Identifying Human Control Behavior

In the SIMONA Research Simulator

Dr. ir. Herman Damveld

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TU Delft
Delft University of Technology

Outline

- Aerospace Engineering
- Human Control Research at Aerospace Engineering
- Identifying pilot control parameters using visual, vestibular and haptic cues.
    1. Experimental Behavior Measurement Method:
       Aircraft Handling Qualities
    2. VIDI: Simulator Fidelity
    3. Boeing: Measuring Neuromuscular System Contribution

Aerospace Engineering

Control & Simulation Division

Staff:

- 2 full professor (Max Mulder, Bob Mulder)
- 2 associate professors
- Scientific, technical & support staff
- 25 PhD students

25-35 MSc students annually

Research areas:

- Human-machine systems and flight simulation
- Guidance and control of aircraft and rotorcraft
- Flight deck avionics and air traffic management
- Dynamics and control of spacecraft

Facilities

- Human-Machine Systems Lab
- Cessna Citation II
- SIMONA Research Simulator



Case 1:
Experimental Behavior Measurement Method

Experimental Behavior Measurement Method

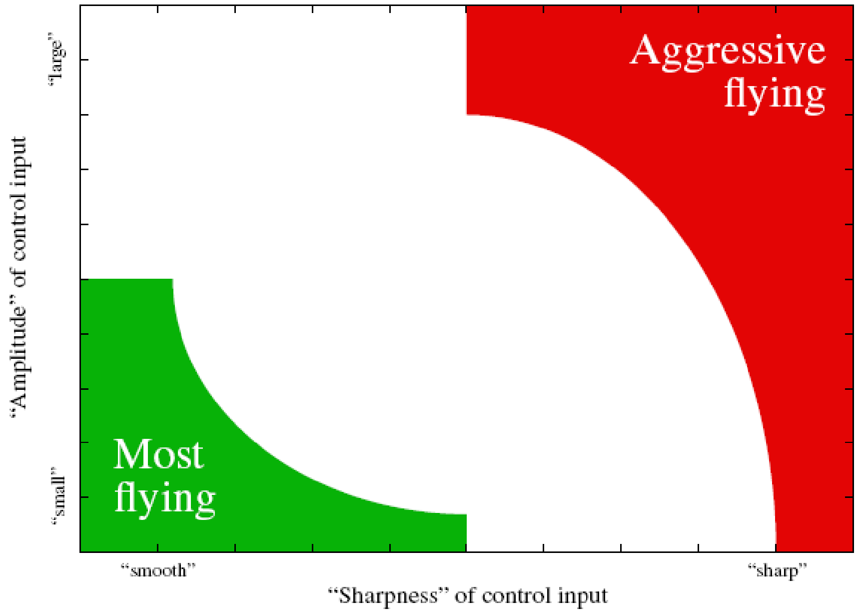
Aircraft Handling Qualities

Current status:
Pilot evaluation

Phase 1:
Familiarization

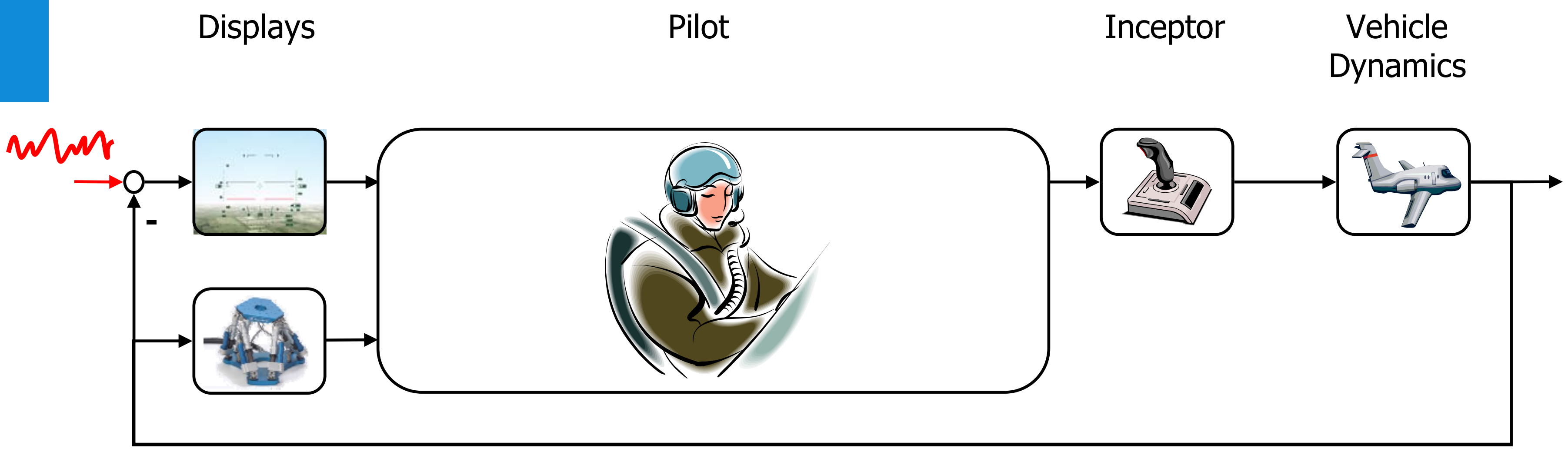
Phase 2:
Full envelope evaluation

Phase 3:
Operational task evaluation



How can we measure handling qualities
- objectively
- over full handling qualities envelope

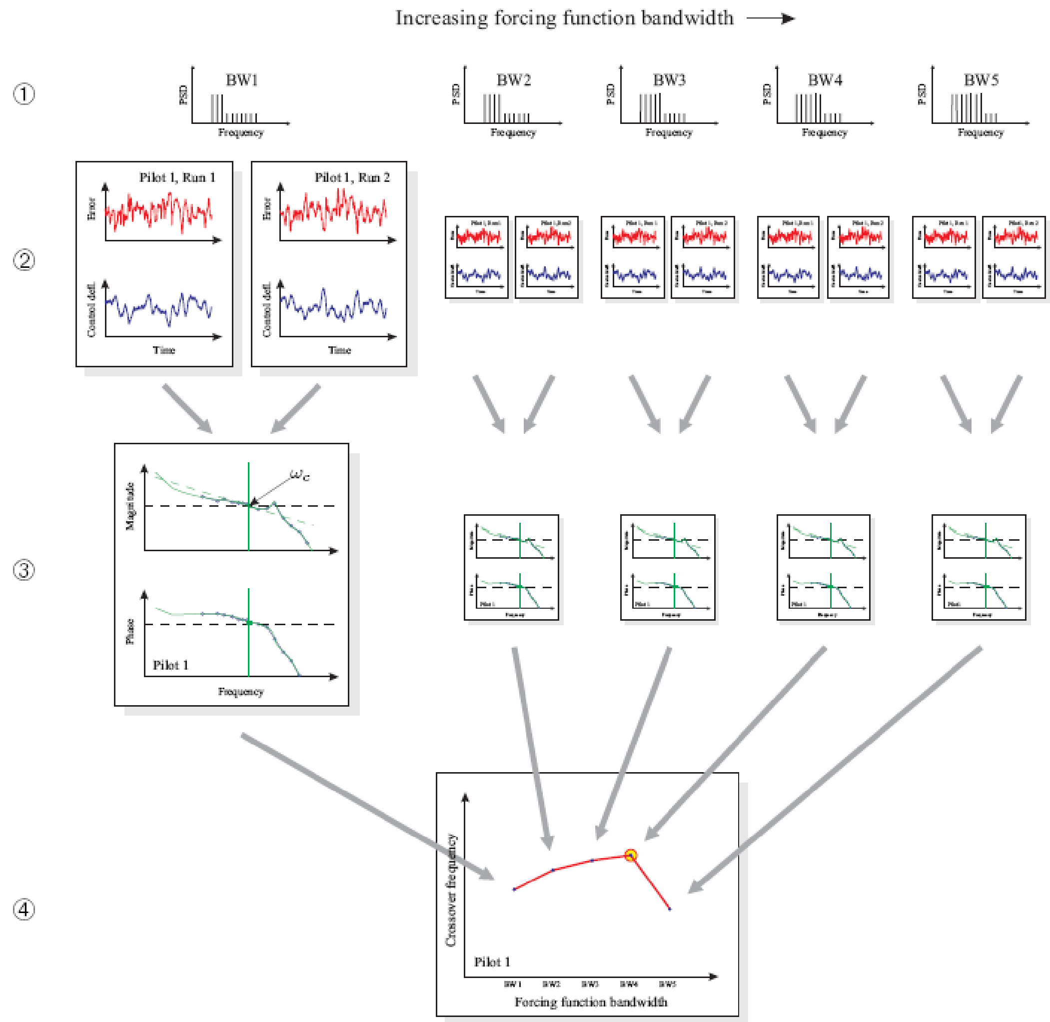
Experimental Behavior Measurement Method



By measuring the *pilot* control behavior conclusions can be drawn about the handling qualities of the *aircraft*.

The forcing function on the head-up display forces the pilot to adopt a high-frequency control strategy.

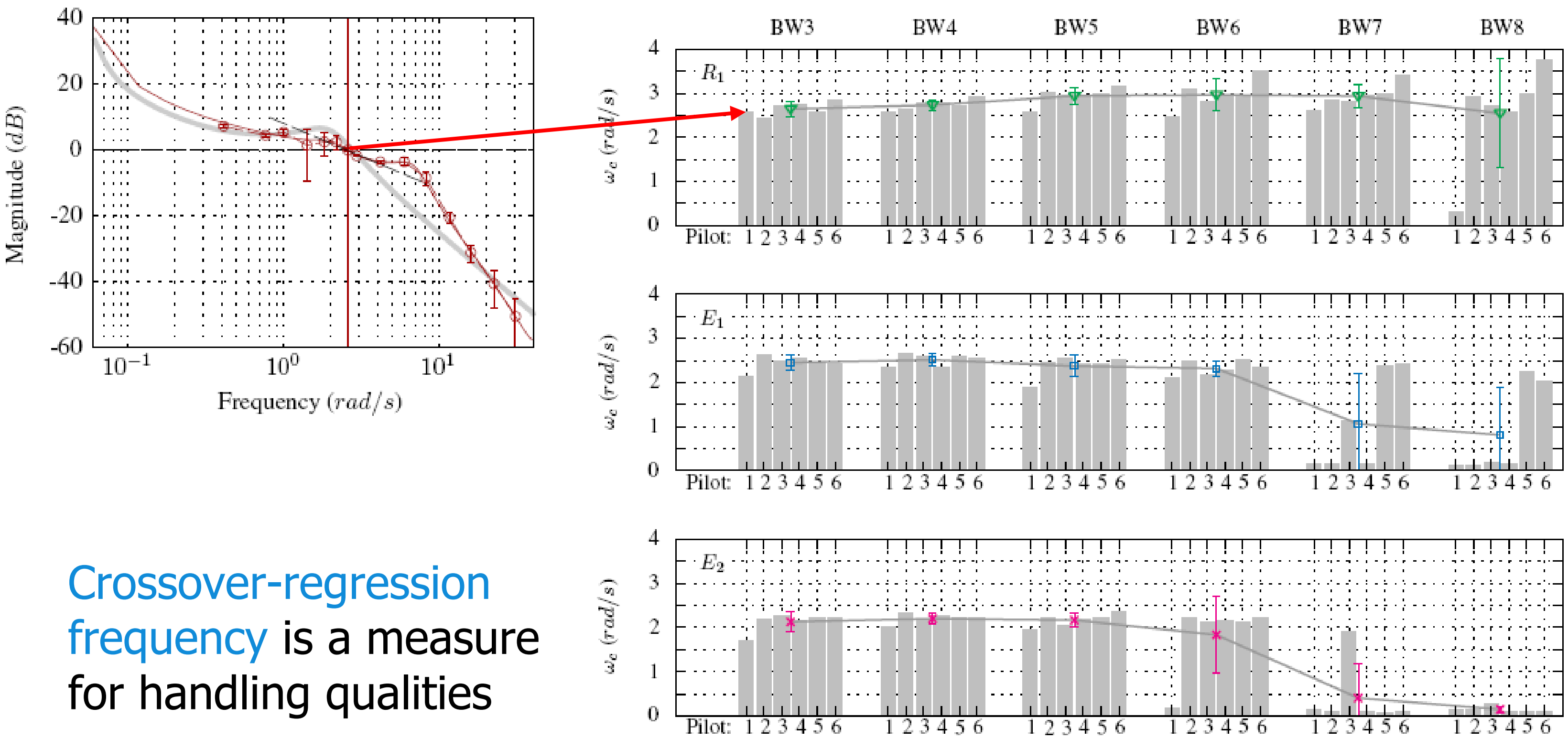
Experimental Behavior Measurement Method



Experimental Behavior Measurement Method

Experimental Behavior Measurement Method

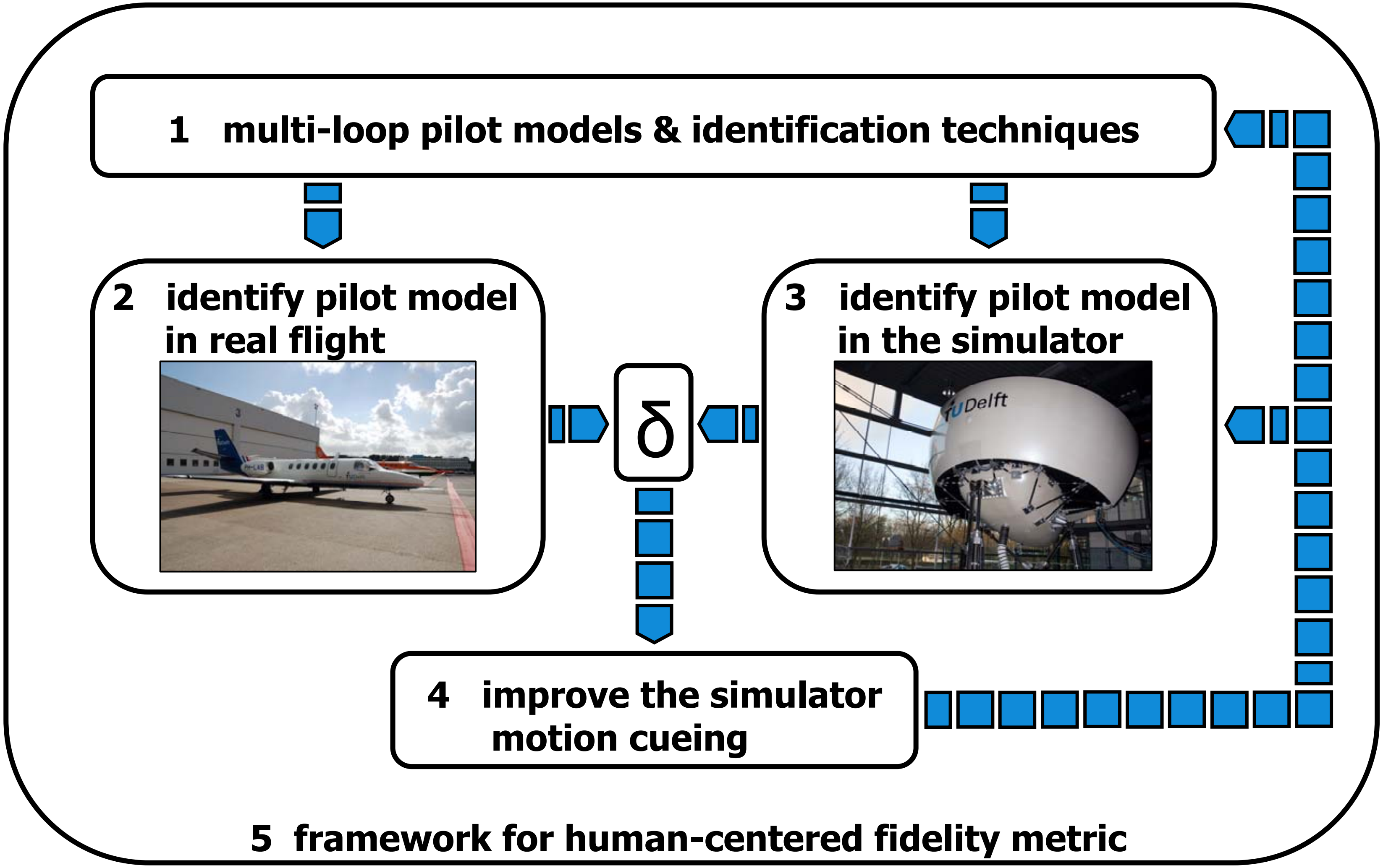
Results



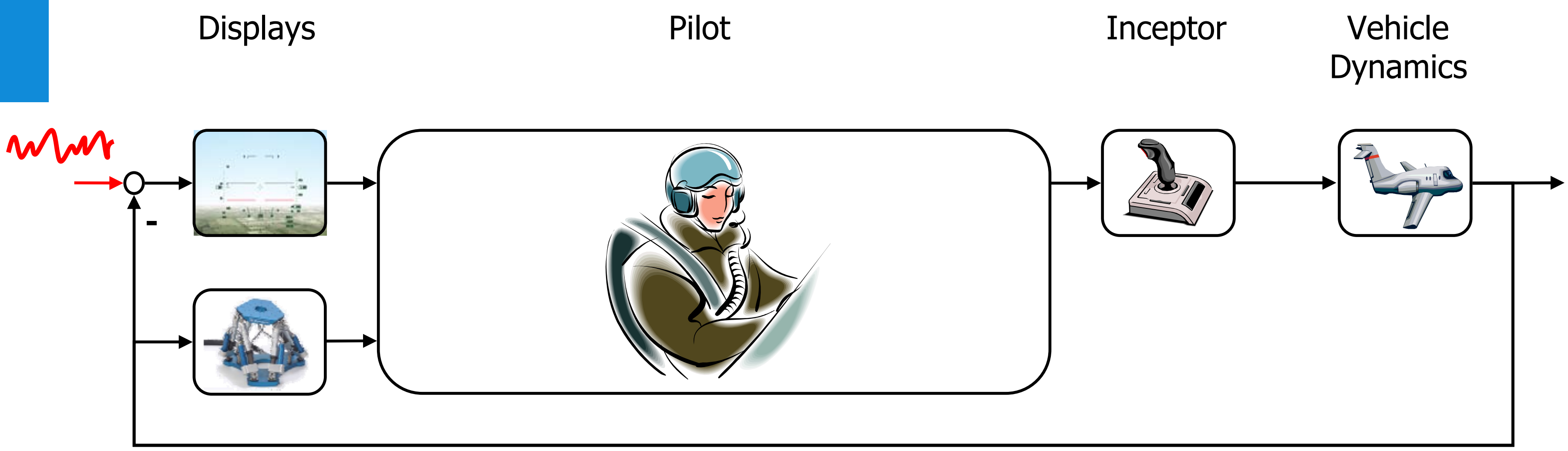
Crossover-regression frequency is a measure for handling qualities

Case 2:
VIDI Project / Simulator Fidelity

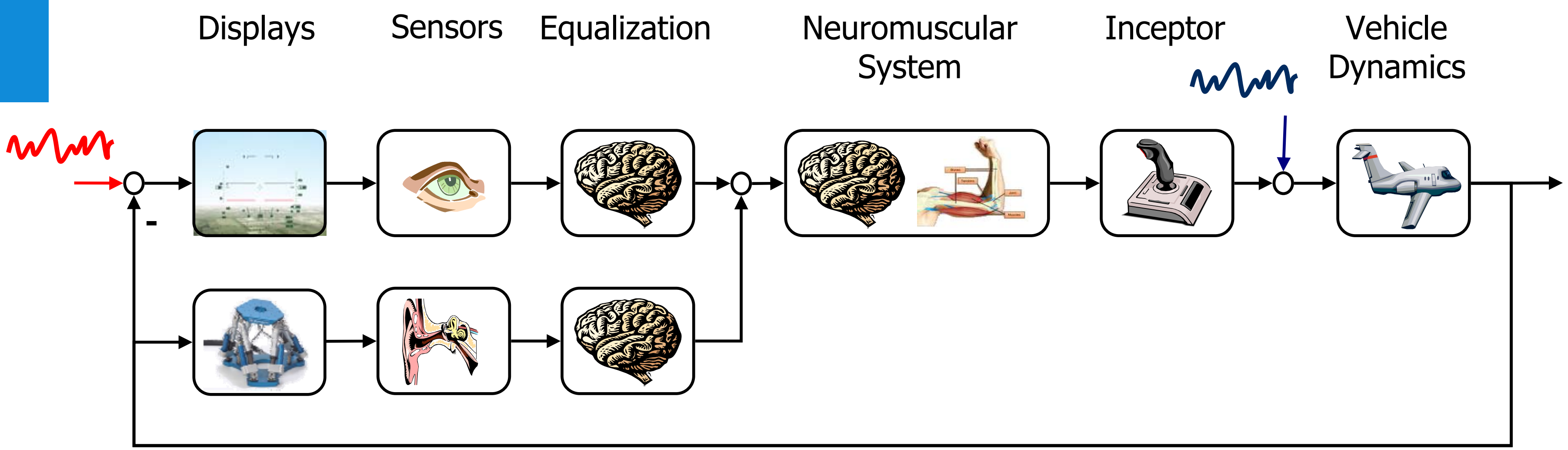
VIDI: Simulator Fidelity



VIDI: Simulator Fidelity

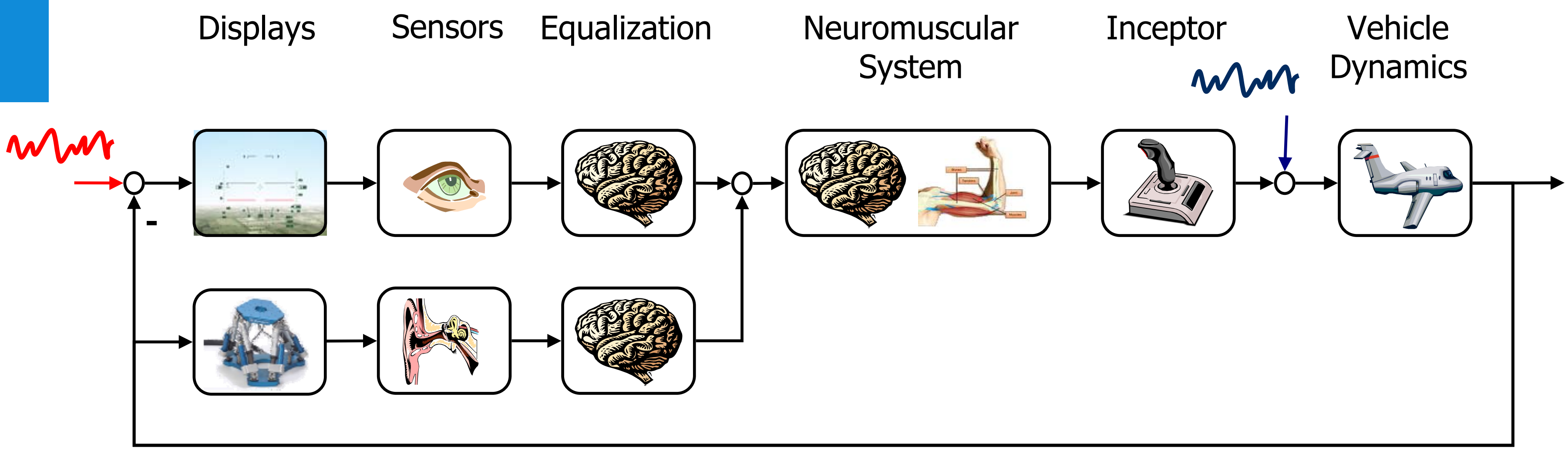


VIDI: Simulator Fidelity



A second forcing function perturbs the elevator of the aircraft and is needed to identify the contributions of the visual and vestibular systems separately.

VIDI: Simulator Fidelity



$$K_{vis} \frac{1 + sT_{lead}}{1 + sT_{lag}} e^{-s\tau_{vis}} \qquad K_{vest}\, e^{-s\tau_{vest}} \qquad \frac{\omega_{nm}^2}{\omega_{nm}^2 + 2\zeta_{nm}\omega_{nm}s + s^2}$$

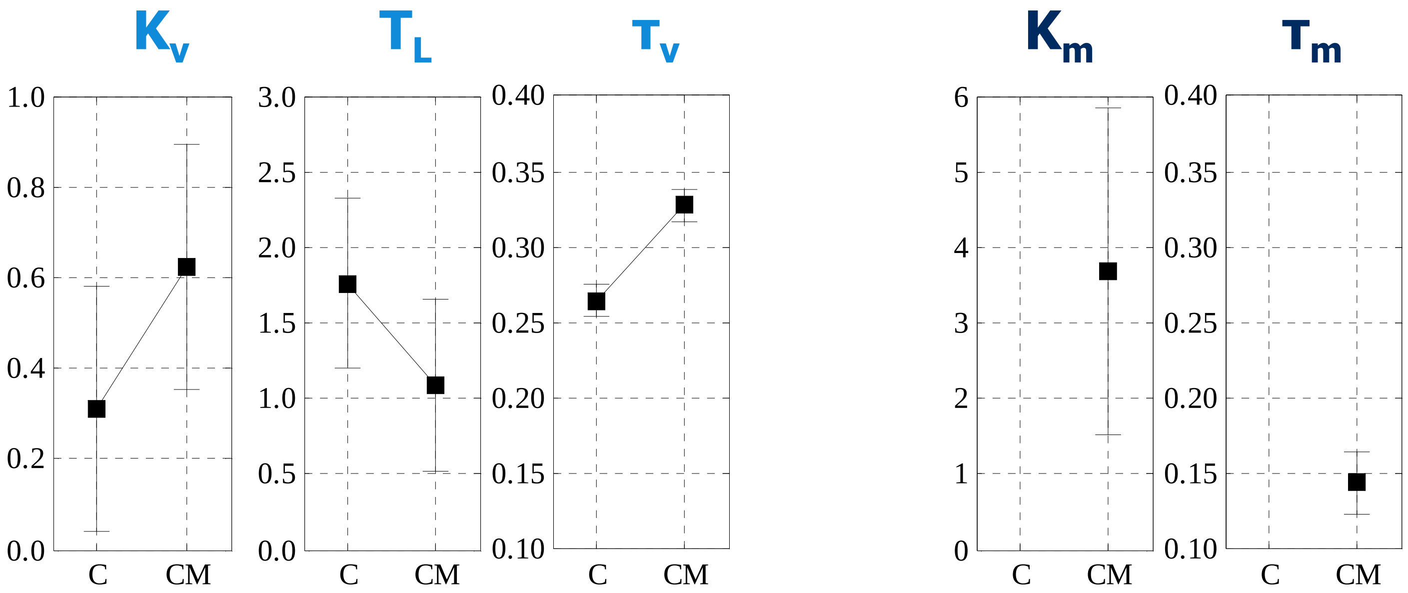
The pilot is described by 8 parameters which we can determine using system identification techniques.

VIDI: Simulator Fidelity

Results

visual model parameters

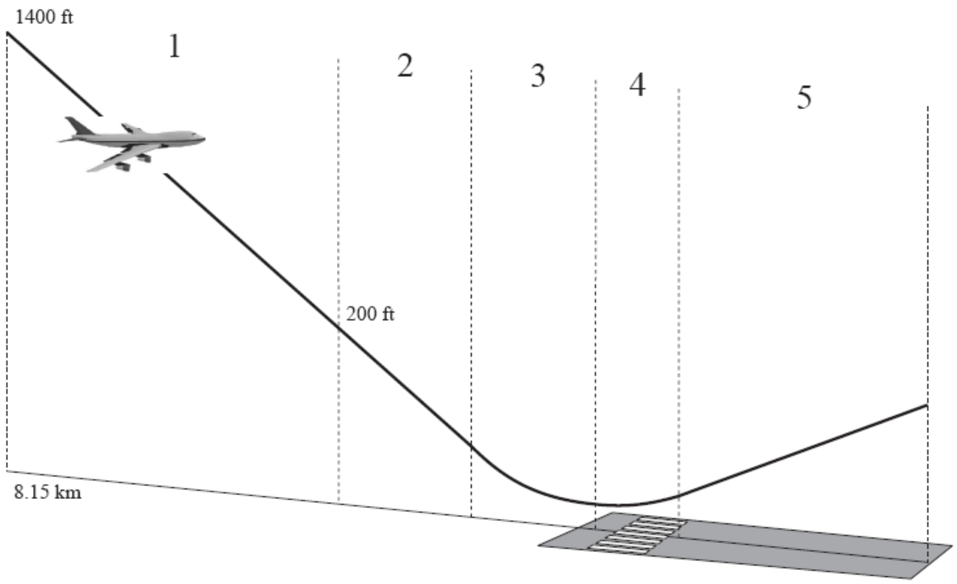
vestibular model parameters



Case 3:
Boeing Balked Landing Study

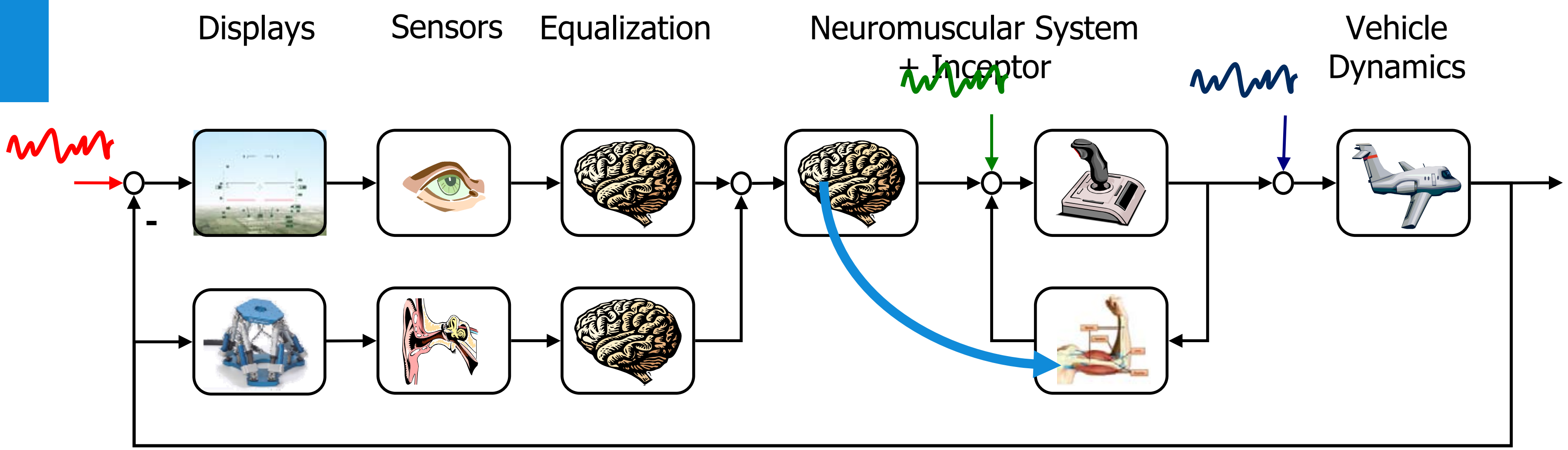
Boeing: Measuring the NMS Contribution

Balked Landing Study



Goal: Improve the model of the neuromuscular system and estimate its parameters

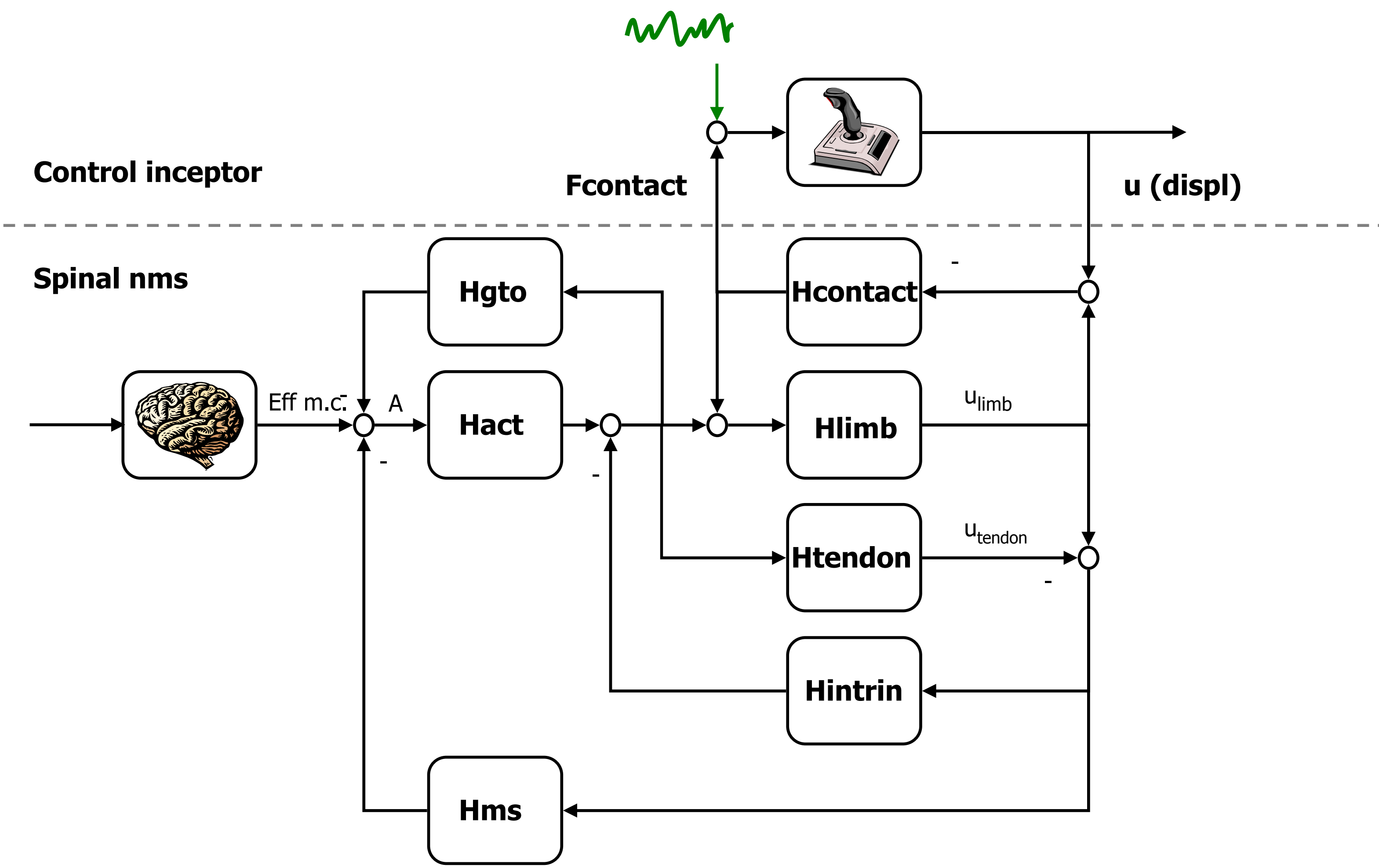
Boeing: Measuring the NMS Contribution



A third forcing function adds force perturbations to the control inceptor and is required to identify the *admittance* of the spinal neuromuskuloskeletal dynamics as well as the combined physical interaction.

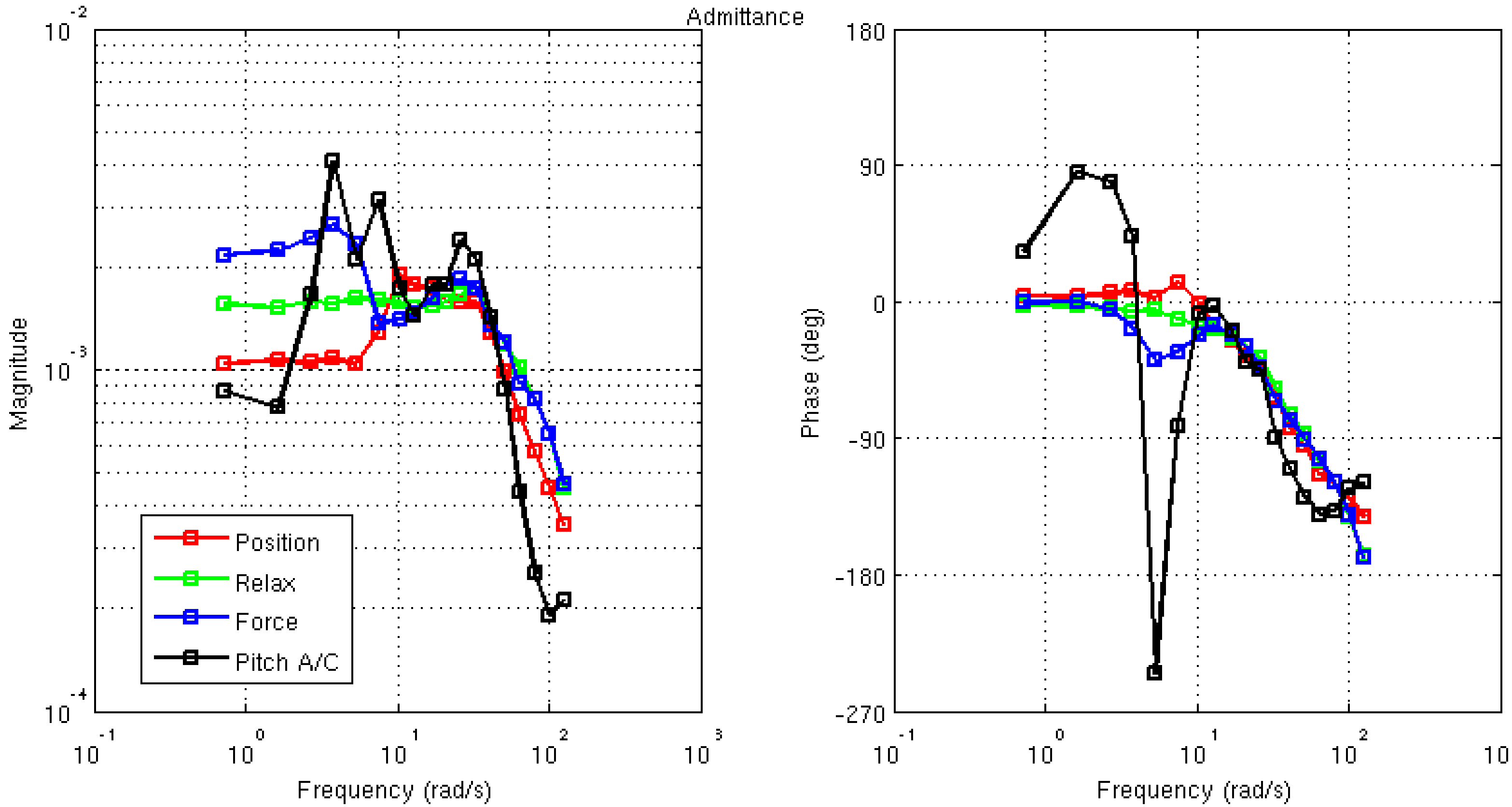
This allows us to subdivide the McRuer NMS in a feedback part (combined physical interaction) and an equalization part.

Boeing: Measuring the NMS Contribution



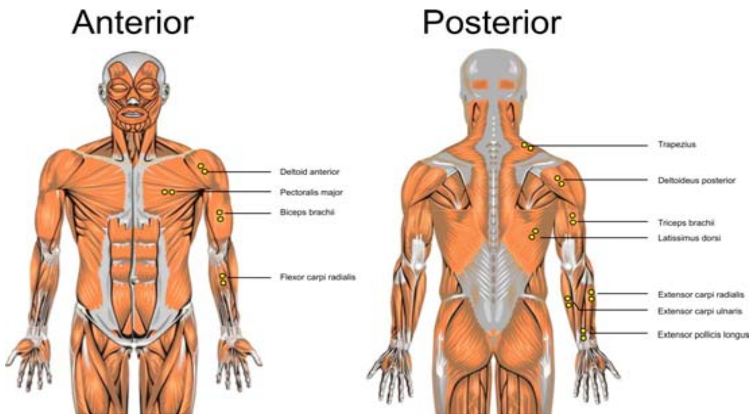
Boeing: Measuring the NMS Contribution

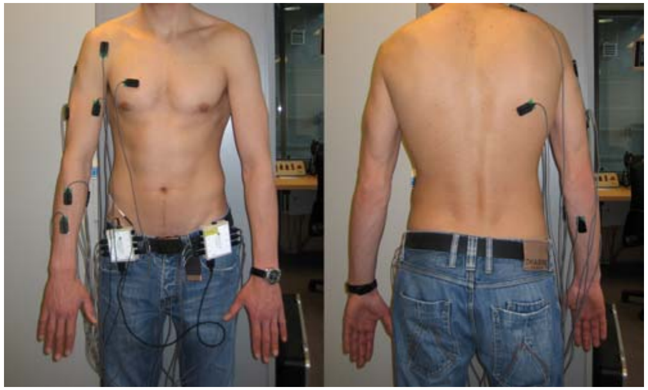
Admittance



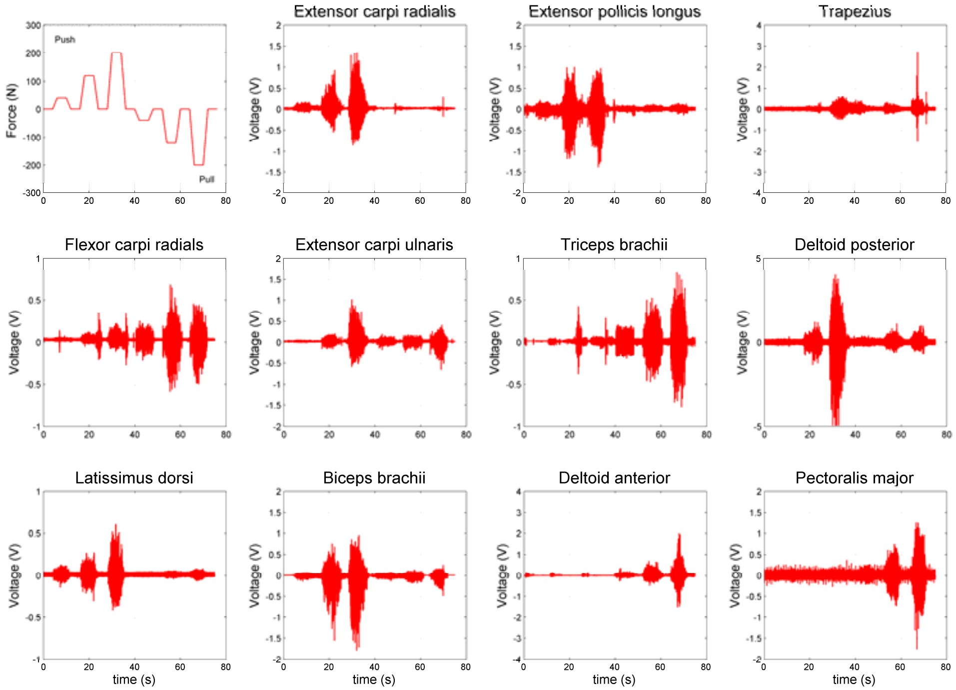
Boeing: Measuring the NMS Contribution

Validation: Electromyographic Measurements



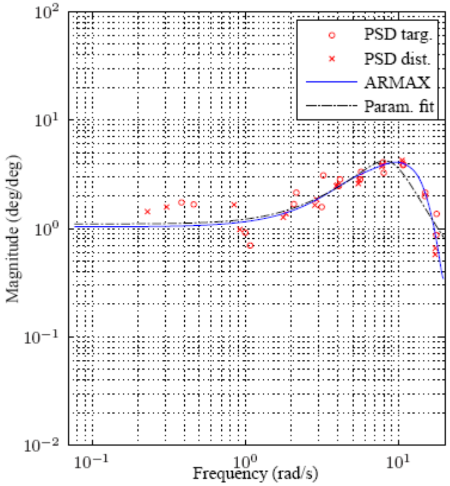


Isometric Force Measurement

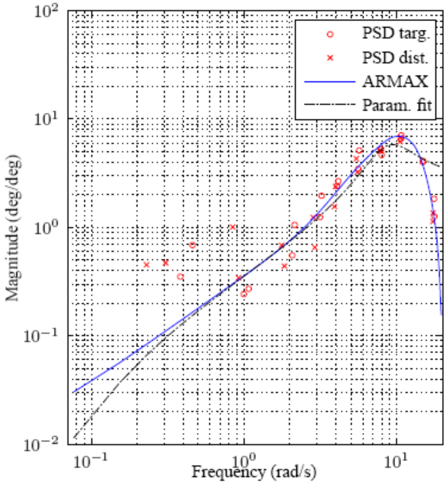


Boeing: Measuring the NMS Contribution

Results



Visual response



Vestibular response

Visual

Parameter	*Value*	*Unit*
K_{vis}	1.1009	-
T_{lead}	0.4797	s
T_{lag}	0.1421	s
τ_{vis}	0.2701	s

Vestibular

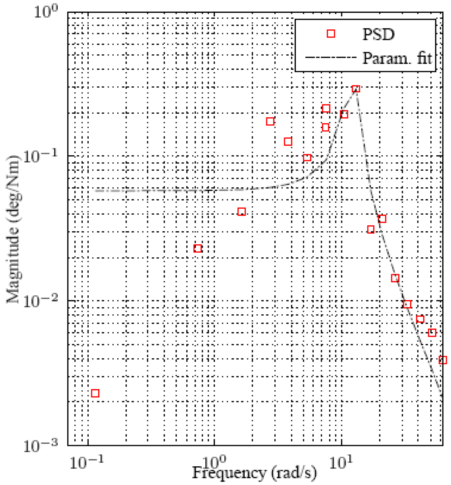
Parameter	*Value*	*Unit*
K_{ves}	2.1293	-
τ_{ves}	0.2168	s

McRuer NMS

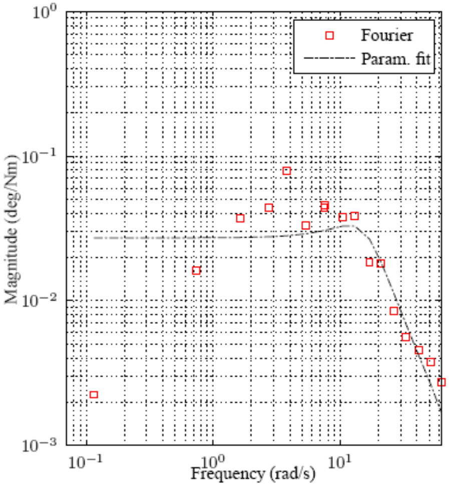
Parameter	*Value*	*Unit*
ζ_{nm}	0.3651	-
ω_{nm}	8.8360	rad/s

Boeing: Measuring the NMS Contribution

Results



Spinal NMS



Combined physical interaction

	Symbol	*SNMS*	*CPI*	*Unit*
Stiffness	K	17.3	36.72	Nm/°
Damping	B	0.14	2.16	Nms/°
Inertia	I	0.12	0.46	Nms^2/°
Natural freq.	ω_n	12	15.64	rad/s
Damping ratio	ζ	0.05	0.46	-

The difference between the parameters in the McRuer NMS and the CPI is assumed to be caused by the equalization part of the NMS (current investigation).

Summary / Conclusions

Present techniques allow us describe the pilot control behavior by identifying the contributions to the total pilot model of the:

- Visual system (4 parameters)
- Vestibular system (2 parameters)
- The McRuer neuromuscular system (2 parameters)
- The full spinal NMS (15 parameters)

These parameters can provide information about:

- The vehicle handling qualities
- The use of modal information (visual, vestibular, haptic)
- The human actuator settings