Reducing oxygen mask induced nasal discomfort in F-16 pilots of the RNLAF

– user, university and industry working together

Center for Man in Aviation
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The golden Triangle: Knowledge/Innovation

INDUSTRY

- YOU
- Life support equipment
- Commercial business
- Selling products
- Happy customers
The golden Triangle: Knowledge/Innovation

GOVERNMENT

• WE: RNLAF
• Customer
  • COTS/MOTS
• USER: aircrew, technicians
• User knowledge!

GOVERNMENT

INDUSTRY

SCIENCE
The golden Triangle: Knowledge/Innovation

SCIENCE

- WE: CML
- Center of excellence in human factors in aviation and space
Center for Man in Aviation

Aeromedical examinations
Psychological selections
Education and training
Research and development
The golden Triangle: Knowledge/Innovation

**SCIENCE**

- **WE: CML**
- Center of excellence in human factors in aviation and space
- Government
- Customer
- Sponsor/funder
- TNO, NLA, Universities
- Semi-government
Problem

• Nasal discomfort: minor bruising - severe deformation
The golden Triangle: Knowledge/Innovation

- TAA
- Internship
- Master student Industrial Design

RNLAF/CML

CML and University of Twente

GENTEX
Purpose

1. To gain insight in the background and origins of the nasal problems associated with the use of oxygen masks by F-16 pilots and to identify possible causes for these issues.

2. To create solutions addressing the problems identified, that may be realised in the near future as well as options that can lead to improved products in the further future.
Oxygen Mask

MBU-20/p

- Hard shell
- Soft shell
- Valves
- Microphone
- Oxygen hose
- Webbing
- Bayonets
Methods

Purpose 1 (identifying factors)
• Literature research
• Product comparison
• Interviews
• Prototype testing

Purpose 2 (creating solutions)
• Requirements
• Idea generation
• Concept ideas
Literature research

Interviews

• Semi-structured interviews
• 18 pilots (data saturation)

Product comparison
Mask

Soft shell

The construction does not provide enough stability on the face

The mask shifts downward during flight

Shifting and bringing the mask back into position causes friction

Friction causes skin irritation, eventually injuries

The skin is injured

Repeated movement of the mask causes the seal to dig into the skin

The shape of the soft shell enables the seal to flip over under G

Bad seal causes leakage

Pulling mask overly tight to avoid leakage (creating pressure hot-spots)

Mask fit quality often insufficient

Long-term skin damage causes permanent discolouration

Prolonged pressure causes exostosis to develop
Conclusions bottleneck analysis

Factors influencing (dis)comfort:

• Shifting downward of mask
• Necessity of pulling the mask tight
  • To prevent/reduce the mask from shifting down
  • To prevent/reduce leakage (caused by shape and/or bad fit)
  • To keep the helmet in place
• Rotating of the helmet
• Sharp edges
• Other factors:
  • Bayonets and webbing
  • Shape and material of soft shell
  • Shape of the hard shell

Prototyping testing
## Prototype testing

### Methods:
8 prototypes

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Hard shell</th>
<th>Soft shell</th>
<th>Bayonet</th>
<th>Expected ranking</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Original</td>
<td>New</td>
<td>Silicone</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>worst</td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>X</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>X</td>
<td></td>
<td>X</td>
<td>best</td>
</tr>
</tbody>
</table>
Royal Netherlands Air Force
Oxygen mask
Prototype testing

Methods:
• 7 participants (pilots and instructors)
• Helmet and mask fitting according to standardized protocol
• Displacement test

• Questionnaire
Prototype testing: Outcome measures

• Displacement

• Questionnaire (VAS):
  • Stability
  • Fit
  • Discomfort
  • Pressure distribution
  • Hot-spots
  • Sharp edges
  • Anticipated problems
Conclusions Prototype testing

- Silicone soft shell less discomfort, but greater displacement
- 12/p bayonets better on all outcome measures, and significant on Displacement, Fit and Pressure distribution
- New hard shell better on all outcome measures, but never reached significant level
- Silicone soft shell significantly better on all outcome measures except for Displacement and Stability
- Most stable mask: mask 6 (new hard shell, rubber soft shell, 12/p bayonets)
- Overall winner: mask 8 (new hard shell, silicone soft shell, 12p bayonets)
Methods

Purpose 1 (identifying factors)
• Literature research
• Product comparison
• Interviews
• Prototype testing

Purpose 2 (creating solutions)
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• Concept ideas

Bottleneck analysis

Visual solution matrix
the mask shifts downward during flight [working principle]

the suspension of the mask enables rotation and shifting [connectors]

- using cavity pressure for suctioning effect
- broader mask on the cheeks = more space for webbing outside field of view
- straps are placed on the helmet independently
- change webbing for a rigid setup
- keeps separate soft shell in place
- maxillofacial shield
- helmet must be perfectly secure
- no room for movement inside the receivers
- separate mechanism keeps nose area in place
- between the eyes
- webbing closer to the skin
- using clear material
- webbing connects to multiple points on the helmet
- broader suspension
- two receivers
- larger receivers
- different bayonet orientation
- narrower straps but broad suspension
- cables instead of straps
- twaron / kevlar
- wire rope
- adjustment levers
<table>
<thead>
<tr>
<th>topic</th>
<th>solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>inner seal flips over on the nose</td>
<td>1. inner seal compartment</td>
</tr>
<tr>
<td>not enough frictional resistance</td>
<td>2. larger contact surface GeckSkin</td>
</tr>
<tr>
<td>sharp edges</td>
<td>3. seal over shell</td>
</tr>
<tr>
<td>pressure distribution is not optimal</td>
<td>4. mouldable shell</td>
</tr>
<tr>
<td>geometry results in perpendicular angles to the face</td>
<td>5. contour follows face single piece mask</td>
</tr>
<tr>
<td>the suspension of the mask enables rotation and shifting</td>
<td>6. webbing -&gt; rigid setup independently placed straps</td>
</tr>
<tr>
<td>mask shifts downwards during flight</td>
<td>7. two receivers</td>
</tr>
</tbody>
</table>
The golden Triangle: Knowledge/Innovation

- University of Twente: HAPPY!
- CML: HAPPY!
- GENTEX: HAPPY!
- RNLAF: HAPPY!
- Almost HAPPY!

CML and University of Twente

RNLAF/CML

GENTEX