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

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Mitigating the APC Threat - AT

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

continues

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Mitigating the APC Threat - AT

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)

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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 cueing, AvWk, p.53, 22Feb99

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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]Runqudqwist, Lars, Phase compensation of rate limiters in JAS-39 Grippen, AIAA Paper 96-3368

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Mitigating the APC Threat - CAT

Ground/Flight Test

- From ground calibration tests, determine the cockpit controls to surface response time delay and hystersis characteristics for inputs up to the maximum input rate & deflection capability of the pilot
- If values exceed expectations /guidance /specifications, evaluate options for improvement
- Altemately, evaluate on variable stability aircraft while perfoming 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 inflight

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Mitigating the APC Threat - CAT

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 bench mark tasks
- Would not attempt Cat. II in-flight evaluation until ~~safe~~ and effective test technique is identified

continues

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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

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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

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Mitigating the APC Threat - CAT

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.

continues

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Mitigating the APC Threat - CAT

Airline Safety

- 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

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