The Future of Recreational General Aviation in the United States

A Data-Driven Assessment of Participation, Fleet Trends, and Forward Market Outlook

C. Strommen

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Executive Summary

Recreational general aviation (GA) in the United States has entered a period of structural stagnation characterized by modest demand, rising costs, and long-term supply constraints across aircraft, maintenance labor, fuel infrastructure, and pilot demographics. Using FAA Airmen Certification data, the FAA General Aviation Survey (1999–2023), and FAA General Aviation Profile tables (1960–2024), this report provides a comprehensive assessment of long-run trends in recreational pilot participation, aircraft utilization, and fleet health. The analysis combines pilot demographics, certificate flows, fuel consumption patterns, fleet size and composition, instructional vs personal hour shares, and GA-adjacent economic indicators to evaluate the present and future viability of the recreational piston-aircraft ecosystem.

Recreational pilot participation has stabilized but not rebounded. Total pilot counts have risen sharply since 2016, but this expansion has been overwhelmingly driven by professional and pre-professional pilots responding to airline hiring demand. Non-professional pilots have grown only modestly, and the non-professional share, after declining from roughly 78% in 1999 to 73% in 2016, has recovered back to ~78–79% but remains far below historical highs once adjusted for population growth and activity levels. This stabilization indicates that recreational GA is no longer shrinking rapidly, but it is not exhibiting sustained structural growth either.

Pilot demographics point toward long-term participation challenges. The average age of active pilots has increased across all major certificate categories, with Private pilots aging approximately 3–4 years since 1999 and ATPs aging even more sharply as the industry approaches a mandatory-retirement cliff. The aging of Private pilots suggests that recreational participation faces demographic headwinds. This reinforces concerns about limited generational replacement among leisure pilots.

Flying activity has declined even as certificate numbers stabilized. Avgas consumption, a direct indicator of piston GA activity, has fallen from ~340 million gallons in 1999 to roughly 200–220 million gallons in the 2014–2023 period. This decline far outpaces the modest reduction in Private pilot certificates and confirms that utilization per pilot has dropped meaningfully. Instructional flight activity now occupies a larger share of GA operations, while personal flying has declined, indicating that training, not recreation, is driving most piston-aircraft utilization.

The GA fleet is shrinking, old, and supply constrained. Fleet size has remained essentially stagnant for two decades, and both the GA Survey and the GA Profile data series indicate no meaningful net growth. At the same time, new production of certified piston aircraft remains historically low, far below the rate of retirement or attrition. A significant portion of the fleet consists of 50-year-old designs, many with increasingly limited parts support. This reliance on legacy airframes constrains aircraft availability, elevates used-aircraft prices, and increases maintenance burdens.

Fuel and infrastructure trends disadvantage recreational GA. While total GA fuel consumption has increased due to growth in turbine and business aviation activity, avgas continues a long-term decline in both relative and absolute terms. The shrinking share of piston activity is reshaping FBO economics, leading to reduced 100LL infrastructure, less support for piston operations, and a progressive reorientation toward turbine customers. Environmental pressures related to lead emissions add further uncertainty to future avgas availability, even with ongoing developments in unleaded alternatives (e.g., UL94, G100UL).

Major forward-looking implications include:

- Elevated and rising aircraft prices, especially for clean, IFR-capable piston singles.
- Growing training-sector dominance, driving demand for CFIs, maintenance labor, and durable trainer aircraft.
- Maintenance and parts bottlenecks, with A&P shortages and aging airframes increasing downtime and operating costs.
- Potential localized fuel fragility, especially if 100LL availability declines faster than unleaded replacements scale.
- Structural limits on recreational GA growth, even if demand rises, due to systemic bottlenecks in aircraft supply, infrastructure, and workforce capacity.

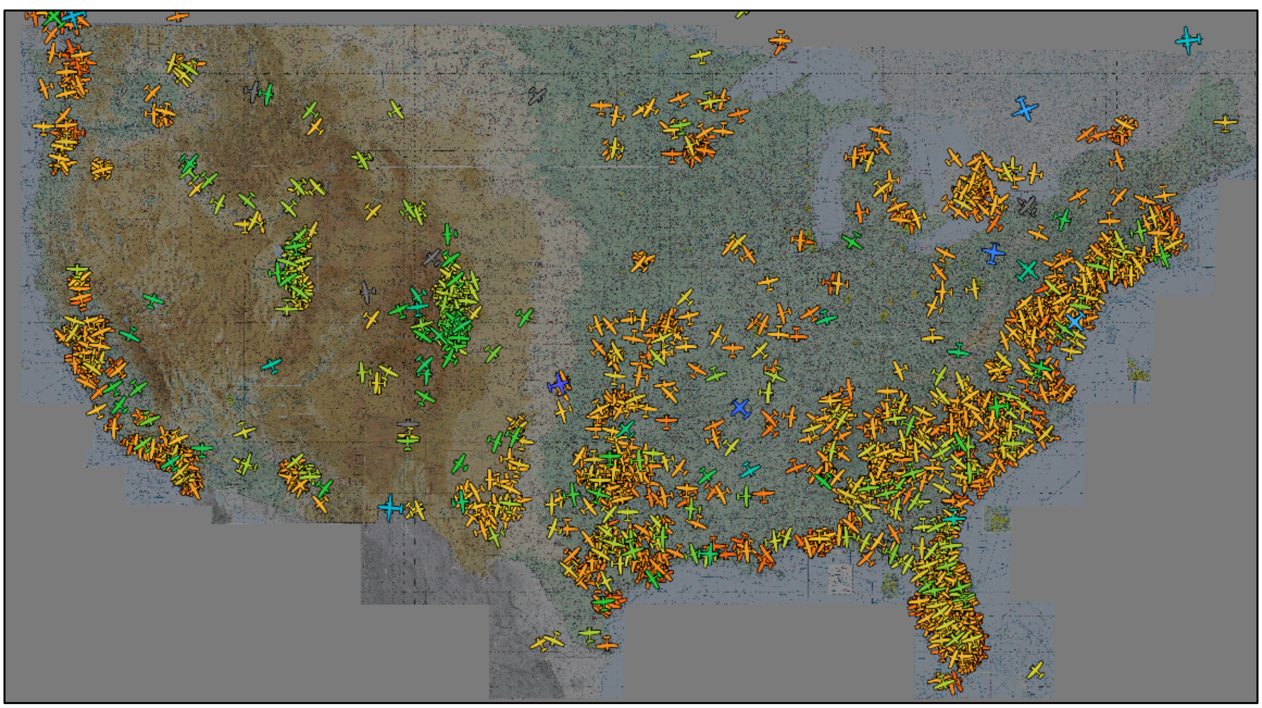

Figure 1: US GA Aircraft ADSB Tracks at Noon CST on a Tuesday

Introduction

Purpose

Recreational general aviation (GA) plays a critical but often under-analyzed role in the broader U.S. aviation ecosystem. Although it represents only a portion of total flight activity, recreational GA supports a wide range of downstream effects in serving as the primary gateway for new pilots entering the workforce, sustaining the viability of thousands of airports and FBOs in rural and suburban areas, and anchoring the economic base for piston-aircraft OEMs, parts suppliers, and independent maintenance shops. Trends in recreational flying directly influence the health of the flight-training pipeline, the availability of skilled aviation labor, and the financial stability of GA infrastructure. Understanding the long-run trajectory of recreational GA is therefore essential not only for hobbyist pilots but also for forecasting workforce capacity, informing regulatory policy, and assessing the stability of OEM/MRO supply chains that depend on piston aircraft utilization.

Scope

- Primary focus: "True recreational GA," defined as:
    - Private pilots flying for personal use
    - Student pilots engaged in non-commercial training
    - Piston aircraft operations (single-engine and light twin)
    - Personal and recreational flight hours reported in FAA GA Survey tables
- Included where relevant: Instructional activity to the extent that it influences pilot supply, aircraft utilization, and the availability of training infrastructure (CFIs, trainers, maintenance capacity).
- Excluded from quantitative analysis:
    - Business aviation (Part 91 corporate, Part 135 charter, turbine/jet operations)
    - Airline operations (Part 121)
    - Large-scale flight academies (Part 141), unless their activity materially affects student pilot trends

Data Sources

- FAA Airmen Certification Data (1999–2024)
    - Annual U.S. Civil Airmen Statistics
    - XLSX Tables 1 (Active Certificates), 13 (Average Age), 17 (Original Certificates), 22 (Student Certificates Issued)
- FAA General Aviation and Part 135 Activity Survey (1999–2023)
    - Tables 1.1 (Active Aircraft by Type), 2.1 (Fleet Totals), and supplemental tables on hours, utilization, and aircraft categories
- FAA General Aviation Profile (1960–2024)
    - Long-run series on fleet size, flight hours, instructional vs personal use, and fuel consumption (total vs avgas)

- Extracted CSV datasets (produced from FAA datasets)
    - *ga_demand_panel.csv* (shown in Figure 11)
    - *ga_fleet_mix_buckets.csv* (shown in Figure 13)
    - *ga_use_shares.csv* (shown in Figure 14)
    - *nonprof_vs_fleet.csv* (shown in Figure 15)

Methods

This report relies on publicly available FAA statistical series and industry summary reports to construct a coherent, longitudinal view of recreational general aviation in the United States. Core pilot demographics and certificate flows are drawn from the FAA *U.S. Civil Airmen Statistics* tables, with particular emphasis on active certificates, original certificates issued, student certificates issued, and average age of active pilots by certificate. This data was ingested from annual XLSX workbooks and reshaped into panel datasets to enable time-series analysis from 1999 through the most recent available year. Recreational activity and fleet metrics are derived from the *General Aviation and Part 135 Activity Survey* (GA Survey) and the *General Aviation Profile* tables, which provide annual estimates of active aircraft, flight hours by use category (e.g., instructional vs personal), and fuel consumption by type (total vs avgas). These FAA series are supplemented by top-level trends from AOPA fact sheets, GAMA shipment and billing reports, and FAA aerospace forecasts to contextualize participation and production patterns. All transformations (e.g., aggregation of fleet "buckets," computation of shares, indexing of instructional vs personal use) are documented in the analysis script reproduced in Appendix B: Analysis Code, and key intermediate tables are provided in Appendix A: Data Tables.

Limitations

Several limitations should be considered when interpreting the results. Firstly, FAA statistical series are not perfectly consistent over time as definitions, survey methodologies, and table layouts occasionally change, which can introduce artifacts (e.g., the sharp one-year drop in GA Profile fleet counts around 2010). Where possible, these discontinuities are identified and treated as methodological rather than real-world shocks. Secondly, the analysis primarily uses national-level aggregates, which can obscure meaningful regional variation in participation, infrastructure, and fleet composition. Thirdly, certificate counts and fleet inventories are stock measures; they do not directly capture intensity of use. Avgas consumption and flight-hour data are used as behavioral proxies, but these too have sampling error and are not broken out cleanly between purely recreational and career-track flying. Additionally, this report focuses on certificated piston GA and relies on the FAA's category definitions, which do not always map neatly onto how pilots and operators self-identify (e.g., experimental and LSA segments embedded in "other/misc." buckets). Finally, the forward-looking assessments are inherently scenario-based in that they extrapolate from historical data and structural constraints rather than attempting to forecast specific numerical outcomes. These limitations do not invalidate the core conclusions, but they argue for reading the results as directional and structural, rather than as precise predictions for any individual airport, aircraft type, or operator.

Definitions

- Recreational General Aviation (recreational GA) – Non-commercial flying by Private and Student pilots in piston-powered aircraft (primarily fixed-wing singles and light twins) for personal, leisure, or proficiency purposes. This excludes business, corporate, charter, and airline operations.
- Non-professional pilots – All certificated pilots other than Airline Transport Pilots (ATPs). In practice, this encompasses Student, Sport, Recreational, Private, and Commercial pilots, even though some Commercial pilots may be employed in aviation.
- Professional pilots / professional pipeline – ATPs and those clearly on an ATP-track, including Commercial and Student pilots whose training and flight activity are primarily oriented toward airline or corporate careers.
- Avgas / 100LL – Leaded aviation gasoline used by the majority of legacy piston aircraft. In this report, avgas consumption is used as a proxy for aggregate piston GA activity.
- Jet-A / turbine GA – Fuel and operations associated with turboprop and turbojet/turbofan aircraft, including business jets, turbine trainers, and many Part 135 operations.
- Active fleet / active aircraft – Aircraft counted by FAA datasets as actively registered and in use during a given year. This includes aircraft with very low annual utilization; therefore, "active" does not imply high flight-hour levels.
- Flight hours – instructional vs personal – Categories from the GA Survey that distinguish training (instructional) hours from personal/recreational use. While these categories are not perfect proxies for career vs leisure flying, they provide a directional indicator of how GA time is allocated.
- Piston GA ecosystem – The interdependent network of pilots, aircraft, flight schools, maintenance shops, parts suppliers, FBOs, and fuel providers that support piston-powered general aviation activity, especially in the recreational and training segments.

Pilot Demographics and Recreational Participation

Total vs Non-Professional Pilot Population

The long-running, declining trend in the U.S. pilot population, shown in Figure 2, illustrates a pronounced structural shift in general aviation participation over the last 25 years. From 1999 through roughly 2016, the total number of certificated pilots declined steadily showing a continuation of the post-1980s contraction documented in prior FAA forecasts and AOPA participation analyses. Over this same period, the non-professional (i.e., non-ATP) pilot population followed a similar pattern but with a shallower decline, suggesting that the attrition was driven disproportionately by career-track pilots rather than recreational aviators. Beginning around 2016–2017, the trend reversed sharply as total pilot counts surged, driven almost entirely by an acceleration in ATP and ATP-bound pilot production in response to the well-publicized professional pilot shortage, airline hiring demand, and aggressive Part 141/Part 61 pipeline expansion. While the non-professional segment also increased during this recovery, the gap between the two curves widened substantially, reflecting a measurable "professionalization" of the pilot population. Growth is occurring fastest in career-oriented certificates rather than among purely recreational pilots. This divergence has meaningful implications for the future size of the recreational GA base and its economic support structure, which is increasingly overshadowed by ATP-driven growth.

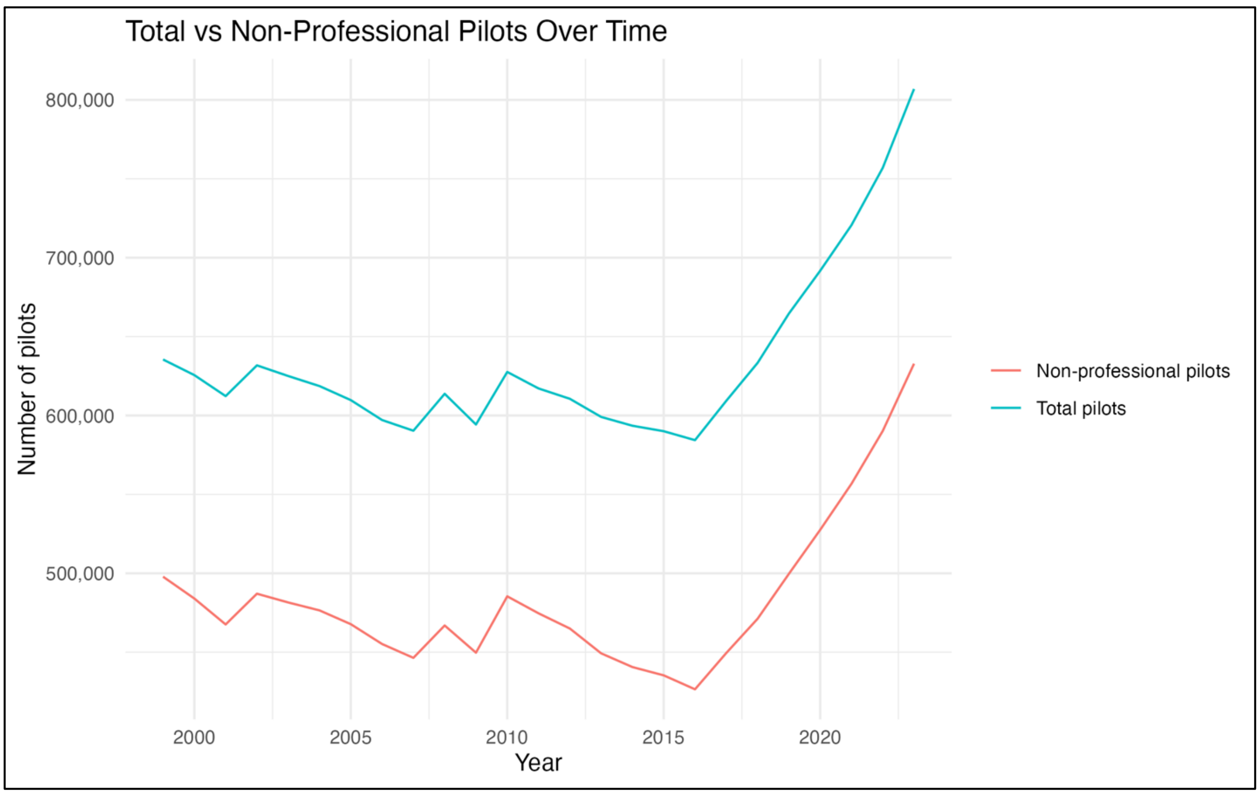

Figure 2: Total vs Non-Professional Pilots Over Time

Share of Non-Professional Pilots

As shown in Figure 3, the composition of the pilot population has shifted meaningfully over the last two decades. The non-professional share declined from roughly 78 percent in 1999 to a low near 73 percent in 2016, reflecting the period in which recreational pilot participation softened while career-track certificates held relatively steady. Following 2016, this ratio began to recover, and by 2022–2023 the non-professional share had climbed back to approximately 78–79 percent. This rebound likely reflects a combination of renewed recreational entry especially post-2020, when pandemic-era discretionary flying increased as well as natural attrition among older ATPs aging out of the workforce. Importantly, however, the recovery in share should not be interpreted as a structural expansion of recreational GA; rather, it indicates stabilization. The underlying non-professional headcount remains well below its late-1990s level, suggesting that recreational GA has regained equilibrium but is not yet experiencing strong secular growth.

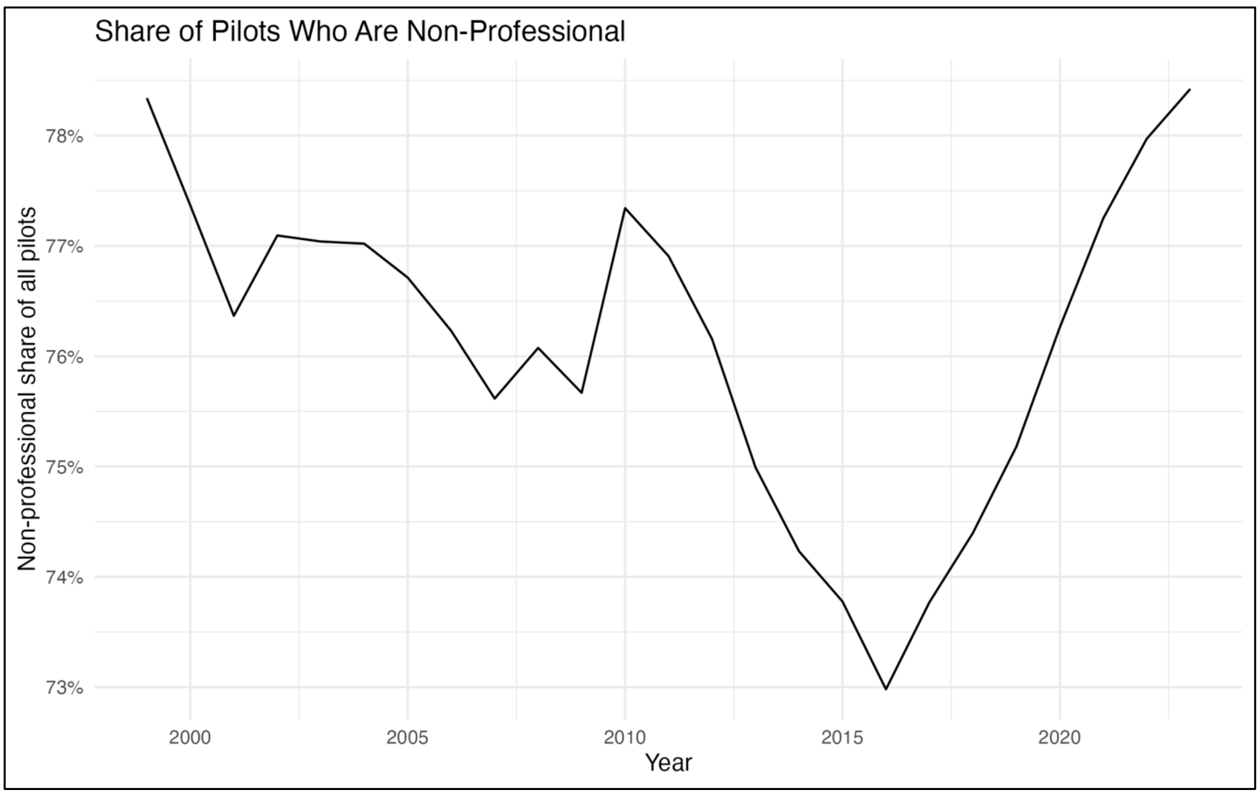

Figure 3: Share of Pilots Who are Non-Professional

Student Pilot Flows

As illustrated in Figure 4, student pilot issuance has historically tracked broader economic cycles and the availability of training pathways. Both Table 22 (student certificates issued) and Table 17 (original certificates issued by category) show a pronounced surge during the mid-2000s expansion, followed by a sharp contraction after the 2008 financial crisis a period when both discretionary spending and aviation career pipelines tightened significantly. Although student inflows gradually recovered throughout the 2010s, the most substantial rebound occurs post-2020, coinciding with aggressive airline hiring and widespread industry shortages rather than a broad resurgence in recreational flight training. The magnitude and timing of this growth strongly suggest that recent student pilot activity is primarily career-motivated, with only modest spillover into the recreational GA pool.

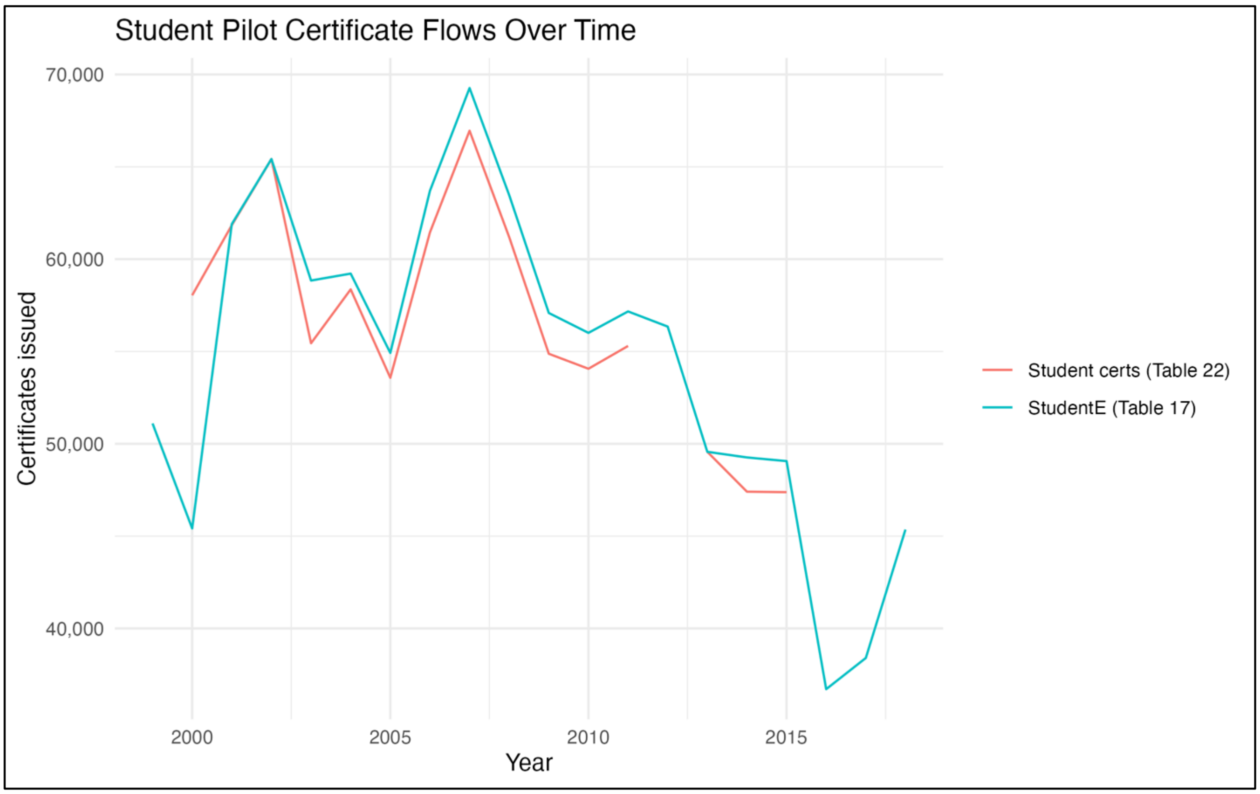

Figure 4: Student Pilot Certificate Flows Over Time

Average Age of Active Pilots

Figure 5 provides critical context for understanding the long-run dynamics of both professional and recreational GA. Across every major certificate category, pilot age has trended upward since 1999, but the rate of increase differs meaningfully by segment. Airline Transport Pilots (ATPs) show the steepest rise, reflecting the well-documented wave of upcoming mandatory retirements and the backlog of pilots who entered the industry in the 1980s and early 1990s. This aging effect aligns with earlier findings that the sharp post-2020 growth in total pilot counts is driven by career-track entrants backfilling the pipeline, not by broad-based recreational revival. Private pilots have also aged by roughly 3–4 years over the period, a slower but still significant shift that signals weaker inflow of younger, leisure-oriented participants. When viewed alongside declining non-professional share through the 2000s, cyclical student inflows tied to airline hiring, and the relatively modest rebound in recreational certificates, the aging trend underscores a structural challenge: recreational GA is not attracting new pilots at a rate sufficient to offset demographic aging. This dynamic foreshadows long-term pressure on flying clubs, flight schools dependent on non-career students, and the broader recreational aviation ecosystem.

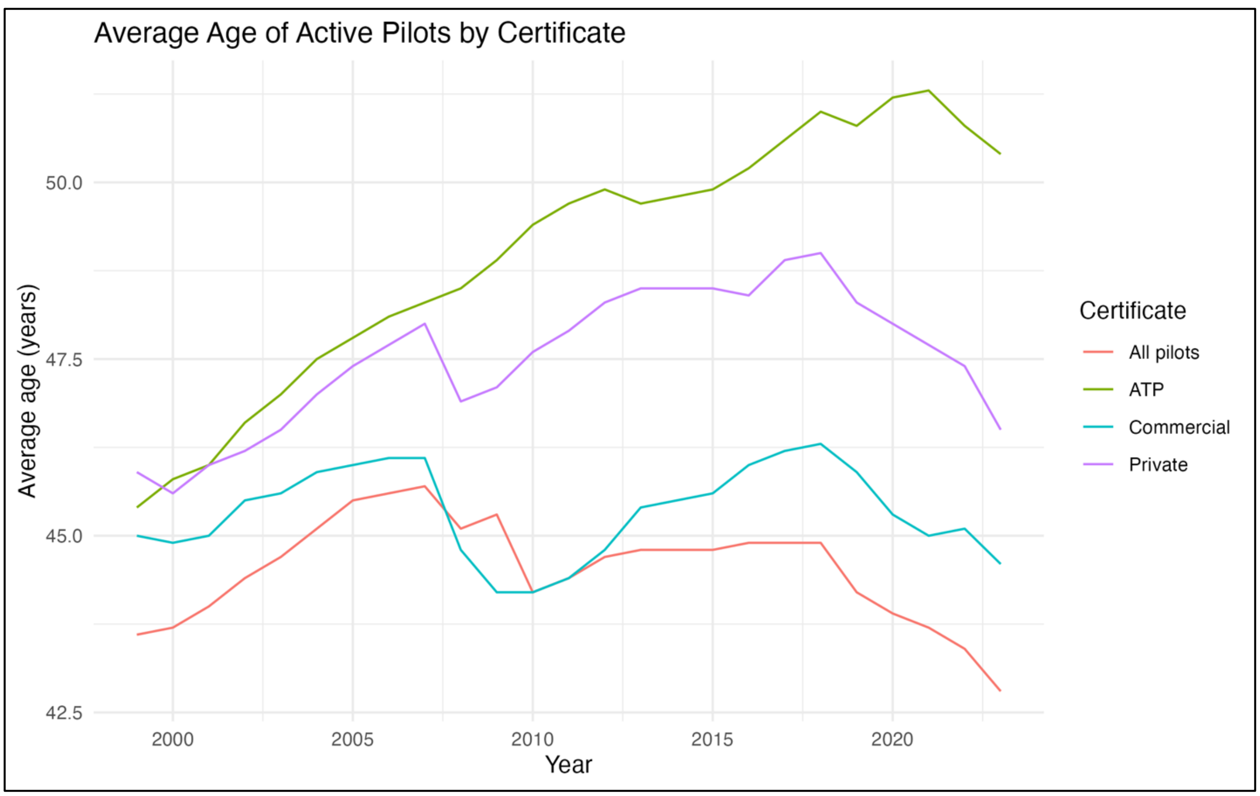

Figure 5: Average Age of Active Pilots by Certificate

Recreational Aircraft Activity and Utilization

Avgas as a Proxy for Piston Activity

Figure 6: Avgas Consumption Over Time offers one of the clearest objective indicators of long-term trends in recreational piston flying. Unlike certificate counts, which reflect stock rather than activity levels, avgas consumption directly captures how much piston aircraft are actually being flown. The decline is substantial: national avgas use has fallen from roughly 340 million gallons in 1999 to the low-200-million-gallon range from 2014 through 2023, a reduction of more than one-third. This sustained downturn confirms that the observed stability in private and non-professional certificate numbers does not translate into stable flying activity. Instead, many pilots appear to be flying less, aging out, or maintaining certificates without meaningful utilization. The modest post-COVID bump in avgas sales is visible but does not approach 1990s levels, reinforcing that any pandemic-era surge in recreational interest was temporary rather than structural. In the broader analysis, this metric is critical as it provides hard behavioral evidence that recreational GA activity has materially decreased over two decades even when the pilot population headline numbers appear flat or improving.

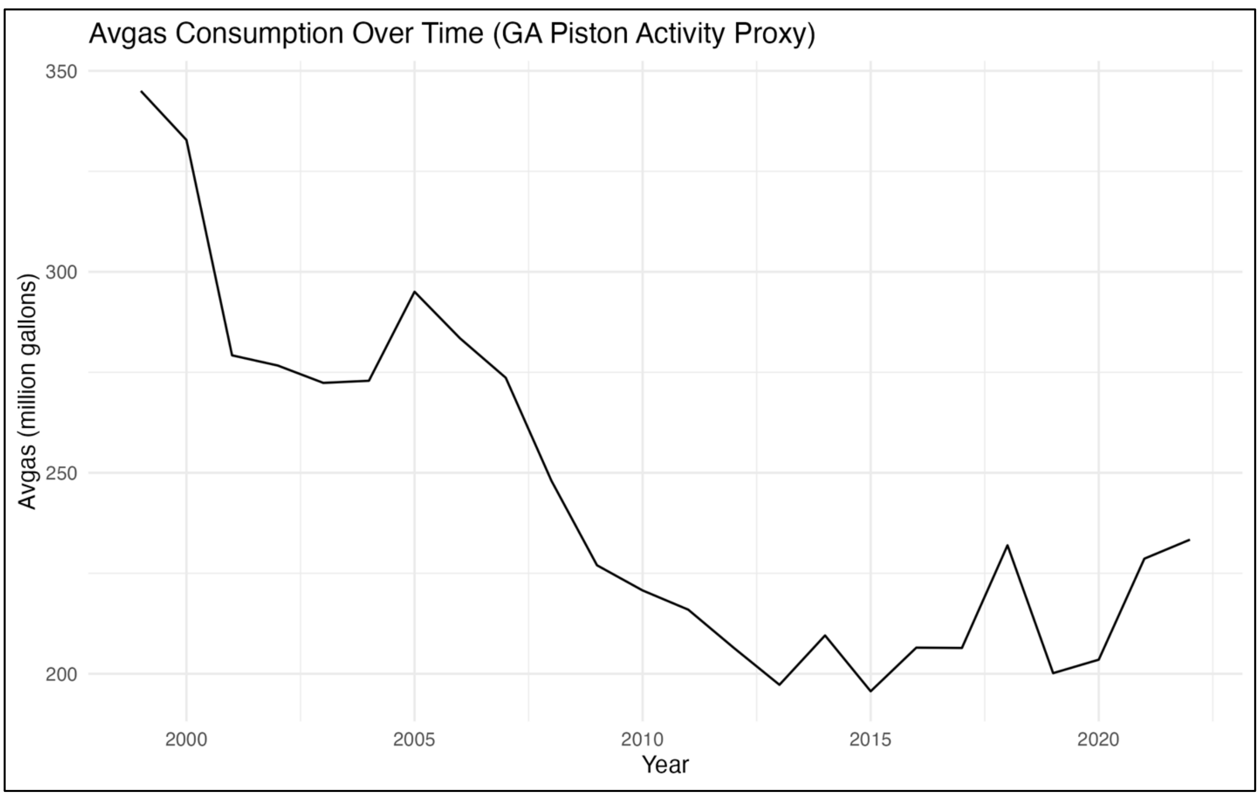

Figure 6: Avgas Consumption Over Time

Instructional vs Personal Flying Trends

Figure 7: Share of GA Flight Hours underscores one of the most important structural shifts in general aviation over the past two decades in the migration of activity away from recreational personal flying and toward training. Instructional flying has steadily increased as a share of total GA hours, while personal flying, historically the backbone of recreational piston GA, has trended downward or remained flat. By the mid-2010s, the instructional share had clearly risen, reflecting accelerated demand for flight training driven by airline hiring cycles, Part 141 school expansion, and greater professionalization of the pilot pipeline. Conversely, the declining relative share of personal flying indicates weakening recreational engagement per pilot, consistent with trends seen in avgas consumption and the aging of private certificate holders. Collectively, these patterns suggest that the economic center of gravity in GA has shifted: flight schools and training infrastructure are expanding, while recreational OEMs, aftermarket suppliers, and MROs tied primarily to personal piston flying are facing stagnant or shrinking markets.

Why do the percentages exceed 100%?
In the FAA General Aviation Survey, "shares" for instructional and personal flying are reported relative to category totals, not normalized to sum to 100% across all GA operations. This occurs because instructional and personal hours are broken out within their own subcategories (e.g., fixed-wing piston, turbine, rotorcraft), and when aggregated, the denominators differ from the overall GA total used in the chart. As a result, the plotted shares represent indexed ratios rather than literal fractions of total GA activity, meaning they signal directional change very clearly, but should not be interpreted as percentages that add to 100%.

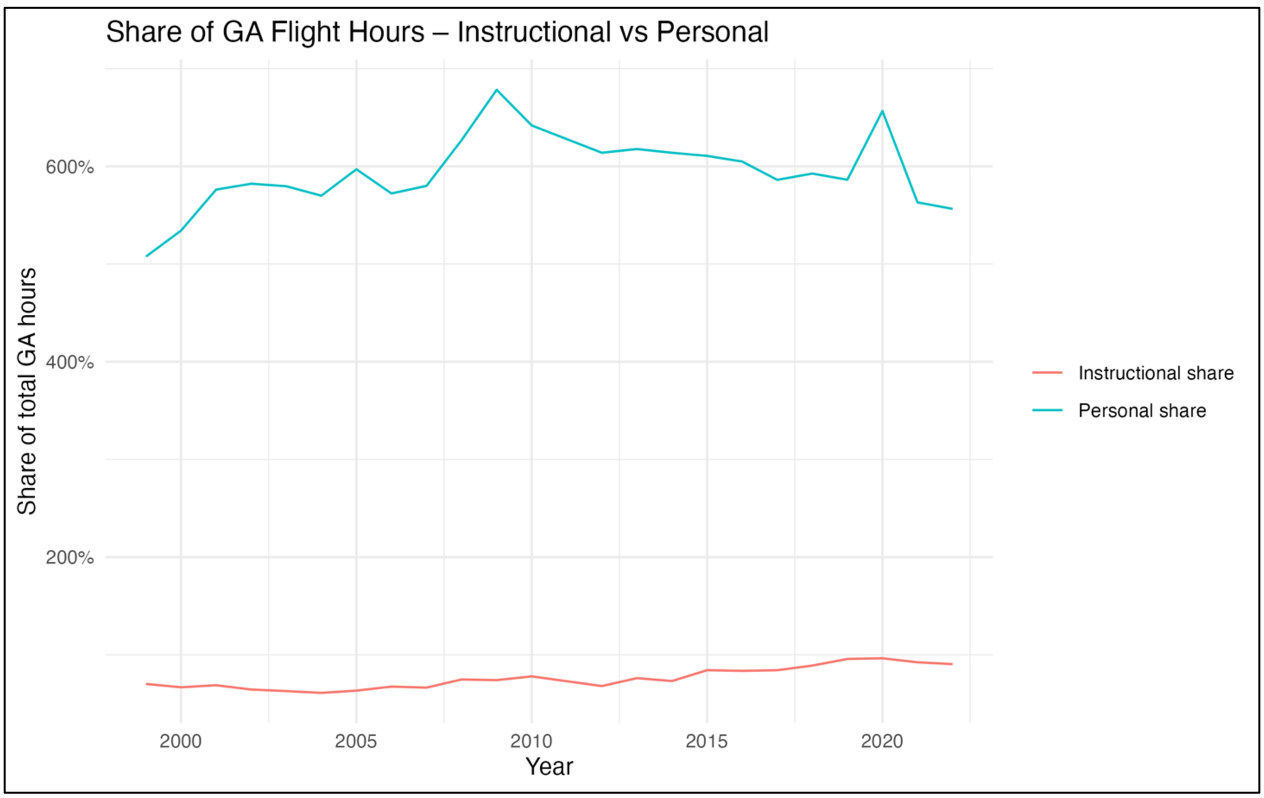

Figure 7: Share of GA Flight Hours

Total GA Fuel Consumption

Figure 8: GA Fuel Consumption Over Time highlights a major structural divergence within general aviation: total GA fuel consumption has increased meaningfully since the early 2000s, while avgas, the primary fuel for piston aircraft, has steadily declined as a share of overall usage. Jet-A demand, driven by business aviation, turbine training, fractional ownership growth, charter operations (Part 135), and corporate flight departments, has expanded consistently. This shift indicates that the economic and operational center of GA has tilted heavily toward turbine equipment, even as the piston sector has stagnated. The shrinking relative contribution of avgas reinforces the broader pattern seen elsewhere in the data: recreational flying intensity is decreasing, while business and commercial GA activities are expanding. These dynamics also carry infrastructure implications: FBOs increasingly orient their revenue models toward turbine services, which further marginalizes piston aircraft support and contributes to rising costs for recreational GA users.

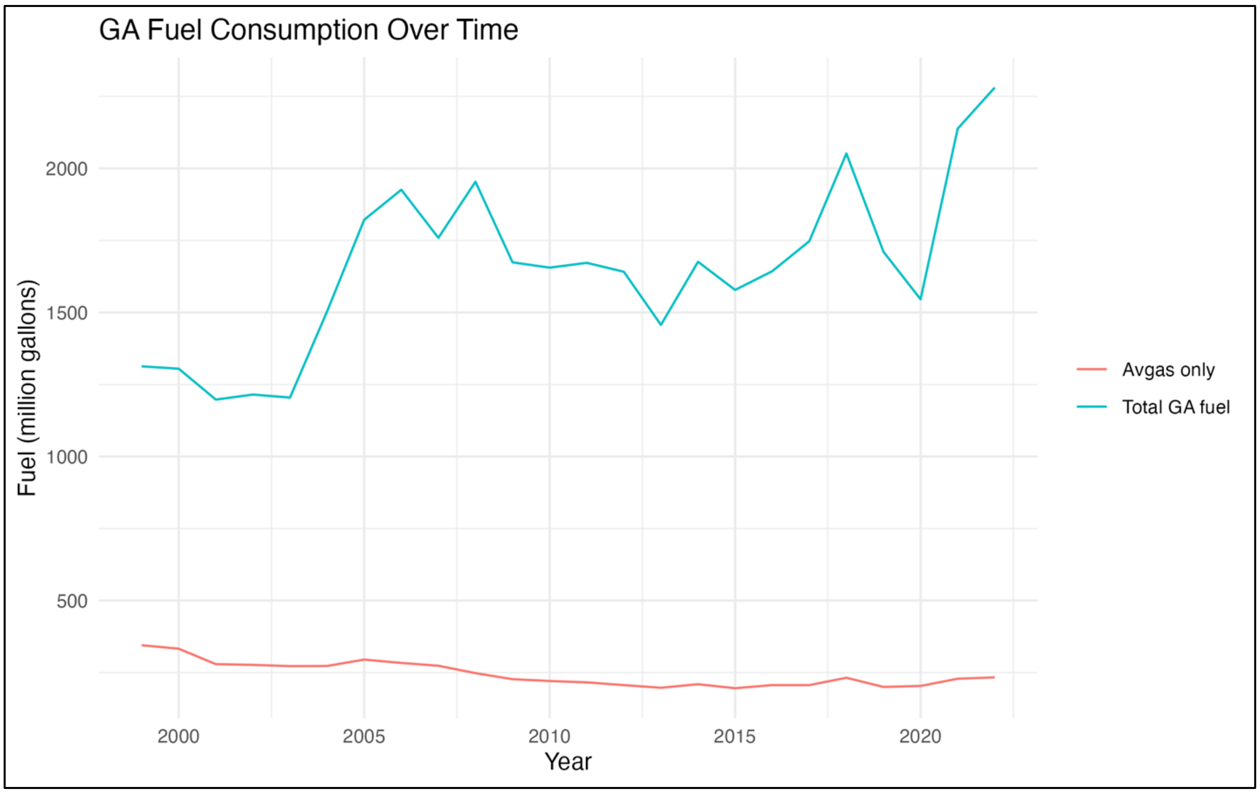

Figure 8: GA Fuel Consumption Over Time

At the same time, several structural forces are driving a long-term transition away from 100LL avgas, including environmental pressures associated with lead particulate emissions and regulatory momentum toward unleaded alternatives (e.g., 100UL). Many airports and communities are beginning to restrict 100LL sales, and manufacturers such as Diamond (Austro diesel engines) and Cirrus (Continental Jet-A piston conversions under development) demonstrate a clear industry trend toward Jet-A–burning piston platforms. Additionally, the

FAA's Piston Aviation Fuels Initiative (PAFI) and GAMI's G100UL approval further indicate the sector's move toward unleaded solutions. However, these structural declines in 100LL do not weaken the central finding of this research. Even adjusting for fuel-type transitions, the total quantity of piston fuel consumed has fallen dramatically since the late 1990s, and the trend aligns with declines in recreational flying hours, aging pilot demographics, stagnant student inflow for non-career pilots, and rising cost barriers. Whether avgas is displaced by mogas or 100UL is secondary to the core conclusion that piston GA activity, specifically recreational flying, is in long-term structural decline, and fuel data strongly corroborate that story.

Fleet Size, Composition, and Equipment Trends

GA Fleet Size – Profile vs Survey

Figure 9: GA Fleet Size Over Time comparison illustrates both methodological divergence and a consistent underlying reality: the active fleet of small GA aircraft is not growing. The FAA's GA Survey series shows a gently shrinking active fleet, while the GA Profile dataset exhibits a sharp but almost certainly spurious drop around 2010, likely a definitional or reporting artifact rather than a real collapse in aircraft availability. Still, when read together, both datasets show that the U.S. piston and light-aircraft fleet has remained flat to declining for over two decades, with retirements outpacing new production. This stagnant supply environment is structurally important because modern certified piston aircraft production runs are extremely low by historical standards, meaning the recreational GA ecosystem increasingly relies on aging airframes remaining airworthy as many are 70+ years old. Limited inflow of new certified aircraft, combined with steady attrition, places upward pressure on used-aircraft prices and concentrates maintenance, overhaul, and upgrade demand into a shrinking but aging fleet.

Figure 9: GA Fleet Size Over Time

Fleet Composition – Latest-Year Breakdown

The composition of the GA fleet by type, shown in Figure 10, underscores the overwhelming dominance of piston single-engine aircraft in the U.S. general aviation fleet: roughly 140,000 piston singles, representing ~17–18% of all active aircraft, and nearly the entire "practical" recreational GA segment. Even when including piston twins, the piston fleet collectively accounts for less than one-fifth of the total active fleet, dwarfed numerically by large "other/misc." categories that include experimental, light-sport, agricultural, and utility aircraft. Turbojets, turbofans, and turboprops constitute only a few percent of the fleet and are economically and operationally irrelevant to the recreational GA ecosystem despite their outsized impact on fuel consumption and airport operations. The structural issue revealed by this composition is that the piston fleet's age continues to climb as new certified piston aircraft production remains far below retirement and attrition rates, forcing the recreational GA ecosystem to rely heavily on legacy airframes built from the 1950s through 1980s. This aging, high-utilization fleet heightens maintenance demand, drives scarcity in certain aircraft categories, and contributes to rising prices across the used piston market.

Fixed-wing piston single	139124	797052	0.17454821
Fixed-wing piston total	142209	797052	0.17841872
Fixed-wing piston twin	16554	797052	0.02076903
Fixed-wing total	166788	797052	0.20925611
Other / misc	294838	797052	0.36991062
Rotorcraft total	10051	797052	0.01261022
Turbojet / Turbofan	16537	797052	0.02074771
Turboprop	10951	797052	0.01373938

Figure 10: GA Fleet Composition by Aircraft Type

Light Sport Aircraft (LSA), Experimental Aircraft, and MOSAIC

While this report focuses primarily on certificated piston aircraft, a growing share of recreational flying occurs in light sport and experimental amateur-built (E-AB) categories that are partially obscured within the FAA's "other/misc." fleet buckets. Light Sport Aircraft (LSA) and experimental aircraft offer lower acquisition costs, modern avionics, and in many cases superior performance-to-price ratios compared with legacy certified trainers and four-seat singles. The Sport Pilot certificate, introduced in the mid-2000s, was intended to create a lower-cost, lower-medical-burden on-ramp into aviation, and the experimental community has long provided a path for technically inclined pilots to access higher performance at lower capital cost.

The FAA's emerging MOSAIC (Modernization of Special Airworthiness Certification) rulemaking framework further blurs traditional boundaries by expanding the performance envelope and use cases for aircraft that can operate under LSA-like privileges. Under MOSAIC, more capable aircraft including some with higher maximum takeoff weights, additional seats, and more advanced avionics are expected to become eligible for simplified certification and pilot privileges compared with traditional Part 23 standards. This could shift a portion of future recreational demand away from legacy certified four-seat aircraft toward newer, semi-simplified designs that are cheaper to produce and equip with modern technology.

However, several caveats limit the extent to which LSA, experimental aircraft, and MOSAIC-class aircraft can fully offset the constraints identified in the certified piston fleet. First, these aircraft still rely on the same constrained maintenance and hangar infrastructure as the rest of GA, and in many cases on the same avgas or Jet-A supply. Second, insurance, training, and perceived risk profiles differ across LSA and experimental categories, which can dampen adoption among newer or more cautious pilots. Third, the scale of the LSA/experimental fleet, while meaningful locally, remains small compared with the legacy Cessna/Piper/Mooney/Bonanza universe that underpins much of recreational GA today. As MOSAIC matures, it may relieve some pressure by enabling new designs and lower-cost ownership options, but it is unlikely to fully solve the core structural issues of aging fleets, limited maintenance capacity, and fuel-infrastructure fragility.

Market Implications for Recreational GA

The structural trends outlined in the earlier sections point toward a recreational GA market characterized by tight supply, rising operating costs, and limited organic growth potential. The shrinking active piston fleet, the aging aircraft base, and the near absence of meaningful new certified aircraft production combine to collectively reduce the availability of affordable, entry-level aircraft. The recreational GA market depends on relatively low-cost access points in older Cessnas, Pipers, and Mooney's, but the steady attrition of these aircraft without equivalent replacement, exerts continuous upward pressure on prices. At the same time, declining avgas consumption suggests lower utilization rates, which means owners are less inclined to sell. Aircraft that are flown less often tend to stay in service longer under the same ownership, further reducing market turnover.

Demographics reinforce this supply squeeze. The average age of Private pilots has risen steadily for more than two decades, indicating that younger recreational entrants are not arriving in sufficient numbers to refresh the market. Importantly, however, an aging pilot base also means many long-time owners are nearing the point at which they might sell or exit aviation entirely, but this process is slower and less predictable than the rate at which new pilots enter the system. Combined with the fact that many older pilots are financially secure and in no rush to liquidate assets, the net effect is a market that becomes progressively tighter each year. These structural features suggest that the recreational GA ecosystem will continue transitioning from a broadly accessible leisure activity to a more capital-intensive, niche pursuit.

Implications for Used Aircraft Prices

The used aircraft market is now dominated by aircraft that are mostly 40–60 years old, with very few modern replacements entering the fleet. This creates a unique economic reality: aircraft that in most industries would be fully depreciated continue to appreciate in real terms because the alternatives (new production or substantially upgraded modern designs) are either cost-prohibitive or nonexistent. The combination of a shrinking fleet, owners holding onto airframes longer, and demand from both recreational pilots and flight schools ensures that prices remain elevated across the piston single category. Even economic downturns have shown limited impact on values, as supply remains constrained regardless of demand softening.

The decline in avgas utilization adds another layer to this dynamic. Reduced flying activity typically implies more owners operate their aircraft as "hangar queens," flying just enough to maintain airworthiness while waiting for the right market conditions to sell. This behavior suppresses turnover and keeps effective supply low. Meanwhile, demographic changes shown in the aging of the Private pilot population do not meaningfully increase sales volume. Many older pilots prefer to retain ownership longer or pass on the aircraft to family members, which delays supply from reaching the used market. All signs point to continued upward or at least stable price pressure over the next decade, especially for clean, well-maintained, IFR-capable piston singles.

Implications for Flight Schools & Training Capacity

The rising share of instructional flight hours signals a major shift in the center of gravity for general aviation. Flight schools have become the single largest driver of piston aircraft utilization, largely because the surge in commercial pilot demand has pulled thousands of students into the training pipeline. As a result, demand for training aircraft, CFIs, and maintenance support has climbed sharply. The Cessna 172, Piper PA-28 series, and Diamond DA40/DA42 have all experienced significant price inflation with some doubling in price over the past decade as training demand continues to outpace available supply. Schools increasingly face 6–12 month waitlists for aircraft deliveries or must purchase older airframes at premium prices or at higher total airframe time.

These training bottlenecks feed directly back into recreational GA. When flight schools absorb most of the available maintenance capacity, tie-downs, and aircraft inventory, individual recreational pilots are pushed into the margins. This reality manifests in long maintenance lead times, scarcity of affordable rentals, and limited instructor availability, creating friction for new recreational entrants and increasing the likelihood that prospective pilots drop out before solo or private certification. The training pipeline, while booming, crowds out the recreational segment by absorbing the majority of finite industry resources. Unless new training-focused aircraft production scales up significantly (which is unlikely under current certification economics), these imbalances will persist.

Implications for Maintenance, Parts, and FBO Infrastructure

The aging GA fleet naturally increases the demand for maintenance, parts fabrication, avionics upgrades, and structural repairs. However, this demand collides with a declining pipeline of A&P mechanics, many of whom are nearing retirement age. The supply-demand imbalance in the maintenance labor market creates longer downtime for aircraft, higher hourly rates, and reduced capacity for discretionary work, conditions that disproportionately affect the recreational pilot who is not flying under commercial or institutional priority status. At the same time, parts availability for legacy aircraft is becoming increasingly uneven, with OEM support shrinking and third-party PMA or salvage suppliers filling the gap.

FBO infrastructure trends further weaken the support ecosystem for piston GA. As turbine operations and on-demand charter flying grow, FBOs increasingly allocate ramp space, hangar capacity, and service resources toward higher-revenue turbine customers. This shift leads to fewer facilities carrying full-service avgas operations, reduced 100LL inventory turnover and in some cases the removal of avgas from the ramp altogether. Profitability pressures accelerate this trend as turbine fueling and support yield far higher margins than piston GA. The result is a patchier, less reliable infrastructure network for recreational pilots. Even where avgas remains available, the declining consumption makes the business case fragile, increasing the risk of localized shortages or closures.

Regional Variations in Recreational GA

Although this report primarily analyzes national-level data, recreational GA is highly uneven across regions, and the practical experience of pilots varies considerably by geography. High-density GA regions such as the U.S. Sunbelt, parts of the Midwest, and certain coastal corridors benefit from clusters of flight schools, competitive maintenance markets, and multiple airports within reasonable distance, which can partially offset rising costs through competition and scale. In these areas, avgas availability remains relatively robust, used aircraft inventory turns more quickly, and the presence of training pipelines helps sustain local MRO capacity.

By contrast, many rural, mountainous, or low-density regions face more acute versions of the structural constraints identified in this report. Single-FBO airports with modest traffic volumes may struggle to justify continued avgas stocking, dedicated piston maintenance staff, or even full-time line service. When an A&P retires or an FBO shifts focus towards turbine customers, recreational pilots in these regions can experience abrupt increases in downtime and operating costs or may be forced to reposition aircraft long distances for maintenance and fuel. Weather patterns and seasonal demand further amplify these disparities. As a result, the average national picture understates both the resilience of some high-density GA clusters and the vulnerability of marginal airports where a single closure or business decision can dramatically reduce access for local recreational pilots.

Forward Looking Outlook for Recreational GA

A best-case scenario for recreational GA envisions slow, steady, and stable participation sustained by lifestyle-oriented pilots, homebuilders, and the small but durable aviation hobbyist community. In this scenario, modest post-COVID re-engagement and continued demand from aviation-interested younger demographics offset some of the attrition from aging pilots. Prices remain elevated but stable, and sufficient avgas infrastructure survives in most regions. Recreational GA becomes leaner but remains culturally and economically viable.

The base-case outlook is more cautionary, showing a gradual long-run decline driven by demographic attrition, rising ownership costs, and continued constraints in training, maintenance, and aircraft availability. Structural bottlenecks, particularly aircraft supply and maintenance labor, cap potential growth regardless of demand. In this scenario, recreational GA persists but becomes increasingly expensive and geographically concentrated, resembling today's communities surrounding antique cars, gliders, or polo.

The worst-case scenario centers around fuel fragility. If avgas supply reliability declines due to lead restrictions, limited local availability, or price spikes, the remaining piston fleet could experience accelerated attrition. While unleaded alternatives such as G100UL and UL94 exist, deployment remains slow, uneven, and likely to raise operating costs. The introduction of Jet-A-burning piston alternatives (e.g., SMA/Continental diesels) helps but will not arrive at a scale capable of replacing the legacy fleet. Aviation gasoline remains a chokepoint in that without broad availability, the recreational segment could contract sharply.

Across all scenarios, the conclusion emerges that structural constraints are the principal limiting factor for recreational GA going forward. Even if interest rebounds, growth will be hampered by high aircraft prices, limited maintenance capacity, and a diminishing infrastructure footprint. The recreational GA ecosystem is transitioning into a constrained-market environment where resource scarcity, rather than participation desire, determines long-term outcomes.

Conclusion

Recreational general aviation stands at a crossroads shaped by demographic aging, aircraft scarcity, infrastructure pressures, and a training-driven reorientation of the GA economy. The data presented throughout this report collectively tell a consistent story in that the long-term trajectory of recreational GA is one of constrained supply rather than collapsing demand. Interest in aviation remains culturally durable, but the system that supports personal piston flying is increasingly stressed.

The recreational pilot base is aging and not being replenished at historical rates, even as airline-driven training inflows boost total pilot counts. Actual flight activity among recreational pilots has declined significantly, as evidenced by the 20-year contraction in avgas consumption. Meanwhile, aircraft supply is fundamentally limited as the U.S. continues to rely on a fleet dominated by airframes built between the 1950s and 1980s, with retirements accelerating and new production at historically low levels. Maintenance capacity, parts availability, and hangar infrastructure are similarly constrained, reflecting decades of slow contraction in piston-focused aviation services.

These structural limitations constrain growth across all scenarios examined. In a best-case environment, recreational GA stabilizes as a niche, enthusiast-driven activity supported by a committed pilot community and slow expansion of unleaded avgas alternatives. In the base case, demographic and economic pressures result in gradual decline, with rising costs and reduced accessibility thinning participation over time. In the worst case, fuel availability disruptions or rapid regulatory transitions away from leaded fuels accelerate fleet attrition and sharply contract the piston GA ecosystem.

Across all outcomes, recreational GA's future will depend on regulatory clarity, OEM innovation, targeted infrastructure support, and the expansion of the maintenance and training workforce. Without intervention or significant technological change, the recreational segment will remain limited by the availability of aging airframes, finite maintenance labor, and a fuel ecosystem in transition. Nonetheless, recreational aviation continues to hold cultural, economic, and workforce importance serving as the on-ramp for future professional pilots and sustaining the viability of thousands of local airports. Protecting and modernizing this segment is therefore not merely a hobbyist concern, but a strategic imperative for the health of the broader U.S. aviation system.

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Appendix A: Data Tables

GA Demand Panel

year	pilot_total	non_professional	student_total	student_issued_total	studentE_issued	pct_non_prof	pct_private	pct_commercial	pct_atp	active_fleet_total	hours_total_thousands	hours_instruction_thousands	hours_personal_thousands
1999	635472	497830	NA	NA	51102	0.78340194	0.40717608	0.19554127	0.21659806	219464	31231	21914	158540
2000	625581	483985	NA	58042	45418	0.77365681	0.40212379	0.19479172	0.22634319	217533	29960	19998	160053
2001	612274	467572	NA	61839	61897	0.76366463	0.3982253	0.19681058	0.23633537	211446	27017	18601	155671
2002	631762	487054	NA	65421	65421	0.77094539	0.38816833	0.19931557	0.22905461	211244	27040.1	17424.032	157430.998
2003	625011	481507	NA	55446	58842	0.77039764	0.38566521	0.19838051	0.22960236	209708	27329.43	17178.216	158415.623
2004	618633	476473	NA	58362	59217	0.77020301	0.38147658	0.19816596	0.22979699	219426	28125.896	17165.486	160308.363
2005	609737	467745	NA	53576	54922	0.76712583	0.3749469	0.19781316	0.23287417	224352	26982.383	17080.282	161092.592
2006	597109	455174	NA	61448	63698	0.76229633	0.36715742	0.19696571	0.23770367	221943	27705.164	18683.583	158544.172
2007	590349	446396	NA	66953	69265	0.7561561	0.35757831	0.19501515	0.2438439	231607	27851.982	18484.234	161548.136
2008	613746	466908	NA	61194	63468	0.76075119	0.36268424	0.20325346	0.23924881	228663	26009.375	19438.476	163031.244
2009	594285	449685	NA	54876	57084	0.7566824	0.35609009	0.21157862	0.2433176	223877	23762.526	17599.904	161194.774
2010	627588	485390	119119	54064	56008	0.77342142	0.32189908	0.1971118	0.22657858	223370	24801.627	19317.338	159187.183
2011	617128	474617	118657	55298	57168	0.76907384	0.31507402	0.19585078	0.23092616	0	0	26	342
2012	610576	464986	119946	NA	56347.93	0.76155303	0.30790762	0.19063966	0.23844697	209034	24402.967	16594.714	149817.69
2013	599086	449262	120285	49566.3727	49566.3727	0.74991237	0.30081491	0.18061848	0.25008763	199927	22875.95	17403.686	141314.475
2014	593499	440566	120546	47407	49261	0.7423197	0.29466435	0.17577452	0.2576803	204400	23271.186	17020.247	142862.729
2015	590039	435309	122729	47381	49062	0.7377631	0.28933342	0.17145307	0.2622369	210000	24141.9	20335.448	147435.602
2016	584362	426468	128501	NA	36712	0.72980105	0.27776105	0.16442034	0.27019895	211793	24833.264	20740.521	150223.484
2017	609306	449481	149121	NA	38401	0.73769338	0.26662301	0.16110296	0.26230662	211757	25212.17	21231.805	147790.926
2018	633317	471172	167804	NA	45354	0.74397498	0.25847246	0.15770933	0.25602502	211749	25505.932	22685.845	151154.39
2019	664565	499618	197665	NA	NA	0.75179704	0.24242173	0.15177296	0.24820296	210981	25565.93	24466.192	149892.421

2020	691691	527498	222629	NA	NA	0.76262088	0.23256049	0.15018122	0.23737912	204138	22491.871	21687.215	147704.218
2021	720605	556671	250197	NA	NA	0.77250505	0.22406034	0.14516968	0.22749495	209200	26440.574	24410.482	148900.678
2022	756928	590190	280582	NA	NA	0.77971749	0.21678416	0.1380554	0.22028251	209540	26953.421	24380.519	149990.631
2023	806940	632827	316470	NA	NA	0.78423055	0.20783577	0.13224155	0.21576945	NA	NA	NA	NA
2024	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Figure 11: GA Demand Panel 1

year	fuel_total_million_gal	fuel_avgas_million_gal	avg_hours_per_aircraft	active_aircraft_survey
1999	1313	345	142.3058	NA
2000	1304.8	332.8	137.72623	NA
2001	1197.5664	279.2255	127.772576	NA
2002	1215.0182	276.6942	128.004109	NA
2003	1204.6555	272.374	130.321352	NA
2004	1503.8014	272.8983	128.179414	NA
2005	1821.72285	295.043935	120.268074	NA
2006	1926.02809	283.431755	124.830087	NA
2007	1759.22098	273.645565	120.255355	NA
2008	1953.75166	248.050118	113.745446	NA
2009	1674	227	106.140988	NA
2010	1655.5717	220.737104	111.033832	NA
2011	1672.30717	215.960711	NA	NA
2012	1641.34401	206.447964	116.741616	NA
2013	1456.90148	197.263471	114.421514	NA
2014	1675.95689	209.537003	113.851204	NA
2015	1578.2402	195.644855	114.961429	NA
2016	1643.20124	206.499629	117.252525	NA
2017	1747.37748	206.418727	119.061802	940893

2018	2051.92639	231.965642	120.453613	940609
2019	1710.63918	200.158444	121.176457	935542
2020	1545.75605	203.511326	110.179736	904013
2021	2137.89172	228.641194	126.388977	924427
2022	2280.94215	233.371702	128.631388	924014
2023	NA	NA	NA	941181
2024	NA	NA	NA	NA

Figure 12: GA Demand Panel 2

GA Fleet Mix Buckets

year	aircraft_bucket	active_aircraft	total_year	share
2016	Fixed-wing piston single	139685	792551	0.17624733
2016	Fixed-wing piston total	145982	792551	0.18419256
2016	Fixed-wing piston twin	18198	792551	0.0229613
2016	Fixed-wing total	166167	792551	0.20966096
2016	Other / misc	288412	792551	0.3639034
2016	Rotorcraft total	10577	792551	0.01334551
2016	Turbojet / Turbofan	13751	792551	0.0173503
2016	Turboprop	9779	792551	0.01233864
2017	Fixed-wing piston single	140013	792827	0.17659969
2017	Fixed-wing piston total	146186	792827	0.18438575
2017	Fixed-wing piston twin	18232	792827	0.02299619
2017	Fixed-wing total	167082	792827	0.21074207
2017	Other / misc	286637	792827	0.36153789
2017	Rotorcraft total	10511	792827	0.01325762
2017	Turbojet / Turbofan	14217	792827	0.01793203
2017	Turboprop	9949	792827	0.01254877
2018	Fixed-wing piston single	140308	792564	0.1770305
2018	Fixed-wing piston total	146122	792564	0.18436618
2018	Fixed-wing piston twin	17866	792564	0.02254203
2018	Fixed-wing total	167560	792564	0.2114151
2018	Other / misc	286197	792564	0.3611027
2018	Rotorcraft total	9990	792564	0.01260466
2018	Turbojet / Turbofan	14596	792564	0.01841618
2018	Turboprop	9925	792564	0.01252265
2019	Fixed-wing piston single	139299	789015	0.17654797
2019	Fixed-wing piston total	144485	789015	0.18312073
2019	Fixed-wing piston twin	17601	789015	0.02230756
2019	Fixed-wing total	166525	789015	0.21105429
2019	Other / misc	285776	789015	0.36219337
2019	Rotorcraft total	10199	789015	0.01292624
2019	Turbojet / Turbofan	14888	789015	0.0188691
2019	Turboprop	10242	789015	0.01298074
2020	Fixed-wing piston single	134451	762983	0.17621756
2020	Fixed-wing piston total	138936	762983	0.1820958
2020	Fixed-wing piston twin	16971	762983	0.02224296
2020	Fixed-wing total	161638	762983	0.21185007

2020	Other / misc	275609	762983	0.36122561
2020	Rotorcraft total	9745	762983	0.01277224
2020	Turbojet / Turbofan	15316	762983	0.02007384
2020	Turboprop	10317	762983	0.01352193
2021	Fixed-wing piston single	137392	780966	0.17592571
2021	Fixed-wing piston total	141633	780966	0.18135617
2021	Fixed-wing piston twin	16726	780966	0.02141707
2021	Fixed-wing total	164282	780966	0.21035743
2021	Other / misc	285240	780966	0.36523997
2021	Rotorcraft total	10032	780966	0.01284563
2021	Turbojet / Turbofan	15270	780966	0.01955271
2021	Turboprop	10391	780966	0.01330532
2022	Fixed-wing piston single	137142	781415	0.17550469
2022	Fixed-wing piston total	140476	781415	0.17977131
2022	Fixed-wing piston twin	16522	781415	0.02114369
2022	Fixed-wing total	164567	781415	0.21060128
2022	Other / misc	286100	781415	0.36613067
2022	Rotorcraft total	9769	781415	0.01250168
2022	Turbojet / Turbofan	16126	781415	0.02063692
2022	Turboprop	10713	781415	0.01370974
2023	Fixed-wing piston single	139124	797052	0.17454821
2023	Fixed-wing piston total	142209	797052	0.17841872
2023	Fixed-wing piston twin	16554	797052	0.02076903
2023	Fixed-wing total	166788	797052	0.20925611
2023	Other / misc	294838	797052	0.36991062
2023	Rotorcraft total	10051	797052	0.01261022
2023	Turbojet / Turbofan	16537	797052	0.02074771
2023	Turboprop	10951	797052	0.01373938

Figure 13: GA Fleet Mix Buckets

GA Use Shares

year	hours_total_thousands	hours_instruction_thousands	hours_personal_thousands	share_instr	share_personal
1999	31231	21914	158540	0.70167462	5.07636643
2000	29960	19998	160053	0.66748999	5.34222296
2001	27017	18601	155671	0.68849243	5.76196469
2002	27040.1	17424.032	157430.998	0.6443775	5.82213076
2003	27329.43	17178.216	158415.623	0.62856108	5.7965213
2004	28125.896	17165.486	160308.363	0.61030895	5.69967133
2005	26982.383	17080.282	161092.592	0.63301607	5.9702878
2006	27705.164	18683.583	158544.172	0.67437186	5.72254949
2007	27851.982	18484.234	161548.136	0.66365956	5.80023842
2008	26009.375	19438.476	163031.244	0.74736421	6.2681723
2009	23762.526	17599.904	161194.774	0.74065796	6.78357065
2010	24801.627	19317.338	159187.183	0.77887382	6.41841694
2012	24402.967	16594.714	149817.69	0.68002854	6.13932273
2013	22875.95	17403.686	141314.475	0.76078528	6.17742542
2014	23271.186	17020.247	142862.729	0.73138718	6.13903945
2015	24141.9	20335.448	147435.602	0.84233006	6.1070422
2016	24833.264	20740.521	150223.484	0.8351911	6.0492847
2017	25212.17	21231.805	147790.926	0.84212525	5.86188837
2018	25505.932	22685.845	151154.39	0.88943407	5.92624453
2019	25565.93	24466.192	149892.421	0.95698424	5.86297549
2020	22491.871	21687.215	147704.218	0.96422459	6.5670045
2021	26440.574	24410.482	148900.678	0.92322058	5.63152214
2022	26953.421	24380.519	149990.631	0.90454266	5.56480867

Figure 14: GA Use Shares

Non-Professional vs Fleet

year	non_professional	pilot_total	active_fleet_total	active_aircraft_survey
1999	497830	635472	219464	NA
2000	483985	625581	217533	NA
2001	467572	612274	211446	NA
2002	487054	631762	211244	NA
2003	481507	625011	209708	NA
2004	476473	618633	219426	NA
2005	467745	609737	224352	NA
2006	455174	597109	221943	NA
2007	446396	590349	231607	NA
2008	466908	613746	228663	NA
2009	449685	594285	223877	NA
2010	485390	627588	223370	NA
2011	474617	617128	0	NA
2012	464986	610576	209034	NA
2013	449262	599086	199927	NA
2014	440566	593499	204400	NA
2015	435309	590039	210000	NA
2016	426468	584362	211793	NA
2017	449481	609306	211757	940893
2018	471172	633317	211749	940609
2019	499618	664565	210981	935542
2020	527498	691691	204138	904013
2021	556671	720605	209200	924427
2022	590190	756928	209540	924014
2023	632827	806940	NA	941181
2024	NA	NA	NA	NA

Figure 15: Non-Professional vs Fleet

Appendix B: Analysis Code

```
################################################################
# GA Demand & Pilot Trends – Master Analysis Script
#
# This script:
#  - Loads FAA Airmen Statistics (1999–2024, xlsx)
#  - Extracts:
#       * pilot certificate counts by type
#       * student pilot flows
#       * average age of active pilots by certificate (Table 13
/ Avg Age sheet)
#  - Loads GA Profile table (fleet, hours, fuel, use mix)
#  - Loads GA Survey tables (fleet by type, fleet totals)
#
# Outputs (all to ./outputs/):
#  - ga_demand_panel.csv
#  - ga_fleet_mix_buckets.csv
#  - ga_use_shares.csv
#  - nonprof_vs_fleet.csv
#  - airmen_avg_age.csv
#
#  - PNG charts:
#      * pilots_total_nonprof.png
#      * nonprof_share.png
#      * student_flows.png
#      * avg_age_by_cert.png
#      * fleet_size.png
#      * use_shares.png
#      * fuel_trends.png
#      * avgas_only.png
#      * fleet_mix_pie_latest.png
#
# NOTE: flight-plan counts and truly granular airframe-hours-
per-tail
# would require additional data sources; those remain out of
scope here.
################################################################

# ── 0. Libraries & options
────────────────────────────────────────────────

library(tidyverse)
library(readxl)
library(janitor)
library(stringr)
```

```
options(
  scipen = 999,
  dplyr.summarise.inform = FALSE
)

# ── 1. Paths
────────────────────────────────────────────────────────────

airmen_dir    <- "airmen-stats"   # FAA Airmen Statistics .xlsx
ga_survey_dir <- "ga-survey"      # GA Survey .xlsx chunks 1-7
ga_profile_fn <- "table_general_aviation_profile_111824.xlsx"

# ensure outputs directory exists
if (!dir.exists("outputs")) dir.create("outputs")

# ── 2. Helper: robust read_excel
────────────────────────────────────────

safe_read_excel <- function(path, sheet, col_names = TRUE, ...)
{
  read_excel(
    path,
    sheet      = sheet,
    col_names  = col_names,
    .name_repair = "minimal",
    ...
  )
}

# ── 3. AIRMEN STATISTICS – pilot certs & student flows
───────────────────

# We use (sheet names vary slightly by year):
#   - Table 1  → Estimated active airmen certificates held (by
category)
#   - Table 17 → Original airmen certificates issued by category
(flow)
#   - Table 22 → Student certificates issued by month & total
(flow)

# Helper: pull a single numeric value from a "wide by year"
table
get_table_value <- function(df, label, year) {
  if (nrow(df) == 0) return(NA_real_)

  # header row that has "CATEGORY", "Category of Certificates",
or "YEAR"
  header_row <- which(df[[1]] %in% c("CATEGORY",
```

```
                                     "Category of Certificates",
                                     "YEAR"))[1]
  if (is.na(header_row)) return(NA_real_)

  # column corresponding to the requested year
  year_num <- suppressWarnings(as.numeric(year))
  yr_col   <- which(df[header_row, ] == year_num)[1]
  if (is.na(yr_col)) return(NA_real_)

  # row with given label
  row_idx <- which(df[[1]] == label)[1]
  if (is.na(row_idx)) return(NA_real_)

  val <- suppressWarnings(as.numeric(df[[yr_col]][row_idx]))
  val
}

# Helper: find sheet name containing a pattern (case-
insensitive)
find_sheet <- function(path, pattern) {
  sheets <- readxl::excel_sheets(path)
  match  <- sheets[str_detect(tolower(sheets),
tolower(pattern))]
  if (length(match) == 0) return(NA_character_)
  match[1]
}

# Parse a single Airmen Statistics file into a tidy row of
counts / flows
parse_airmen_file <- function(path) {
  year <- readr::parse_number(basename(path))

  # detect sheet names
  sheet_tab1  <- find_sheet(path, "table 1")
  sheet_tab17 <- find_sheet(path, "table 17")
  sheet_tab22 <- find_sheet(path, "table 22")

  # if any required table missing, return NA row and continue
  if (is.na(sheet_tab1) | is.na(sheet_tab17) |
is.na(sheet_tab22)) {
    warning(paste("Missing one of required sheets (1,17,22) in
file:", basename(path)))
    return(
      tibble(
        year = year,
        pilot_total = NA_real_,
        student_total = NA_real_,
```

```
        recreational_only = NA_real_,
        sport_only = NA_real_,
        private_pilot = NA_real_,
        commercial_pilot = NA_real_,
        atp_pilot = NA_real_,
        non_professional = NA_real_,
        student_issued_total = NA_real_,
        studentE_issued = NA_real_
      )
    )
  }

  # read sheets (no col names; we position by row/col)
  tab1  <- safe_read_excel(path, sheet = sheet_tab1,  col_names
= FALSE)
  tab17 <- safe_read_excel(path, sheet = sheet_tab17, col_names
= FALSE)
  tab22 <- safe_read_excel(path, sheet = sheet_tab22, col_names
= FALSE)

  # active certificates (stock)
  pilot_total        <- get_table_value(tab1, "Pilot--Total",
year)
  student_total      <- get_table_value(tab1, "Student  1/",
year)
  recreational_only  <- get_table_value(tab1, "Recreational
(only)", year)
  sport_only         <- get_table_value(tab1, "Sport (only)",
year)
  private_pilot      <- get_table_value(tab1, "Private",
year)
  commercial_pilot   <- get_table_value(tab1, "Commercial",
year)
  atp_pilot          <- get_table_value(tab1, "Airline
Transport",   year)

  non_professional <- if (!is.na(pilot_total) &&
!is.na(atp_pilot)) {
    pilot_total - atp_pilot
  } else NA_real_

  # student flows (two definitions)
  student_issued_total <- get_table_value(tab22, "Total",
year)
  studentE_issued      <- get_table_value(tab17, "StudentE",
year)
```

```
  tibble(
    year,
    pilot_total,
    student_total,
    recreational_only,
    sport_only,
    private_pilot,
    commercial_pilot,
    atp_pilot,
    non_professional,
    student_issued_total,
    studentE_issued
  )
}

# list and parse all Airmen Statistics files
airmen_files <- list.files(airmen_dir, pattern = "\\.xlsx$",
full.names = TRUE)

airmen_summary <- purrr::map_dfr(airmen_files,
parse_airmen_file) |>
  arrange(year) |>
  filter(year >= 1999)      # focus on modern era

# derived dataset focusing on “non-professional pilots” and mix
airmen_cert_mix <- airmen_summary |>
  mutate(
    pct_non_prof   = non_professional / pilot_total,
    pct_private    = private_pilot    / pilot_total,
    pct_commercial = commercial_pilot / pilot_total,
    pct_atp        = atp_pilot        / pilot_total
  )

# student flow series
student_flows <- airmen_summary |>
  select(
    year,
    student_issued_total,
    studentE_issued
  )

# —— 3B helper: locate the average-age sheet in an Airmen
workbook ————————
find_avg_age_sheet <- function(path) {
  sheets <- readxl::excel_sheets(path)
  match  <- sheets[stringr::str_detect(
    tolower(sheets),
```

```
    "average age|avg age|table 13"
  )]
  if (length(match) == 0) return(NA_character_)
  match[1]
}

# ── 3B. AIRMEN STATISTICS – average age of active pilots (Table
13) ──────
parse_airmen_avg_age <- function(path) {
  # each workbook has a "Table 13" style sheet with avg age by
cert
  sheet_age <- find_avg_age_sheet(path)
  if (is.na(sheet_age)) {
    warning(paste("Average-age sheet not found in file:",
basename(path)))
    return(tibble())
  }

  # read with NO column names; then give generic names so dplyr
is happy
  df_raw <- safe_read_excel(path, sheet = sheet_age, col_names =
FALSE)
  if (nrow(df_raw) == 0) return(tibble())

  colnames(df_raw) <- paste0("V", seq_len(ncol(df_raw)))  # <--
KEY FIX

  # find the row whose first cell is "Calendar Year" or "Year"
  header_row <- which(df_raw$V1 %in% c("Calendar Year", "Year",
"YEAR"))[1]
  if (is.na(header_row)) {
    warning(paste("Could not find 'Calendar Year' header in
file:", basename(path)))
    return(tibble())
  }

  # take that row as the header, everything below as data
  header_vals <- df_raw[header_row, ] |> unlist() |>
as.character()

  # replace NA / "" header names with safe placeholders
  header_vals_clean <- ifelse(
    is.na(header_vals) | header_vals == "",
    paste0("col_", seq_along(header_vals)),
    header_vals
  )
```

```
  df_data <- df_raw |>
    dplyr::slice((header_row + 1):dplyr::n())
  colnames(df_data) <- header_vals_clean

  # identify which column is the year column
  year_col_name <- intersect(
    c("Calendar Year", "Year", "YEAR"),
    header_vals_clean
  )[1]
  if (is.na(year_col_name) || length(year_col_name) == 0) {
    warning(paste("Could not identify year column in file:",
basename(path)))
    return(tibble())
  }

  df_data <- df_data |>
    dplyr::rename(year = !!rlang::sym(year_col_name)) |>
    dplyr::filter(!is.na(year)) |>
    dplyr::mutate(year = suppressWarnings(as.numeric(year))) |>
    dplyr::filter(!is.na(year))

  # pivot to long: one row per (year, certificate label)
  df_long <- df_data |>
    tidyr::pivot_longer(
      cols      = -year,
      names_to  = "cert_label",
      values_to = "avg_age"
    ) |>
    dplyr::mutate(
      avg_age    = suppressWarnings(as.numeric(avg_age)),
      cert_label = as.character(cert_label)
    ) |>
    dplyr::filter(!is.na(avg_age))

  # standardize certificate labels into neat buckets
  df_long |>
    dplyr::mutate(
      cert_bucket = dplyr::case_when(
        stringr::str_detect(cert_label, regex("Total",
ignore_case = TRUE)) ~ "All pilots",
        stringr::str_detect(cert_label, regex("Airline
Transport", ignore_case = TRUE)) ~ "ATP",
        stringr::str_detect(cert_label, regex("Commercial",
ignore_case = TRUE)) ~ "Commercial",
        stringr::str_detect(cert_label, regex("Private",
ignore_case = TRUE)) ~ "Private",
```

```
        stringr::str_detect(cert_label, regex("Student",
ignore_case = TRUE)) ~ "Student",
        stringr::str_detect(cert_label, regex("Recre",
ignore_case = TRUE)) ~ "Recreational",
        stringr::str_detect(cert_label, regex("Sport",
ignore_case = TRUE)) ~ "Sport",
        stringr::str_detect(cert_label, regex("\\bCFI\\b",
ignore_case = TRUE)) ~ "CFI",
        stringr::str_detect(cert_label, regex("Remote",
ignore_case = TRUE)) ~ "Remote pilot",
        TRUE ~ cert_label
      )
    ) |>
    dplyr::select(year, cert_bucket, avg_age) |>
    dplyr::distinct()
}

# rebuild the panel
airmen_avg_age <- purrr::map_dfr(airmen_files,
parse_airmen_avg_age) |>
  dplyr::filter(!is.na(year), year >= 1999) |>
  dplyr::arrange(year, cert_bucket)

# ── 4. GA PROFILE - fleet size, fuel use, hours, use mix
─────────────────
# FAA "General Aviation Profile" XLS:
#   rows  = metrics
#   cols  = years (1960-2022+)
# We pivot to long, then pick out the rows we care about.

ga_profile_raw <- safe_read_excel(
  ga_profile_fn,
  sheet     = "Aviation profile",
  col_names = FALSE
)

colnames(ga_profile_raw) <- paste0("V",
seq_len(ncol(ga_profile_raw)))

# Row 2 contains the year labels in V2+
year_row <- ga_profile_raw[2, ]
year_vec <-
suppressWarnings(as.numeric(as.character(unlist(year_row[, -
1]))))

ga_profile_long <- ga_profile_raw |>
  mutate(
```

```
    metric = as.character(V1),
    row_id = dplyr::row_number()
  ) |>
  mutate(across(starts_with("V"), as.character)) |>
  pivot_longer(
    cols      = starts_with("V"),
    names_to  = "col_name",
    values_to = "value"
  ) |>
  filter(col_name != "V1") |>
  mutate(
    col_index = as.integer(str_remove(col_name, "V")),
    year      = year_vec[col_index - 1],
    value     = suppressWarnings(as.numeric(value))
  ) |>
  filter(!is.na(year), year >= 1999) |>
  select(year, metric, value)

extract_ga_series <- function(pattern) {
  ga_profile_long |>
    filter(str_detect(metric, pattern)) |>
    group_by(year) |>
    summarise(value = sum(value, na.rm = TRUE), .groups =
"drop")
}

# fleet size
ga_profile_fleet <- extract_ga_series("^Number of active
aircraft by primary use, total") |>
  rename(active_fleet_total = value)

# total flight hours (thousands)
ga_profile_hours_total <- extract_ga_series("^Number of flight
hours by actual use, total") |>
  rename(hours_total_thousands = value)

# flight hours by use: instructional & personal
ga_profile_hours_instr <- extract_ga_series("^Instructional$")
|>
  rename(hours_instruction_thousands = value)

ga_profile_hours_personal <- extract_ga_series("^Personal$") |>
  rename(hours_personal_thousands = value)

ga_profile_use <- ga_profile_hours_total |>
  full_join(ga_profile_hours_instr,  by = "year") |>
  full_join(ga_profile_hours_personal, by = "year")
```

```
# fuel consumption
ga_profile_fuel_total <- extract_ga_series("^Fuel consumed,
total") |>
  rename(fuel_total_million_gal = value)

ga_profile_fuel_avgas <- extract_ga_series("^Aviation gasoline")
|>
  rename(fuel_avgas_million_gal = value)

ga_profile_fuel <- ga_profile_fuel_total |>
  full_join(ga_profile_fuel_avgas, by = "year")

# combined GA profile metrics
ga_profile_summary <- ga_profile_fleet |>
  full_join(ga_profile_use,  by = "year") |>
  full_join(ga_profile_fuel, by = "year") |>
  arrange(year) |>
  mutate(
    avg_hours_per_aircraft =
      ifelse(!is.na(hours_total_thousands) &
               !is.na(active_fleet_total) &
               active_fleet_total > 0,
             (hours_total_thousands * 1000) /
active_fleet_total,
             NA_real_)
  )

# —— 5. GA SURVEY – fleet composition & totals
————————————————————————————

# Helper: GA Survey 1.1 – active aircraft by type for the survey
year
parse_ga_survey_1_1 <- function(path) {
  year_from_name <- readr::parse_number(basename(path))

  df <- safe_read_excel(path, sheet = "1.1", col_names = FALSE)
  colnames(df) <- paste0("V", seq_len(ncol(df)))

  header_row <- which(df$V1 == "AIRCRAFT TYPE")[1]
  if (is.na(header_row)) return(tibble())

  year_row_vals  <- df[header_row + 1, ]
  year_vec_local <-
suppressWarnings(as.numeric(as.character(unlist(year_row_vals[,
-1]))))
```

```
  target_col_idx <- which(year_vec_local == year_from_name)[1]
  if (is.na(target_col_idx)) {
    target_col_idx <- 2L
  } else {
    target_col_idx <- target_col_idx + 1
  }

  fleet <- df |>
    select(V1, !!rlang::sym(paste0("V", target_col_idx))) |>
    rename(
      aircraft_type_raw = V1,
      active_aircraft   = !!rlang::sym(paste0("V",
target_col_idx))
    ) |>
    mutate(
      year = year_from_name,
      active_aircraft =
suppressWarnings(as.numeric(active_aircraft))
    ) |>
    filter(
      !is.na(active_aircraft),
      !str_detect(aircraft_type_raw, "AIRCRAFT TYPE|% Std\\.
Error|Table 1\\.1"),
      aircraft_type_raw != ""
    )

  fleet
}

ga_survey_1_files <- list.files(
  ga_survey_dir,
  pattern    = "-1\\.xlsx$",
  full.names = TRUE
)

ga_survey_fleet_raw <- purrr::map_dfr(ga_survey_1_files,
parse_ga_survey_1_1)

ga_survey_fleet_type <- ga_survey_fleet_raw |>
  mutate(
    aircraft_bucket = case_when(
      str_detect(aircraft_type_raw, regex("^1 Eng", ignore_case
= TRUE)) ~ "Fixed-wing piston single",
      str_detect(aircraft_type_raw, regex("^2 Eng", ignore_case
= TRUE)) ~ "Fixed-wing piston twin",
      str_detect(aircraft_type_raw, regex("^Piston: Total",
ignore_case = TRUE)) ~ "Fixed-wing piston total",
```

```
      str_detect(aircraft_type_raw, regex("^Turboprop",
ignore_case = TRUE)) ~ "Turboprop",
      str_detect(aircraft_type_raw, regex("^Turbojet",
ignore_case = TRUE)) ~ "Turbojet / Turbofan",
      str_detect(aircraft_type_raw, regex("^Fixed Wing: Total",
ignore_case = TRUE)) ~ "Fixed-wing total",
      str_detect(aircraft_type_raw, regex("^Rotorcraft",
ignore_case = TRUE)) ~ "Rotorcraft total",
      TRUE ~ "Other / misc"
    )
  ) |>
  group_by(year, aircraft_bucket) |>
  summarise(
    active_aircraft = sum(active_aircraft, na.rm = TRUE),
    .groups = "drop"
  ) |>
  arrange(year, aircraft_bucket)

# GA Survey 2.1 – fleet totals for cross-check
parse_ga_survey_2_1_total <- function(path) {
  year_from_name <- readr::parse_number(basename(path))

  df <- safe_read_excel(path, sheet = "2.1", col_names = FALSE)
  colnames(df) <- paste0("V", seq_len(ncol(df)))

  header_row <- which(str_detect(df$V1, "AIRCRAFT TYPE"))[1]
  if (is.na(header_row)) return(tibble())

  hdr <- df[header_row + 1, ]
  idx_active <- which(str_detect(as.character(unlist(hdr)),
"Estimated Number Active"))[1]
  if (is.na(idx_active)) return(tibble())

  total_active <- df |>
    slice((header_row + 2):n()) |>
    filter(
      !str_detect(V1, "Table 2\\.1|AIRCRAFT TYPE|Percent
Standard Error"),
      V1 != ""
    ) |>
    summarise(
      active_aircraft = sum(
        suppressWarnings(as.numeric(.data[[paste0("V",
idx_active)]])),
        na.rm = TRUE
      )
    ) |>
```

```
    mutate(year = year_from_name)

  total_active
}

ga_survey_2_files <- list.files(
  ga_survey_dir,
  pattern    = "-2\\.xlsx$",
  full.names = TRUE
)

ga_survey_fleet_total <- purrr::map_dfr(ga_survey_2_files,
parse_ga_survey_2_1_total) |>
  select(year, active_aircraft_survey = active_aircraft) |>
  arrange(year)

# —— 6. Join key series & make “master panel”
```

```
ga_demand_panel <- airmen_cert_mix |>
  select(
    year,
    pilot_total,
    non_professional,
    student_total,
    student_issued_total,
    studentE_issued,
    pct_non_prof,
    pct_private,
    pct_commercial,
    pct_atp
  ) |>
  full_join(ga_profile_summary,    by = "year") |>
  full_join(ga_survey_fleet_total, by = "year") |>
  arrange(year)

# derived tables
nonprof_vs_fleet <- ga_demand_panel |>
  select(
    year,
    non_professional,
    pilot_total,
    active_fleet_total,
    active_aircraft_survey
  )

use_shares <- ga_profile_use |>
```

```
  filter(!is.na(hours_total_thousands), hours_total_thousands >
0) |>
  mutate(
    share_instr    = hours_instruction_thousands /
hours_total_thousands,
    share_personal = hours_personal_thousands   /
hours_total_thousands
  ) |>
  arrange(year)

fleet_mix_buckets <- ga_survey_fleet_type |>
  group_by(year) |>
  mutate(
    total_year = sum(active_aircraft, na.rm = TRUE),
    share      = active_aircraft / total_year
  ) |>
  ungroup()

# ── 7. Write CSV outputs
──────────────────────────────────────────────────

readr::write_csv(ga_demand_panel,   file.path("outputs",
"ga_demand_panel.csv"))
readr::write_csv(fleet_mix_buckets, file.path("outputs",
"ga_fleet_mix_buckets.csv"))
readr::write_csv(use_shares,        file.path("outputs",
"ga_use_shares.csv"))
readr::write_csv(nonprof_vs_fleet,  file.path("outputs",
"nonprof_vs_fleet.csv"))
readr::write_csv(airmen_avg_age,    file.path("outputs",
"airmen_avg_age.csv"))

# ── 8. Charts – saved as PNG in ./outputs/
──────────────────────────────

# 8.1 Total vs non-professional pilots
p_pilots <- ga_demand_panel |>
  filter(!is.na(pilot_total)) |>
  ggplot(aes(x = year)) +
  geom_line(aes(y = pilot_total, colour = "Total pilots")) +
  geom_line(aes(y = non_professional, colour = "Non-professional
pilots")) +
  scale_y_continuous(labels = scales::comma) +
  labs(
    title  = "Total vs Non-Professional Pilots Over Time",
    x      = "Year",
    y      = "Number of pilots",
```

```
    colour = NULL
  ) +
  theme_minimal()

ggplot2::ggsave(
  filename = file.path("outputs", "pilots_total_nonprof.png"),
  plot     = p_pilots,
  width    = 8,
  height   = 5,
  dpi      = 300
)

# 8.2 Share of pilots who are non-professional
p_nonprof_share <- ga_demand_panel |>
  filter(!is.na(pct_non_prof)) |>
  ggplot(aes(x = year, y = pct_non_prof)) +
  geom_line() +
  scale_y_continuous(labels = scales::percent) +
  labs(
    title = "Share of Pilots Who Are Non-Professional",
    x     = "Year",
    y     = "Non-professional share of all pilots"
  ) +
  theme_minimal()

ggplot2::ggsave(
  filename = file.path("outputs", "nonprof_share.png"),
  plot     = p_nonprof_share,
  width    = 8,
  height   = 5,
  dpi      = 300
)

# 8.3 Student pilot flows
p_students <- student_flows |>
  filter(!is.na(student_issued_total) | !is.na(studentE_issued))
|>
  ggplot(aes(x = year)) +
  geom_line(aes(y = student_issued_total, colour = "Student
certs (Table 22)")) +
  geom_line(aes(y = studentE_issued,      colour = "StudentE
(Table 17)")) +
  scale_y_continuous(labels = scales::comma) +
  labs(
    title  = "Student Pilot Certificate Flows Over Time",
    x      = "Year",
    y      = "Certificates issued",
```

```
    colour = NULL
  ) +
  theme_minimal()

ggplot2::ggsave(
  filename = file.path("outputs", "student_flows.png"),
  plot     = p_students,
  width    = 8,
  height   = 5,
  dpi      = 300
)

# 8.4 Average age of active pilots by certificate bucket
# Focus on key categories: All pilots, Private, Commercial, ATP
age_plot_data <- airmen_avg_age |>
  filter(cert_bucket %in% c("All pilots", "Private",
"Commercial", "ATP"))

p_age <- age_plot_data |>
  ggplot(aes(x = year, y = avg_age, colour = cert_bucket)) +
  geom_line() +
  labs(
    title  = "Average Age of Active Pilots by Certificate",
    x      = "Year",
    y      = "Average age (years)",
    colour = "Certificate"
  ) +
  theme_minimal()

ggplot2::ggsave(
  filename = file.path("outputs", "avg_age_by_cert.png"),
  plot     = p_age,
  width    = 8,
  height   = 5,
  dpi      = 300
)

# 8.5 Fleet size - GA profile vs GA survey
p_fleet <- ga_demand_panel |>
  filter(!is.na(active_fleet_total) |
!is.na(active_aircraft_survey)) |>
  ggplot(aes(x = year)) +
  geom_line(aes(y = active_fleet_total,   colour = "Active fleet
(GA profile)")) +
  geom_line(aes(y = active_aircraft_survey, colour = "Active
fleet (GA survey)")) +
  scale_y_continuous(labels = scales::comma) +
```

```
  labs(
    title  = "GA Fleet Size Over Time – Profile vs Survey",
    x      = "Year",
    y      = "Number of active aircraft",
    colour = NULL
  ) +
  theme_minimal()

ggplot2::ggsave(
  filename = file.path("outputs", "fleet_size.png"),
  plot     = p_fleet,
  width    = 8,
  height   = 5,
  dpi      = 300
)

# 8.6 Instructional vs personal share of GA hours
p_use <- use_shares |>
  ggplot(aes(x = year)) +
  geom_line(aes(y = share_instr,   colour = "Instructional
share")) +
  geom_line(aes(y = share_personal, colour = "Personal share"))
+
  scale_y_continuous(labels = scales::percent) +
  labs(
    title  = "Share of GA Flight Hours – Instructional vs
Personal",
    x      = "Year",
    y      = "Share of total GA hours",
    colour = NULL
  ) +
  theme_minimal()

ggplot2::ggsave(
  filename = file.path("outputs", "use_shares.png"),
  plot     = p_use,
  width    = 8,
  height   = 5,
  dpi      = 300
)

# 8.7 Fuel consumption – total vs avgas
p_fuel <- ga_profile_fuel |>
  filter(!is.na(fuel_total_million_gal) |
!is.na(fuel_avgas_million_gal)) |>
  ggplot(aes(x = year)) +
```

```
  geom_line(aes(y = fuel_total_million_gal, colour = "Total GA
fuel")) +
  geom_line(aes(y = fuel_avgas_million_gal, colour = "Avgas
only")) +
  labs(
    title  = "GA Fuel Consumption Over Time",
    x      = "Year",
    y      = "Fuel (million gallons)",
    colour = NULL
  ) +
  theme_minimal()

ggplot2::ggsave(
  filename = file.path("outputs", "fuel_trends.png"),
  plot     = p_fuel,
  width    = 8,
  height   = 5,
  dpi      = 300
)

# 8.8 Avgas alone - highlights piston GA decline
p_avgas <- ga_profile_fuel |>
  filter(!is.na(fuel_avgas_million_gal)) |>
  ggplot(aes(x = year, y = fuel_avgas_million_gal)) +
  geom_line() +
  labs(
    title = "Avgas Consumption Over Time (GA Piston Activity
Proxy)",
    x     = "Year",
    y     = "Avgas (million gallons)"
  ) +
  theme_minimal()

ggplot2::ggsave(
  filename = file.path("outputs", "avgas_only.png"),
  plot     = p_avgas,
  width    = 8,
  height   = 5,
  dpi      = 300
)

# 8.9 Fleet composition - latest GA Survey year pie chart
latest_year_mix <- fleet_mix_buckets |>
  filter(year == max(year, na.rm = TRUE), !is.na(share))

p_mix_pie <- latest_year_mix |>
  ggplot(aes(x = "", y = share, fill = aircraft_bucket)) +
```

```r
  geom_col(color = "white") +
  coord_polar(theta = "y") +
  labs(
    title = paste0(
      "GA Fleet Composition by Aircraft Type (GA Survey ",
      unique(latest_year_mix$year), ")"
    ),
    x    = NULL,
    y    = NULL,
    fill = "Aircraft bucket"
  ) +
  theme_void() +
  theme(legend.position = "right")

ggplot2::ggsave(
  filename = file.path("outputs", "fleet_mix_pie_latest.png"),
  plot     = p_mix_pie,
  width    = 8,
  height   = 8,
  dpi      = 300
)

############################################################
# End of script
############################################################
```