Lessons Learned While Giving Unaugmented Airplanes to Augmentation-Dependent Pilots

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Lessons Learned While Giving Unaugmented Airplanes to Augmentation-dependent Pilots

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Modern technology, including fly-by-wire control systems with envelope protection have increased flight safety and effectiveness.

Modern pilots are dependent upon these systems.

Maintaining skills required to operate without these aids create an immense training burden.

Ground-based simulators cannot duplicate the feel of loss-of-control scenarios.

Failure modes must preserve critical protections.
They all have sticks and rudders, right?

S2B, T-6, A-10

• The stick moves the elevator to create a pitching moment
• The stick moves the ailerons to create a roll moment
• The pedals move the rudder to create a yaw moment
• The airplane then responds as a function of its stability characteristics

F-16

• The stick provides a voltage to the digital flight control computer that interprets it either as a command for pitch rate or g, then moves the stabilators as required to produce the commanded result with a minimal delay or residual motion while ensuring that the aircraft exceeds neither angle-of-attack or g limitations.
• The stick provides a voltage to the digital flight control computer that interprets it as a command for roll rate—with the final rate determined by the aircraft configuration, airspeed, and angle-of-attack—then moves the flaperons, rudder, and stabilators as required to produce the commanded roll rate with minimal delay.
• The pedals provide a voltage to the digital flight control computer that interprets it as a command for a given amount of rudder deflection. Roll commands are overridden to some extent to ensure a normal feel (roll due to yaw, etc.). Rudder pedal commands are only necessary during ground operations and departure recovery.
Command Augmentation and Robust Envelope Protection
Capability ≠ Expertise

Time/Technology

Capability

Expertise
Technologically Enabled Capability

Scientia est Virtus
Augmented Carrier Landings
More Reliance on Automation

- Moving maps
- Electronic engine controls
- Anti-skid brakes
- Stability and Control Augmentation
  - Dampers
  - Fly-by-wire
- GPS navigation
- Autopilots

Many modern pilots are primarily systems managers with minimal stick-and-rudder skills
What Happens When Automation is Lost?

• Surprise!
  – Subconscious reaction: Fly the airplane you were flying before the loss (may cause loss of control)

• If out of control: Reversion to training
  – Must be automatic: Increased training time
  – Must be appropriate: Increased training scenarios

• If in control and time allows: Reorientation
  – What is going on?
  – What do I have?

What is the training overhead to be prepared?
How About Simulators?

- Ground-based simulators cannot reproduce dynamic motions.
  - May encourage inappropriate control inputs
  - Pilots will be surprised by the feel of the real event
- Simulation models are much less accurate at the “edge of the envelope”
  - Surprises remain: *surprises are bad*
  - Pilots left to use trial-and-error in a real situation
  - Augmentation-dependent pilots have a small “tool kit”

Let’s have a case study…
AA587 Vertical Stabilizer Failure
NASA Ames
Vertical Motion Simulator (VMS)
VMS Replication of AA587 Cockpit “Feel”

- Duplicated cockpit motion, control motion, and out-the-window view of the mishap.
- Eight pilot experts observed the mishap events in the cab.

“…sustained accelerations beyond the motion limitations of the VMS were not possible. However, Human Performance group members noted that the VMS was far better in its capability to produce realistic motion cues as compared to a typical hexapod motion-based training simulator.”

DCA02MA001 Human Performance Study Report
Lateral Acceleration

![Graph showing lateral acceleration over time with a peak labeled "Tail Lost".

Time (11 seconds)

Lateral (side-to-side) Cockpit g

AA587 Cockpit NY

Tail Lost
Lateral Acceleration

![Graph showing lateral acceleration over time with annotations for AA587 Cockpit NY and VMS Cab NY, indicating a tail loss at 11 seconds.](image)
Lateral Displacement

![Graph showing lateral displacement over time with labels for AA587 Cockpit Equivalent Lateral Movement and VMS Cab Lateral Movement. The graph highlights a significant lateral displacement event at Tail Lost.]
Cockpit Displacement

\[ \sim 6000 \text{ fpm} \]
So What?

- The best ground-based simulator could not come close to reproducing the feeling in the cockpit of AA 487.
- A ground-based simulator can prepare a pilot for these motions is either impossible or very expensive.

Pilots subconsciously respond by “feel” during loss-of-control. Simulators cannot prepare them.
How About this Simulator?

Calspan NC-131H Total In-flight Simulator (TIFS), Retired 2009
We must not give a non-augmented or differently augmented aircraft to an augmentation-dependent pilot without appropriate training (or an instructor)!
Do Not Give a Pilot a New Aircraft During an Emergency

- Redundancy, redundancy, redundancy
  - Independent backups (hardware, software)
- Design for redundancy
  - Reduce complexity
  - Performance may suffer
  - Fault tolerance is vital
- Minimize motions that cannot be simulated
  - This is part of envelope protection
- Consider a fool-proof automated recovery system
Thesis

- Modern technology, including fly-by-wire control systems with envelope protection have increased flight safety and effectiveness.
- Modern pilots are dependent upon these systems.
- Maintaining skills required to operate without these aids create an immense training burden.
- Ground-based simulators cannot duplicate the feel of loss-of-control scenarios.

*Failure modes must preserve critical protections.*