Experimental evaluation of the contribution of adding a motion system to an EDS

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CENTRO DE COMPETÊNCIA EM MANUFATURA

ITA

- ITA – Aeronautics Institute of Technology
- Engineering school from Brazilian Air Force
- Located in the Brazilian aerospace cluster, in São José dos Campos

Introduction

Introduction

- Flight simulator
  - Cheaper and safer when compared to flight campaigns
- Flight simulator with high degree of fidelity
  - High quality visual system
  - Similar cockpit interface
  - Motion platform

High cost!

SIVOR Project

Flight simulator based on **industrial robot**

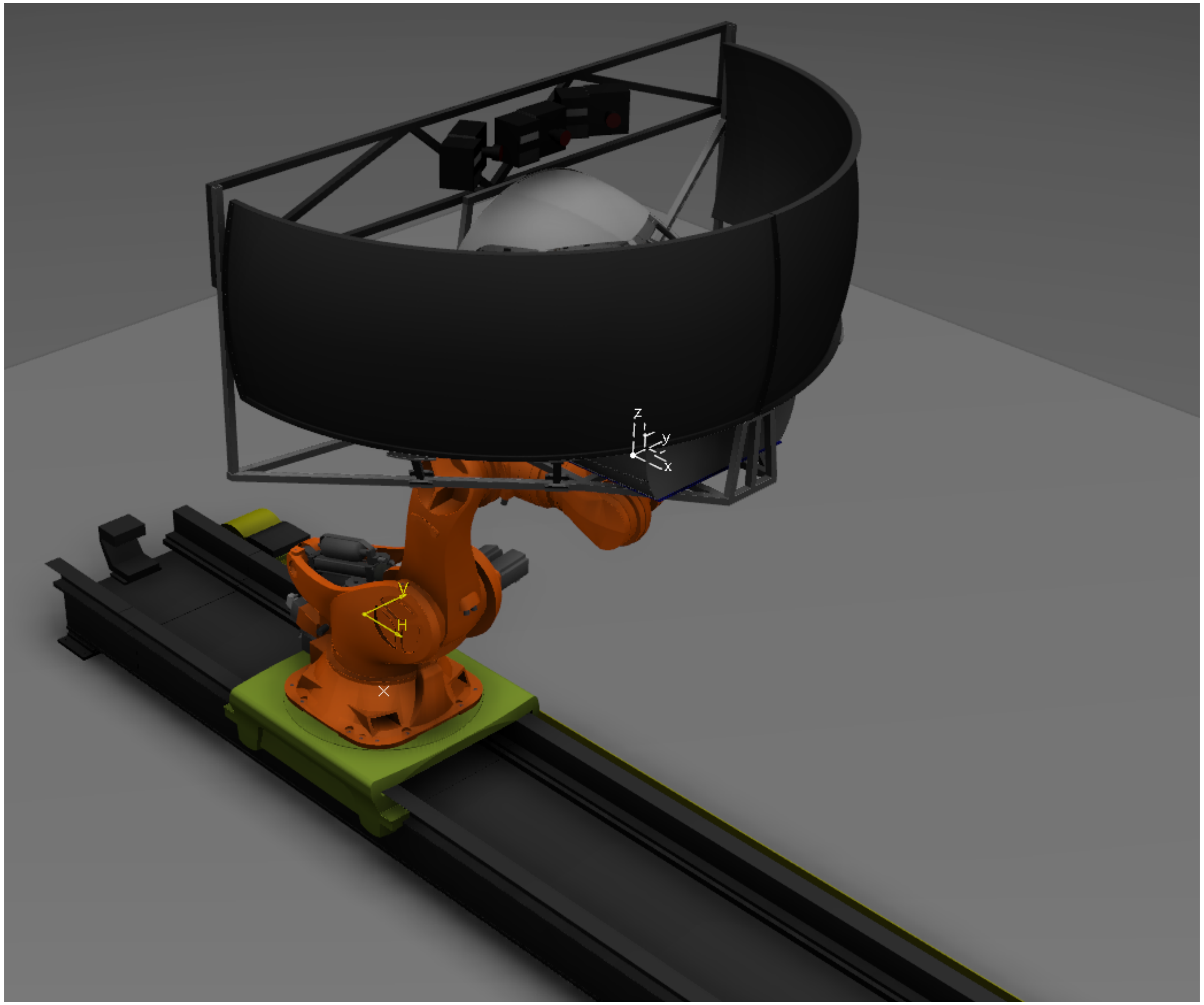
ADVANTAGES

- Larger workspace when compared with Stewart platform
- Low cost, easily adapted to different aircrafts

APPLICATIONS

- Use as EDS at early stage of aircraft development (e.g. design of fly-by-wire control laws)
- Train pilots in a high fidelity platform, allowing the execution of high risk maneuvers

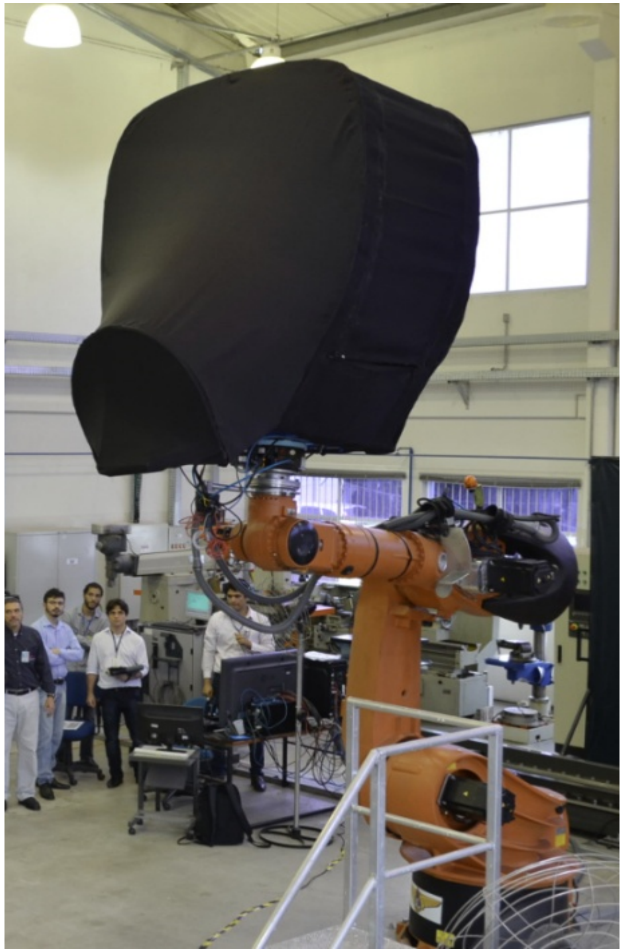
SIVOR Project

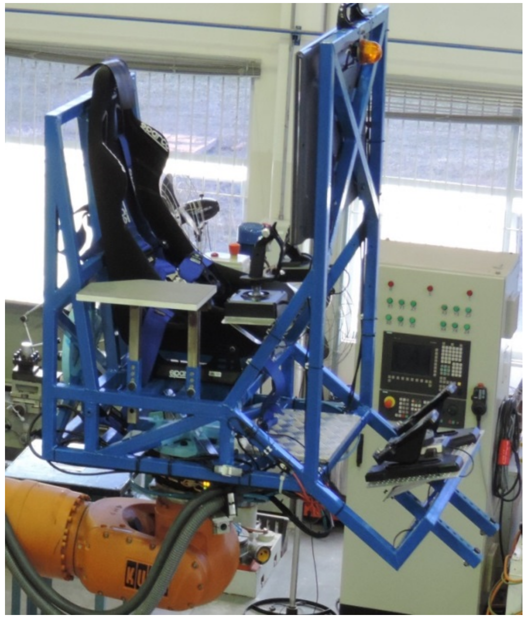


SIVOR under development
High degree of fidelity

SIVOR Project

SIVOR preliminary version

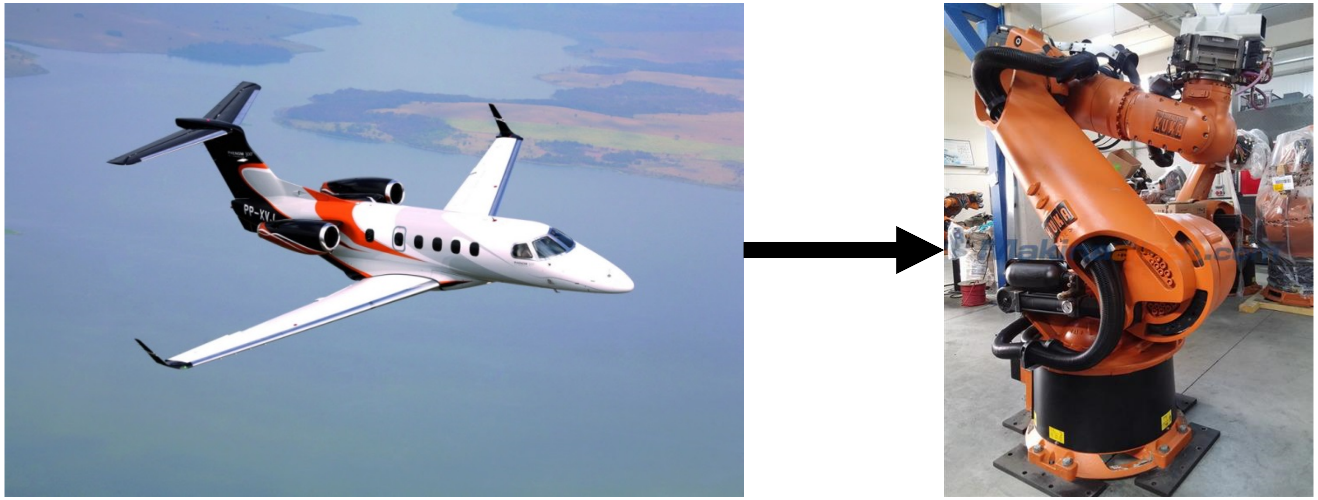




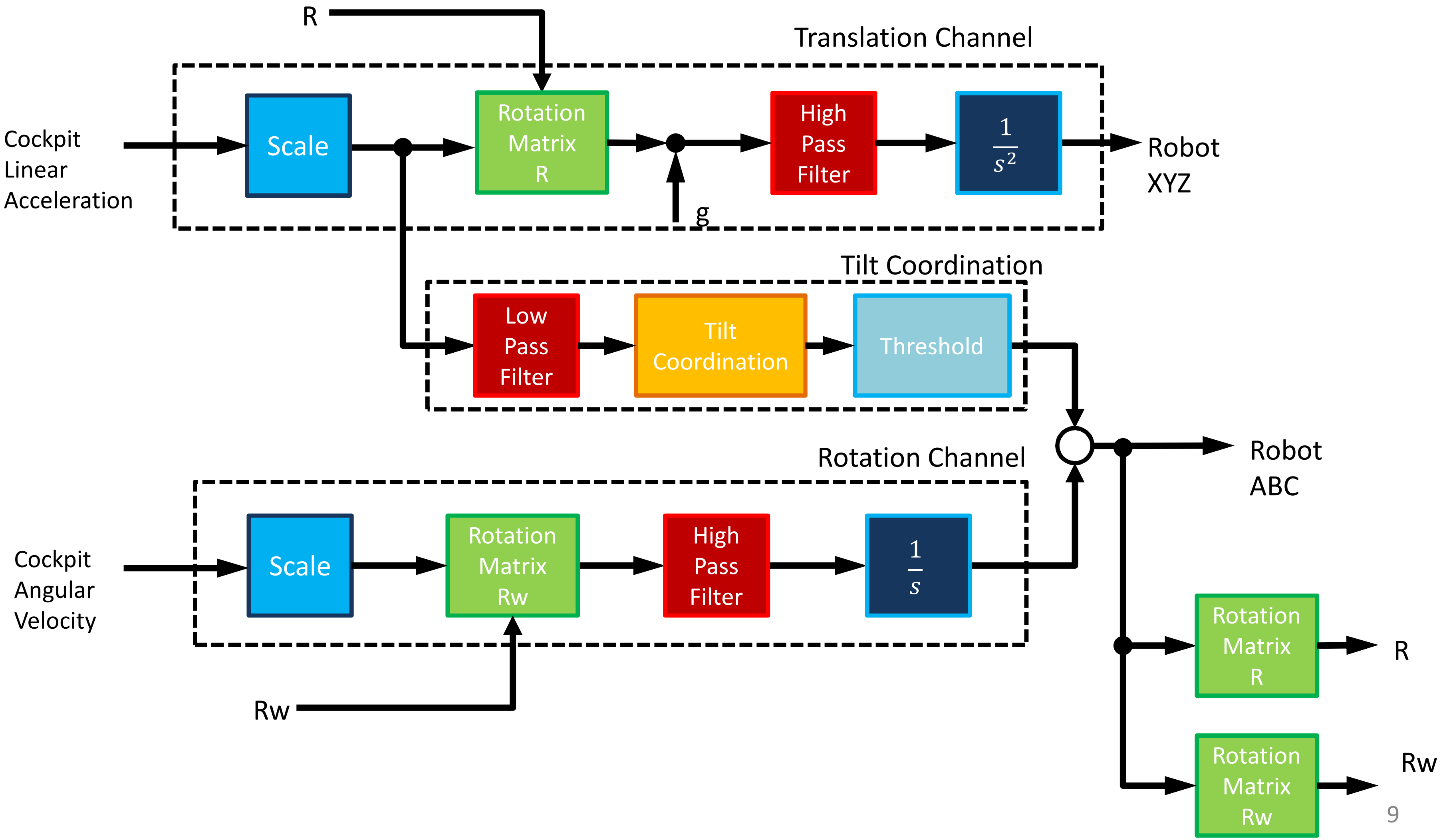
- Motion platform:
  - KUKA robot KR500-2
    - Payload: 500 kg
    - Maximum reach: 2826 mm
- Inceptors:
  - Saitek™ X52 Pro Flight System
    - Throttle + sidestick + rudder pedals
- Display:
  - Full HD LCD TV 50”
  - Visual system is rendered by XPlane 10

Washout Filter

- From the ‘infinite’ aircraft workspace to the finite robot envelope



Washout Filter



The Problem

How can we **evaluate** the contribution of the **motion** system to an EDS in an **objective** way?

Part 1: FOQA derived maneuvers

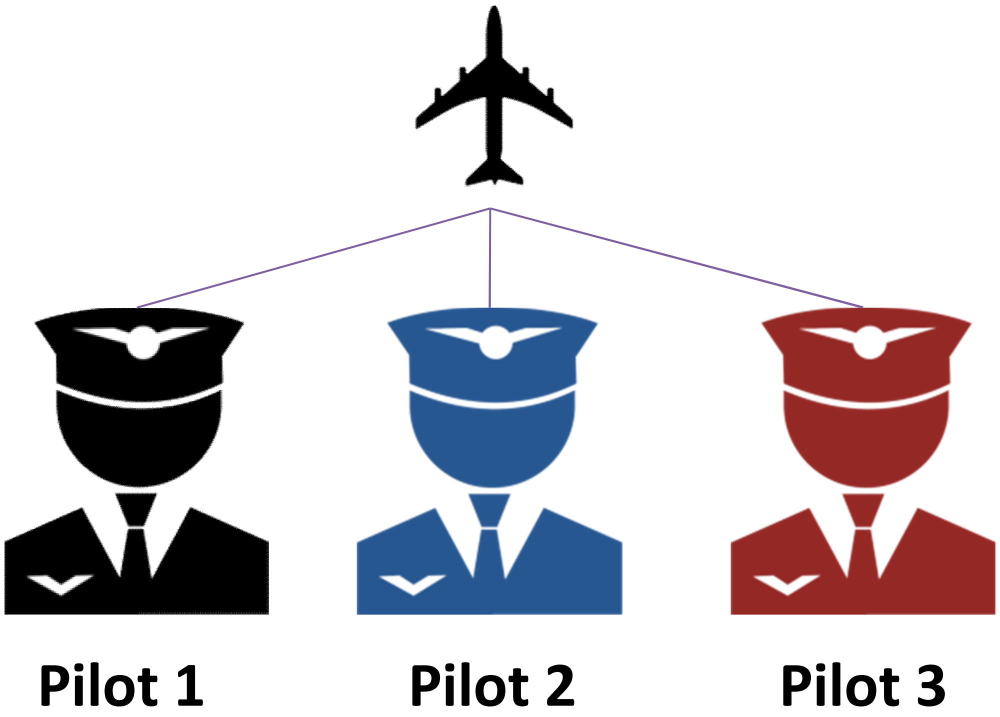
Session C9,
Wed 12, 9:00

Part 2: Maneuvers with high compensation

The Experiment

Participants

- Experienced pilots

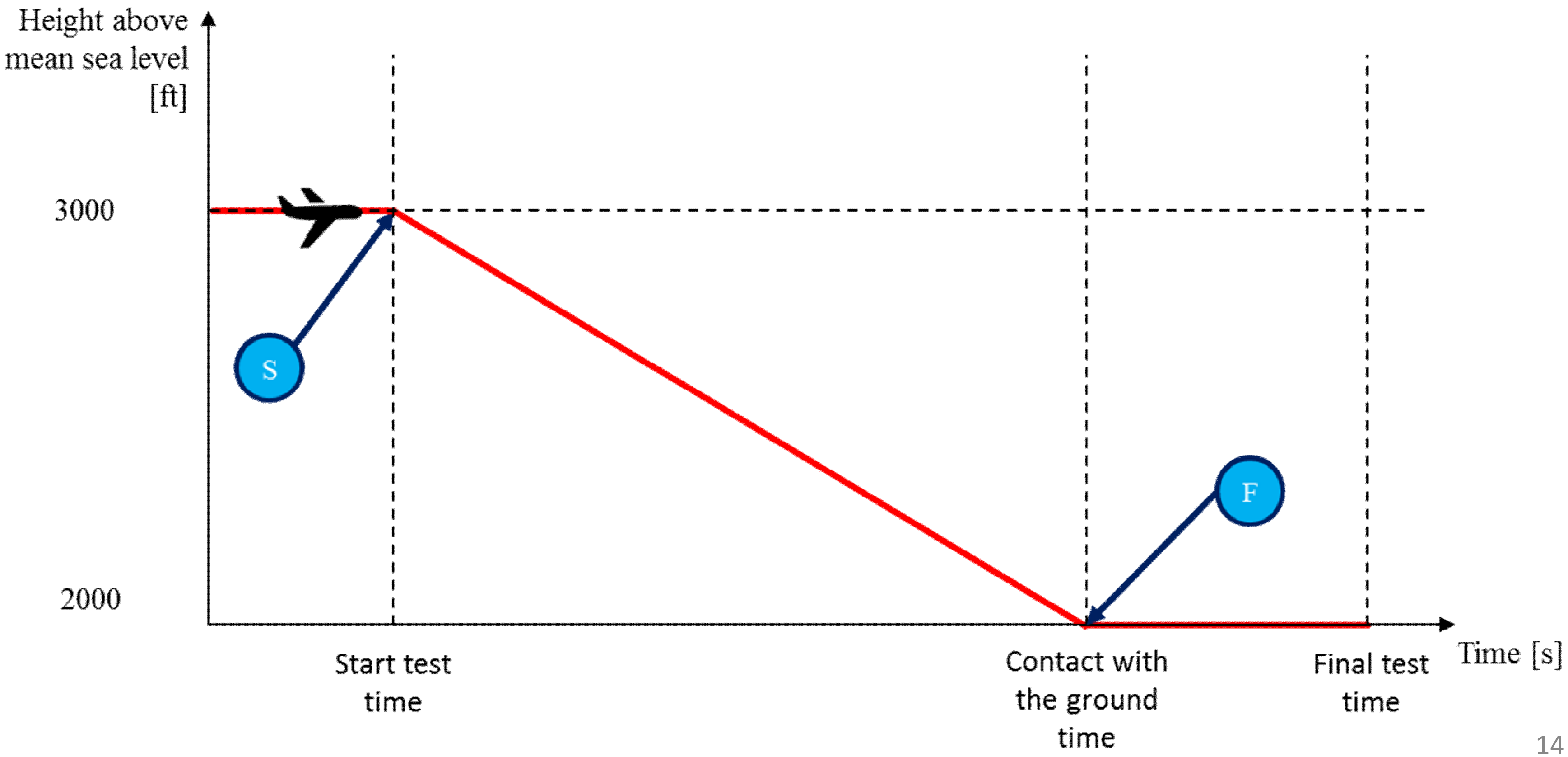


Experimental Procedure

- Three different flight plans:
  - Landing
  - Offset landing
  - Stall recovery
- High-gain maneuvers:
  - High degree of pilot compensation

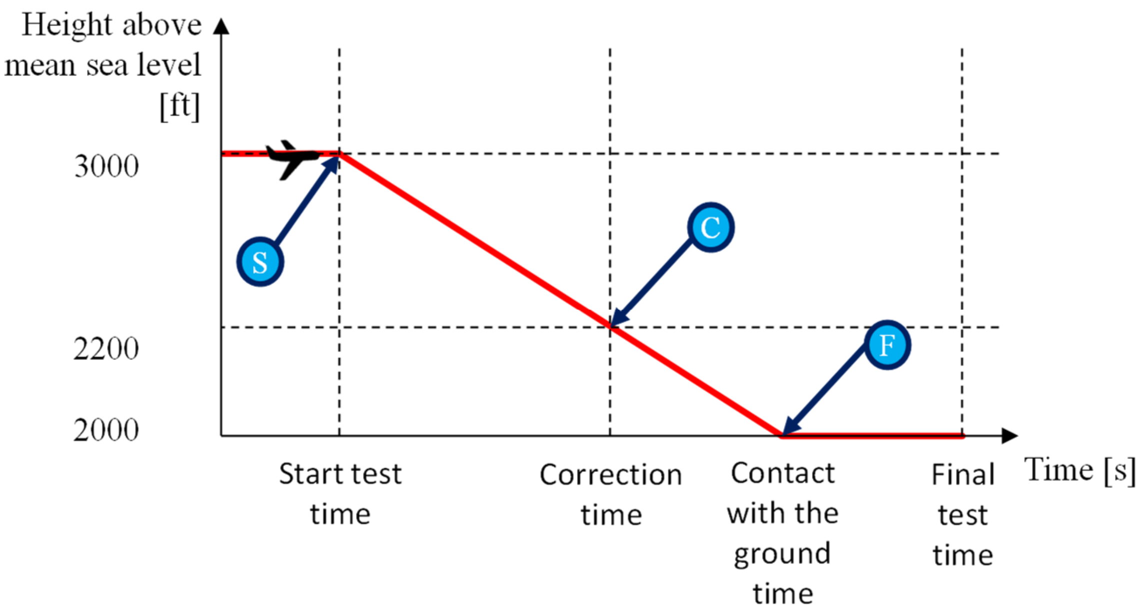
Experimental Procedure

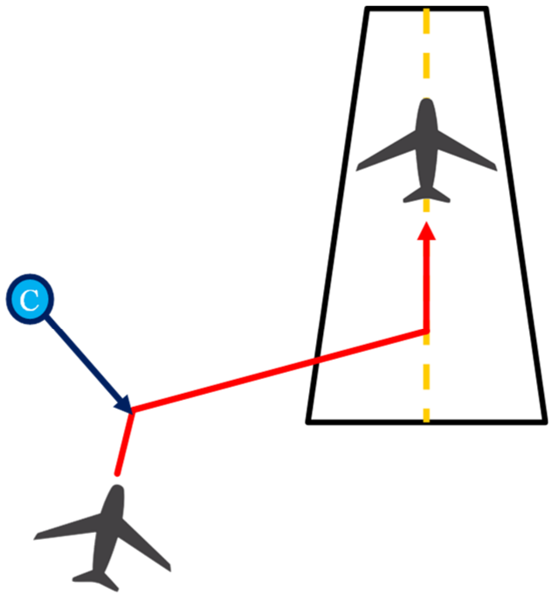
- Landing



Experimental Procedure

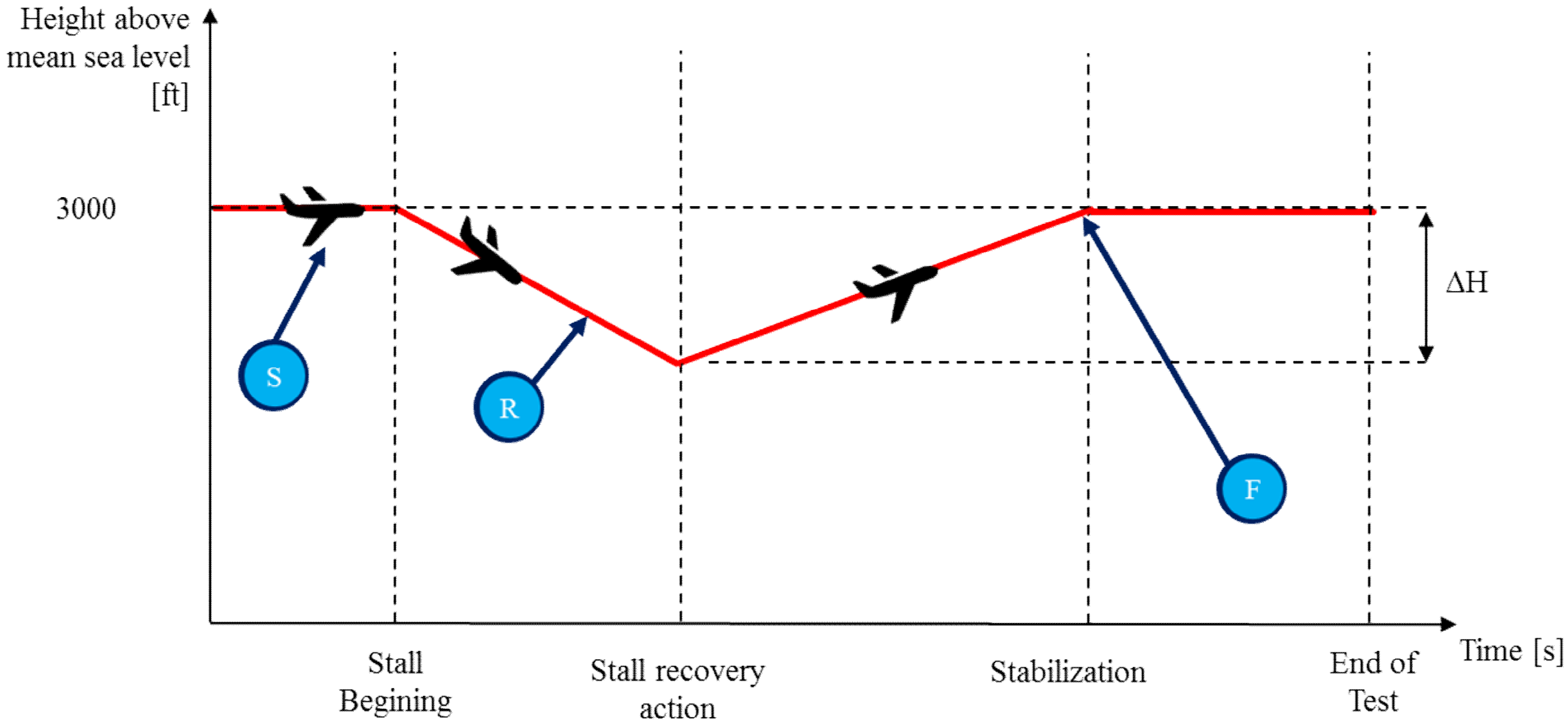
- Offset landing





Experimental Procedure

- Recovery from stall



Measured variables

Manoeuvre	*Variable Name*	*Behavioural Parameter*
Landing	CLand	Workload
Offset landing	COLand	Workload
Recovery from stall	CStall	Workload
	PStall	Precision

- Workload: integral of side stick position
- Precision: altitude loss

Statistical Analysis

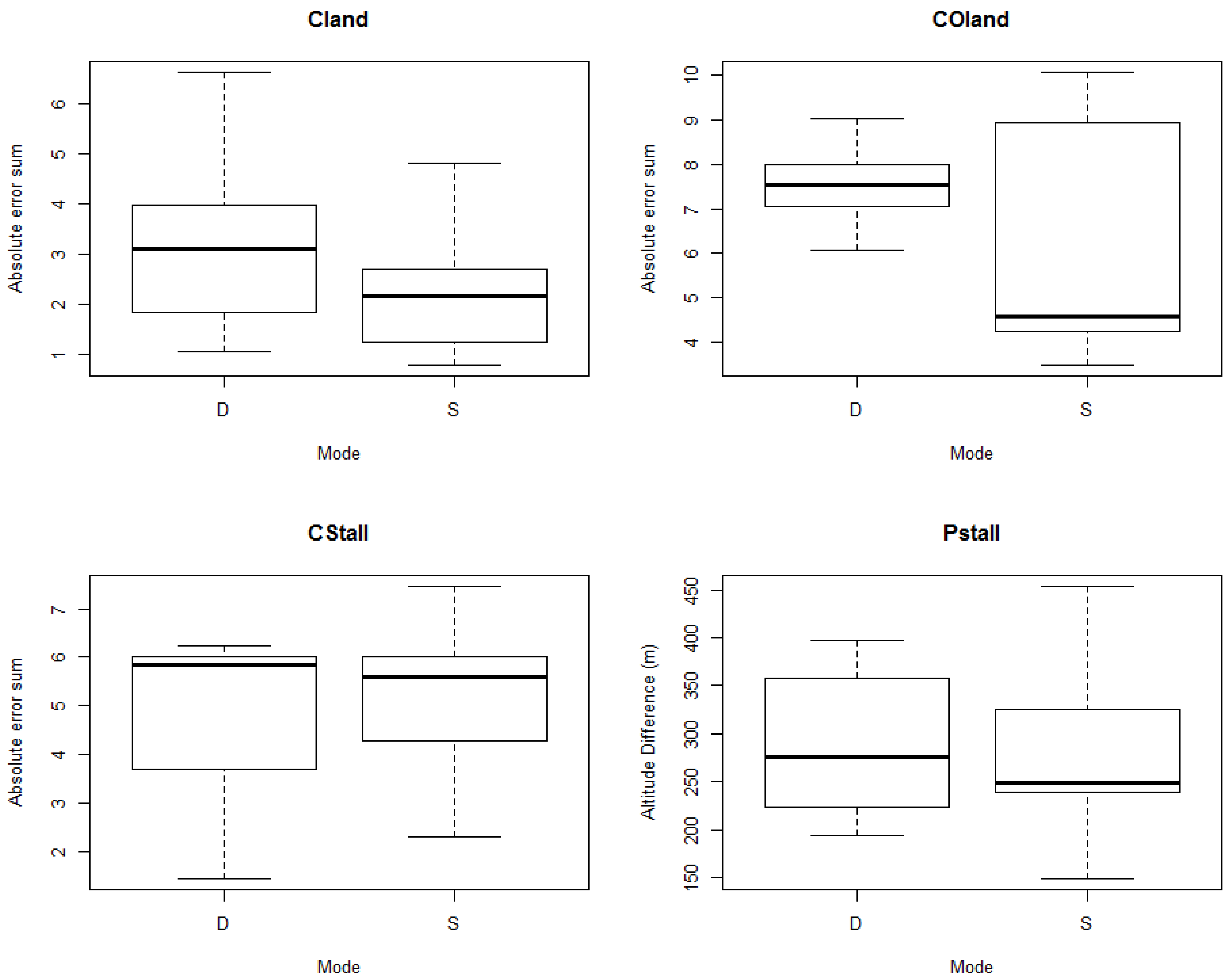
$$V_{ij} = \mu + M_i + \beta_j + e_{ij}$$

where:

- V_{ij}: Output value: workload or precision.
- μ: General output mean
- M_i: Simulation mode variance
- β_j: Pilot block variance
- e_{ij}: Random error variance

Results and Discussions

Results



Cland
Absolute error sum
1
2
3
4
5
6
D
S
Mode
COland
Absolute error sum
4
5
6
7
8
9
10
D
S
Mode
CStall
Absolute error sum
2
3
4
5
6
7
D
S
Mode
Pstall
Altitude Difference (m)
150
200
250
300
350
400
450
D
S
Mode

Results

ANOVA results of workload on offset landing

COland - Offset Landing Workload					
	Df	**Sum Sq**	**Mean Sq**	**F-Value**	**Pr (>F)**
M	1	9,73	9,726	3,857	0.0697
P	2	30,96	15,481	6,139	
Residuals	14	35,31	2,522		

MOTION IS SIGNIFICANT

ANOVA results of workload on landing

Cland - Landing Workload					
	Df	**Sum Sq**	**Mean Sq**	**F-Value**	**Pr (>F)**
M	1	3,023	3,023	4,941	0.0432
P	2	31,12	15,561	25,43	
Residuals	14	8,566	0,612		

Results

ANOVA results of precision on stall recovery

Dstall - Precision on Stall Recovery					
	Df	**Sum Sq**	**Mean Sq**	**F-Value**	**Pr (>F)**
M	1	40	40	0,01	0,9205
P	2	55964	27982	7,28	
Residuals	14	53812	3844		

MOTION IS NOT SIGNIFICANT

ANOVA results of workload on stall recovery

Cstall – Stall Recovery Workload					
	Df	**Sum Sq**	**Mean Sq**	**F-Value**	**Pr (>F)**
M	1	0,89	0,886	1,555	0,238
P	2	38,64	19,322	33,89	
Residuals	11	6,27	0,57		

Discussion

- Significance of the motion platform addition:
  - Landing
  - Offset Landing
- Tendency of workload increasing
- No significance on stall recovery
  - Non-representative dynamic model of the aircraft

Conclusion

- Tendency of the relevance in the addition of motion
  - Not enough data to make a definitive claim
- Future works:
  - Extension of the testing procedures
  - Including other manoeuvres
  - Implementing the avionics in the pilot’s control panel
  - Installing a control load system

Thank you!

Questions?