Pilot Training In Spatial Disorientation, Upset Prevention & Recovery

Appendix 2 - Syllabus

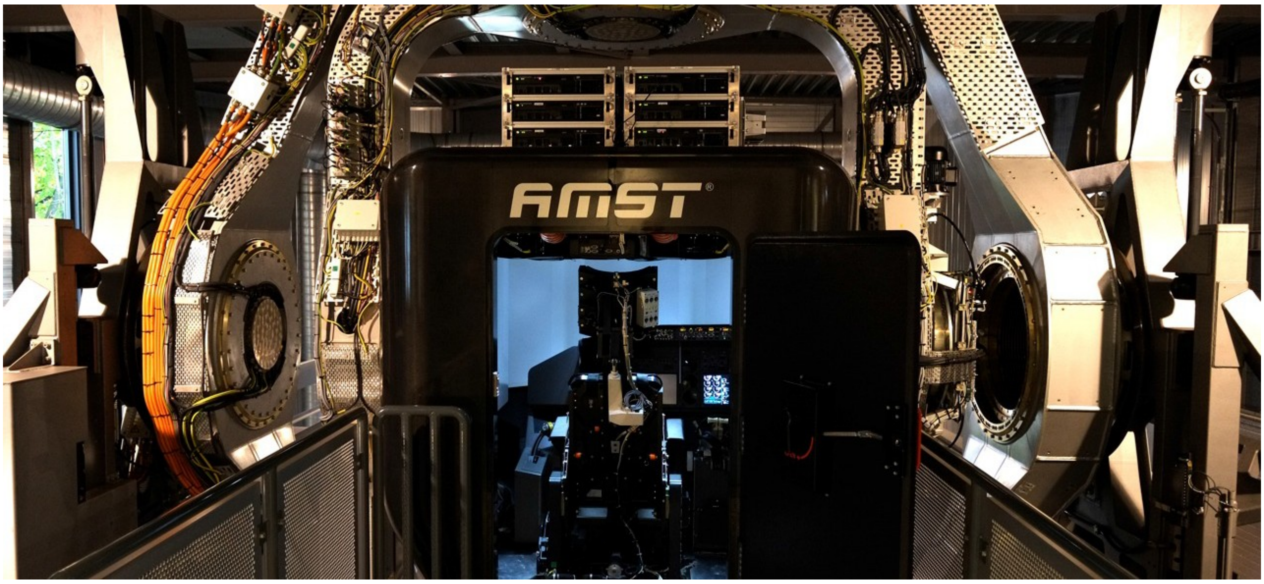

Figure 1: Desdemona is the world's most advanced motion simulator

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1 Goal

To demonstrate to pilots the basic limitations of the human perceptual system that can potentially lead to flight conditions close to, or over the limits of the aircraft. The training was developed by international subject matter experts to satisfy the actual standards set by ICAO (Doc. 10011), FAA (NOTICE N 8900.241, AC 120-111, AC 120-109A) and EASA (ED Decision 2015/012/R). The course provides relevant knowledge and experience, which are requested for UPRT instructors. All elements of the IATA Syllabus released within the Document 'Guidance Material and Best Practices for Implementation of Upset Prevention and Recovery Training' could be trained on the Specialized-UPRT-Flight-Simulator Desdemona.

To provide pilots the knowledge and skills to avoid, recognize, and recover aircraft states at the limits of the flight envelope, in scenarios that include 'high'-G upset recoveries, approach-to-stall, and full stall.

2 Course Design

The course was developed on a synergetic approach, while facilitating best scientific knowledge in combination with senior subject matter experts. Substantial expert knowledge and experience has been invested in the design of the course. During the three-years project SUPRA (2009-12) more than 10 international knowledgeable scientists and test pilots have shaped the core part of this course. Due to continuous improvement of details of the program, the course finally has been fine-tuned according to the SARPS, rules, AMCs and GM issued by the respective competent authorities and other stakeholder organisations.

The course at it exists now is a basis, which includes all important elements. Depending on the specific need of airlines and ATOs the course could be easily adapted to any specific need. A valuable contribution could be the integration of airline type-specific additional material within the academics.

The course concept includes academics and in-flight-training. The academic course is split in several lessons. Topics that are covered are:

- Spatial Disorientation
- Aerodynamics & stall behaviour
- Aircraft & simulator limitations
- Human Factors
- Case studies of relevant accidents
- SOP / OEM Recommendations

The extensive practical training is performed during several session using the Desdemona Specialized-UPRT-Flight-Simulator with realistic G-FORCES. Within Desdemona someone could experience the real situation facing during any undesired aircraft state in a safe and the most realistic way. The pilot will be immersed by the full situation, including realistic G-loading and attitude and realistic out-of-the-normal-flight-envelope aircraft behaviour of a typical transport class aircraft.

Most relevant SD phenomena, like sub-threshold roll, coriolis in fast turn, somatogyral illusion (graveyard spin) and somatogravic illusion are presented and experience during the first practical session.

16 leveraging manoeuvre-based scenarios build the foundation of the second and third session of practical training. During the second sessions the pilots may fly the scenarios like in a FFS (hexapod mode). Within session three the recovery scenarios are then flown in a full motion (including realistic G-loading and attitude replication). The comparison of the two motion experiences may help the pilot (instructor) to assess the impact of real physical pilot loading on pilot's performance. This is an important element, that the instructor is well aware upon the shortcoming of conventional FFS, especially when it comes to motion cueing and the valid-training-envelope.

The typical approach is to train the pilots (instructors) to gain proficiency rather than using the course a check. Based on the performance the pilot showed during the exercises plus his own feedback regarding his or her confidence to cope in future with such threatening flight scenarios the pilot my repeat those scenarios that are relevant to him or her.

3 Programme Overview

- Briefing pilot limits & Spatial Disorientation 70 min.
  - Simulator SD awareness demo's 25 min.
- Briefing aircraft model & stall behaviour 60 min.
  - simulator improved hexapod mode 60 min.
    - familiarisation
    - unusual attitude recovery
    - full stall recovery
  - simulator G-forces mode 30 min.
    - unusual attitude recovery
    - full stall recover

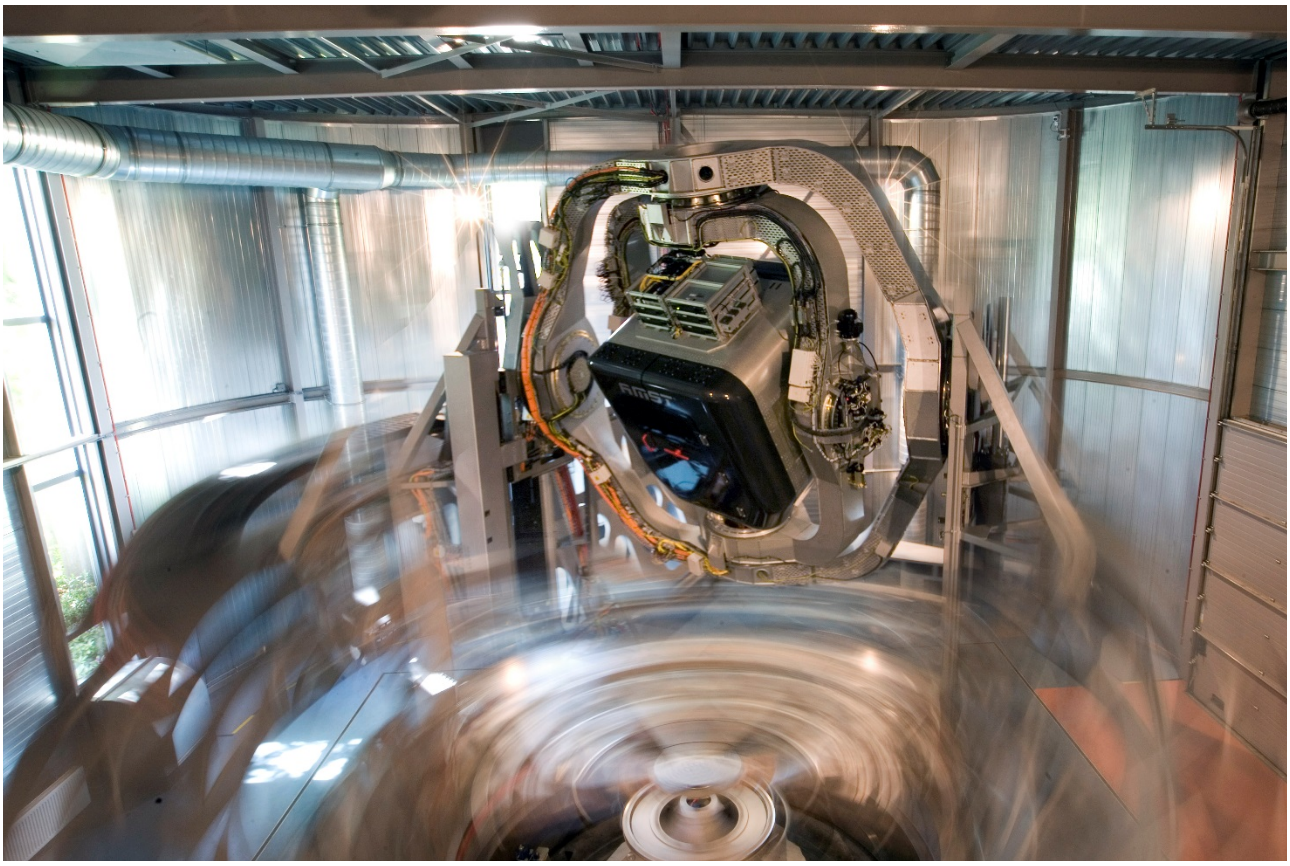


Figure 2: The Desdemona simulator can simulate recoveries up to 3G

4 Instructors

4.1 Chief instructor

Captain Chris Roberts FRAeS
Aviation Consultant
London, UK

As Chris Roberts served in the Royal Air Force as a fighter pilot, flying Instructor, weapons instructor and test pilot. Subsequently he flew for British Aerospace as Chief Test Pilot on Hawk, T45, Harrier and Sea Harrier programmes in the UK and USA. In 1994 he joined MyTravel International Airways on the MD83, and then operated as a Captain on Airbus A320/321 and A330 in addition to duties as a senior airline manager. Now a self-employed aviation consultant he is involved in instructional, regulatory, simulator and safety tasks, and is an expert witness in the UK courts.

4.2 Scientific experts

Mark Wentink, MSc. PhD
DESDEMONA BV and Simendo Ltd.
Soesterberg, The Netherlands

As co-owner and director of technology of two simulator companies, Mark Wentink has a wide experience in the field of applied simulation for research, training and education. At Simendo Ltd. he is responsible for research and development of training solutions in surgery and at Desdemona Ltd. he operates a unique motion simulator for (military) pilot training and perception research. In DESDEMONA pilots train to handle upset conditions in flight, such as disorientation and stalls.

Mark Wentink received his master of science degree at Aeronautical Engineering working on flight simulation at the Delft University, and obtained his PhD-degree ‘cum laude’ with a thesis entitled: Hand-eye coordination in minimally invasive surgery: Theory, practice & training.

Dr. Bernd de Graaf
DESDEMONA BV
Soesterberg, The Netherlands

Dr. Bernd de Graaf studied psychophysics and philosophy. In 1990 he defended his PhD. thesis on the influence of eye movements on visual perception. Since then he worked in different positions at TNO Human Factors in Soesterberg. In the old days he developed a disorientation demonstration course for aviators, and a desensitisation training for aircrew who suffer from air sickness. He build a Mission Simulation Centre for the Royal Netherlands Air Force, to determine which elements of flying hours can be trained on the ground, with other words, to validate military flight simulation. Furthermore a large synthetic research environment has been developed for joint and combined Ops in Network Centric Warfare (“SimNEC”). He managed several research programs for the Dutch Armed Forces and a series of projects for, for example, the entertainment industry (rollercoasters). From 2001-2011 he was a member of the NATO Research & Technology Organisation: Human Factors and Medicine Panel. In 2007 he was elected Vice Chairman. In 2009-2011 he served as Chairman. In 2010 he left TNO to start his own company. He now is managing director of Desdemona, the new advanced moving base simulation facility in the Netherlands

5 Briefing Pilot Limits

Useful and informative briefing about the peculiarities of the human visual, vestibular and somatosensory systems, required to understand spatial disorientation, human operator behaviour in flight and other human factor related issues affecting pilots.

6 SD Awareness Demonstration on Desdemona

Demonstration of basic spatial disorientation (SD) effects that clearly show the limits of the human perceptual system, and that can potentially lead to adverse flying conditions, if not recognized by the pilot flying. The demonstrated effects include:

- 'seat of the pants' pitch estimation
- sub-threshold roll
- coriolis in fast turn
- somatogyral illusion in spin
- nystagmus demonstration
- somatogravic illusion (false pitch sensation when accelerating in e.g. go-around)

Most of the pilots being trained for their military service already passed their SD training during ab-initio course. This SD awareness demonstrations are based on the more than 20 years of experience in training the military staff. Those SD phenomena, which are relevant for civil commercial pilots have been adapted and some further important elements have been added to make this a comprehensive experience.

Figure 3: SD awareness is key for any pilot

7 Briefing Aircraft Model & Stall Behaviour

The SUPRA[1] flight model (see section 9) represents a class-specific reconfigurable aircraft, and is capable of simulating aircraft states up to 90 degrees angle-of-attack and 20 degrees side-slip. Typical phenomenon and handling at the limits of the flight envelope can be demonstrated. The briefing includes topics such as:

- refresher about angle-of-attack versus body angle (pitch)
- swept wing aerodynamics and Lift curves
- underwing-mounted engines effects
- Airspeed limits
- effects of weight and G-loading on speed limits (V-n)
- Energy management
- Typical FFS limitations
- Typical aircraft handling close to stall and in full stall (SOP and OEM recommendations)

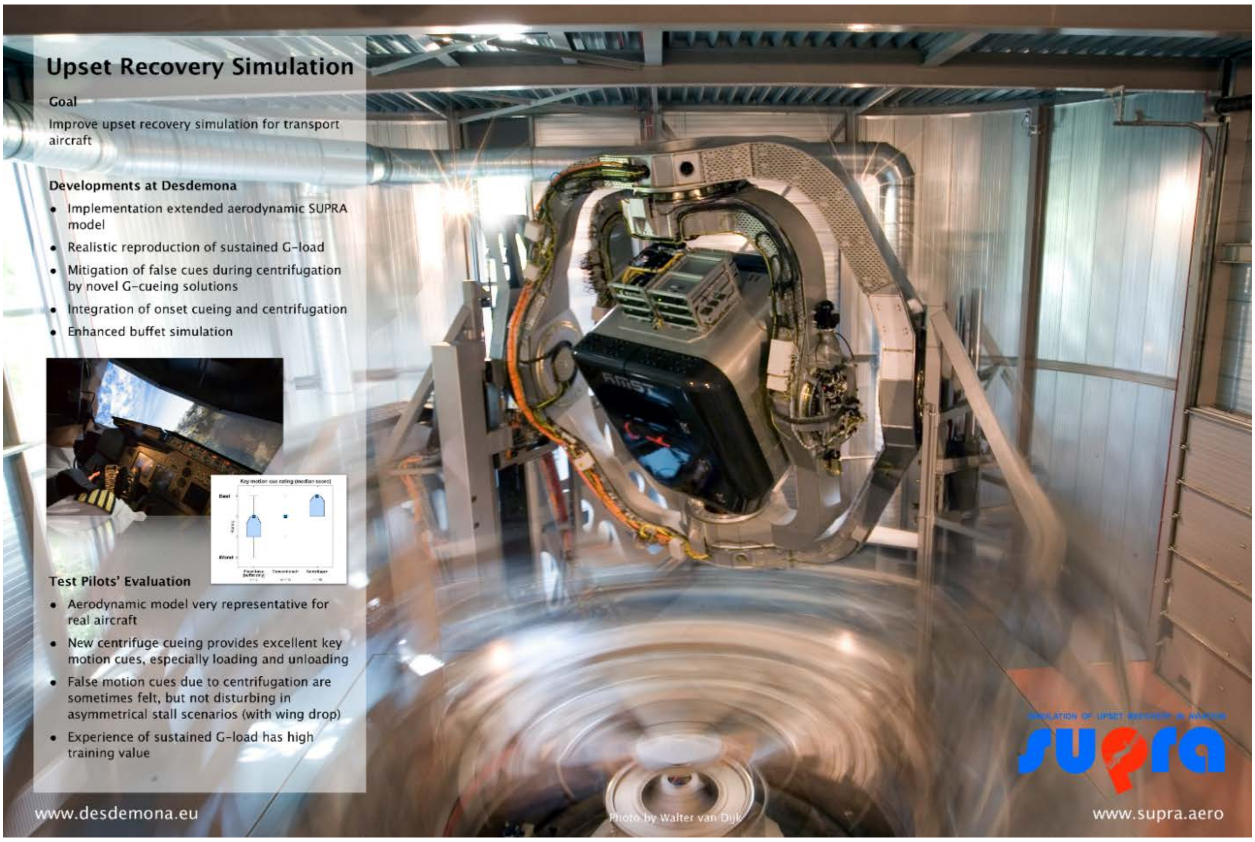


Figure 4: The Desdemona simulator can simulate recoveries up to 3G

[1] SUPRA is a European project on upset recovery and stall simulation for pilot training (2009-2012)

8 Training Scenario's on Desdemona in Improved Hexapod Mode

Figure 5: Generic B737 style cockpit

8.1 Familiarisation

Scenario 1: aircraft familiarisation

- FL 200 SPD 240 AP1 on AT on HDG 041
- disengage AP / AT
- manual flight, familiarisation

8.2 Unusual attitude prevention exercises

Scenario 2: steep dive recovery

- FL 200 SPD 210 AP1 off AT on HDG 041
- manual symmetric flight, pull G, at least up to 2G
- notice G-forces and control forces

Scenario 3: nose high recovery

- FL050 SPD 240 AP1 on AT on HDG 041
- disengage AP1 / AT
- nose high recovery
- pitch recovery and / or recovery with bank, notice effect on unloading

Scenario 4: wake vortex encounter on approach

- 2000ft SPD 220 AP1 on AT on HDG 041
- wake vortex rolls aircraft on approach, overbank disengages autopilot
- recover

Scenario 5: nose low recovery

- FL370 SPD 250 AP1 on AT on HDG 041
- disengage AP1 / AT
- nose low recovery at high altitude
- notice small speed margin, Mach buffet in over speed

8.3 Unusual attitude recovery exercises

Scenario 6: steep dive, 120° bank recovery

- FL 200 SPD 210 AP1 off AT on HDG 041
- manual symmetric flight, pull G, at least up to 2G
- roll to nearest horizon, then pull

Scenario 7: nose low, low altitude recovery

- 2000ft
- disengage AP1 / AT
- recover

Figure 6: B737 wing drop during approach (low altitude)

8.4 Stall prevention exercises

Scenario 8: approach to level stall

- FL200 SPD 220 AP1 on AT on HDG 041
- use AT to decrease speed (to minimum speed)
- disengage AP1 / AT
- manual flight up to stick shaker activation
- recover
- notice control surface effectiveness, roll instabilities, effect of power on pitch, hysteresis of shaker, etc.

Scenario 9: approach to stall in low-level circuit (clean)

- 3000ft SPD 220 AP1 on AT on HDG 041 to 210
- unexpected disengage of auto throttles
- speed decreases, approach to stall in tur
- disengage AP1 / AT
- recover level flight @ 3000ft
- notice small speed margins, decreasing speed, decrease in roll effectiveness near stall

8.5 Stall recovery exercises

Scenario 10: fully developed stall with wing drop

- FL380 SPD 230 AP1 on AT on HDG 041
- accelerated stall in AP climb
- disengage AP1 / AT
- recover
- notice nose low attitude required for safe, efficient recovery, small speed margins

Scenario 11: fully developed stall with strong wing drop

- FL200 SPD 250 AP1 on AT on HDG 041
- accelerated stall in AP climb
- disengage AP1 / AT
- recover
- notice extreme wing drop, safe recovery @ ~1.6G

9 Training Scenario's on Desdemona in G-Forces Mode

9.1 Unusual attitude recovery exercises

Scenario 12 (like 2): steep dive recovery

- FL 200 SPD 210 AP1 off AT on HDG 041
- manual symmetric flight, pull G, at least up to 2G
- notice G-forces and control forces

Scenario 13: extreme attitude recovery

- FL300 SPD 250 AP1 off AT on HDG 041
- disengage AT
- restore bank then nose attitude, long recovery
- pull max (2.5) G

Scenario 14 (like 6): steep dive, 120° bank recovery

- FL 200 SPD 210 AP1 off AT on HDG 041
- manual symmetric flight, pull G, at least up to 2G
- roll to nearest horizon, then pull

9.2 Stall recovery exercises

Scenario 15 (like 10): fully developed stall with wing drop

- FL380 SPD 230 AP1 on AT on HDG 041
- accelerated stall in AP climb
- disengage AP1 / AT
- recover
- notice nose low attitude required for safe, efficient recovery, small speed margins

Scenario 16 (like 11): fully developed stall with strong wing drop

- FL200 SPD 250 AP1 on AT on HDG 041
- accelerated stall in AP climb
- disengage AP1 / AT
- recover
- notice extreme wing drop, safe recovery @ ~1.6G

10 Background on SUPRA Flight Model evaluation[2]

SUPRA successfully extended a generic aerodynamic model to capture the key aerodynamic behaviour of transport category aircraft at high incidence flight. Through the simulator experiments, the SUPRA project has demonstrated that motion based simulators have an essential part to play in upset recovery. The enhancement of the aerodynamic model, combined with modifications to the motion cueing on both hexapod and centrifuge simulators provide a state-of-the-art platform for upset prevention and recovery training. Based on the judgments of highly experienced test pilots it was shown that current hexapod motion can be improved without introducing new unacceptable false cues, so as to provide realistic feedback about the lateral and directional dynamics occurring at the initial part of the upset and stall entry. Centrifuge-based motion cueing was considered useful to increase the pilot's G-awareness during pitch recoveries.

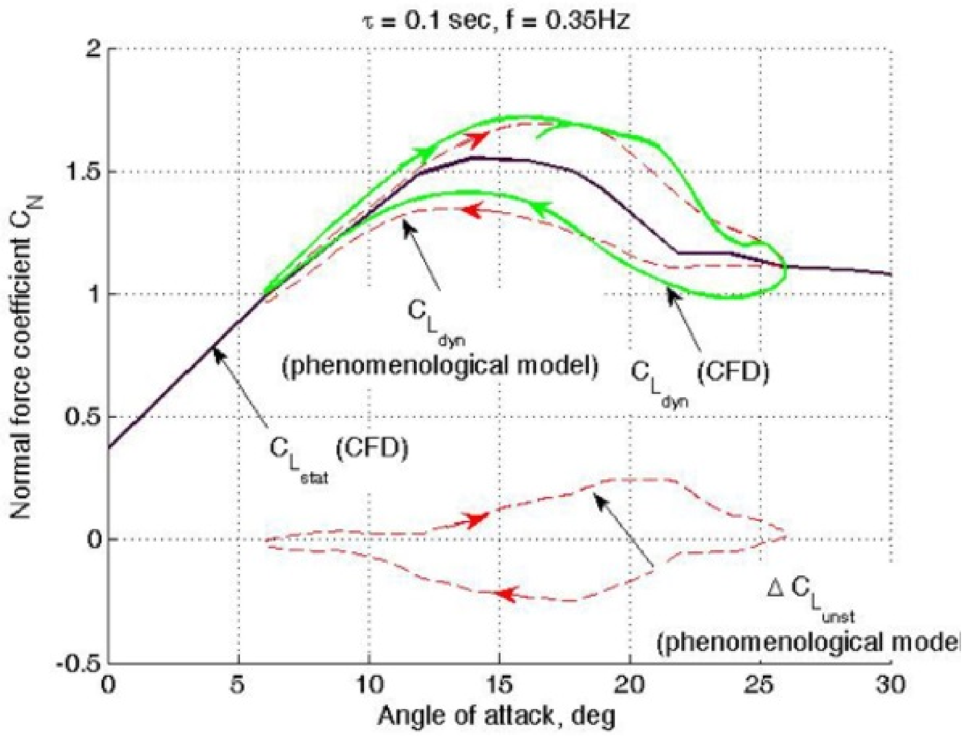
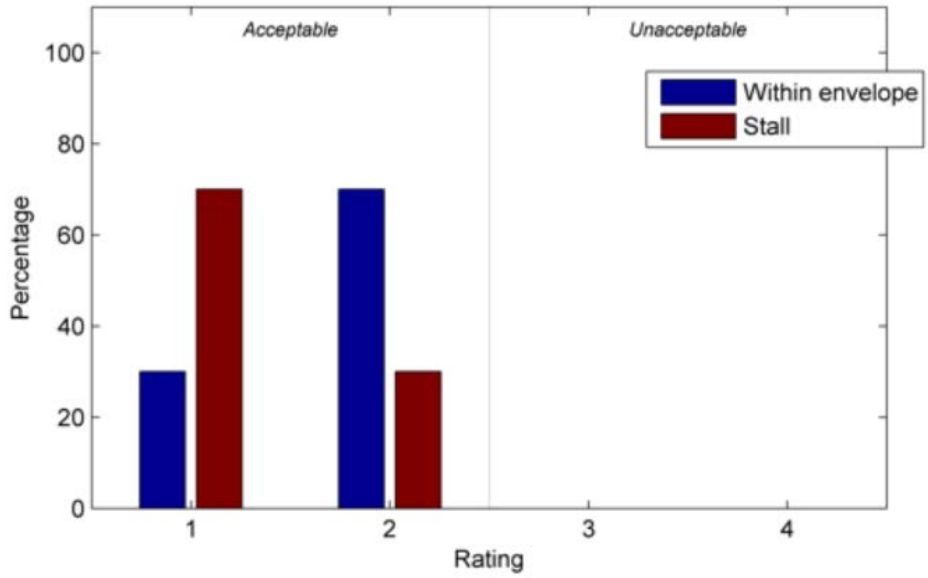


Figure 7: Phenomenological approach was used to model typical behaviour

The objective of the flight dynamics and aerodynamic modelling within SUPRA was to extend the normal flight envelope and reproduce the non-linear aerodynamic effects that may dramatically change aircraft behaviour in high incidence flight conditions. Using a phenomenological approach previously applied successfully to similar problems with military aircraft, supported by wind tunnel and unsteady Computational Fluid Dynamics (CFD) methods, SUPRA developed a reconfigurable, class-specific model of transport aircraft, which can be reconfigured rapidly to represent different stall departure characteristics. The model is capable of reproducing key aerodynamic non-linearity's that occur at high angle-of-attack and side-slip angles, as well lateral-directional instabilities (autorotation).

[2] from Simulation of UPset Recovery in Aviation final project report, dr. E.L. Groen, TNO The Netherlands

The extended aerodynamic model and the optimized motion cueing algorithms were integrated into the hexapod- and centrifuge-type research simulators of SUPRA for the final evaluation. Flight deck characteristics such as displays and controls were brought to a common generic commercial transport standard facilitating comparison of evaluation results between simulators. A group of 12 highly qualified experimental test pilots (42-61 years; between 7,200-22,000 flight hours), familiar with upset situations from real flight, participated in the validation of the simulator concept. These expert pilots rated the stall behaviour of the SUPRA aerodynamic model as quite accurate and acceptable for pilot training.



12 test pilots rated the SUPRA flight model. Rating 1 means: Representative of the class of airplane, minimal pilot adaptation required. Rating 2 means: mostly representative to class of airplane, requires minor pilot adaptation.

Regarding motion fidelity, the pilots noted that the enhanced buffet motion cueing at the onset of aerodynamic stall was very realistic both in the hexapod simulator and in DESDEMONA. The optimized motion cueing in the hexapod was rated higher than the standard cueing, and did not introduce additional false cues. In DESDEMONA, the large roll-off manoeuvres were especially judged realistic and were considered a big advantage over current hexapod simulators. The g-cueing seemed to reproduce key motion cues of appropriate magnitude, rated as “equivalent to the real airplane”. Although the spin-up and spin-down of the centrifuge caused some false cues which were noticeable during symmetrical stall scenarios, they were masked by the dynamic cueing environment related to asymmetrical stall scenarios. As a result, “g-cueing” was selected as the preferred cueing option for asymmetric stalls by 90% of the pilots.

"The flight model represents typical stall behaviour quite accurately"

12 TEST PILOTS IN SUPRA EVALUATIONS