New Concepts in Pilot G-Protection
Presentation at the Royal Aeronautical Society – Hamburg Branch

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CONTENTS:

- Some facts about AUTOFLUG
- Gravitational Forces and their physiological impact
- Means of Protection
- Development, Testing & Qualification
- Most recent project: the G-Race Suit

1940s Prototype of a Pneumatic G Suit
[Source: McDonnell Aircraft Company]
AUTOFLUG was founded in 1919 by pioneer aviator Gerhard Sedlmayr at Berlin-Johannisthal.

From its early beginnings until today AUTOFLUG has remained as an independent family-owned enterprise.
Safety Has a Name

Company History

- Gerhard Sedlmayr received the German Pilot licence No. 162, dated 20th February 1912.

- He set a German flight record with a flight time of more than 6 hours – performed on 14th March 1913.

Gerhard Sedlmayr on Wright „Doppeldecker“ [1913]
In 1956, Dr. med. Gerhard Sedlmayr restored the company in Rellingen near Hamburg.

The main product areas in Rellingen are:
• Rescue and Safety Technology
• Measurement and Control Systems
Safety Has a Name

The AUTOFLUG Locations

**AUTOFLUG Steuerungs- und Sensortechnik, Kirchheim**
Main activities:
- Gyroscopes
- Inertial Measurement Systems

**GECO Systemtechnik, Brüsewitz**
Main activities:
- Locking Devices

**AUTOFLUG Safety Systems, El Paso, TX**
Main activities:
- Textile Safety Seat Systems for the US Armed Forces
Safety Has a Name
Aviation in itself is not inherently dangerous. But to an even greater degree than the sea, it is terribly unforgiving of any carelessness, incapacity or neglect.
„It is not the resistance of material which limits the aerobatic performance of the artificial bird, but the physiological resistance of man, who is the brain of the artificial bird“

Louis Bleriot, 1922
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Gravitational Forces

[Source: Flugmedizinisches Institut der Luftwaffe, Königsbrück]
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Human Body and G-Forces

Drop of blood pressure and lack of oxygen will cause visual symptoms. Prolonged exposition to Gs may lead to G-induced loss of consciousness (G-LOC).

Increased heart rate due to reduced blood volume.

Due to blood pooling, the amount of blood circulating will be reduced.
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[Source: Flugmedizinisches Institut der Luftwaffe, Königsbrück]
**Safety Has a Name**

**Natural (relaxed) $G_z$-Tolerance as a Result of negative $G_z$-Preload**

<table>
<thead>
<tr>
<th>Preload: $G_z$</th>
<th>30 sec</th>
<th>16 sec</th>
<th>2 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 1.1 $G_z$</td>
<td>4.11 ± 0.43</td>
<td>4.23 ± 0.33</td>
<td>4.13 ± 0.30</td>
</tr>
<tr>
<td>- 1.0 $G_z$</td>
<td>2.66 ± 0.44</td>
<td>3.00 ± 0.39</td>
<td>3.36 ± 0.27</td>
</tr>
<tr>
<td>- 1.4 $G_z$</td>
<td>2.49 ± 0.51</td>
<td>2.80 ± 0.26</td>
<td>3.30 ± 0.21</td>
</tr>
<tr>
<td>- 1.8 $G_z$</td>
<td>2.47 ± 0.21</td>
<td>2.67 ± 0.24</td>
<td>3.19 ± 0.23</td>
</tr>
</tbody>
</table>

A.K. Lehr et. al.: ASMA 1992
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G-Forces: Means of Protection

- Pilot Equipment (G-Protection Systems)
- Aircraft Provisions (Seat Angle, Arm & Foot Position)

- Pilot Conditioning & Training
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Examples for a prone pilot position

Henschel HS 132 (1945)

XP-79 "Flying Ram" (1945)

Gloster Meteor F8 "Prone pilot" (1954)
Physiological Factors adversely affecting G-Tolerance

- Dehydration
- Low blood sugar level
- Low blood pressure
- Fatigue
- Illness / use of medications
- Smoking
- Drugs & Alcohol
- Cardiovasular fitness level
- …
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Early G-Suit Developments

Figure 2. 1940s Prototype of a Pneumatic G Suit

Figure 5. Frank’s Flying Suit
1940s prototype of a fluid-filled G protection garment.

[Source: McDonnell Aircraft Company]
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First Patent Anti-g Suit
Figure 4. Bathtub Tested at the Mayo Clinic
1940s investigations proved the principle of fluidic G protection

[Source: McDonnell Aircraft Company]
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Atlantis Warrior Prototype by McDonnell Aircraft Company

Figure 1. Atlantis Warrior™ Prototype

Figure 3. Principle of Hydrostatic G Protection
A fluid-based protection system reacts to G in the same way as the body, resulting in a balance of internal and external forces and improved G protection.

[Source: McDonnell Aircraft Company]
Pneumatic Systems - Developments

• Five Bladder Suit
  Example: CSU-13 B/P

• CSU-13 B/P plus PBG/CCPB
  Example: Combat Edge

• Full Coverage Anti-G Trousers
  plus PBG/CCPB
  Example: EF2000 AEA
Shortfalls of operational pneumatic G-Protection Systems

- Time delay (compensated by newest onboard regulators)
- Significant thermal discomfort
- Pain (depending on system used and cockpit layout)
- G-induced fatigue
- No means to compensate system malfunction
- Physiological long term effects due to positive pressure breathing (PBG)?
- Restricted communication/voice recognition at G
- Newer Systems: single aircraft solutions
- “Onionshell Design”
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The third and fourth generation challenge

• Highly agile fighter aircraft:
  - sustained 9 G capability
  - G-Onset rates of up to 15 G/sec

• Complex operational scenarios
• New theatres of operation
• New threats
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The perfect solution:
Same hydrostatic height,
same density of liquid

The practical solution:
The Immersion or
Buoyancy Suit

Back to the roots
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Hydrostatic compensation under G’s (demonstration in a Learjet)

[Pictures: Prospective Concepts]
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Prototyping and testing (1988-1997)

“Buoyancy“-Principle

[Pictures: Prospective Concepts]
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For basic calibration tests: the rigid „Headless“ (1997)

[Pictures: Prospective Concepts]
“SIGMA“-principle: the first „Fluid Muscles“
(1996 - 1998)

SIGMA-Principle

[Pictures: Prospective Concepts]
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The Hydrostatic Principle

![Diagram showing the hydrostatic principle with stages and blood flow](image-url)
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LIBELLE G-Multiplus®
From Prototyping to Certification

Starting Point:
Prototype in 2000

March 2003
First operational System

June 2006
Fully operational System
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Manufacturing Process

CD-ROM

Data Processing

email data file

Direct Link to

Direct Link to

(automatic) Cutting

(automatic) Cut Processing
Safety Has a Name

Qualification Process
Safety Has a Name

G-RACE SUIT
for the
RED BULL AIR RACE WORLD CHAMPIONSHIP

Paul Bonhomme
Red Bull Air Race World Champion 2009
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G-RACE SUIT
The Task

Use the LIBELLE-Technology to design a G-Suit for the Pilots performing in the Red Bull Air Race World Championship:

- Best possible G-Protection
- Compatible with Race Aircraft
- “Sexy” Design
- Multicolor
- Comfortable to wear
- Very short time frame until start of season

Our Starting Point:

- Military Product (colours limited to sage green and sand)
- Design and Appearance are “third” priority
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How to get the mission accomplished?

- Specify the customer requirements
- Build some prototypes (standard available colour)
- Evaluate system at human centrifuge
- Perform cockpit & equipment compatibility tests and familiarization flights
- Inflight evaluation
  - Step up program (basic flying, high performance manoeuvres, race track)
- Adapt the design
- Fabricate the G-Race Suits (all individual designs and sizes)
- Pilots: individual fitting, briefing, practical training, familiarization flights
- Autoflug acts as Official Safety Supplier and provides constant Product Support
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G-RACE SUIT
Development Process

[Images of people wearing suits and an airplane]
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G-RACE SUIT
Evaluation, Testing & Modification
Safety Has a Name

G-RACE SUIT
Training & Introduction to the Red Bull Air Race
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G-RACE SUIT
Mission „almost“ complete
Provide the best possible G-Protection to pilots *while* minimizing the physiological and medical short-term and long term negative effects.
Thank you very much for your attention!