SUPRA – Simulation of UPset Recovery in Aviation

Project Overview

*Dr. Eric Groen, Scientific Coordinator*
SUPRA project

Funding scheme: Collaborative Research
EU Call: AAT-2008-RTD-1
THEME: AERONAUTICS & AIR TRANSPORT
AREA: Aircraft Safety

Objectives:

• Reduce aircraft accident rate with 80%
• Improve elimination of, and recovery from human error
### SUPRA project

#### Consortium

<table>
<thead>
<tr>
<th>No.</th>
<th>Participant organization name</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TNO</td>
<td>Netherlands</td>
</tr>
<tr>
<td>2</td>
<td>NLR (National Aerospace Laboratory)</td>
<td>Netherlands</td>
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<tr>
<td>3</td>
<td>AMST Systemtechnik</td>
<td>Austria</td>
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<tr>
<td>4</td>
<td>BR&amp;TE (Boeing Research &amp; Technology Europe)</td>
<td>Spain</td>
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<td>5</td>
<td>GFRI (Gromov Flight Research Institute)</td>
<td>Russia</td>
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<td>6</td>
<td>TsAGI (Central Aerohydrodynamic Institute)</td>
<td>Russia</td>
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<td>7</td>
<td>Dinamika</td>
<td>Russia</td>
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<tr>
<td>8</td>
<td>De Montfort University</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>9</td>
<td>Max Planck Institute for Cybernetics</td>
<td>Germany</td>
</tr>
</tbody>
</table>

- **Budget**: 4.9M€
- **September 2009 – 2012**
The problem

- Loss-of-Control (LOC-I) leading cause of fatal accidents
- Unsuccessful upset recovery often contributing factor

### Number of accidents

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>LOC-I:</td>
<td>Loss of control – inflight</td>
<td>12</td>
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<tr>
<td>CFIT:</td>
<td>Controlled flight into or toward terrain</td>
<td>11</td>
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<tr>
<td>F-Post:</td>
<td>Fire/smoke (post-impact)</td>
<td>10</td>
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<tr>
<td>SCF-PP:</td>
<td>Powerplant failure or malfunction</td>
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<tr>
<td>SCF-NP:</td>
<td>System/component failure or malfunction (non-powerplant)</td>
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<td>RAMP:</td>
<td>Ground Handling</td>
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<td>RE:</td>
<td>Runway excursion</td>
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<tr>
<td>ATM:</td>
<td>ATM/CNS</td>
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<tr>
<td>ADRM:</td>
<td>Aerodrome</td>
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<tr>
<td>ARC:</td>
<td>Abnormal runway contact</td>
<td>3</td>
</tr>
<tr>
<td>ICE:</td>
<td>Icing</td>
<td>3</td>
</tr>
<tr>
<td>F-NI:</td>
<td>Fire/smoke (non-impact)</td>
<td>3</td>
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<tr>
<td>OTHR:</td>
<td>Other</td>
<td>3</td>
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<tr>
<td>USOS:</td>
<td>Undershoot/overshoot</td>
<td>2</td>
</tr>
<tr>
<td>RI-VAP:</td>
<td>Runway incursion – vehicle, a/c or person</td>
<td>2</td>
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</tbody>
</table>
The problem

- LOC-I accidents in Russian states:
  - 1994: A-310  (stall, upset, spatial disorientation)
  - 1995: Tu-154  (upset, spatial disorientation)
  - 2000: Yak-40  (stall at takeoff)
  - 2001: Tu-154M  (stall at approach for landing)
  - 2002: Il-86  (upset, stall after takeoff)
  - 2005: An-24  (stall at approach for landing)
  - 2006: A-320  (spatial disorientation, upset)
  - 2006: Tu-154M  (deep stall)

- Russian Center for Upset and Stall Training  
  (Interstate Aviation Committee)
Upset Recovery

The problem

- Airline pilots trained to *avoid* upset situations
- Recognized need for (simulator) training
- Simulator training cost-effective and safe

**However, current FFS inadequate:**

- Aerodynamic models
- Motion envelope (in particular G-load)
SUPRA project

Main objective

- To develop advanced flight simulator technologies for teaching airline pilots to detect and recover from upset conditions

Research activities

- Definition of relevant upset conditions
- Aerodynamic modeling
- Pilot perception modeling
- Motion cueing algorithms
- Final experimental evaluation
Aerodynamic modeling

Baseline aerodynamic models

- Limited to standard flight envelope

(Cunningham et al. 2005)
Aerodynamic modeling

Baseline aerodynamic models

- Limited to standard flight envelope

Required extensions

- Non-linear aerodynamics at high AoA, angular rates
- High load deformations at high incidence
- Dynamic hysteresis
- Validation versus dynamic wind tunnel and flight tests
Aerodynamic modeling

Computational Fluid Dynamics

- Unsteady non-linear aerodynamics
- Load deformations
Aerodynamic modeling

Phenomological modeling

- Captures dynamic hysteresis
- Consistent with flight dynamics equations
Flight tests

- Instrumented TU-154
- High AoA, spin & stall, maximum loading
- To validate extended aerodynamic models
- To determine recovery procedures
SUPRA Research simulators

Hexapod-based FFS
- GRACE (NLR)
- PSPK-102 (TsAGI)

New-generation motion platforms
- DESDEMONA (TNO)
- Kuka (Max Planck)
Motion cueing

- Mathematical filters that confine the motion space of the simulator, while still providing the *relevant* motion cues.

Washout filters

1 km³

0.000000003 km³
Motion cueing

Classical washout filters

- Linear transfer functions
- Optimized for normal flight envelope

Advanced motion filters (TNO, NLR, TsAGI):

- Extreme attitudes
- High angular rates
- G-cueing
Motion cueing

New motion cueing strategies

- Hexapod emulation (4x2x2m)
- Spherical washout (∞ x2x2m)
Motion cueing

New motion cueing strategies

- **G-cueing**
  - Currently being developed for F-16 (and SUPRA)
  - Smart use of extra DoF’s (e.g. extra Heave onset)
Motion perception modeling

**TNO model**

- Transfer functions of visual-vestibular interactions
- Validated at 1g in hexapod FFS (takeoff, decrab)
Motion perception modeling

Research issues

- Motion perception under G-load
- Detection thresholds and tolerances
  - False cues (e.g. Coriolis stimulation)
Experimental validation

- Experimental test pilots
- Airline pilots
- Quasi transfer-of-training

Aircraft model
Motion cueing
Upset scenario
End result

Efficacy of different simulator configurations for upset recovery

- Hexapod
- DESDEMONA

Recommendations

- Upset recovery procedures
- Aerodynamic model extensions
- Motion cueing requirements
<table>
<thead>
<tr>
<th>Expert</th>
<th>Organisation</th>
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<tbody>
<tr>
<td>Cpt. Dave Carbaugh</td>
<td>Boeing</td>
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<tr>
<td>Cpt. Etienne Tarnowski</td>
<td>Airbus</td>
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<tr>
<td>Cpt. Vladimir Birykov</td>
<td>Russian Interstate Aviation Committee</td>
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<tr>
<td>Cpt. Wilhelm Brugger</td>
<td>Austrian Cockpit Association</td>
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<tr>
<td>Cpt. Heinz Fruewirth</td>
<td>European Cockpit Association</td>
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<tr>
<td>Cpt. Dieter Reisinger</td>
<td>IATA Accident Classification Task Force</td>
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<td>Cpt. Raymond Teunissen</td>
<td>KLM</td>
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<tr>
<td>Cpt. Fili van Biervliet</td>
<td>Sabena Flight Academy</td>
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<td>Dr. Sunjoo Advani</td>
<td>IDT</td>
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<tr>
<td>Ir. Victor Fuchs</td>
<td>AUA Flying School</td>
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Conclusion

The SUPRA project:

- Integrative approach to stretch the envelope of ground-based simulators for upset recovery
- Unique expertise and facilities