Next-Generation Aircraft Systems: Training, Real-time Response, and Licensing v. "status quo"

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My beginnings in aviation…

Training

- **Pilot:**
  - Acquires knowledge of concepts from a book and "lectures"
  - Obtains skill and practice by flying with mentorship then alone
  - A well-trained pilot will <u>recall and apply knowledge/skill</u> 99.999…9% of the time they fly commercially; learning is the remaining 0.000…1%

- **Autonomy:**
  - Product of a sound systems engineering process (incl. V&V)
  - Needs to recall and apply knowledge/skill 99.999…9% of the time; learning is the remaining 0.000…1%
  - Learning systems can be licensed but not straightforwardly verified or certified using conventional methods
  - Run-time monitors can help avoid ridiculous (and unsafe) exceptions that occasionally occur during learning

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Real-time Response: The Plane

- Pilot (real-time → 1-3 seconds)
  - Sense:
    - Auditory cues (voice and alert) are processed quickly
    - Glass cockpit supports fast visual processing of sensor information
  - Decide (mission, safety):
    - Procedures and "instinct" with hard real-time deadlines
    - Collaborative pilot-automation systems make long-term decisions
  - Act:
    - Natural language (voice) allows rapid enunciation of thoughts
    - "Stick-and-rudder" interfaces translate motion intent to aircraft actuation
    - Keyboarding/touch screen allow rapid selection of options

- Autonomy (real-time: 1 – 100 msec or "as needed")
  - Sense: Fusion of GPS, INS, ILS et al, radar, vision, ADS-B, …
  - Decide (mission, safety): Mode selection, flight planning and replanning
  - Act: Trajectory tracking (control), communication, exploration

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Real-time Response: The System

- Let's get to redundant datalink → easier to V&V and even secure than voice

- ATC / Detect-and-Avoid → Let's get to optimal traffic prediction and management as well as heterogeneous traffic management to "open the skies" to everyone

- What if we had next-generation autonomy……
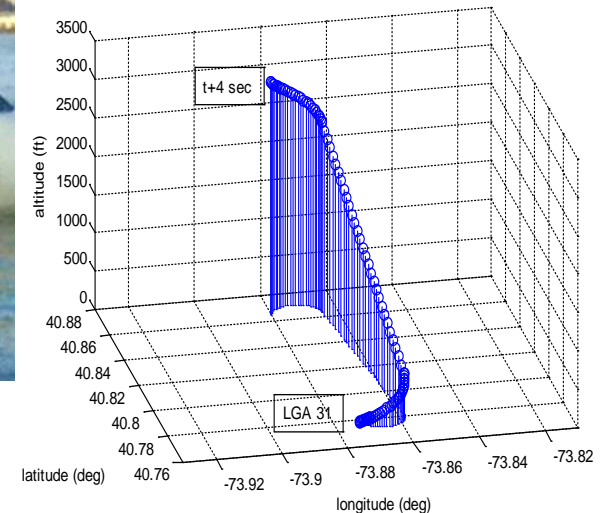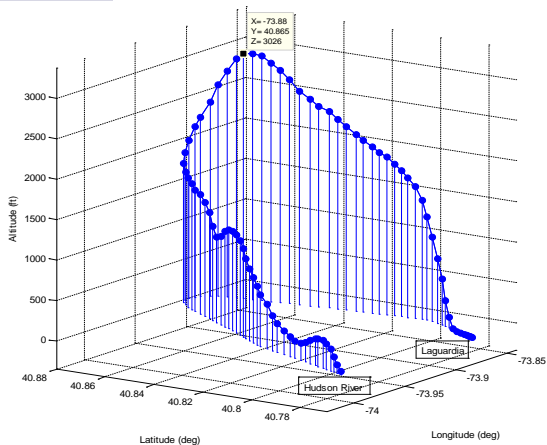
Run-time Monitors ~ Common Sense

- Fly like you "know how" (envelope protection)
- Don't go where you're not supposed to (geofencing, ROPS)
- Declare emergencies accurately, immediately (don't delay)
  - Aviate, navigate, communicate → avionics can perform these in parallel with speed and effectiveness
- Switch to backups as needed
  - Backups can be human or software "sense, decide, act" entities
  - Don't make assumptions – choose the best solutions independent of legacy

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Licensing and the "Status quo"

- **Pilot: Licensed**
  - Textbooks and FAR/AIM specify requirements
  - Multiple choice tests: evaluates "book learning"
    - People can miss several questions and pass
    - Not comprehensive – a form of "sparse sampling"
  - Practical test (flight examination): Evaluates knowledge and skill
    - People can make small mistakes and pass – lessons are learned this way
    - Pilots are not forced into unexpected adverse conditions in real flight…
- **Autonomy: Certified**
  - Systems engineers specify requirements
  - Certification: Based on docs of design, fault/failure analysis, tests (sim. and flight)
  - Verification:
    - Formal modeling & analysis of components, systems, software
  - Verification and certification are both challenged by complexity…
    - *Human cognition is partially observable and complex → licensing can handle this challenge for autonomy as well as human pilots*

A thought experiment on human pilot training…

Some Concluding Questions…

- Why are humans licensed and autonomy certified?
  - Both are engaged in "sense-decide-act" (or OODA – observe, orient, decide, act) behaviors
  - Since we can't read minds, we can't V&V humans (yet); let's not keep losing lives because we similarly can't scale V&V methods to interacting complex auto-OODA systems

- What training should be required for next-generation pilots and controllers?
  - Is stick-and-rudder still the primary required skill? → No
  - Is algorithmic and data thinking the foundation on which autonomy-human collaboration will rest? → Yes
  - Why do we tend to trust human learning more than autonomy learning, and how can both perceived and real trust gaps be reconciled? (Thurs morning panel on Trust!)

- Re: the FARs…
  - Requirements are hard to "get right"…
  - Legal and social questions must be debated by legislators… but…
  - Why are the safety-oriented FARs manually written by people rather than iteratively improved through "supervised" feedback processes?

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