The Path to FAA Certification of Powered Lift Aircraft

And, Can Indirect Flight Controls Reduce Loss of Control Accidents?

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Advanced Air Mobility Reality Index

- Over 1000 Entrants
- Funding from…
  - Venture capital
  - SPACS
  - Automotive Companies
  - Legacy Aerospace OEMs
  - Legacy Airlines
- S&P 500 levels of market cap for companies that have yet to sell a product

OEM (stock ticker)		ARI	Funding ($M)	Use Case	Vehicle Type	Propulsion	Operation
Ehang (NASDAQ: EH)	↔	8.5	$262.0	Tourism,EMS,Firefighting,Air Taxi	Multicopter/ Lift + Cruise	Electric	Autonomous
Volocopter (Wafeng Diamond)	↑	8.2	Corporate backed	Air Taxi, Tourism, EMS,Cargo	Multicopter/ Multicopter/ Lift + Cruise	Electric	Piloted
Beta Technologies (NYSE: BETA)	↔	8.0	$3,016.6	Cargo, MIL, Regional, Air Taxi	Conventional/Lift + Cruise	Electric	Piloted
Joby Aviation (NYSE: JOBY)	↔	8.0	$3,854.5	Air Taxi, MIL	Vectored Thrust	Electric	Piloted
Volant Aerotech	↑	8.0	$261.0	Air Taxi, EMS, Tourism	Lift + Cruise	Electric	Piloted
AutoFlight	↑	7.9	$640.0	Cargo, Air Taxi	Lift + Cruise	Electric	Piloted
Archer (NYSE: ACHR)	↔	7.8	$2,864.2	Air Taxi	Vectored Thrust	Electric	Piloted

The Challenges of Powered-lift Certification

- No defined certification standards
  - Evaluation and certification of indirect flight controls
  - Continued safe flight and landing
  - Electric propulsion
- New pilot certification category

Aircraft Certification Standards

- Prior to May 2022, the FAA allowed defining novel aircraft as “airplanes” even if they met the “powered-lift” definition
- In May 2022, the FAA reversed this position and dictated 21.17(b) as the required certification path
  - Each aircraft will have different regulations for certification
  - Design specific regulations must go through public comment

- 2025 Activity…
  - Advisory Circular for the Type Certification of Powered-Lift AC 21.17-4, 7/18/2025
  - Policy Statement Regarding Safety Continuum for Powered-Lift, PS-AIR-21.17-01 (still draft)

Evaluation of Indirect Flight Controls

- The US Military adopted ADS-33 as a handling qualities specification in 1987
- Favors evaluation of MTE's using the Cooper-Harper HQRS instead of prescriptive system tasks
- Necessary for evaluation of indirect flight control system
- Regulatory application is uncertain

- March 2024…

DOT/FAA/TC-23/59

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Handling Qualities Test Guide for Powered Lift VTOL Capable Aircraft with Indirect Flight Controls and Operating in Day Time Visual Flight Rules

Continued Safe Flight and Landing

- Current rules
  - Airplanes Must Glide
  - Helicopters Must Autorotate
- Some current designs…
  - can glide but not autorotate
  - some do neither
- New certification concepts…
  - Credit for limited exposure, and…
  - Distributed electric propulsion

- XX-2105(g)
- (g) The aircraft must be capable of a controlled emergency landing, after loss of power or thrust, by gliding or autorotation, ***or an equivalent means***, to mitigate the risk of loss of power or thrust.

Electric Propulsion

- To an extent greater than powered-lift, there are no existing certification standards
- Defaulting to ASTM F39

A New Pilot Certification Category

- "Powered-lift" was added as a new airman cert category in 1997
- no action on implementation until…
- 2017: ACWG meetings and draft guidance
- 2025: PART 194—Special federal aviation regulation no. 120—powered-lift: pilot certification and training; operations requirements

- *All aircraft to be type-rated*
- *No relief from flight hour requirements*
- *Requires supervised operating experience*

- *Onerous requirements, but* "…SFAR No. 120, will remain in effect until January 21, 2035."

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11270
11920
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2 MIN TURN
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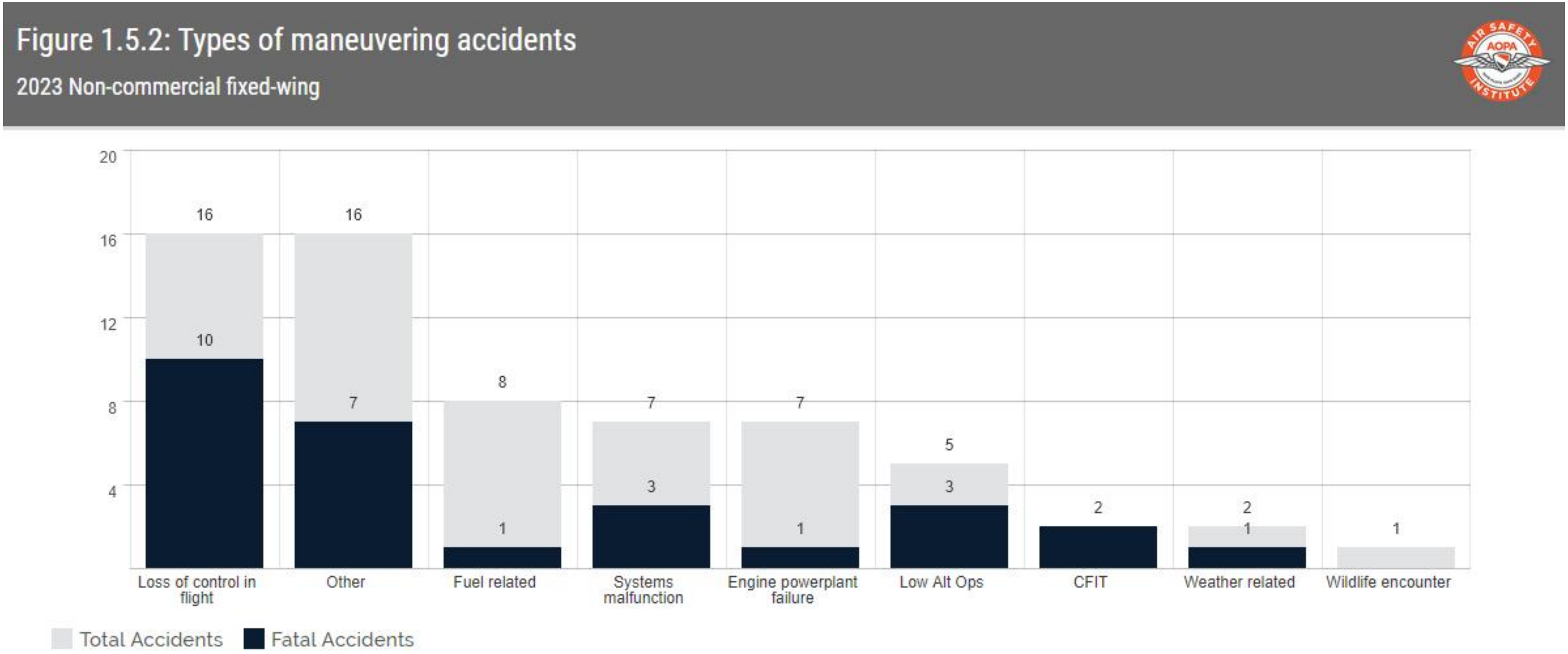
REC
ADF
TEST
BFO
400 XPDR
REPLY
ALT
ON
SBY
ID
TEST
1200
MAN PRESS IN HG
FUEL FLOW GAL/HR
RPM
X100
94524
HOURS
L R
40 E 0
101 1/4 55
108 1/2 117
111 3/4 124
157 F 152
LIGHTS
STROBE LIGHTS
TAXI
LANDING
A/P
NAV 1
NAV 2


GARMIN
GARMIN
WARNING
N916KT
SMOKING PROHIBITED
NO GPS POSITION
SKYHAWK SP
SKYHAWK SP

- Moving Map and Ownship Position
- Database Driven Communication and Navigation
- Traffic Awareness Systems
- Terrain Awareness and Alerting
- Real-Time Weather and NOTAMs
- Angle of Attack Displays
- Systems Monitoring
- All-Axis, Envelope Protection Autopilots

34th AOPA Air Safety Institute McSpadden Report



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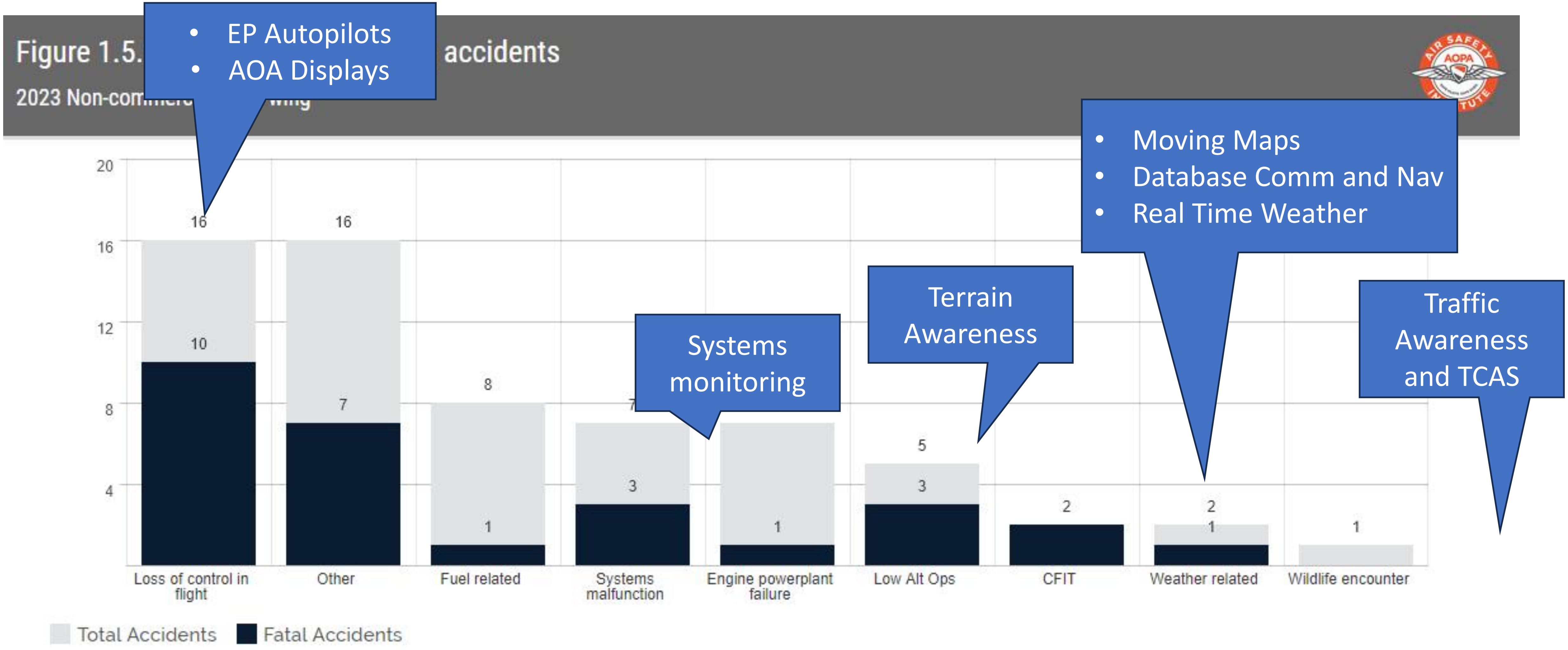
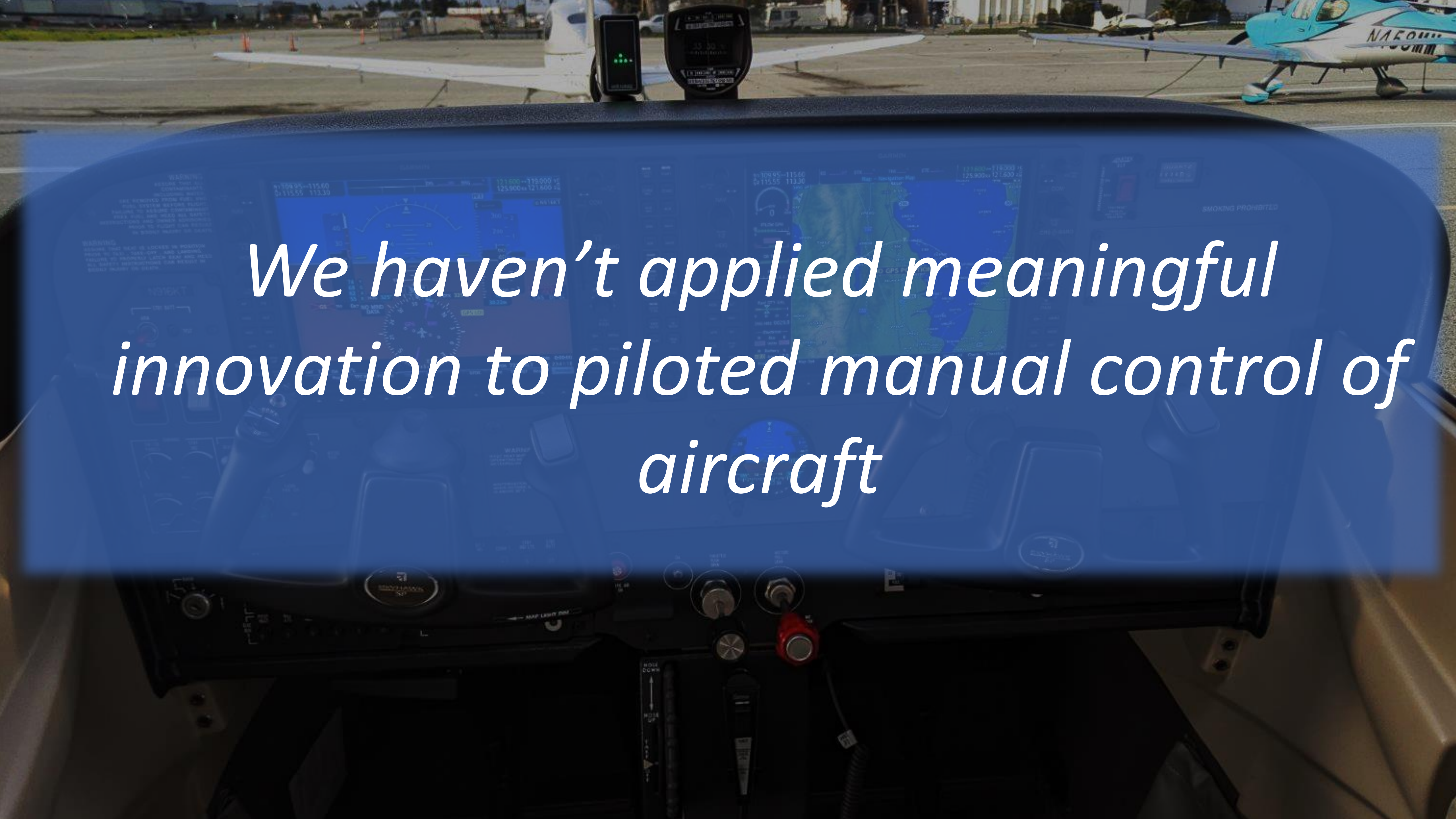


Fly-by-wire and modern autopilots…

- Reduce pilot workload
- Increase safety
- Point to an autonomous future

… by removing the pilot from the control loop



We haven't applied meaningful innovation to piloted manual control of aircraft

Another Way to Solve Loss of Control

- We've had years of strong technological innovation, but our chosen focus areas have not effectively addressed the #1 cause of aircraft accidents
- Pilots are less (10^{-5}) reliable than safety critical (10^{-9}) technology
- Absent full autonomy, pilots still, at times, must assume manual control of the aircraft and this is where the gap lies between the introduction of new technology and the desired effect on safety outcomes

Another Way to Solve Loss of Control

Indirect flight controls that provide stability and control as a baseline (non pilot selectable) function:

- Aircraft rate and attitude stabilization
- Envelope protection to allow care-free operation of interceptors
- Harmonized mapping of inceptors to aircraft response (rather than effector response)
- Design systems so that pilot awareness of control margins, and FCS mode transitions is not a factor for safe outcomes

Direct vs Indirect Control Strategies

- Direct Longitudinal Control
  - Inceptor (longitudinal stick) mapped to an effector (elevator)

Situation	Control Strategy
Airspeed $> L/D_{max}$	Pitch Attitude and Rate of Climb
Airspeed $< L/D_{max}$	Pitch Attitude and Airspeed
AOA $> Cl_{max}$	Any long stick reduces pitch attitude. You must push the stick forward to recover an ability to climb
AOA $> Cl_{max}$ with uncommanded roll	Forward long stick to stop the roll
Steep turn	Nz controller

Direct Vs Indirect Control Strategies

- Indirect Longitudinal Controls
  - Inceptor mapped to an aircraft level effect
  - The system, not the pilot, is responsible for determining effector motion

Situation	Control Strategy
All	Long stick controls rate of climb

EXPERIMENTAL
QinetiQ
Active Control Technology
VAAC
U.S. ARMY
4147
XV-3
BELL AIRCR
BELL
N280BH
U.S. ARMY
4148
XV-3
XV-1
BA609
Tilt Rotor
N609AG


SKYRYSE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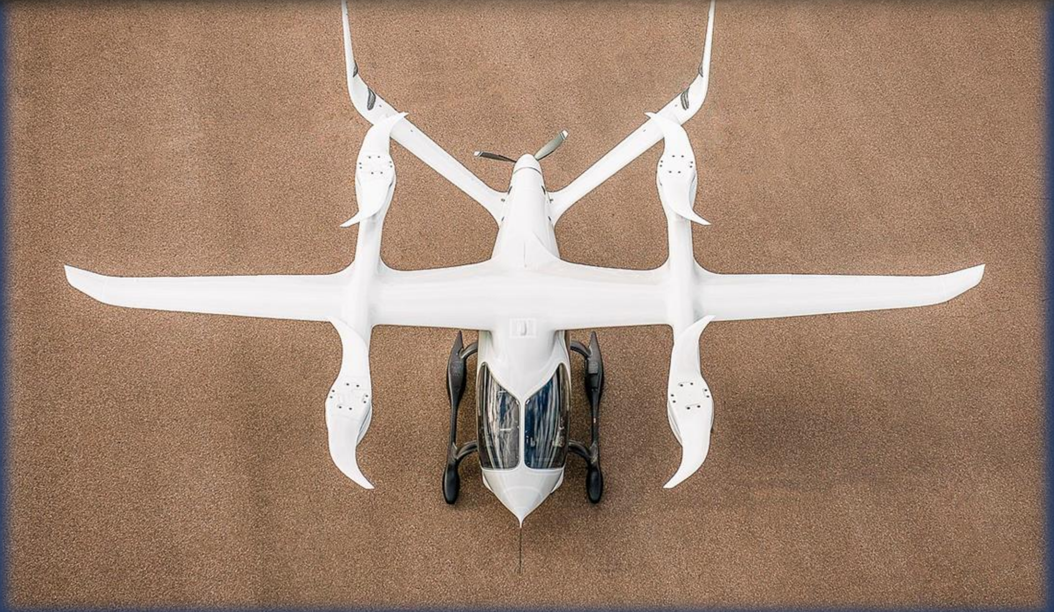
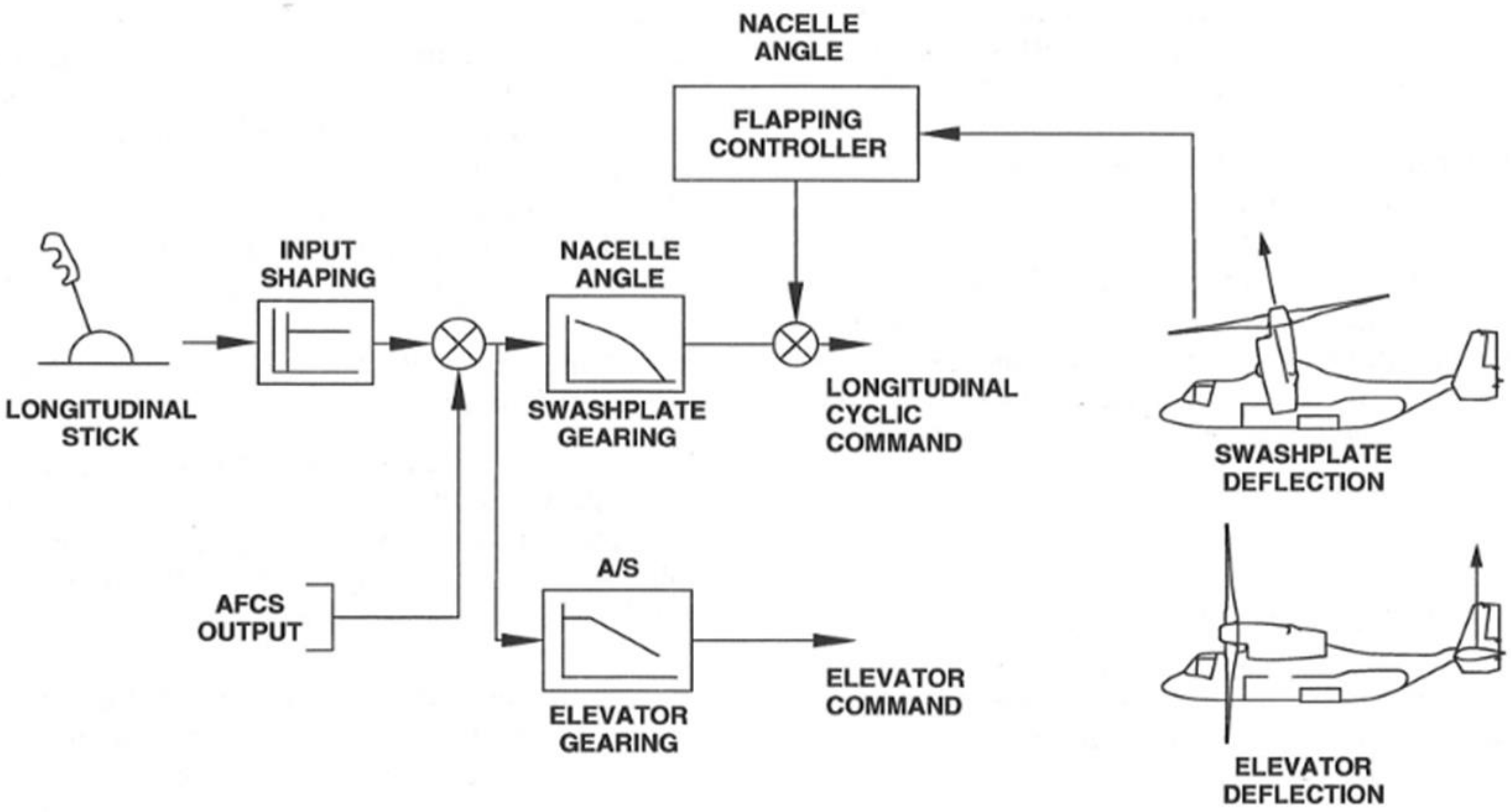



N302AX

V-22 Osprey Inceptor Mapping



Center stick maps to a pitch command regardless of thrust vector

This is either a rotor cyclic command or an elevator command

The pilot doesn't need to know which effector is controlling the aircraft

	Legacy (V-22) IDFC			Unified (F-35) IDFC	
	Thrust Borne	Wing Borne		Thrust Borne	Wing Borne
Left Hand	h-dot	Thrust		x-dot	Airspeed command
Left Thumb	Thrust Vector			No direct pilot control of the thrust vector angle	
Right Hand Long	Pitch or x-dot	Pitch		h-dot	Climb angle
Right Hand Lat	Roll cmd, bank hold or y-dot	Roll cmd, bank hold		y-dot	Roll cmd, bank hold
Pedals or Twist	Yaw rate, heading hold	Turn coordination		Yaw rate, heading hold	Turn coordination

500

		HOVER 410	TRANSITION 420	CTOL 430
LEFT LONGITUDINAL	**Inceptor Command**	Longitudinal Inertial Speed	Airspeed Rate	Airspeed Rate
	Hold (in detent)	Longitudinal Position	Airspeed	Airspeed
	Primary Response	Propeller Nacelle Tilt with Minimal Pitch Motion	Propeller Nacelle Tilt and Propeller Speed	Propeller Speed
LEFT LATERAL	**Inceptor Command**	Lateral Inertial Speed	Lateral Air-Relative Speed	Lateral Air-Relative Speed
	Hold (in detent)	Lateral Position	Turn-Coordination	Turn-Coordination
	Primary Response	Roll Angle	Propeller Speed, Rudder Deflection, and Compensating Roll	Rudder Deflection (Propeller Speed for Large Commands)
RIGHT LONGITUDINAL	**Inceptor Command**	Vertical Speed	Flight Path Angle Rate	Flight Path Angle Rate
	Hold (in detent)	Altitude	Flight Path Angle	Flight Path Angle
	Primary Response	Propeller Speed, No Attitude Change	Propeller Speed and Pitch Attitude Change	Propeller Speed and Pitch Attitude Change
RIGHT LATERAL	**Inceptor Command**	Turn-Rate (Hover Turn)	Turn-Rate (Banked Turn)	Turn-Rate (Banked Turn)
	Hold (in detent)	Heading	Heading	Heading
	Primary Response	Asymmetric Propeller Nacelle Tilt	Roll Angle	Roll Angle

FIG. 5

Skyryse One

DESIGNED FOR SAFETY, SIMPLICITY, AND STABILITY

The Motivation for Innovation

While safety may be a by-product, the motivation for this innovation is to allow low paid, minimally trained pilots to operate aircraft in aggressive, high-density operations.

- GAMA EPIC
  - “the potential for human-centered automation to reduce or replace training”
  - “use of automation to reduce pilot/operator training while increasing the level of safety”
- NASA
  - “the use of automation to reduce the number of skills a pilot or operator of an aircraft must acquire”
  - “Long-term goals: automotive-like training and workload with better-than automotive safety”
- EASA
  - “explore whether it is feasible to operate commercial air transport with reduced flight crews in large aeroplanes”

Safety Advantage of Indirect Flight Controls

- The pilot is decoupled from motion of effectors
  - Instead, the pilot directly controls the aircraft response
- Allows greater safety by providing…
  - Aircraft rate and attitude stabilization
  - Harmonized mapping of inceptors to aircraft response
  - Envelope protection to allow care-free operation of interceptors
  - Carefree control where pilot awareness of control margins and FCS mode transitions isn't required

Why Does this Matter to a Private Pilot?

- Be disciples of aviation safety…Study incident reports and learn about the causes and prevention techniques for common loss of control accidents
- Train beyond the level required to maintain your certificate
- Practice the maneuvers beyond the rote stage of learning that's required to pass a checkride
- Pilot response to an upset/LOC always met with immediate, and correct, application of controls through repetitive motor learning
- Become a master of minimalism... learn how to compartmentalize distractions and give priority to aircraft control above any other task on the flight deck