Human Centrifuge: Past and Future

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TYPES OF G FORCES

- Negative Gx
- Positive Gx
- Negative Gz
- Positive Gy

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TYPES OF G FORCES

Y-Axis
Lateral Transl

X-Axis
Longitudinal Translation

Z-Axis
Vertical Translation
G-LOC: HISTORICAL PERSPECTIVE

- First reported in 1918 “fainting in the air”
- Aggressive dive-bombing techniques (1930s)
- G-trousers and straining maneuver (1940s)
- G-LOC is exacerbated in modern highly maneuverable aircraft
G-LOC

A state of altered perception wherein one’s awareness of reality is absent as a result of a sudden critical reduction of cerebral blood circulation caused by increased G-force.

Burton RR (1988)
MORE ABOUT G-LOC

Absolute Incapacitation Period

• classic LOC

• varies 1-18 sec, mean 12 sec
  • typical in-flight G-LOC is shorter: 1-6 sec
  • as pilot goes off the stick, plane goes to 1G

• flailing and amnesia are common
MORE ABOUT G-LOC

Relative Incapacitation Period

- 1-24 sec additional
- lights are on, but nobody is home
  - subject is upright, looks OK, but…
  - is incapable of thinking or responding
- terminates abruptly with reintegration of mental functions and return to near normal capabilities
- may lose SA
G-LOC PATHOPHYSIOLOGY

- EEG delta activity (sleep, hypoxia, coma)
- rSO₂ decreased below 90%
- After return to normal rSO₂, delta activity continues up to 60 sec after the G-LOC onset

Wilson GF et Al.: “EEG Correlates of G-Induced Loss of Consciousness”
Aviation Space and Envir. Medicine: 76, 19-27, January 2005

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STANAG 3827 (Edition 4, Draft 1)
Minimum Requirements For Physiological Training
Of Aircrew In High-G Environment

High and sustained G (HSG) is defined as a gravitoinertial (G) force equal to or greater than +7 Gz for 15 seconds.

High onset rate is defined as an onset rate of at least 3G/sec”
CENTRIFUGE TRAINING

Training Criteria

- GOR (0.1 G/sec) profile
- ROR (6G/sec) profiles
  +6 Gz for 30 sec
  +9 Gz for 15 sec
SACM (4 ÷ 9 Gz)
GAF CENTRIFUGE TRAINING

Evaluation score:

- **Natural G tolerance**
  - 3.5 - 3.9 g\(_z\): 2 points
  - 4.0 - 4.6 g\(_z\): 4 points
  - > 4.6 g\(_z\): 6 points

- **Heart rate (at 3 g\(_z\))**
  - > 160/min: 0 points
  - 140 – 159/min: 1 point
  - 120 – 139/min: 2 points
  - < 120/min: 3 points

- **Heart rate (before run)**
  - > 120/min: 0 points
  - 100 – 119/min: 1 point
  - 80 – 99/min: 2 points
  - < 80/min: 3 points

Results:

- Especially qualified: 9-12
- Qualified: 6-8
- Less qualified: < 6

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GAF PILOT SELECTION

Evaluation in the human centrifuge

especially qualified
39 %

qualified
42 %

less qualified
19 %

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GAF CENTRIFUGE TRAINING

Relaxed G - Tolerance

Pilot candidates: $4.6 \pm 0.6 \, g_z$
Student pilots: $4.8 \pm 0.7 \, g_z$
Pilots: $5.7 \pm 0.8 \, g_z$
HUMAN CENTRIFUGE OR DFS
DFS: WHAT IS IT?

- Addresses all elements of fidelity: cockpit, visual display, aeromodel, motion cueing, environmental, and mission. Provides a learning environment with authentic physical stresses and virtual experience.
- Integrates G-Pointing with a high fidelity cockpit, vehicle-performance model, tactical systems and simulated mission systems in a Virtual Battle Space.
- Provides G onset/offset rates and sustained G forces of actual tactical aircraft.
MOTION

Integrates High Fidelity Simulation With a High Performance Centrifuge-based Motion System

- Onset Rates
  - Up to 10 G/Sec
- Maximum G Capability
  - -8 Gz to +15 Gz
  - +/- 8 Gx
  - +/- 6 Gy
- Powered gimbals for accurate Pitch and Roll Control
- Aircraft Specific modules
  - Authentic Cockpits with Realistic Flight Controls and Instrumentation
- High Definition, Wide FOV Visuals
- G-Pointing
- Aircraft Specific
- Virtual Battlespace
G-POINTING

A Process Whereby the Centrifuge Gondola is Continuously and Actively Oriented to Provide Pilots with…

High Fidelity, Sustained G Levels to Stress Pilots in the Same Manner as in Tactical Aircraft
MULTIAXIAL ACCELERATION

- **Gx/Gz**: $-3G_x; +7.5\ G_z$
  $\pm 4G_x; -1.5\ G_z$

- **Gy/Gz**: $\pm 3\ G_y; +7.5\ G_z$
  $\pm 3\ G_y; -1.5\ G_z$

- **Gx/Gy**: $\pm 4G_x; \pm 3\ G_y$

- **Gx/Gy/Gz**: $-3G_x; -2G_y; +7.5\ G_z$
  $\pm 3G_x; \pm 2G_y; -1.5G_z$
VISUAL DISPLAY SYSTEM

- High Definition, Wide FOV Visuals - 120° By 70°
- Image Created Using High Resolution Projection
- Incorporates Real-Time Updates With High Resolution Graphics
- Out-The-Window Visuals created by Computer Generated Image (CGI) System

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DFS PROVIDES

- Primary Training/Ops
  - Initial and Refresher G-Training
  - Visual Tactical Maneuvering
  - Dissimilar Air Combat Training (DACT)
  - Interdiction/CAS Maneuvering
  - Defensive Maneuvers
  - Departure from Controlled Flight Training

- Other Training/Ops
  - High Angle of Attack (AOA) Maneuvering
  - Electronic Warfare Training
  - Edge of the Flight Envelop Training
  - Aircraft Handling with Simulated Combat Damage
  - Mission Rehearsal
  - Instrument Training
  - Mishap Investigation
## DFS PAYOFF

<table>
<thead>
<tr>
<th>DOMAIN</th>
<th>Pilot</th>
<th>Tactics</th>
<th>Aircraft</th>
</tr>
</thead>
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<td><strong>Operational</strong></td>
<td>• Fly To Edge Of Personal Envelope</td>
<td>• Evaluate Proposed Tactics</td>
<td>• Improve Aircraft Flight Control Model</td>
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<tr>
<td><strong>Acquisition</strong></td>
<td>• Reduce Wear And Tear On Aircraft</td>
<td>• Enhance Man-System Interface</td>
<td>• Better Modification Strategies</td>
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<td><strong>Logistics</strong></td>
<td>• Better Post-Flight “Gripes”</td>
<td>• Optimize Weapons Control Models</td>
<td>• Improved Automated System Features</td>
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<tr>
<td><strong>Readiness</strong></td>
<td>• Enhanced Operational Readiness</td>
<td>• Optimize Doctrine</td>
<td>• Extend Aircraft &amp; System Service Life</td>
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<tr>
<td><strong>Operating Costs</strong></td>
<td>• Lower Cost To Train</td>
<td>• Better Resource Allocation Model</td>
<td>• Utilize Aircraft Better</td>
</tr>
</tbody>
</table>
WHY DFS?

PILOT CAPABILITY
TACTICS
AIRCRAFT CAPABILITY

MAXIMIZE COMBAT CAPABILITY
BY CREATING A HIGH FIDELITY ENVIRONMENT WHEREIN PILOTS CAN SAFELY TRAIN LIKE THEY WILL FIGHT
TACTICAL DFS CONCEPT

- Complete Flight Training and Simulation Solution
- Three Modes of Operation:
  - Stand-alone, Stationary Tactical Simulator
  - Basic Human centrifuge for G-familiarization
  - Motion-based, High-G Tactical Flight Simulation System
DFS IS THE FUTURE

- Achieve Training Goals Safely and Economically While Maintaining Aircrew Combat Readiness
- Integrated with Distributed Mission Training

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IT IS NO LONGER SUFFICIENT FOR COMBAT PILOTS TO JUST TOLERATE HIGH G. . . . RATHER PILOTS MUST BE ABLE TO EFFECTIVELY FIGHT IN THE HIGH G ENVIRONMENT

TRAIN AS THEY FLY
NOTHING COMES CLOSER TO THE REAL THING

DFS
HIGH FIDELITY  INTERACTIVE  MISSION REALISTIC

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CONCLUSIONS

“THE G-ENVIRONMENT IMPOSED BY AIR COMBAT … IS NOW SUFFICIENTLY HAZARDOUS THAT FIGHTER AIRCREW, WHO ARE NOT THOROUGHLY FAMILIAR WITH THE PHYSIOLOGICAL EFFECTS OF SUSTAINED HIGH G FORCES, AND WHO HAVE NOT MASTERED THE MEANS OF PREVENTING INCAPACITATION DUE TO THESE EFFECTS, ARE AT HIGH RISK OF BECOMING INVOLVED IN A FATAL AIRCRAFT MISHAP”

K. GILLINGHAM, 1988
CONCLUSIONS

THE DYNAMIC THREAT ENVIRONMENT IN THE SUPERMANEUVRABLE, AGILE, THRUST-VECTORED AIRCRAFTS MANDATES A HIGHER LEVEL OF SYSTEMS INTEGRATION AND, PERHAPS, NEW AIRCREW SKILLS TO BE DEFINED
NEW AIRCREW SKILLS

- Information management
- Situation awareness
- Spare mental capability
- Team-worker
- Sustained OPS
THANK YOU VERY MUCH