Model 525 Relentless Advanced Fly-By-Wire – The Pilot's Safety Advantage

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Helicopter Safety Review

- **Differ from fixed-wing**
  - Operate low speed, low altitude, DVE, IMC
- **Controlled Flight into Terrain (CFIT)**
  - 60% of CFIT accidents result in fatalities (NTSB)
  - Occur IMC, VMC, mountainous, flat terrain
  - Flight phases for CFIT accidents (FAA AC 61-134)
    - Takeoff and climb: 25%
    - Approach and landing: 41%
    - Cruise: 4.5%
- **Causes**
  - Loss of situational awareness (in both vertical and horizontal axes)
  - Spatial disorientation affected by visual cues and aircraft handling qualities

Selected Helicopter Case Studies

- **Night flight in the Gulf of Mexico**
  - "the flight crew's failure to identify and arrest the helicopter's descent for undetermined reason, which resulted in controlled flight into terrain"
- **Approach in the Shetland Islands**
  - "the combination of the nose-high attitude, low airspeed, high rate of descent, and high power placed the helicopter in a vortex-ring state"
- **HEMS helicopter crash into terrain in DVE conditions**
  - "continued flight into unknown weather conditions, which resulted in his failure to maintain clearance with the ground"
  - "pressure to complete the mission induced by the pilot-in-command as a result of the emergency medical services operation"
- **Divided pilot attention**
  - "The pilot stated that during lift-off he was distracted by persons on the ground waving arms. The aircraft drifted to the left and contacted a tree after which the pilot landed the aircraft and it rolled over"

Common themes – low situational awareness, high pilot workload, and spatial disorientation

Fixed-Wing FBW

- **Fixed-wing industry ahead of commercial rotorcraft in adoption of FBW**
- **Not all fixed-wing issues translate to helicopters**
- **FBW Side-stick controller issues**
  - **An accident caused by spatial disorientation was compounded by conflicting control inputs from the pilot and co-pilot side stick controllers.**
  - **An incident where the co-pilot unintentionally activated the stick "takeover" button while the pilot was commanding a flare for landing.**
  - **Several incidents where both pilot and copilot are making control inputs and the FBW system summed the inputs causing "abrupt maneuvers".**
- **Newman and Lambregt closing comment**
  - **"overall FBW and envelope protection have prevented accidents and saved lives. In the past 15 years, there have been 27 stall accidents in commercial transport operations with 848 fatalities – not one was a FBW airplane"**

FBW Technology has made Commercial Fixed-Wing Aviation Safer

Proposed Solutions

- **From FAA, CAA**
  - Increased use of Terrain Awareness and Warning System (TAWS)
  - Define more consistent procedures for dispatch into IMC
  - Increased pilot training – especially in the use of autopilots or related systems as well as better monitoring of aircraft state by the flight crew

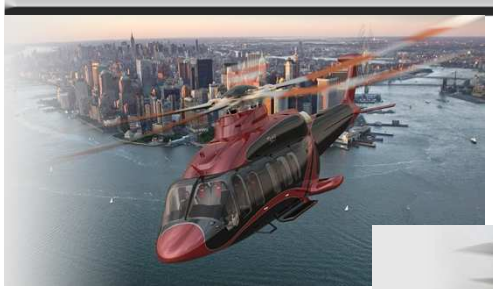
- **From Roger Hoh, J. W. Harding studies**
  - Use of stability and control augmentation to decrease pilot workload
  - Linked pilot workload, spatial awareness to helicopter handling qualities
  - Use of Translational Rate Command (TRC) and Position Hold (PH) to significantly lower pilot attention demand and reduce spatial disorientation in low speed/low altitude
  - Simulation studies showed TRC & PH reduced pilot workload and improved handling qualities

Common themes – Address Pilot workload, awareness, training, procedures

Bell's Solution for Safety - FBW

- **Bell 525 Relentless**
- **Multi-role Part 29 Civil Transport**
- ***World's first commercial Fly-by-Wire helicopter***

Voice of the Customer – Improved Helicopter Safety



- Customer Advisory Panel
  - Corporate and VIP
  - Firefighting
  - Oil & Gas Producers (OGP)
  - Search and Rescue (SAR)/Parapublic
  - Helicopter Emergency Medical Service (HEMS)

525 FBW Design for Safety Philosophy

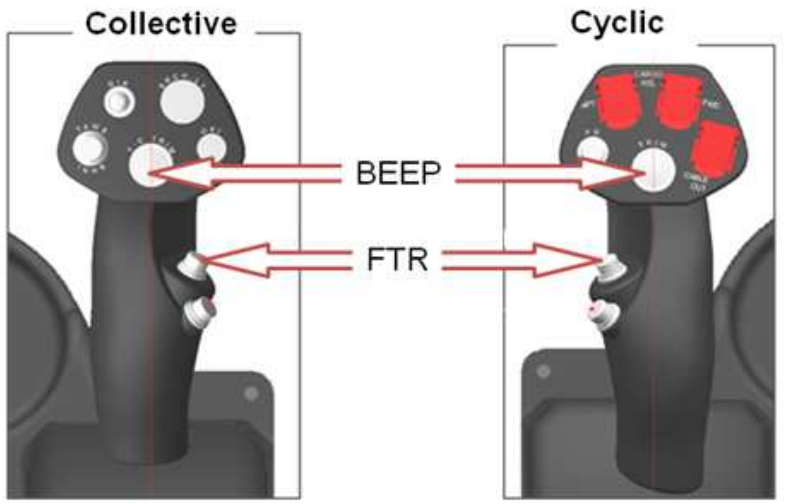
- **Provide default features which automatically reduce pilot workload, increase pilot situational awareness, and improve aircraft handling qualities**

- **Pilot is always in command directing the computer while the control laws achieve the pilot's desire with accuracy, smoothness, and grace**

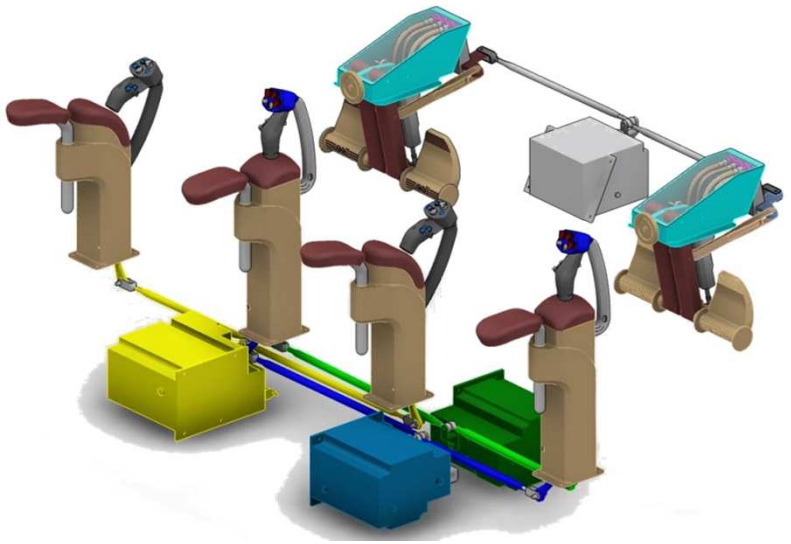
- **If reduced augmentation is necessary (perhaps due to a system failure), the pilot always has the option of reverting to a baseline "always available" direct control strategy**

Pilot Controls

- **Side-Stick Cyclic & Collective**
  - Detent detection
    - In-detent – CLAW default
    - Out-of-detent – Pilot command
  - Beeps slew reference speed, altitude …
  - Force Trim Release resets detent, reference, and releases forces



- **Traditional Pedals**
  - Detent detection
    - In-detent – CLAW default
    - Out-of detent – Pilot command



- **Mechanically interconnected pilot and copilot controls**
  - Lessons learned from fixed-wing FBW issues

525 FBW– Pilot Workload Reduction

- **Continuous full time stabilization in response to wind, gusts and other disturbances**

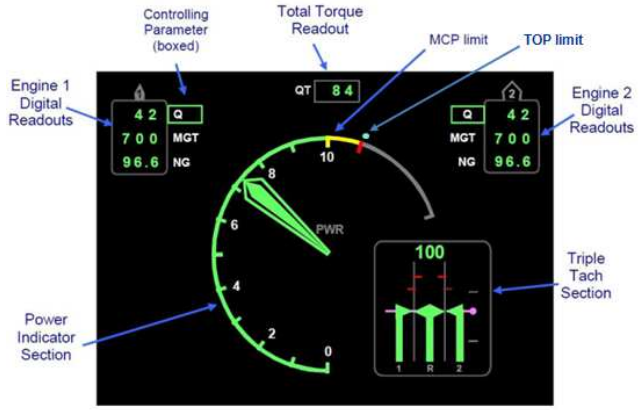
- **Full time default attitude, speed, vertical speed, and altitude holds depending upon the control axis and airspeed**
  - **Speed hold frees the pilot from having to make pitch attitude corrections via longitudinal cyclic to regulate air speed**

- **Decoupling the control axes**
  - **Actively command the longitudinal axis for example, but will still hold the altitude (vertical), bank angle (lateral), and heading (directional)**
  - **Provide the appropriate tail rotor thrust command to counteract the main rotor torque**
  - **Limiting the reference vertical descent rate as a function of airspeed – VRS protection**

- **TRC/PH at Hover and Low Speed**
  - **Critical in low altitude and DVE where helicopter missions commonly occur – HEMS, SAR, Firefighting, Oil & Gas**

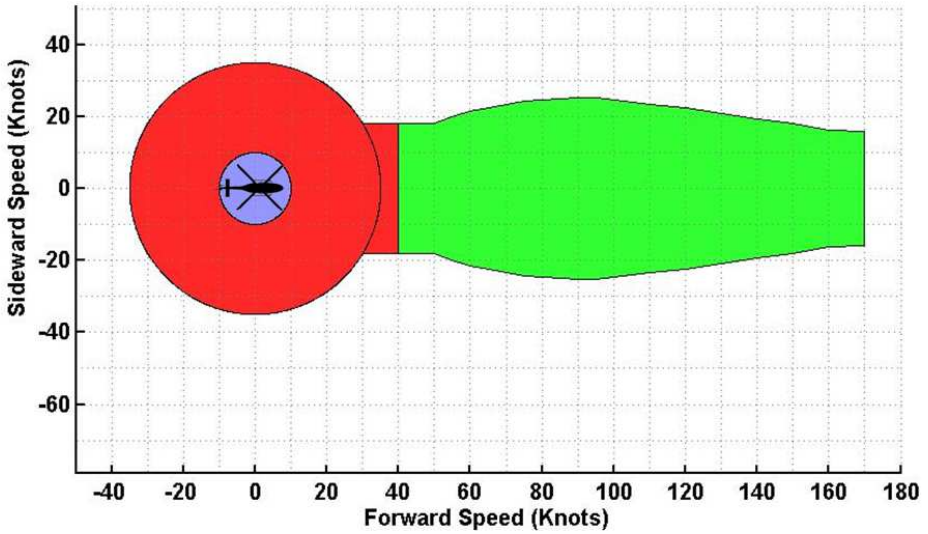
525 FBW – Increased Situational Awareness

- **Displacement trim for cyclic and collective**
  - Main rotor swashplate margin awareness
- **Collective Tactile Cueing**
  - AEO: MCP, TOP limits
  - OEI: Continuous, 2 min, 30 sec limits
  - Pilot "pull-through" of tactile cue
- **ARC Horizon Flight Deck**
  - Integrated Glass Flight Deck
  - Increased over-the-nose visibility
  - TCAS-II, HTAWS, Synthetic Vision
  - De-cluttered cockpit layout



525 FBW– Standardized Behavior

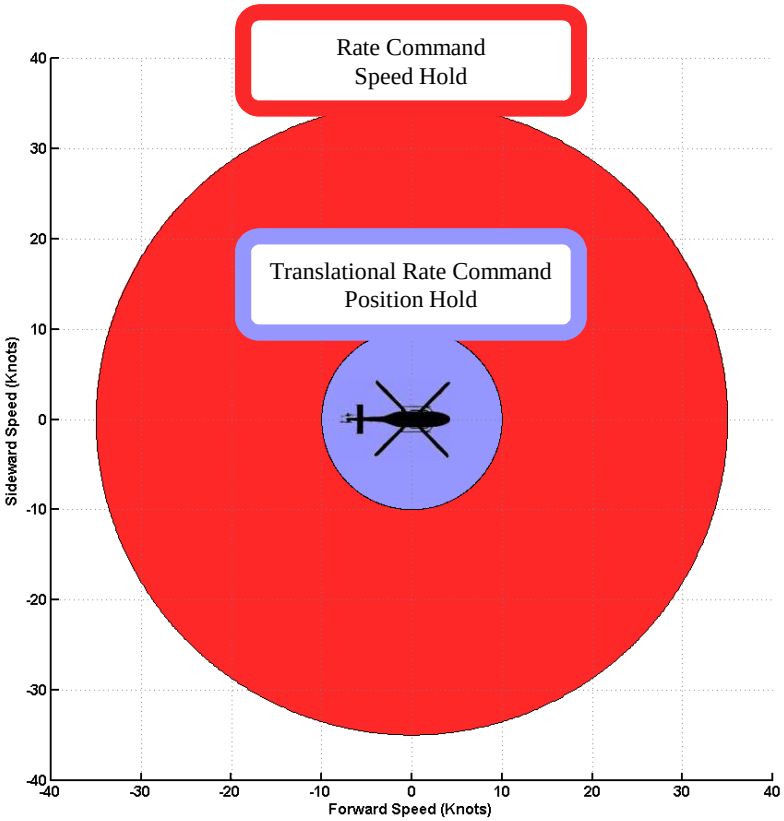
- **Automatic switching between flight regimes**
  - HOVER/TRC
  - Low Speed
  - High Speed



- **Consistent CAT-A Performance**
  - Take advantage of TRC/PH
  - Standardized training
  - No exposure during OEI

- **Autorotation Assist**
  - Minimize rotor droop
  - Standardized autorotation entry for training

Hover/TRC Performance - Simulation



Conclusion

- **Contributing factors to Helicopter CFIT and related accidents**
  - **High pilot workload**
  - **Loss of situational awareness**
  - **Low altitude, low speed, IMC and DVE**

- **Use of FBW improves helicopter handling qualities and therefore safety**
  - **Reduced pilot workload**
  - **Increased spatial awareness**

- **Specific 525 design-for-safety FBW strategies include**
  - **TRC/PH at low speed, low altitude**
  - **default speed, attitude, and vertical speed hold functionality**
  - **mechanically interconnected side-stick controllers**
  - **collective tactile cueing**
  - **displacement trim with margin awareness**
  - **control axis decoupling**
  - **CAT-A performance**

Questions