Mitigating the APC Threat - a work in progress

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My Perspective

- What I would do if I was responsible for
  - Research
  - Design & Development
  - Flight Test
  - Certification
  - Airline Safety
  - Accident Investigation
... relative to mitigating the APC threat
Mitigating the APC Threat - CAT

Cat. II APC Research

• Task Identification
  - e.g., a large ("over driving") correction to an upset, followed by closed-loop control to get back on original flight path

• Subject Identification
  - e.g., APC evaluation results from naïve "line" pilots compared with experienced test pilots

• Vehicle Identification
  - Variable stability aircraft, or ground based flight simulator, or actual aircraft

Mitigating the APC Threat - CAT

Cat. II APC Research, continued

• Design and demonstrate a control system that is free from Cat. II APC characteristics for a wide range of surface rate limits (e.g., from 1% to 100% of the maximum achievable surface rate)
Mitigating the APC Threat - CAT

Design & Development

- Incorporate favorite PIO criteria into Mark Tischler’s Conduit* Program to address Cat. I
- Minimize the actuator energy metric (cost function) in Conduit (Control Designer’s Unified Interface)
  - to reduce probability of “over driving” beyond rate limits, a Cat. II condition
  - to increase actuator life
- Utilize tactile control feedback\(^1\) on primary controls to warn of approach to rate and/or position limiting, with active stops to preclude “over driving” continues

\(^1\)analogous to NRC’s collective limit curving. AvWk, p.53. 22Feb99

Mitigating the APC Threat - CAT

Design & Development, continued

- Backup tactile control feedback on primary controls design with adaptive filtering\(^1,2\) to compensate for time delay caused by “over driving”
- Isolate pilot controlled surfaces and actuators from non-pilot controlled surfaces and actuators
  - Reduce erosion of pilot control response and authority from non-piloted intrusion

\(^1\)Hanke, Dietrich. Phase compensation: a means of preventing APC caused by rate limiting. Forschungbericht 98-15

\(^2\)Runqudwist, Lars. Phase compensation of rate limiters in JAS-39 Gripen. AIAA Paper 96-3368
### Mitigating the APC Threat - CAT

#### Ground/Flight Test
- From ground calibration tests, determine the cockpit controls to surface response time delay and hysteresis characteristics for inputs up to the maximum input rate & deflection capability of the pilot.
- If values exceed expectations/guidance/specifications, evaluate options for improvement.
- Alternately, evaluate on variable stability aircraft while performing off-set landing, large upset correction, etc., Cat. 2 APC maneuvers to define criticality of the problem.

*Note: The issue here is the consistent ability of line pilots to accommodate the change in time delay and hysteresis characteristics that may be experienced as part of a "hair-raising" experience such as a large upset, or an eminent in-flight...*

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#### Certification
- Continue APC exposure/training of certification pilots, using a variable stability aircraft.
- Emphasize the determination of evaluation tasks for Cat. II APC that are both safe and effective.
- Evaluate in flight APC Cat. I characteristics using existing FAA APC testing benchmark tasks.
- Would not attempt Cat. II in-flight evaluation until safe and effective test technique is identified.

*continues...*
Mitigating the APC Threat - CAT

Certification, continued
- From ground calibration tests, determine the cockpit controls to surface response time delay and hysteresis characteristics for inputs up to the maximum input rate & deflection capability of the pilot

continues

Mitigating the APC Threat - CAT

Certification, continued
- If time delay or hysteresis values exceed expectations/guidance/specifications, evaluate on variable stability aircraft while performing off-set landing, large upset correction, etc., Cat. 2 APC maneuvers

Note: The issue here is the consistent ability of line pilots to accommodate the change in time delay and hysteresis characteristics that may be experienced as part of a “hair raising” experience
Mitigating the APC Threat - Airline Safety

Airline Safety

- For the cockpit primary control inputs and the resulting control surface outputs, record at data rates of 20 Hz or greater on the QAR.
- Initial APC Precursor
  - Monitor QAR data for the time lapse between reversal of the cockpit control rate and the associated reversal of the surface rate as APC precursor.
  - Flag occurrences with $t_D > 100$ msec.
  - Flag & record values of $t_D$ when $t_D > 150$ msec.
- Involve APC specialist for consistent flags, or values of $t_D > 150$ msec.

Growth APC Precursor

- Utilize 20 Hz. or greater data rates on primary controls, primary control surfaces, aircraft accelerations, and warning, such as “stall” and “over-speed”.
- Utilize QAR data to support Conduit as a monitor.
  - Flag occurrences violating Level 1 criteria.
  - Flag & record values of $t_D$ when $t_D > 150$ msec., and Level 2 criteria.
  - Involve APC specialist for consistent flags, or values of $t_D > 150$ msec.