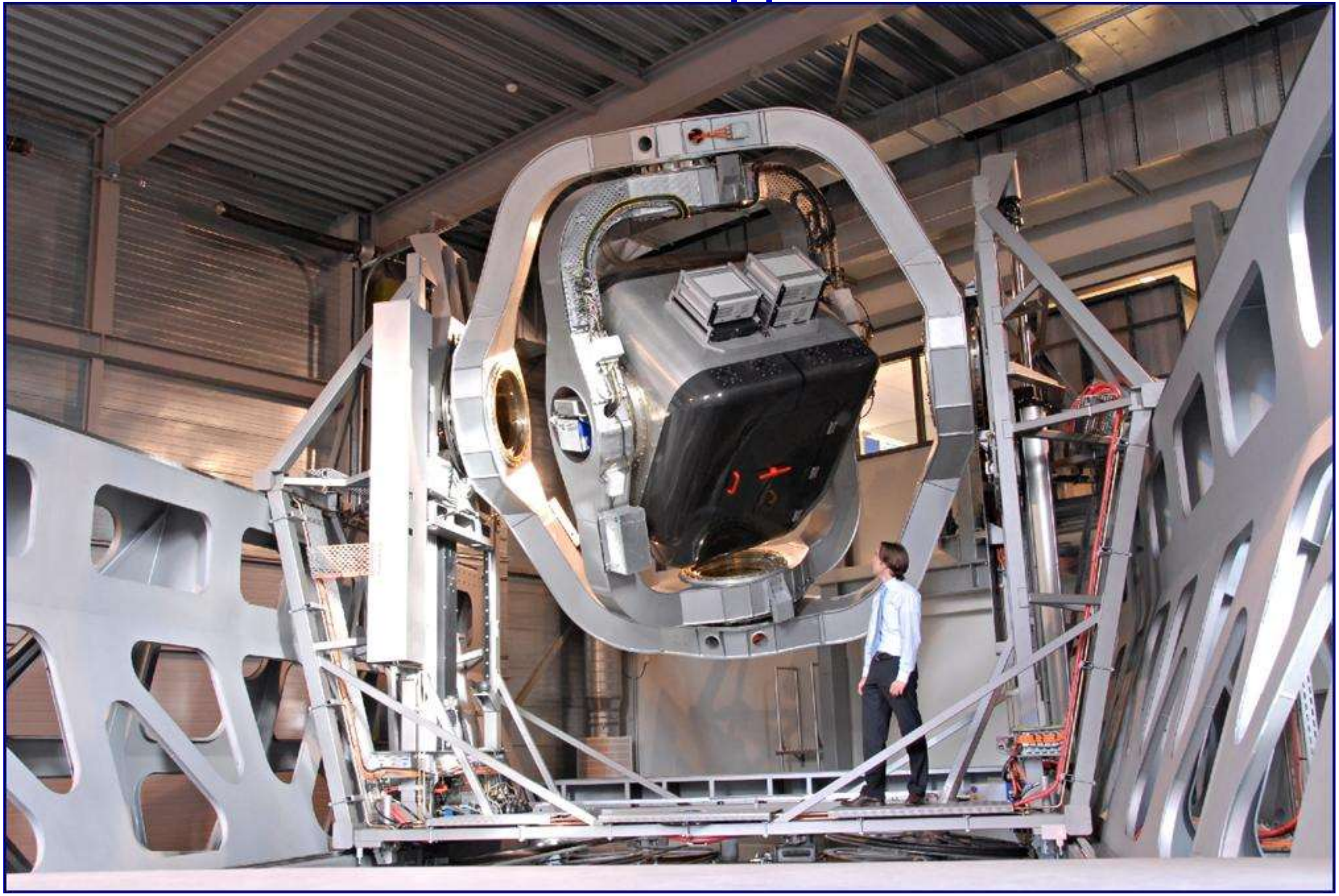
Aircraft Upset Recovery Simulation

The Dutch Approach



Willem Bles, SDPT Consult, The Netherlands

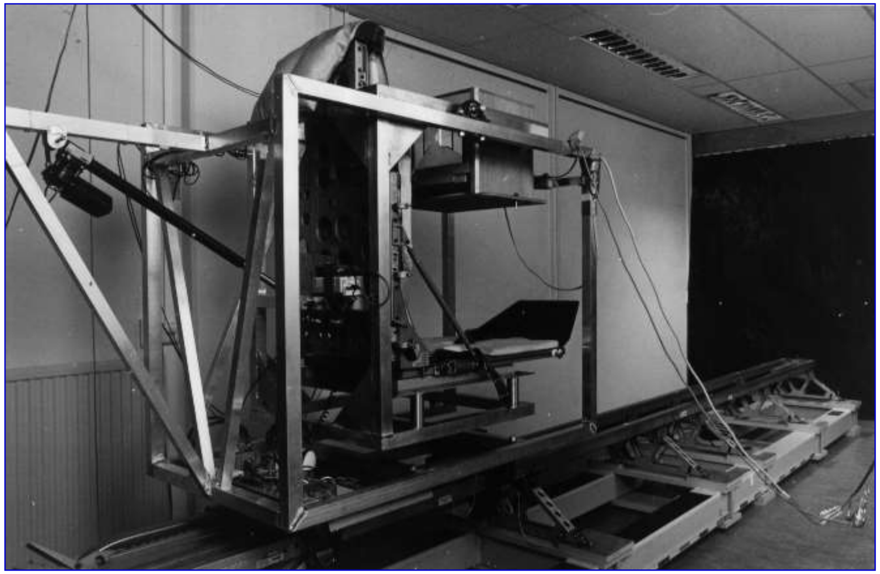
Military Aviation

- 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

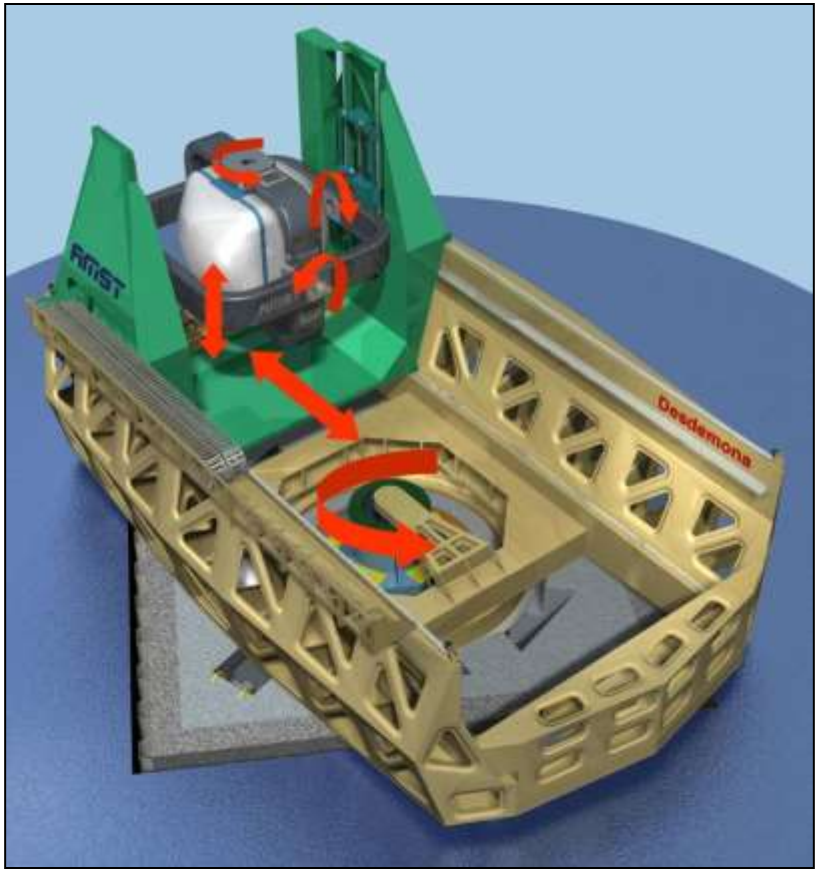
- Aeromedical Institute acquired the Airfox DISO
  - Man in the loop
  - Demos of in-flight illusions on the ground
    - Generic aircraft model
    - Generic cockpit
    - Out the Window visuals

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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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”

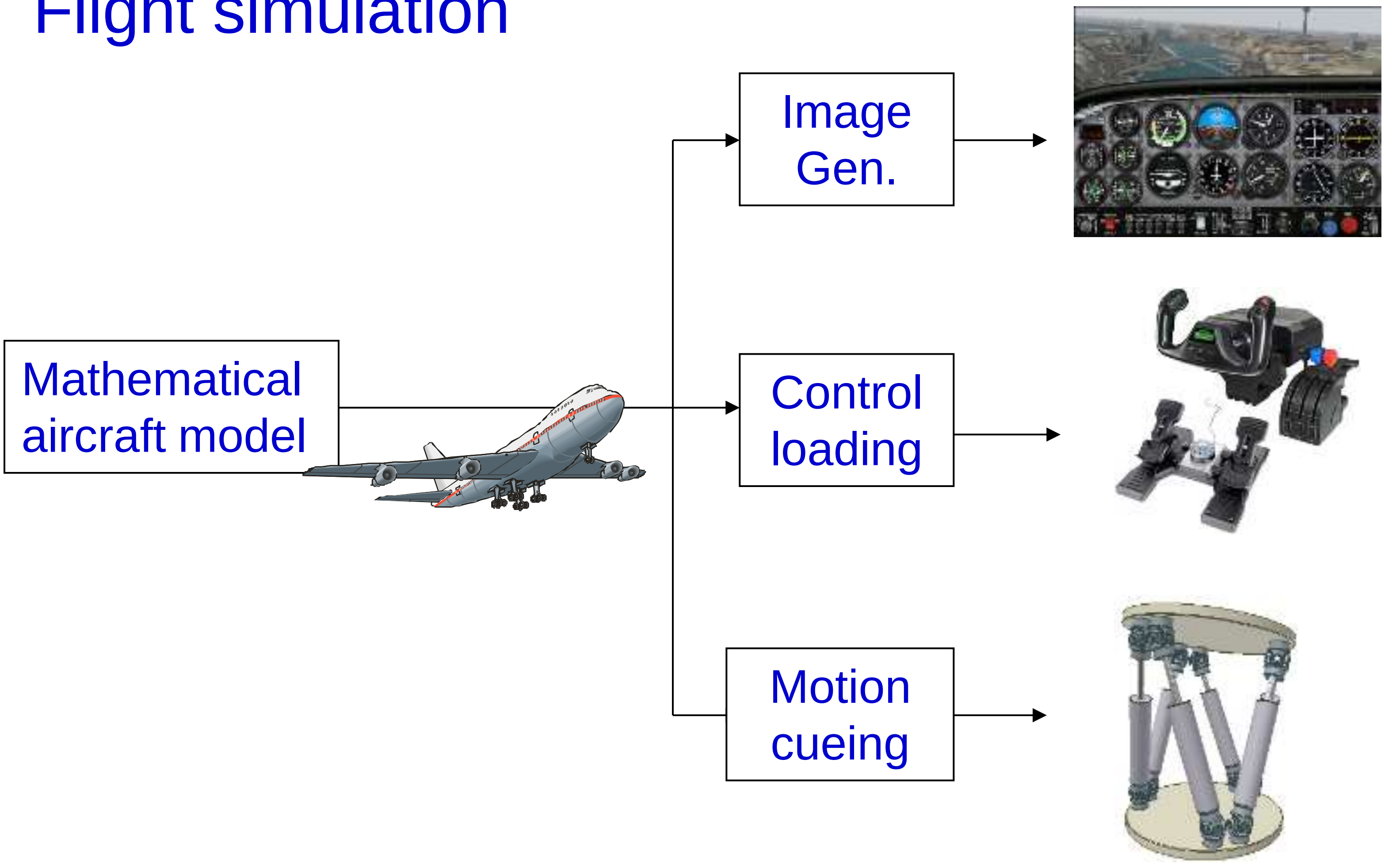
(UK) DeMontfort University

(AT) AMST

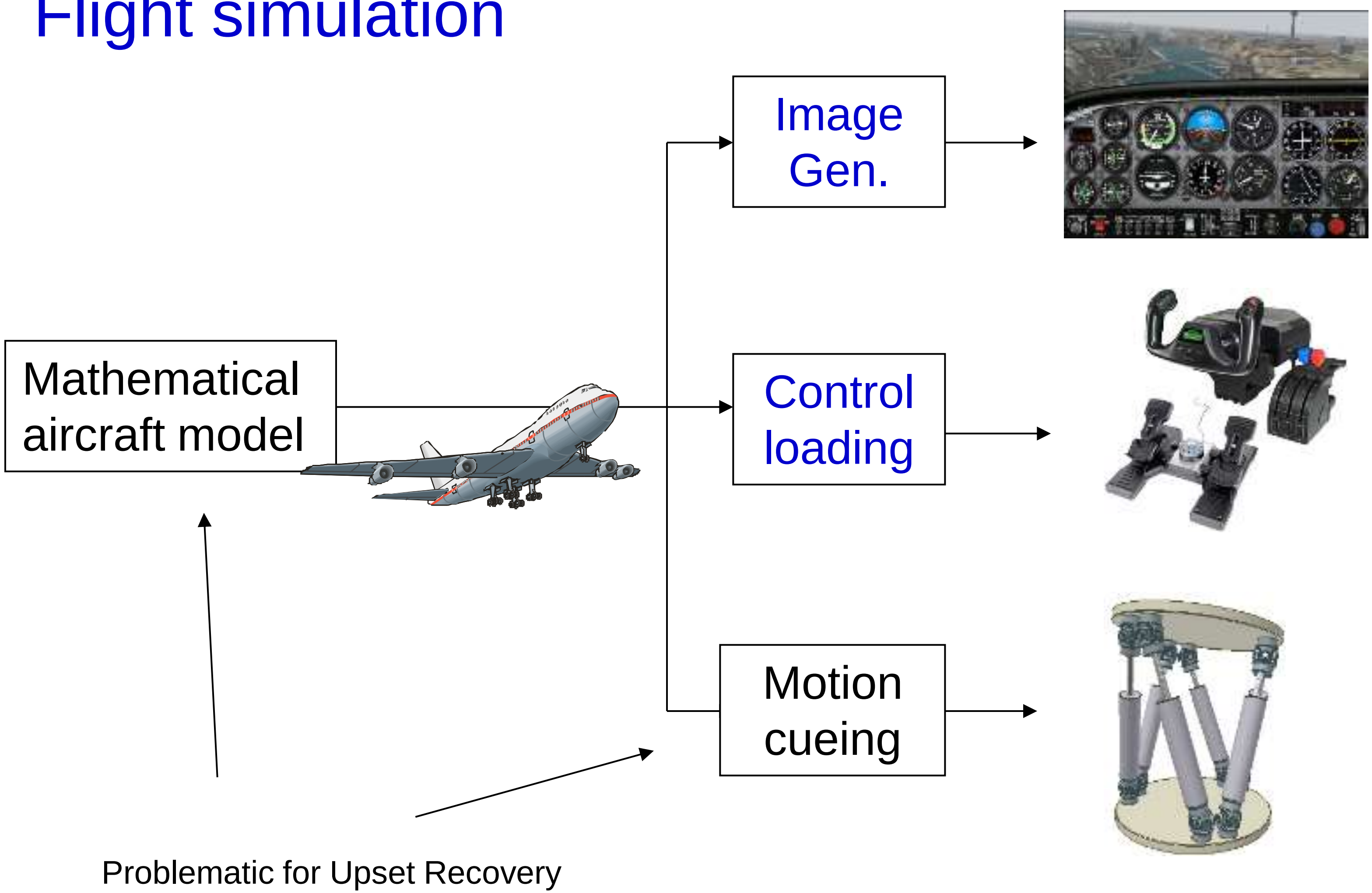
(DE) Max Planck Institute

(ES) BR&TE

Flight simulation

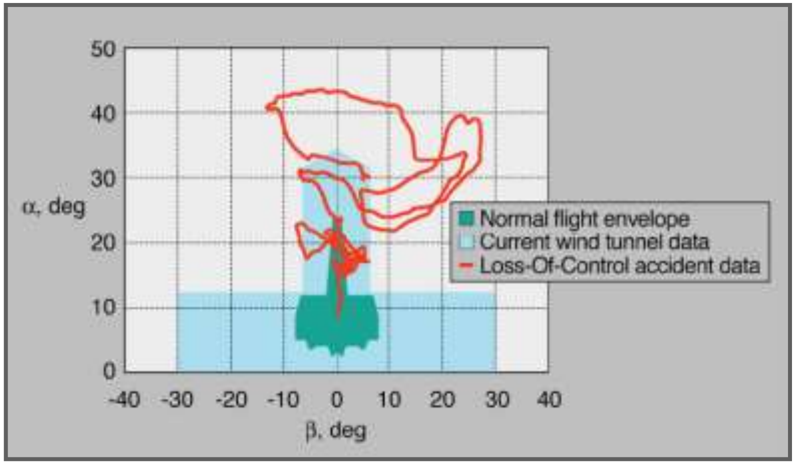


Flight simulation



Limitation of flight simulator

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

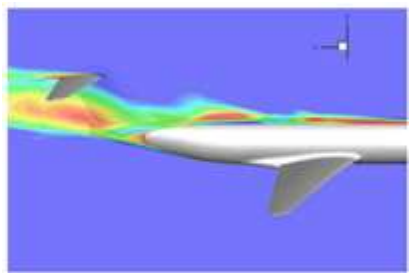


- Motion cueing
  - Adequate for normal flight operations
  - Only onset motion cues
  - No sustained rates / G-loads

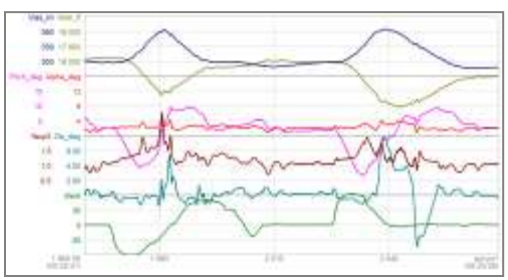
Advanced aerodynamic modeling

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

Wind tunnel data



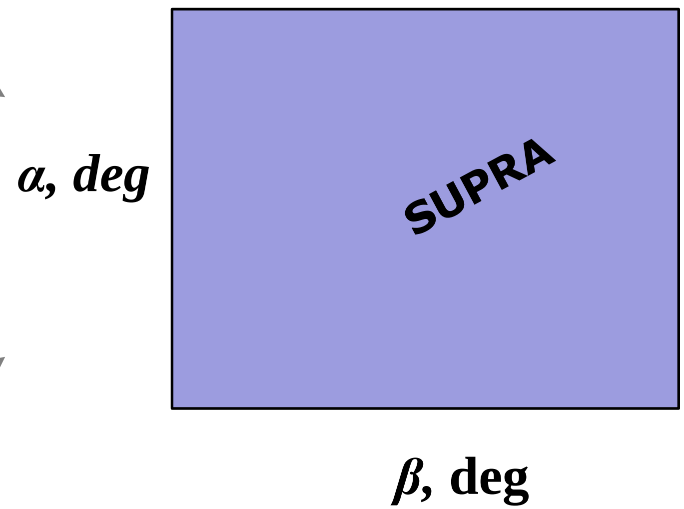
CFD Predictions



Flight test data

$$C_{dyn} = \frac{\tau s}{\tau s + 1} \Delta C(\alpha)$$

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

Any Questions?