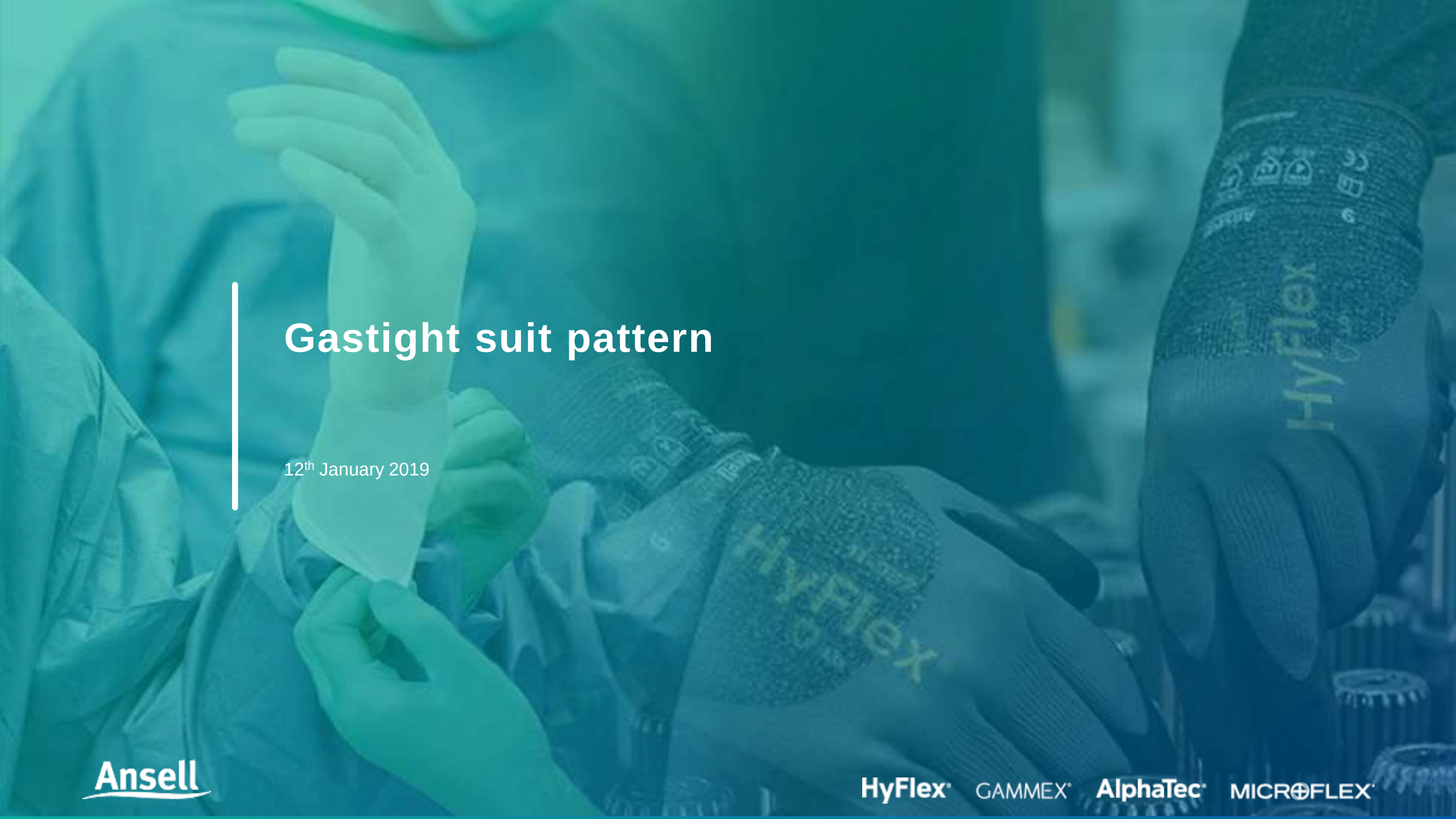
Rovaniemi, 2019 02 05



Gastight suit pattern

12th January 2019

Ansell

HyFlex® GAMMEX® AlphaTec® MICROFLEX®

1st final prototype

Interreg Baltic Sea Region

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2nd final prototype

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Comparison according to seam crossings

Seam type	Original suit (big visor, sock version)	1st Interreg prototype (big visor, sock version)	2nd Interreg Prototype (big visor, sock version)
T seam	**14** (+2 for socks)	**8** (+2 for socks)	**10** (+2 for socks)
+ Cross	**1**(+2 for socks)	**1** (+2 for socks)	**1** (+2 for socks)
Overlap of continuous seam	**3**	**2**	**2**
Folding	4 (at the end of leg) *Because it is sock version*	4 (at the end of leg) *Because it is sock version*	4 (at the end of leg) *Because it is sock version*
 seam	-	**2**	-
Total	26	17	17
Total without socks	18	13	13

Conclusions

- Visually original pattern looks more shaped. Interreg prototypes are close to current design according to visual appearance.

- Number of seam junctions is the same if eliminating socks. Number of seam junctions represents the stops of taping. Stops does not show the suit suitability for taping. The most important are: sequence of taping seams, handling of suit according it, if there are sharp curves.

- Top of the hood seam and sock seams looks to be the most difficult for taping (Interreg prototypes, Current original gastight suit).

Summary

	Seam length (excluding zipper and its flap gluing, visor gluing, bayonets gluing).	Pattern consumption	Possible savings of manufacturing cost
Interreg 1st prototype (big visor, sock v., size XL)	17.46	4.55	
Interreg 2nd prototype (big visor, sock v., size XL)	16.12	4.88	4.83eur for pattern, 9.39EUR because of shorter production time **14.22eur in overall.**
Original suit (big visor, sock version, XL size)	18.42	4.94	
Original suit, but with smaller hump (1 canister)	~17.82 (Hump itself has 0,6m less seams)	4.55	Smaller hump has at least 0.6m savings for seam length (production time).

Interreg 2nd prototype is better in terms of comfort and brings 14,22 eur/suit savings

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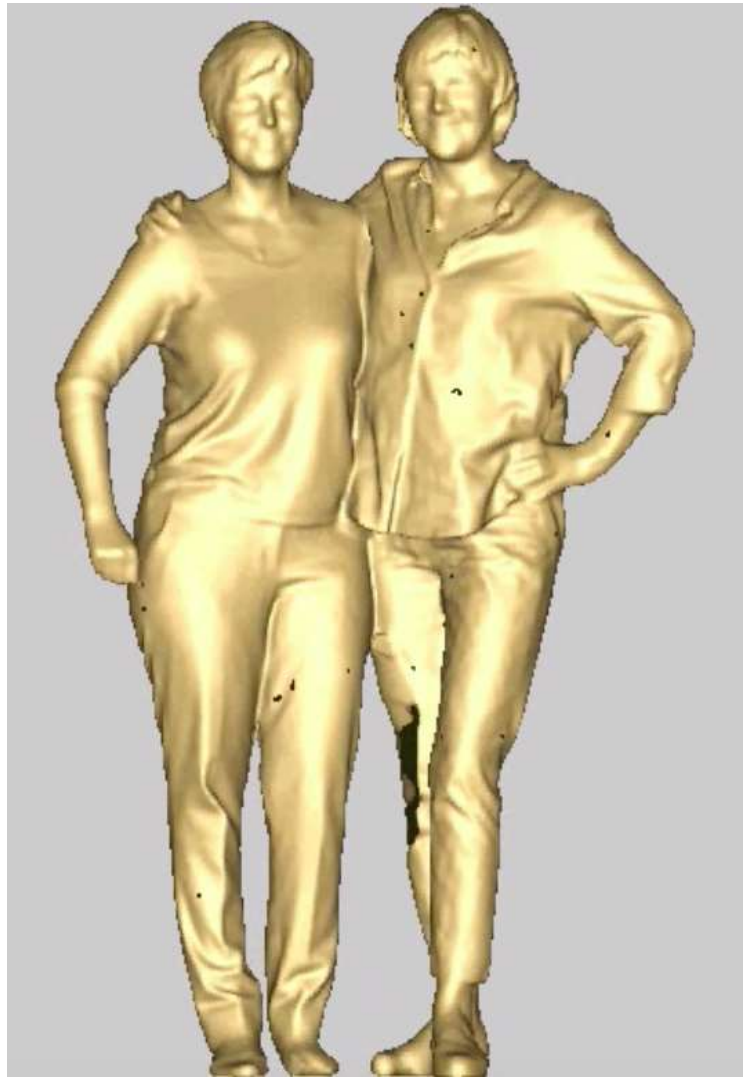

Thank you for friendship and fruitful cooperation!

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