Aircraft Upset Recovery Simulation
The Dutch Approach

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Military Aviation

- Upset recovery simulation in the RNLAF is the result of a close cooperation between the Air Force (aeromedical institute) and TNO (research), and later AMST (industry)
- It is an end product of the steady SD training development over the last 50 years, which will be shown in the subsequent slides.
≈1960: RNLAF demonstration of limitations of vestibular system to student pilots
≈1970 more sophisticated device....
≈1985: basic visual-vestibular demonstrations
1998: Significant changes in SD training

- Aeromedical Institute acquired the Airfox DISO
  - Man in the loop
  - Demos of in-flight illusions on the ground
    - Generic aircraft model
    - Generic cockpit
    - Out the Window visuals
2013: replacement of DISO by ASD

- Training and R&D
- >> OtW visuals
- 1-/2-seater
2008: Desdemona 6DoF motion research platform, result of close cooperation between AMST and TNO

• Nested design requires new motion cueing solutions
  – Smooth transitions from e.g. hexapod ↔ centrifuge motion

• Example applications:
  – Spatial Disorientation
  – F-16 simulation
  – Upset Recovery
F-16 simulation

- Requires semi realistic cockpit
- Requires highly sophisticated aircraft model
- Requires specific motion cueing solutions
- Test pilots needed for final tuning of motion cueing and validation
Results

– Comparison of ULT (fixed base), Desdemona and in flight:
  • Judgement of experienced pilots was that in all investigated aspects Desdemona matched the real in flight (inverted) stall recovery.
  • The ULT stall recovery was judged much lower.

– Training of RNLAF F16 pilots.
Commercial Aviation

• Loss of Control in flight causes 33% of all accident fatalities in last 10 years
  – Unsuccessful upset recovery often contributing factor
  – Pilots have hardly any experience in upset recovery
  – Upset recovery training in the air is rather tricky
  – Standard hexapod systems not ideal for this simulation
  – European project SUPRA (2009-2012) addressed this issue:
    the consortium consisted of:
    (NL) TNO NLR DESDEMONA
    (RU) TsAGI GFRI CSTS “Dinamika”
    (UK) DeMontfort University
    (AT) AMST
    (DE) Max Planck Institute
    (ES) BR&TE
Flight simulation

Mathematical aircraft model

Image Gen.

Control loading

Motion cueing
Flight simulation

Mathematical aircraft model

Image Gen.

Control loading

Motion cueing

Problematic for Upset Recovery
Limitation of flight simulator

- Aerodynamic model
  - Applies to normal flight envelope
  - Not valid outside this envelope
  - Unrepresentative upset behavior

- Motion cueing
  - Adequate for normal flight operations
  - Only onset motion cues
  - No sustained rates / G-loads
Advanced aerodynamic modeling

- Unique combination of engineering methods
- Non-linear aerodynamics at high angle-of-attack
- Unsteady effects, lateral-directional instability

Wind tunnel data

CFD Predictions

\[ C_{dyn} = \frac{\tau_s}{\tau_s + 1} \Delta C(\alpha) \]

Flight test data

Phenomenological
Desdemona motion cueing
SUPRA Evaluation

- Piloted evaluations

- Phase 1
  - Expert test pilots
  - Model qualification

- Phase 2
  - Line pilots
  - No previous upset exposure
  - Objective metrics

Capt. Vladimir Biryukov

Capt. Dave Carbaugh
Results from SUPRA

• SUPRA successfully extended the aerodynamic flight envelope
• Optimized filter superior to current hexapod designs
• G-cueing is the preferred solution, when available
Conclusions

• Ground based flight training is with the right simulation methods a validated, reliable, safe and cost-effective approach, for military as well as for civil aviation.

• An analysis of the maneuvers to be simulated should indicate the type of simulator to be used