Scenarios of Over-Automation in Flight Testing of Manned Aircraft

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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

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

Sampling Rate: 32 Hz

Short period
Inputs and Outputs

Aircraft Dynamics

- **Ailerons**
  - $(\delta a)$
- **Rudder**
  - $(\delta r)$
- **Elevator**
  - $(\delta e)$
- **Throttle**
  - $(\delta T)$

Translational Speeds
- $(u, v, w)$

Angular Speeds
- $(p, q, r)$

Euler Angles
- $(\phi, \theta, \psi)$

Linear Accelerations
- $(a_x, a_y, a_z)$

Incidence Angles
- $(\alpha, \beta)$
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 ($\alpha$) [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

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Statistics of Data Collected in Flight Testing

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

Doublet

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

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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

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<th>Controller</th>
<th>Control action</th>
<th>Controlled process</th>
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<td>Longitudinal movement of stick</td>
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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

The QF-16 is controlled remotely by two pilots in a ground control station
Control Structure - Autopilot Mode for Fly by Wire Flight Controls

Certification Agency → Aircraft Manufacturer → Clients

Flight Testing Manager

Test Pilot

FT Autopilot mode / ALIAS

Yoke / Flying stick

Flight Controls

Airflow

Remote Pilot

Computer
STPA Step 1

“Not provided”

• 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

“Too late, too soon or wrong order”

• 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 pursue 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?
Questions?

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