Scenarios of Over-Automation in Flight Testing of Manned Aircraft

3/30/2017

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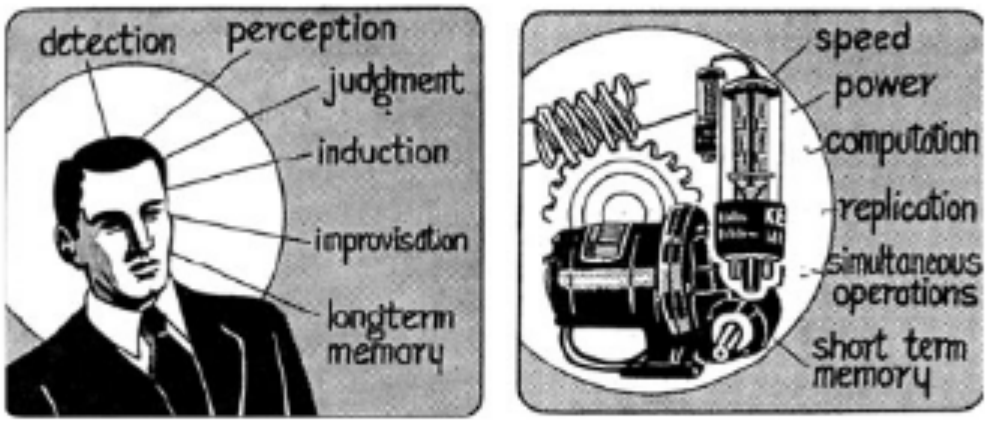
Human vs Automation

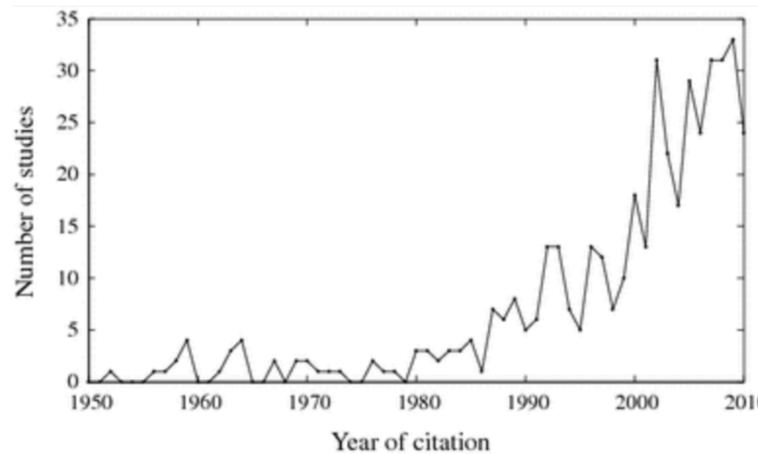
"Allocate to the human the tasks best suited to the human, allocate to the automation the tasks best suited to it."

Thomas Sheridan

Who is better at what?



MABA–MABA ('Men are better at, Machines are better at') (Fitts 1951)



Precision and Repeatability

Summary

Should we use dedicated automation in Flight Testing (FT)?

- FT Events that could be beneficiated
- STPA
- Scenarios of over-automation
- Requirements and constraints

Where in FT automation could help?

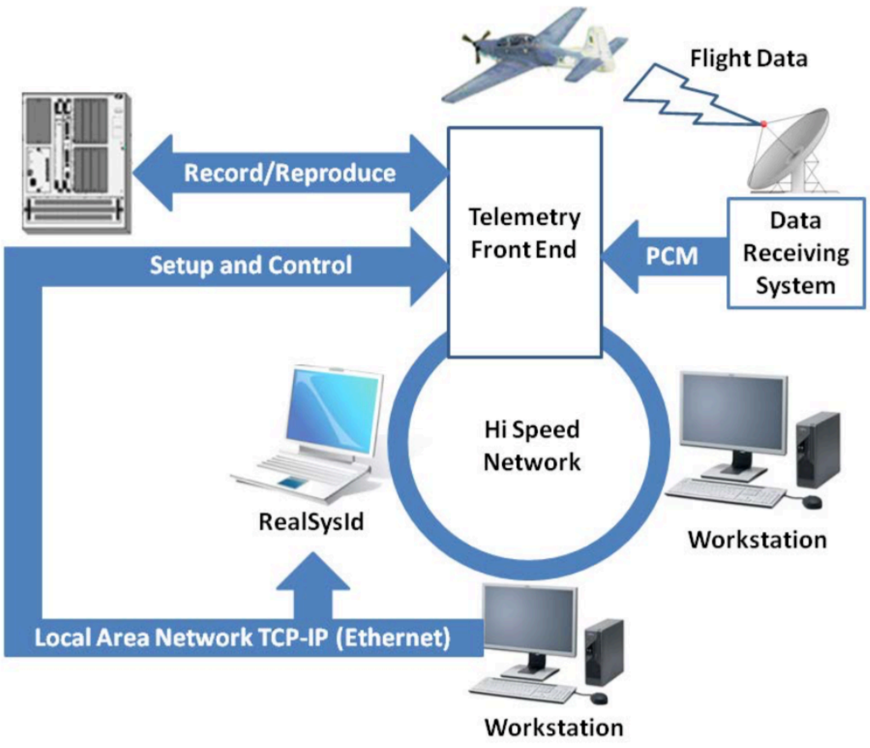
- Autopilot dedicated modes for input precision
    - Short Period pitch doublet
    - Dutch Roll yaw doublet
    - Windup Turns / Push Over

  } Statistical Data

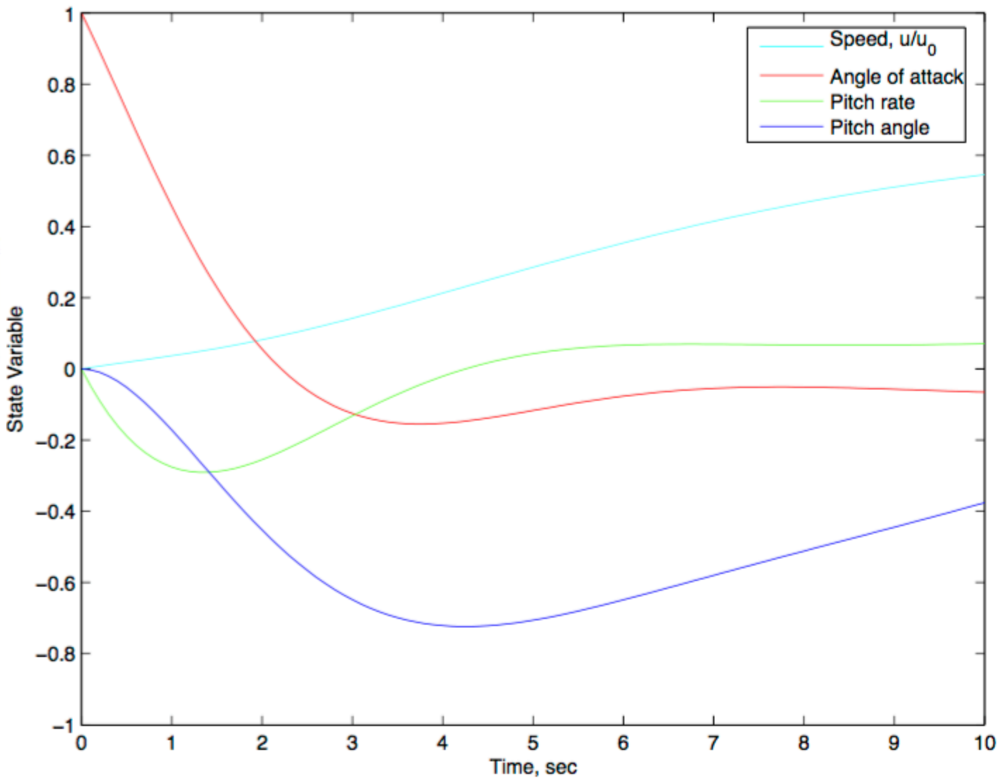
- Remote / autonomous control for dangerous events
    - First Takeoff
    - Performance - Flight Envelope:
        - Speed
        - Altitude
        - Load Factor
    - Handling Qualities:
        - Spins
    - Systems:
        - Weapons Separation

  } RPA History + Cognitive Analysis

Flight Testing

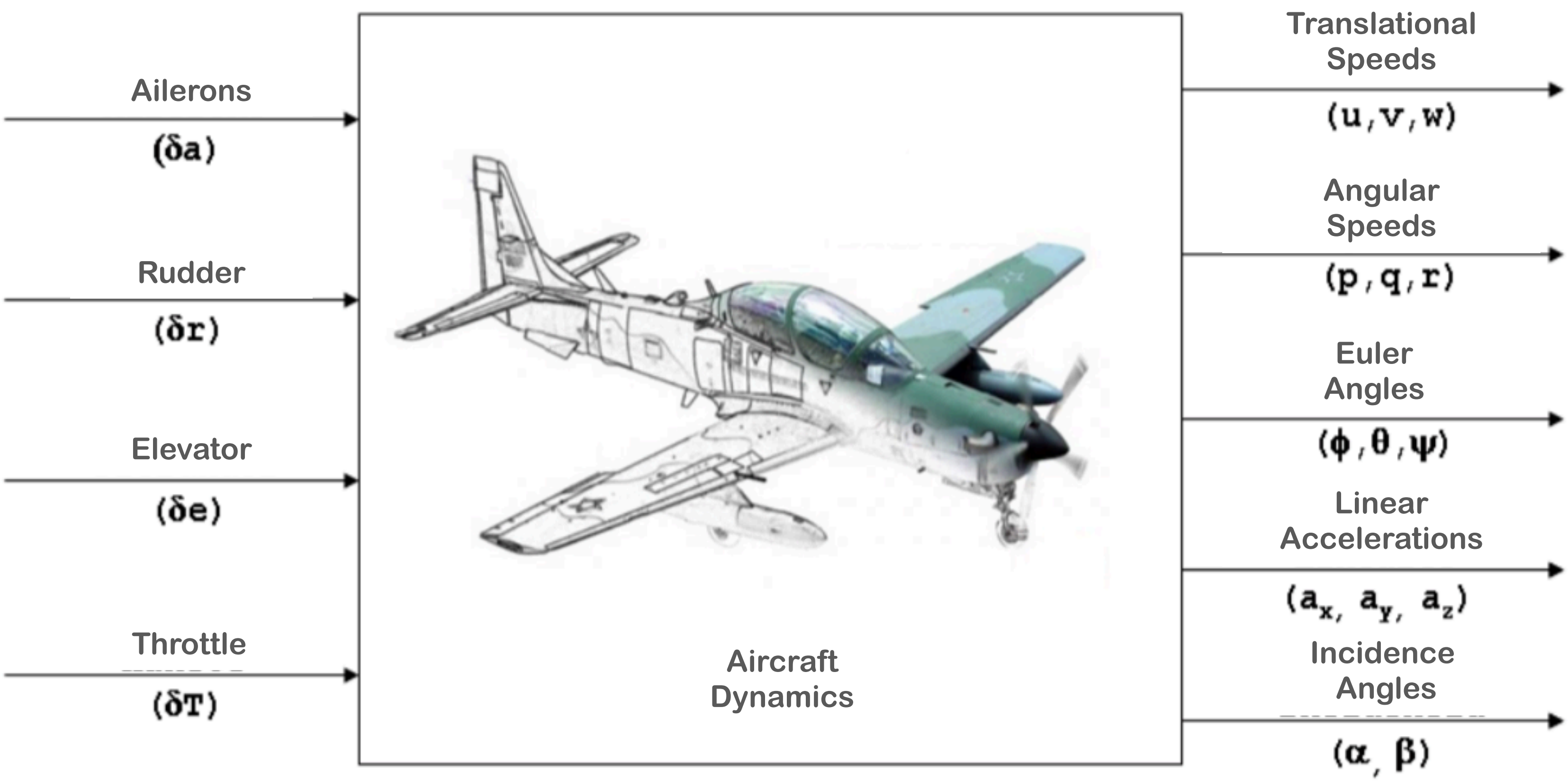


Sampling Rate: 32 Hz

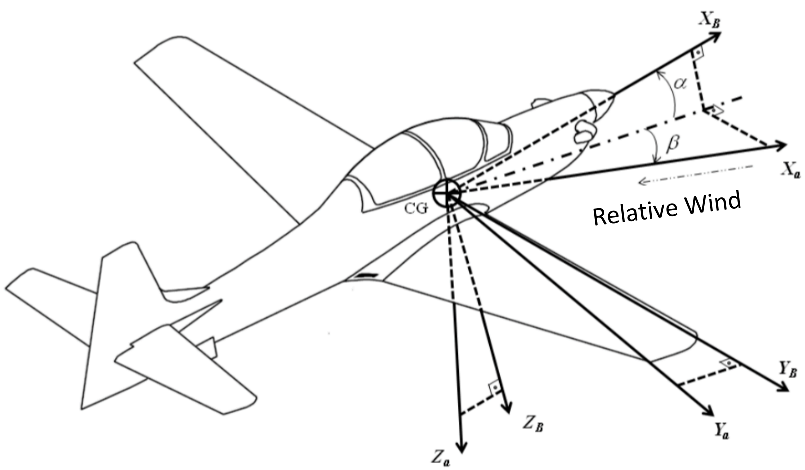


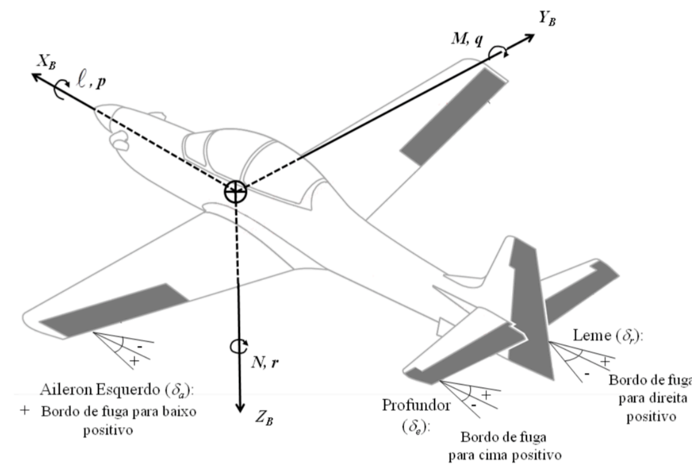
Short period

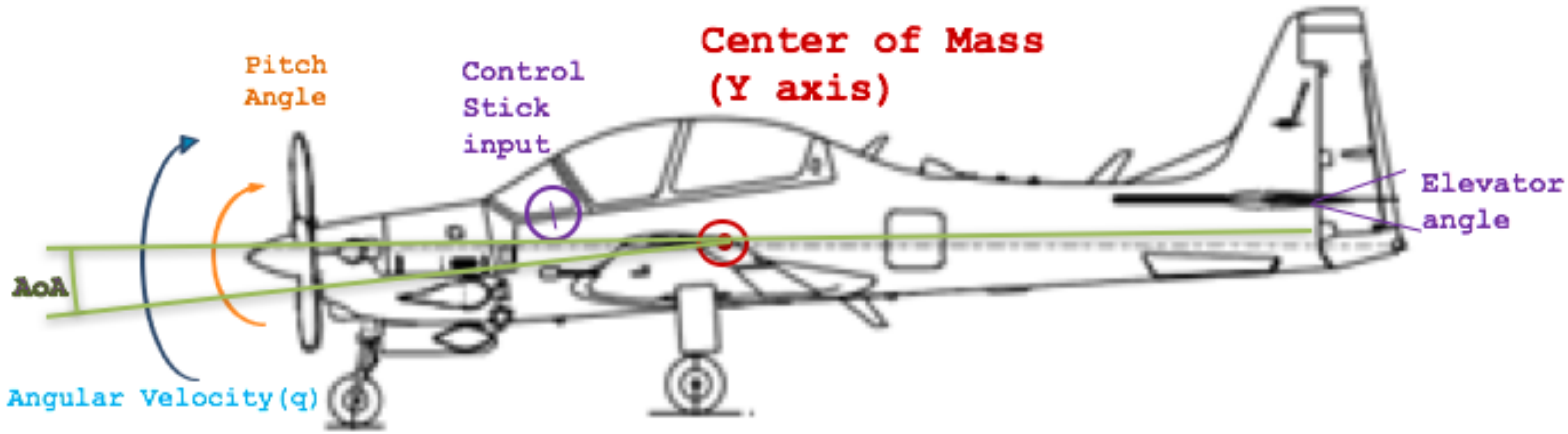
Inputs and Outputs



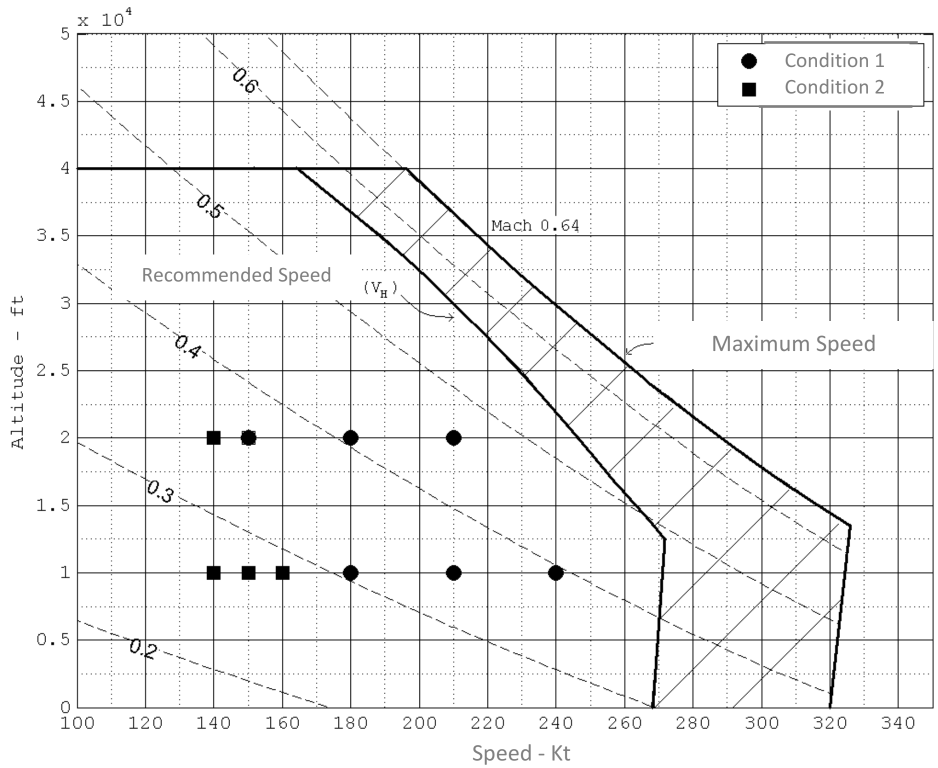
Variables Considered







Events distribution in Flight Envelope



We need more events!

Constrained by Time

As precise as possible

Automation is welcome

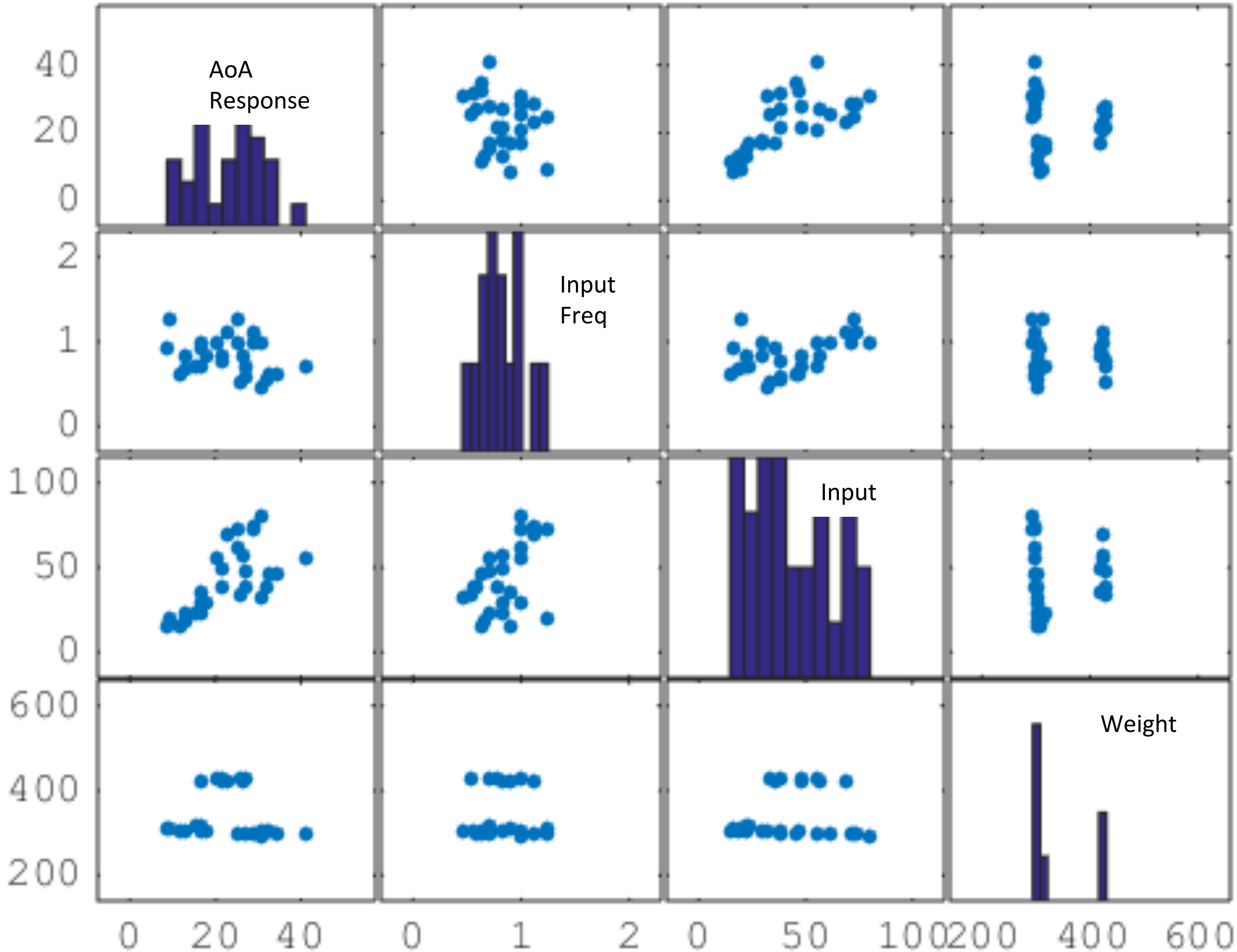
Transfer Function for air model

Study Characterization

Data collected from the Flight Testing and Research Institute - Brazil

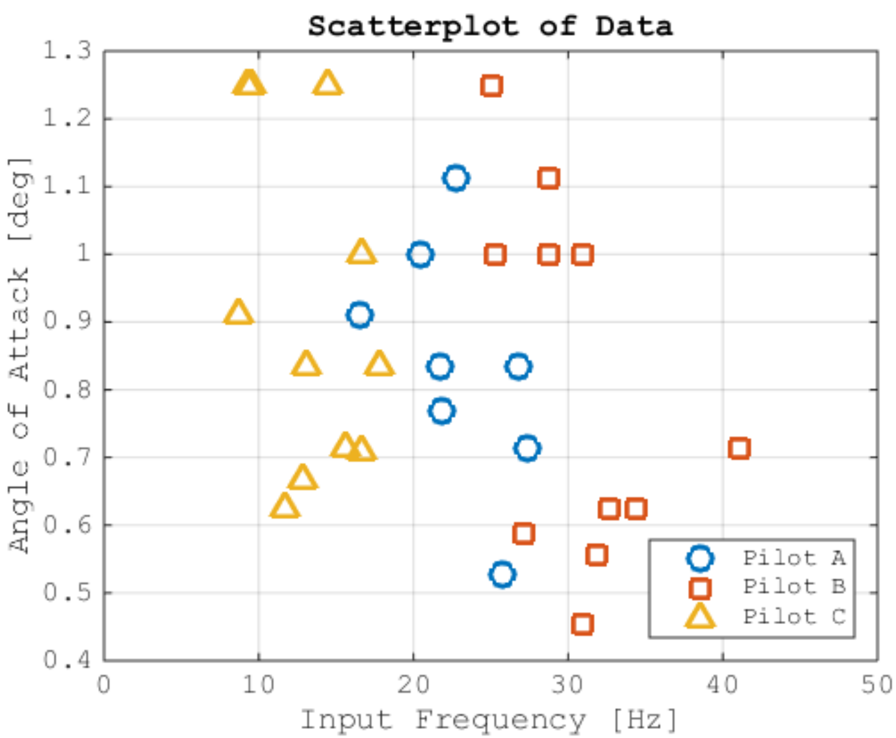
- Only the doublet technique was considered
- Main Dependent / Response Variable: Angle of Attack (α) [degrees]
- Independent Variables:
  - Control Input Amplitude [degrees]
  - Control Input frequency [Hz]
  - Weight [kg]
  - Aircraft Configuration (Categorical – clean vs. flaps down/gears down)
- Data set: 3 Pilots, each with 8-11 maneuver replicates
- Blocking: Pilots
- Nuisance Factors: Altitude [ft] kept constant

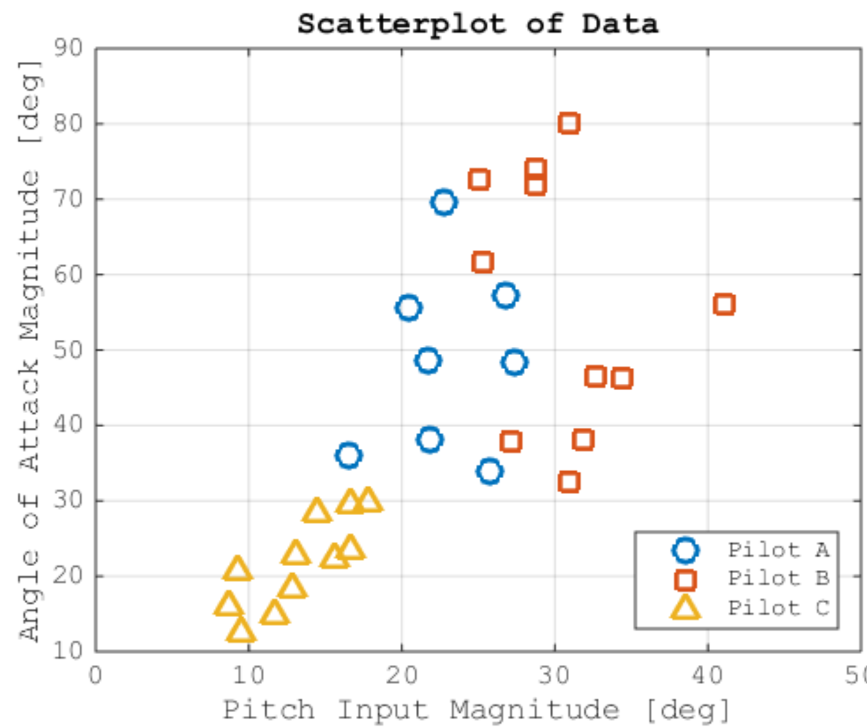
Statistics of Data Collected in Flight Testing



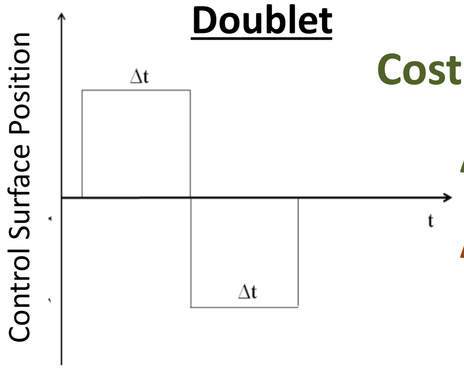
Statistics of Data Collected in Flight Testing

- Same: aircraft, configuration, instrumentation, one pilot + one engineer
- Conditions:
  - Pilot A and B: V_{app} gear down flaps down
  - Pilot C: 200kts gear up flaps up





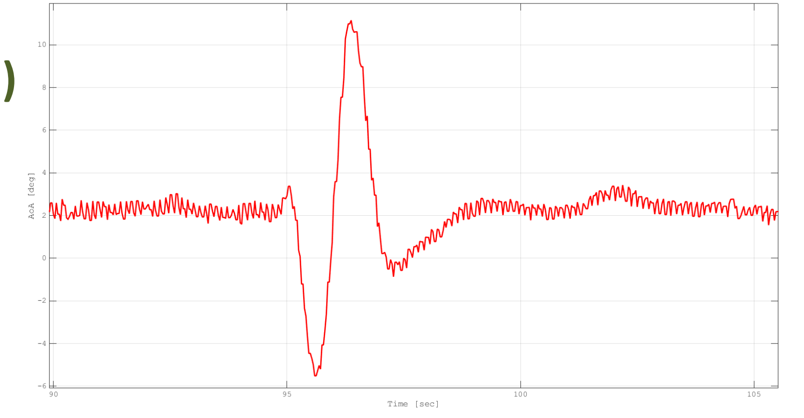
Short Period

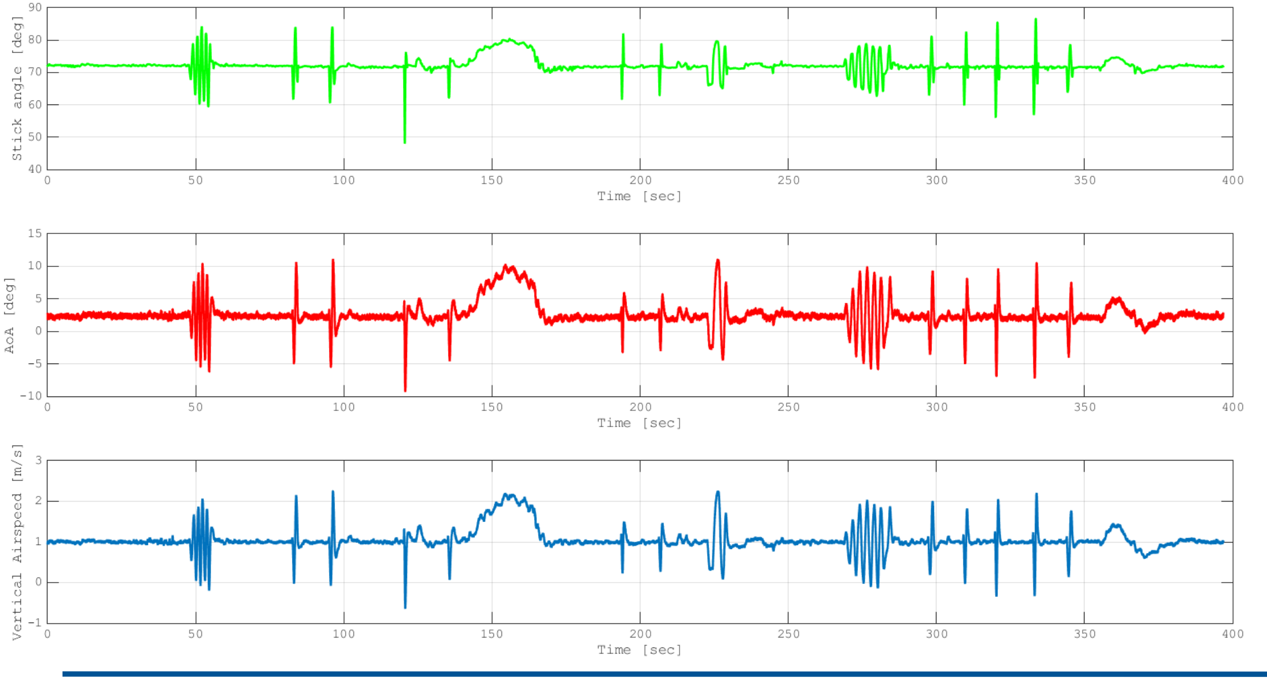


Cost of 1h of flight (2017)

A-29: US$ 1,393.78

A-1: US$ 12,819.55





Characterization of A-29:

- High dampening at this speed
- Weak third peak

Natural Frequency
&
Dampening

Findings

Range in frequency was from 0.45 to 1.25Hz

variations up to 175%

Just after training, test pilots are already applying

significantly different frequency inputs

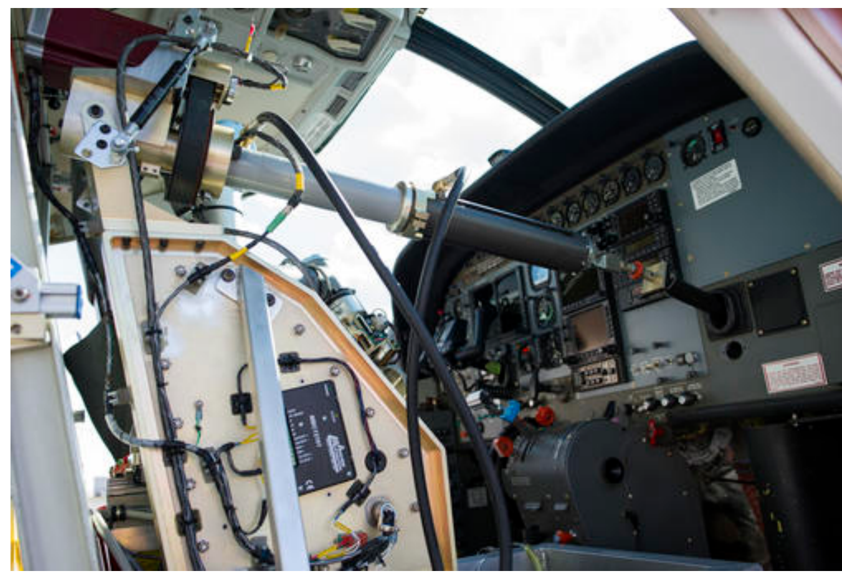
when performing the Doublet inputs

Controller	Control action	Controlled process
Test Pilot	Longitudinal movement of stick	Pitch doublet for Short Period
Test Pilot	Pedals	Yaw doublet for Dutch Roll
Test Pilot	Lateral & Longitudinal movement of stick	Roll + Pitch for windup turns
Autopilot	Longitudinal movement of stick	Pitch doublet for Short Period
Autopilot	Pedals	Yaw doublet for Dutch Roll
Autopilot	Lateral & Longitudinal movement of stick	Roll + Pitch for windup turns
ALIAS	Longitudinal movement of stick	Pitch doublet for Short Period
ALIAS	Pedals	Yaw doublet for Dutch Roll
ALIAS	Lateral & Longitudinal movement of stick	Roll + Pitch for windup turns

If we don’t have a fly-by-wire

DARPA - AURORA

ALIAS (Aircrew Labor In-Cockpit Automation System)



No Artificial Intelligence

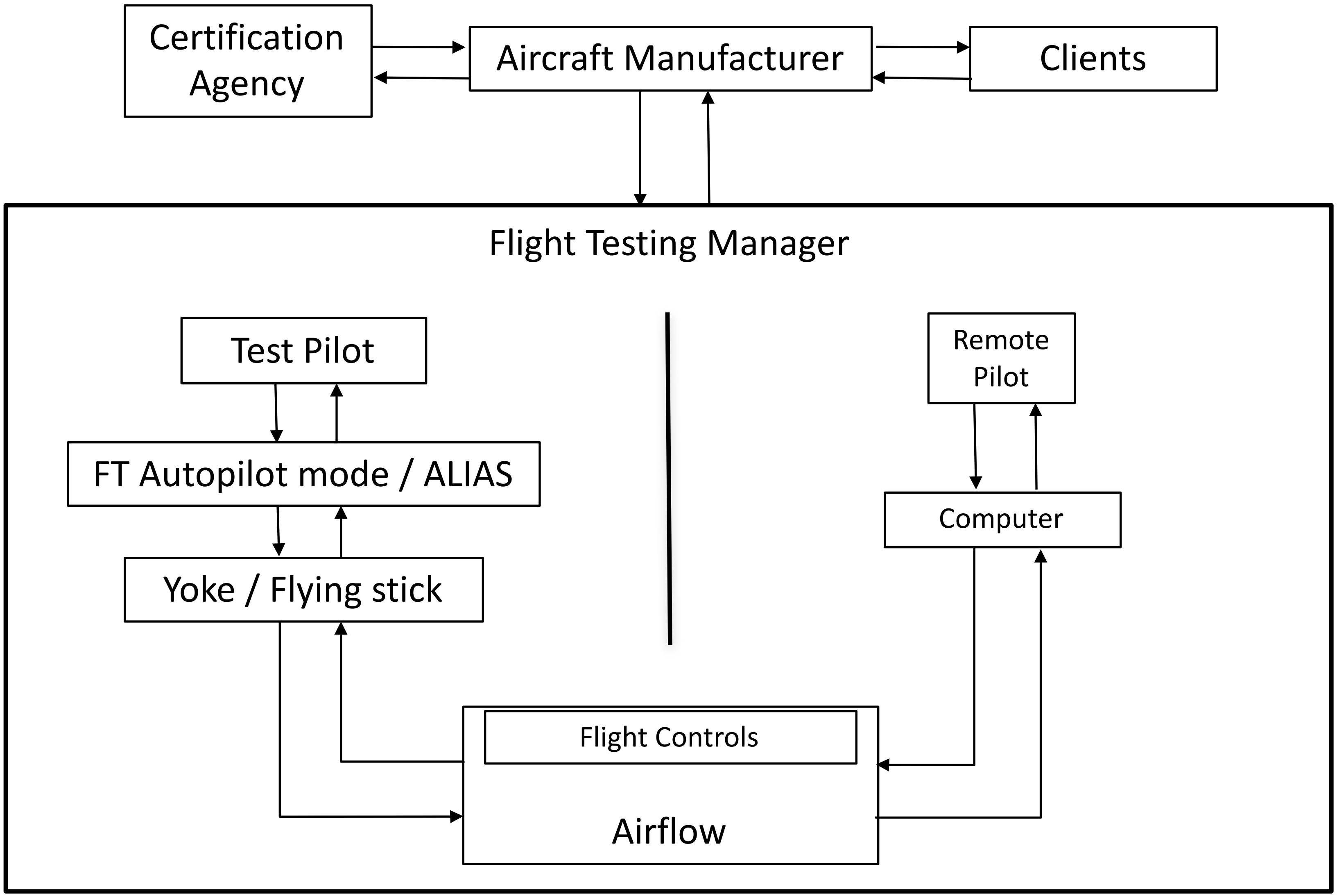
Robot copilot with computer vision reads gauges

Remote Control for Dangerous Events

- First Takeoff
- Performance - Flight Envelope:
  - Speed (Stall, Mach Buffeting)
  - Altitude (Operational Ceiling)
  - Load Factor (both limits)
- Handling Qualities:
  - Spins (recoverability)
- Systems:
  - Weapons Separation

STPA

Control Structure - Autopilot Mode for Fly by Wire Flight Controls



STPA Step 1

<u>“Not provided”</u>

- Precision: delays on the diagnosis of the problem by the test pilot.
- Dangerous: Failures of the system that terminate the test.

Result: any malfunction leads to higher cost

<u>“Too late, too soon or wrong order”</u>

- Precision: Related with the inadvertent engagement of the system during critical phases of the flight. Demand pilot action.
- Dangerous: Delays on transmissions or execution when the planned initial conditions are not met. Forbid the recover from dynamic conditions.

Result: unreliable automation and human factors like mode confusion brings the system to a more dangerous state than it was before

Scenarios from “Provide” and “Too long”

UCA 2: Pitch frequency Sweep continues with inputs when Pilot-Aircraft coupling or flutter happens

How many sensors would be needed to match human perception?

UCA 7: Dutch Roll Frequency Sweep continues when aircraft speed is dropping

UCA 15: Wind up Turn / Pull Over keeps rolling to pursuit Mach at high g putting the aircraft in unrecoverable condition

UCA 18: Wind up Turn / Pull Over inadvertent supersonic boom when reducing g with nose down

What is the target complexity of software when a human is monitoring?

UCA 13: Wind up Turn / Pull Over continues when pilot had faded out

How to deal with machine control when human is not able to intervene?

UCA 28: ALIAS continues acting when equipment was displaced from planned position

How to prevent automation surprises (Woods and Sarter, 2000)?

Lessons

- The tradeoff between the investment and reduction in flight time or risk reduction on FT using higher levels of automation must consider extra training and new constraints.

- The FT Campaign Cost and Risk Analysis must address the automation as a new source of risk with a dedicated analysis.

Are we ready?

AEROASTRO

Questions?

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