Next Generation Fleet Replacement at Embry-Riddle Aeronautical University: The Diamond DA42 or Piper PA44 Seminole

Embry-Riddle Aeronautical University

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Abstract

This analytical report examines the potential replacement of Embry-Riddle Aeronautical University's current Diamond DA42 fleet with the Piper Seminole, focusing on three main aspects: Pilot Perspective, Maintenance and Operation, and Engineering/Design. The objective is to provide a research-based recommendation on the feasibility of adopting the Piper Seminole as a suitable alternative for the DA42 fleet. The report will analyze the pros and cons of both aircraft types from a pilot's perspective, compare costs and maintenance requirements, and assess the engineering and design aspects, including safety records and accident history. Various sources will be used, such as technical handbooks, service manuals, library resources, and external research from other universities' Aeronautical Science programs. Additionally, aircraft records and statistics will be gathered from the National Transportation Safety Board (NTSB) and flight manufacturer databases. The final recommendation will consider the university's needs, requirements, potential cost savings, and safety benefits of the Piper Seminole. This report finds that although the Diamond DA42 outperforms the Piper Seminole, it is simply to cost ineffective to remain in the riddle fleet. Maintenance and Operating costs have grown to be further than anticipated, and their high initial purchase price has resulted in a small fleet at Embry Riddle. As the current fleet of Diamond DA42s are reaching their 8-year service life, we recommend that ERAU works with its lease partner and Piper Aircraft to reintroduce Piper aircraft at ERAU.

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Introduction

Embry-Riddle Aeronautical University's esteemed flight program was established in 1925 by visionaries T. Higbee Embry and John Paul Riddle, with the noble objective of educating intrepid individuals in the art of flying. Over the years, the program has expanded exponentially, currently boasting over 900 students and 120 dedicated instructors. With flight operations spanning 51 weeks per year and 18 hours per day, the university's aircraft fleet is subject to constant, rigorous use. As the demands on the aircraft fleet continue to grow, inevitable replacement becomes a critical consideration. At present, the university is deliberating on the replacement of the Diamond DA42, assessing the Piper PA-44 as a viable alternative. Key factors influencing this decision include the distinct cost implications of maintaining these aircraft, stemming from their structural and system differences. In order to make an informed decision that benefits both the institution and its students, this report will analyze the costs associated with each aircraft, taking into account maintenance, pilot expenses, and leasing fees. Ultimately, the goal is to determine the most financially sustainable and advantageous option for Embry-Riddle Aeronautical University's flight program, ensuring its continued success and growth.

Structures and Design

Introduction

The structures of the Piper Seminole and the Diamond DA42 play crucial parts in the overall performance of the aircraft. When looked at as a whole, the aircraft seem remarkably similar to each other, but compared side by side, small aspects reveal significant differences. The most notable difference between the PA-44 and DA42 is the wing design and construction material. This section will compare the design and structure of the Diamond DA42 and the Piper Seminole and introduce differences that contribute to higher costs.

Wing Design

The wings of the DA42 and the PA-44 have different aspect ratios. The DA42 has a wing aspect ratio of approximately 10.53 according to the Diamond Aircraft Industries GMBH flight manual (Airplane flight manual, 2000). The PA-44 has a calculated aspect ratio of approximately 8 according to specifications given by Let's Fly San Diego (Elig, n.d.). As seen in the table below, a higher aspect ratio comes from a larger wingspan and a smaller wing area. The higher ratio wings have slightly less drag and higher lift than lower aspect ratio. This means the Diamond DA42 is better for performance and stability. However, the PA-44 has better maneuverability.

	Diamond DA42	Piper Seminole PA-44
Wing*span* (meters)	13.5	11.13
Wing Area (square meter)	16.29	17.08
Aspect Ratio	10.53	8

Table 1. Wing specifications for the Diamond DA42 and the Piper Seminole PA-44

Both the Piper Seminole and the Diamond DA42 have a monocoque wing design, which allows for better aerodynamic and structural efficiency. The Piper Seminole has a semi-monocoque design while the Diamond DA42 has a full-monocoque design. The semi-monocoque design makes it so the sections of the wing are put together in smaller pieces. This can make repairs and replacements faster, easier, and less expensive. The full-monocoque of the Diamond DA42 means the wing is mostly one piece. This makes it harder to repair because the entire section of wing must be taken apart and replaced.

Material

The cost of material for the two different planes adds significantly to the overall cost of maintaining them. The Piper Seminole is made mostly of aluminum whereas the Diamond DA42 is made of mostly carbon fiber. The cost of carbon fiber is over 30 times more expensive than the cost of aluminum. Due to the wing designs of the planes, the wings of the Piper Seminole can be repaired in smaller sections when compared to the Diamond. With carbon fiber costing 90 dollars per kilogram while aluminum costs only 2.44 dollars per kilogram, the Piper Seminole will have a less expensive repair cost. Replacing small pieces of aluminum sheets is not as difficult or expensive as replacing full sections of carbon fiber.

	Carbon Fiber	Aluminum
Cost of Material (per Kilogram)	$90.00	$2.44

Table 2. Average cost of carbon fiber and aluminum in USD per kilogram

Similarities

One similarity between the Diamond DA42 and the Piper Seminole is the landing gear. Both aircraft have fully retractable, hydraulic landing gear. Both have a tricycle design to provide support and structure. Another similarity between the aircraft is the tail design. Both planes have a T-tail design. This is when the horizontal stabilizer is at the top of the vertical stabilizer, forming a T-shape. The figures below show the tails of both the DA42 (to the left) and the PA-44 (to the right). An advantage to this design is that the tail is above the air flow going around the wings, fuselage, and propellors. The tail will have a mostly smooth flow of air, whereas if it were lower on the vertical stabilizer, it would have a more turbulent flow. This makes a stall because of the tail less likely to occur.

Figure 1. The tail section design of the Diamond DA42 (Left) and Piper Seminole (Right)

Summary of Findings

Even though the wing design of the DA42 makes it more aerodynamical efficient than the PA-44, the Piper Seminole costs significantly less in material than the Diamond. Due to the different wing designs, replacing material on the Diamond is a much more in-depth and costly process when compared to the Piper Seminole. The aircraft have similar tails and landing gear, but it does not make up for the fact that the Diamond is made of carbon fiber, which is the more expensive material.

Pilots

Introduction

The flight training students at Embry Riddle depend on the flight department to provide aircraft and ensure ratings can be achieved in a timely manner. The school's student population is also growing rapidly, and with the possibility of growing from around 8,000 students in fall 2021 to 15,000 students in the fall of 2025, more resources will be required to fit the student population. As of right now, the waiting list for the commercial multi engine rating is anywhere from 2-6 months. With graduating seniors getting priority, and now only 9 Diamond aircraft in our fleet, the Embry Riddle Flight Department must consider purchasing more multi engine planes. Many factors play into this decision, but it is best for the multi-engine fleet to consist of the same type of aircraft for student proficiency to be maintained. Furthermore, students are more likely to truly master and fine tune their skills when there are less variables to the procedures and lessons. Embry Riddle is the national leading Aeronautical and Aerospace University, and it is trivial things like this that provide students with the best training available.

On April 24th, all but one of the Diamond aircraft were down for maintenance, meaning only one multi engine student was able to perform their training at a time for an entire day. Unfortunately, this is more common than the flight department and the students at ERAU would hope. Due to frequent maintenance issues, many students training for their multi engine rating often get "nac'd" - meaning no aircraft available. It is crucial to flight training to maintain

proficiency, or continue practicing their skills regularly, to ensure the best possible training and outcomes.

Fleet Options

Embry Riddle currently has 10 Diamond aircraft used for multi engine ratings; however, one has recently crashed, leaving the active fleet at 9 aircraft. Previous fleets have included different multi engine options, like the Piper Seminole, which is used at other flight training universities such as the University of North Dakota. Embry Riddle's multi-engine fleet has consisted of Piper Arrows in the past, but due to a fatal accident leading to a lawsuit, the school switched to the Diamond Twin Stars. Both the Diamond Twin Star and the Piper Seminole allow for students to receive their complex endorsement on top of the multi-engine rating.

In addition, most other flight training schools use Piper Seminoles for multi-engine training, so if a pilot obtained his or her certification for multi engine flight instruction, he or she would already be familiar with the aircraft. This would make it easier to get a job as an instructor at an accredited flight school. Setting students up for successful careers is the main priority of any university, and switching back to the Piper Seminole could be more beneficial to students than continuing with the Diamond Twin Star. The Seminole is one of the most widely used multi engine training aircraft in the United States and globally.

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The primary issue with the Piper Seminole comes from a fatal accident in April 2018. A student at Embry Riddle and the instructor were killed when a wing detached from the fuselage of a Piper Arrow, causing the crash. Due to metal fatigue and fatigue cracking, the left wing detached from the fuselage at about 900 ft above the ground over Tomoka Farms Road. The aircraft had just under 7,700 hours of flight time, less than some of the Cessna Skyhawks in the fleet currently.

Embry Riddle has an excellent safety record, over ten times better than the industry average, so it is no surprise the school chose to switch to the Diamond Twin Stars after the crash. Student safety is and should be the top priority for the school's flight department. Many precautions are taken for the sole purpose of keeping the pilots, the instructors, and the aircraft as safe as possible. Any flight has risks, but minimizing and reducing risk, especially pilot error, is a necessary step in each of the four hundred training flights performed at Embry Riddle every day.

Costs

The multi engine rating in the Diamond fleet is estimated by Embry Riddle to cost around $16,000. At the University of North Dakota and the University of Indiana Purdue, the multi engine rating is estimated to cost $10,700. It is difficult to determine exactly where the price difference comes from. The cost of renting a Diamond at ERAU is just under $350/hour without an instructor. At other flight training schools, a student can rent the Seminole and pay for an instructor for $355/hour. With Embry Riddle's pricing, students face mountains of debt in student loans without scholarships or parental support.

College students do not have access to tens of thousands of dollars on their own without taking out various loans for school. Any amount of money saved can be thousands of dollars in interest saved. Additionally, Embry Riddle's graduation rate for a bachelor's degree is only 62%, with only 33% finishing the four-year degree in four years. Between rigorous engineering degrees and pilots running out of funding for training, the school's overall graduation rate is only 43%.

The overall difference in costs of ratings between three universities can be seen here:

Flight Training Costs by Rating at Different Universities

Rating	Embry Riddle	UND	Purdue
Private Pilot	$31,000	$16,000	$25,400
Instrument	$16,000	*Included in commercial*	$17,000
Commercial	$22,000	$37,000	$21,600
Multi Engine	$16,000	$10,700	$10,700
Total:	**$85,000**	**$63,700**	**$74,700**

Table 3. Flight Training Costs at Different Universities

The vast difference between the cost of flight training at Embry Riddle and the other universities is obvious, with the primary factors being the private pilot rating and multi engine rating. Switching over from the Diamonds to Seminoles could help save students over $5,000.

With most students spending at least the $85,000 estimate and usually more, that $5,000 saved would help over 1,300 students in the coming years at Embry Riddle. That would be over $6.5 million dollars saved by the students currently enrolled in the Aeronautical Science program.

Maintenance and Operations

Embry-Riddle Flight Department's goals and mission statement emphasize safety and cost by focusing on Fiscal Responsibility, Zero Accidents, and a Reduced number of incidents (ERAU College of Aviation, 2023). As Embry-Riddle evaluates the potential replacement of its current Diamond DA42 fleet with new aircraft like the Piper PA-44 Seminole, it is crucial to analyze the

maintenance and operational costs associated with these aircraft. This section will compare the maintenance and operational requirements of both aircraft, including acquisition and operational costs, maintenance needs, and safety records. Through this comparison, we aim to assess the feasibility of the Piper Seminole as a viable replacement for the Diamond DA42 fleet. This analysis will help Embry-Riddle make an informed decision on fleet replacement, emphasizing maintenance and operational aspects.

Operations

Acquisition and Budget Costs

The initial purchase cost of an aircraft is a critical factor when considering replacing a fleet. Embry-Riddle aircraft typically serve in the fleet for approximately 7 years (Kadah (ERAU), 2020). The table below, table 1, shows a summary of the initial purchase cost and basic operating cost per hour. The base cost to lease the aircraft is the "Total Fixed Cost," however it is customary for Embry-Riddle to purchase these planes at a "Total Variable Cost," which includes additional purchases and modifications, such as advance autopilot, navigation systems, upgraded interiors, and any other undisclosed costs. The acquisition costs of an aircraft can be influenced by a multitude of factors, including the model, age, condition, equipment installed, and quantity of order. However, many optional modifications can also impact the level of maintenance required for the aircraft.

	Diamond DA42	Piper Seminole PA-44
Total Fixed Costs	$102,247.50	$101,745.00
Total Variable Costs	$108,553.50	$118,125.00
Annual Budget	$219,801.00	$210,870.00
Cost Per Hour	$668.45	$488.60

Table 4. Costs of Diamond DA42 and Piper Seminole PA44 side by side (Adapted from, Aircraft Cost Calculator validated with manufacturers)

Both aircraft have different maintenance schedules, fuel consumption rates, flight operations, etc. The Piper Seminole typically has higher fuel consumption due to its piston engines, while the Diamond DA42, with its diesel engines, offers better fuel efficiency. These factors are shown in the annual budget and cost per hour, where the Diamond TwinStar has nearly $200 difference in cost per hour. More information on the engine design and specifications can be found within the Engine Specifications section of this report.

Operating Costs

The following section of the report provides a detailed comparison of the Diamond DA42 and Piper Seminole PA44 aircraft, focusing on various aspects such as maintenance time, fuel consumption, and airframe design. These factors significantly influence the operational and logistical costs of these aircraft, which are vital considerations for potential operators and aviation institutions, including Embry-Riddle Aeronautical University (ERAU).

Fuel consumption and fuel cost per hour of flight

Fuel consumption is a major factor in the operational and logistical costs of any fleet. The most notable difference is the difference in fuel type. The Piper PA-44s piston engines generate 180 HP each and utilize 100LL fuel that costs $5.30 per gallon as of 2022 (Federal Aviation Administration, 2022). The fuel burn rate for the PA44 is approximately twelve gallons per hour, resulting in an hourly fuel cost of around $60 to $70 considering real-world fuel trends.

On the other hand, the Austro Engine diesel engines powering the Diamond DA42 generate 168 HP each. These engines operate on Jet A-1 fuel, which has an average cost of $4.90 per gallon as of 2022 (Federal Aviation Administration, 2022). The DA42 has a fuel burn rate of approximately 9 gallons per hour, translating to an hourly fuel cost of around $40 to $50 considering relative real-world fuel trends.

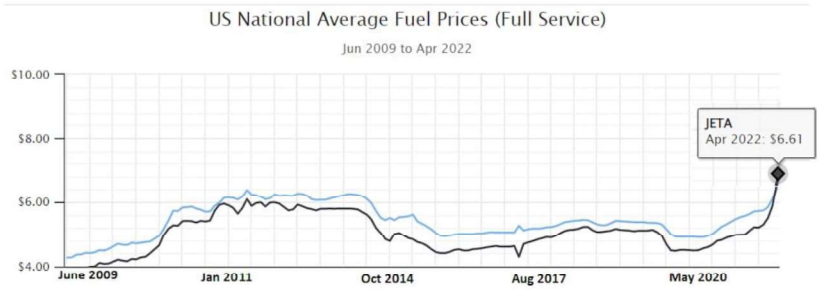

Figure 2. US National Average Fuel Princes (Jet A1) from 2009 to 2022 from NTSB (National Transportation Safety Board) Annual Report

While the Piper Seminole PA44 boasts slightly greater horsepower, the Diamond DA42 offers superior fuel efficiency via lower hourly fuel costs, potentially compensating for some of the increased maintenance expenses associated with the DA42's engines.

Preflight and Turnaround Time

Preflight checks and turnaround times are essential components of an aircraft's operational efficiency. These factors can impact the overall effectiveness of a flight training program and the ability to maximize aircraft utilization.

The Diamond DA42's preflight inspection process, as detailed in the DA42 flight manual (Diamond Aircraft, 2021), is designed to ensure a thorough and efficient assessment of the aircraft's condition before flight. The aircraft's streamlined design and efficient fueling system, as outlined in the maintenance and design sections of this report, allow for a swift transition between flights assuming an average turnaround time of 1 hour (Diamond Aircraft, 2021).

However, potential maintenance issues, such as those related to its complex airframe design, and larger diesel engines result in longer turnaround times or groundings, where an aircraft is

completely taken out of flight rotation. Problems like these have grounded ERAU Diamond aircraft, forcing these planes to spend more time on the ground.

In contrast, the Piper PA-44 Seminole preflight inspection, outlined in the PA-44 QRH (Piper Aircraft, 2021), is similarly comprehensive but may require more attention to the aircraft's generic piston engines and associated systems. The inspection process for the PA-44 covers various components, including the airframe, engines, and avionics. Maintenance issues related to its piston engines, such as oil leaks or fouled spark plugs, may necessitate a more cautious approach and could result in exacerbated turnaround times. However, the issues found to increase turnaround time of the Piper Seminole typically do not require grounding. Assuming an average turnaround time of 1.5 hours, the PA-44 might complete up to 12 flight cycles in an 18-hour day. More information related to turnaround time and groundings related to maintenance issues can be found in the maintenance requirements section of the report.

Maintenance Requirements

To evaluate the feasibility of replacing ERAU's DA42 fleet with the Piper Seminole, it is important to understand the maintenance requirements of both aircraft. This section will provide an overview of the maintenance schedules for these planes, including routine and unscheduled maintenance. It will also analyze the time and labor needed for maintenance, which is a crucial factor in evaluating the overall cost-effectiveness. As aircraft are required to follow strict maintenance regulations set by the FAA, this section will also highlight the FAA regulations for maintenance records, flight hours, and flight cycles that apply to both aircraft.

The following subsections will then delve into the specific engine and airframe specifications and maintenance requirements for both the Diamond DA42 and Piper Seminole, as well as the scheduled and unscheduled maintenance times and the associated labor and cost. By analyzing these factors, we can determine the maintenance needs of each aircraft and assess their overall maintenance costs.

Scheduled Maintenance

General Repairs

The most common types of scheduled maintenance for the Piper PA44 Seminole and Diamond DA42 include regular engine oil changes, inspection of engine and propeller components, landing gear and brakes, flight control surfaces and systems, and of the fuel system. Adhering to the manufacturer's recommendations and FAA guidelines, the maintenance schedule is determined by the aircraft's flight hours, cycles, and calendar time. As fleet planes these aircraft are pushed to the extreme, used extensively in daily operations and experiencing numerous take-offs and landings as training aircraft. As a result, Embry Riddle planes are classified with A and B use ratings, designating them as "High-Cycle Aircraft" (FAA, 2018).

General maintenance provides a useful point of comparison between the Piper Seminole and Diamond DA42 aircraft. Routine checks, such as oil changes and fluid levels are a normal check

before any flight. On average, a basic oil change for a Piper Seminole can cost anywhere from $100 to $300 according to the Piper Service Center. In contrast, the DA42 on average, a basic oil change for a Diamond DA42 can cost between $250 and $400 according to the EVA Diamond Certified Service Center.

While these figures may shift to a myriad of varied factors, based on this metric everyday operational maintenance tends to be slightly higher for the Diamond DA42.

Engine Maintenance

	Diamond DA42 TwinStar	Piper PA-44 Seminole
Time Between Overhaul (TBO)	1800 Hours	2200 Hours
Estimated Maintenance Time	~3 weeks	~2 weeks
Cost of TBO	$62,500 per engine	$24,500 per engine
Cost of TBO Per Flight Hour	$69.40	$22.27

Table 5. TBO Costs associated with the Piper Seminole and Diamond TwinStar

The Piper PA-44 Seminole is powered by twin Lycoming O-360-B1G6 engines, each boasting a recommended Time Between Overhaul (TBO) of 2,200 hours, as outlined in the manufacturer's documentation (Wright, 2016). A study by the University of North Dakota (Johnson & Brown, 2022) approximates the average overhaul cost for a Lycoming O-360-B engine to be around $24,500 per engine, a figure that aligns with Lycoming Engines' data. Given the association between Lycoming engines and the Piper PA family, particularly the Piper PA-28, maintenance personnel frequently possess experience working on these engines. It is noteworthy that the Piper PA-28 Archer III was once part of the Embry-Riddle fleet, equipped with Lycoming IO-360-B1E and IO-360-A1H6 engines, further indicating that maintenance engineers and technicians are well-versed with the design and upkeep requirements of these engines.

In contrast, the Diamond DA42 is powered by a pair of Austro Engine AE300 diesel engines, each having a TBO of 1,800 hours, as stated by the manufacturer's documentation. The aforementioned study by the University of North Dakota (Johnson & Brown, 2022) reveals that the average overhaul cost for an Austro Engine AE300 is approximately $62,500 per engine. A figure that is over 2.5 times greater than the Piper Seminole. The DA42's engines exhibit an intricate design, necessitating specialized training for proper maintenance. Consequently, the higher cost of engine overhauls and specialized maintenance contributes to an increased cost of ownership for the Diamond DA42. When equating the cost per hour, TBO is 3.2 times greater on the Diamond TwinStar compared to the Piper Seminole.

Figure 3. Lycoming O-360-B1G6 (Piper) (Left) and Austro Engine AE300 (DA42) (Right) CAD (Computer Aided Design) Models

In addition to the maintenance and overhaul (TBO) costs, a comparison of the engine performance of the Diamond DA42 Twin Star and Piper Seminole PA44 reveals further distinctions. The Lycoming engines of the Piper PA-44 Seminole can produce 180 horsepower (HP) each, resulting in a total of 360 HP for the aircraft. This power output allows the PA44 to achieve a climb rate of 1,460 feet per minute (fpm) and a maximum cruise speed of 162 knots (Wright, 2016 (rev. 2022)).

Conversely, the Austro engines powering the Diamond DA42 generate 168 HP each, yielding a combined 336 HP for the aircraft. Despite the slightly lower horsepower, the DA42 can achieve a comparable climb rate of 1,400 fpm and a maximum cruise speed of 167 knots (Thomas & ERAU, 2022). The Diamond DA42's engines exhibit improved specific fuel consumption and better high-altitude performance due to their turbocharged design. In few cases, the Diamond DA42 Twin star can be equipped with Austro AE350 engines which produce increased performance, but these engines have drastically different figures that trend to further increased cost of operations for the DA42.

Considering this metric, the Piper Seminole provides a more conventional engine with greater horsepower, yet it does not match the Diamond DA42's overall engine performance and efficiency. This superior efficiency could potentially offset some of the heightened maintenance costs associated with the DA42's engines.

Unlike the Piper PA-44, the DA42 requires that gearboxes be maintained or replaced every 300 hours (Austro Engines & NTSB Bulletin 2009 – 2022). Originally the gear box was designed to be maintained every 1000 hours, which corresponded with engine and airframe inspections, and/or TBO. But application of the DA42 unveiled issues with the gearbox and forced Diamond aircraft to revise this figure. The increased complexity associated with the Diamond DA42 has caused a reputation of unreliability at Embry-Riddle amongst flight students.

Airframe Maintenance

Additionally, the DA42 has an airframe design and landing gear configuration that is not commonly found on most civil aircraft, which affects the inspection and maintenance procedures for these components. This design creates notable differences between the Piper Seminole and Diamond DA42 contributing to differences in performance, maintenance, and cost.

The Piper PA-44 Seminole features a low-wing design with a semi-monocoque aluminum alloy fuselage, typical of the PA family and of most civil aircraft.

While this design has proven itself, the PA family has been associated with a flaw in the center spar, which has led to accidents, including at Embry-Riddle Aeronautical University (ERAU) in 2018 (National Transportation Safety Board, 2018). In certain circumstances, this design issue raises concerns about the structural integrity of the PA44's wing.

On the other hand, the Diamond DA42 features a unique design with a sleek composite fuselage contributing to its aerodynamic efficiency and reduced drag. This all-carbon airframe allows the DA42 to achieve better overall performance and fuel efficiency compared to the PA44. However, the DA42's specialized cockpit design, which incorporates advanced avionics and materials, is more complex to inspect and maintain. In addition, the DA42s composite airframe means the aircraft has a single-monocoque structure, a fuselage that is made from a single piece. This complexity requires additional training for maintenance personnel and may contribute to higher maintenance costs for the DA42.

Figure 4. Diamond DA42 Airframe (ERAU Livery) Left and Piper PA-44 Seminole Airframe (Factory House Livery) Right

The Diamond DA42's composite construction can result in longer maintenance times compared to the Piper PA-44 Seminole's aluminum airframe. A study conducted by Embry-Riddle Aeronautical University found that the maintenance time for the Diamond DA42 is approximately 40% longer than the Piper PA-44 Seminole (Kadah, 2020). The study attributes the longer maintenance times to the more advanced technology used in the Diamond DA42,

which requires more specialized maintenance and longer troubleshooting times. In addition, the airframe used in the Diamond DA42 is an innovative design and is exclusively used by Diamond Aircraft. Diamond Aircraft Industries recommends a major airframe inspection every 1,000 hours or five years of operation, whichever comes first (Thomas & ERAU 2021).

These design differences between the Piper Seminole PA44 and the Diamond DA42 have a direct impact on their respective performance and maintenance requirements. While the PA44 has a traditional design with a known flaw in the center spar, the DA42 boasts a more advanced and aerodynamically efficient design, albeit with increased complexity in cockpit inspection and maintenance.

Unscheduled Maintenance

Unscheduled maintenance is a critical aspect to consider as it directly impacts the aircraft's reliability and overall cost of operation. The Piper PA-44 Seminole, equipped with Lycoming engines and a traditional aluminum alloy fuselage, is known for its relatively modest maintenance costs, although potential structural concerns related to the center spar could result in unanticipated repairs or inspections (National Transportation Safety Board, 2018). Its traditional design makes it easy for mechanics and engineers to transition maintaining this configuration of aircraft.

In contrast, the Diamond DA42, powered by Austro engines and featuring a composite single-monocoque fuselage, may present higher unscheduled maintenance requirements due to the increased complexity of its design and the specialized training required for proper maintenance (Diamond Aircraft, 2021). Additionally, the advanced avionics and materials used in the DA42's cockpit design may necessitate more frequent unscheduled maintenance and inspections. It has been noted that Embry-Riddle Aeronautical University (ERAU) has experienced difficulties with unscheduled maintenance for the Diamond DA42, further emphasizing the importance of considering this factor when comparing the aircraft (ERAU News, 2020). Flaws with the gearbox inspection periods and other safety bulletins continuously ground the DA42s when used as intensely as training aircraft. The complex and frequent repairs have contributed to the increased cost of operating the DA42 for Embry-Riddle therefore leading to increased costs for students' pilots.

In summary, it is important to weigh the potential benefits of the advanced design and performance of the Diamond DA42 against the challenges that institutions like ERAU have faced in terms of unscheduled maintenance (ERAU News, 2020) when comparing these two aircraft. However, based on the sole factor of maintenance the Piper Seminole is a most cost-effective option due to its simpler design and reliability.

Safety Records and Accident History

Safety is the biggest concern for Embry-Riddle, which makes an analysis of these aircraft's safety and accident records critical before making any type of decision related to these aircraft.

Comparison of the Safety Records and Accident History

Piper PA-44 Seminole

The PA-44 Seminole has been in production since 1978, with several modifications and improvements introduced over the years. Its twin-engine configuration and retractable landing gear make it an ideal platform for multi-engine training. While its safety record is generally good, there have been some accidents involving the PA-44 throughout its history. According to the NTSB database, the PA-44 Seminole has been involved in approximately 130 accidents/incidents between 1982 and 2021 (NTSB, 2021). The graph below shows the extent of accidents. Of the 22 fatal accidents there have been 58 deaths. While this plane has been involved in over 100 crashes, it is important to remember that this plane has been in production for 45 years, over 3 different production runs each with multiple variations and updates (EStaff, 2006 (Rev 2019)). It is safe to say there have been thousands of these aircraft produced since its introduction in 1978.

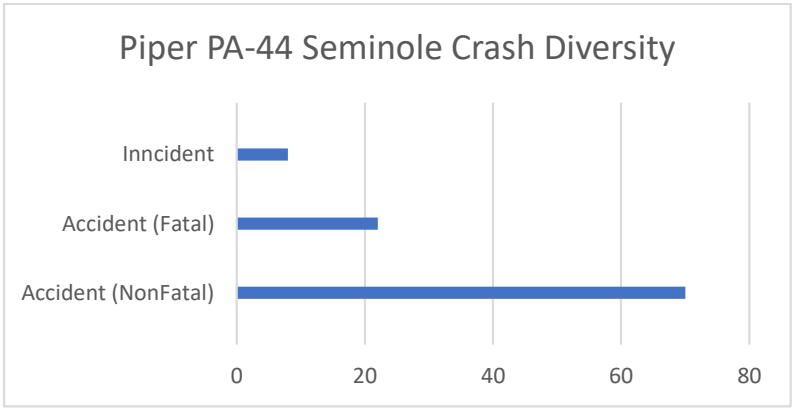

Figure 5. Piper PA-44 crash types (Derived from NTSB CAROL (2008 to Present) and QUERY (1982 to 2008) Databases)

One accident involving a PA-44 occurred on August 14, 1999, when a Seminole crashed in West Chicago, Illinois (NTSB, 2000). The NTSB accident report (NTSB, 2000) indicated that the probable cause of the accident was the pilot's failure to maintain airspeed, resulting in an inadvertent stall and subsequent uncontrolled descent into the ground. The accident led to two fatalities and one severe injury. The NTSB report also noted that contributing factors included the pilot's lack of experience in multi-engine aircraft and his inadequate preflight planning and preparation (NTSB, 2000).

This accident highlights the importance of proper training and preparation for pilots transitioning to multi-engine aircraft, as well as the need for thorough preflight planning to ensure safe flight operations. However, its accident and application history cement its place as an ideal trainer aircraft. This document has referenced many of the ERAU QRH and pilot handbooks for these respective planes, if the Piper Seminole is to enter the fleet, it is important to include these aspects of the aircraft to both improve pilot performance and health of the aircraft.

Embry-Riddle Accident April 4th, 2018

One notable accident involving a Piper aircraft, similar to the PA-44 Seminole, occurred on April 4th, 2018. The accident involved a Piper PA-28R-201 Arrow III (N5062E) operated by Embry-Riddle Aeronautical University (ERAU) (NTSB, 2018). Although the PA-28R and PA-44 are different models, they share similarities in design and systems, which makes it relevant to this discussion. The figure below shows the main spar and bolt map from the 2018 NTSB report featuring the PA-28. A near identical spar and bolt map can be found for the Piper PA-44. The sole difference between the PA28 and PA44 center spar is the length, associated with the increased wing length on the PA44, and consquently the number of bolts is the only difference which is noted on page 20 in the 2018 NTSB crash report. "Each wing main spar on a Piper-28R-201 airplane is attached to the center wing box with 8 attachment bolts through the main spar upper cap and 10 through the main spar lower cap." (NTSB, 2018) found in Figure B-2. This companant of the aircraft is the cause of the accident resulting in the fatalities of both the student pilot and the flight instructor on board.

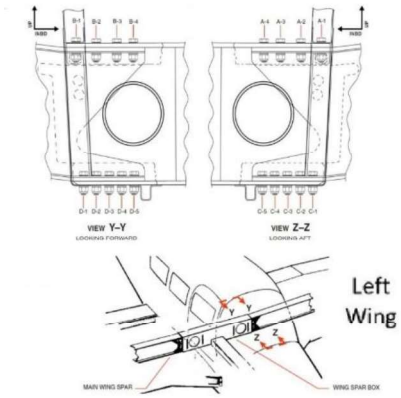

Figure 6. Diagram showing forward and aft side of wing main spars with the associated bolt attachment map. From Piper Aircraft, Inc. found in NTSB report ERA18FA120 (2018)

According to the National Transportation Safety Board (NTSB) accident report, the ERAU crash was caused by the in-flight separation of the left-wing due to fatigue cracking in the wing spar (NTSB, 2018). The fatigue cracking initiated from a corrosion pit on the lower surface of the wing spar, and it propagated undetected until it caused a catastrophic failure of the aircraft structure during a touch-and-go landing (NTSB, 2018). The design of the Piper Seminole made it difficult to inspect this section of the aircraft through regularly visual checks. Access the center wing box required grounding and full maintenance checks to the aircraft.

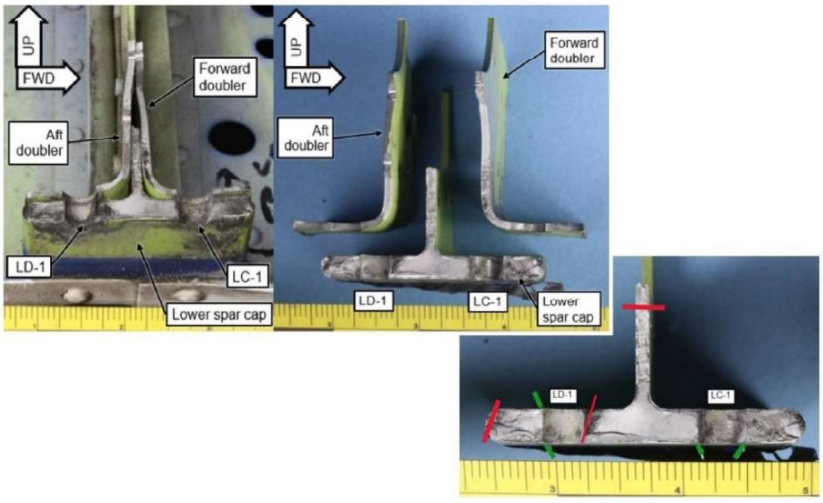

Figure 7. Photographs of the pieces of the left-wing main spar lower cap and doublers before (left) and after (right) sectioning. Close view of the fracture surface (Smaller Photograph) From NTSB report ERA18FA120 (2018).

P*hotograph B-3 dedicates the stress found on the main spar. All edges of the LD-1 and LC-1 areas indicate fatigue origin, shown in green arrows, areas moving to the upper portion of the spar which are fatigue boundaries, show by a red arrow. The NTSB categorized this as class A (Normal Aircraft Use) and B (High-Cycle Aircraft Use) normal usage and therefore categorized this as a manufacturing defect.*

The NTSB report emphasizes the need for thorough and regular inspections of aircraft structures, especially in high-cycle aircraft used in training environments. In response to the accident, the Federal Aviation Administration (FAA) issued an Airworthiness Directive (AD) requiring inspections of the wing spars on certain Piper aircraft models, including the PA-28R and PA-44, for corrosion and cracks (FAA, 2018).

Other Notable Events

One of the most significant accidents involving the PA-44 occurred in 1991 when a Seminole collided with a Cessna 172 in Florida, resulting in six fatalities (NTSB, 1991). The NTSB determined that the probable cause of the accident was the failure of both pilots to maintain an adequate visual lookout, leading to the mid-air collision (NTSB, 1991). This accident underscores the importance of maintaining situational awareness and proper visual scanning techniques, especially in busy airspace. This crash is often categorized as one of the worst accidents involving the Piper PA-44 Seminole.

Potential Safety Risks and Concerns

Considering the safety records, accident history, and known issues with the Piper PA-44 Seminole, there are several potential safety risks and concerns that should be addressed to ensure the safe operation of these aircraft at Embry-Riddle Aeronautical University.

1. Pilot Training and Experience: As demonstrated in the accidents discussed, proper training and experience in multi-engine aircraft are critical to reducing the risk of accidents involving the PA-44 Seminole. Ensuring that pilots receive comprehensive instruction in handling the aircraft, particularly in the areas of airspeed management, stall recovery, and single-engine operations, can help minimize the risk of accidents attributed to pilot error.
2. Aircraft Maintenance and Inspections: Thorough and regular inspections of aircraft structures, especially in high-cycle training environments, are essential for detecting potential issues such as corrosion and fatigue cracking. Following the FAA's Airworthiness Directives and maintenance guidelines for the PA-44, including the inspection of wing spars, can help ensure the structural integrity and safety of the aircraft.
3. Preflight Planning and Preparation: As highlighted in the West Chicago accident, inadequate preflight planning and preparation can contribute to accidents. Ensuring that pilots are well-trained in preflight procedures, including the proper use of checklists and accurate assessment of weather conditions, can help reduce the risk of accidents related to poor planning.
4. Situational Awareness and Collision Avoidance: The mid-air collision incident involving a PA-44 Seminole highlights the importance of maintaining situational awareness and proper visual scanning techniques. Incorporating modern collision avoidance systems, such as Traffic Collision Avoidance Systems (TCAS), and providing training for pilots in their use can further enhance safety in busy airspace.

In conclusion, by addressing the known issues with the Piper PA-44 Seminole, providing comprehensive pilot training, and implementing modern safety systems, the potential safety risks and concerns associated with the PA-44 can be effectively managed. This will ensure a safe and productive training environment for the students and staff at Embry-Riddle Aeronautical University.

Diamond DA42

The Diamond DA42 has been in production since 2004, and its modern design, composite materials, and advanced avionics have contributed to its popularity in flight training and general aviation. With a brief history compared to the Piper PA-44 Seminole, the DA42 has experienced fewer accidents. According to the NTSB database, the DA42 has been involved in approximately 45 accidents between 2004 and 2021 (NTSB, 2021). The majority of these accidents and/or incidents, excluding those of pilot error, are attributed to minor mechanical failures, especially known issues with both the engines and gear box of the DA42.

Crash and Incident History

There is a trend with NTSB reports with issues with the landing gear and engines of the aircraft. Both parts of the aircraft have notable design flaws, and many have been addressed in the numerous safety bulletins posted by Diamond Aircraft.

These flaws and aspects of the aircraft have a major problem for Embry Riddle Aeronautical University. Just recently, on March 31st of 2023 an ERAU Diamond DA42 skid off the runway after the gear collapsed on a rough landing after having engine problems in flight while

performing pattern work at Leesburg International Airport. There was substantial damage reported to the left wing, engine, and landing gear with no reported fatalities (FAA ASIAS). An investigation is underway, however there is limited data on this accident and is only reported in the ASIAS database.

Another accident in landing at Flagler Executive Airport (KFIN), Palm Coast, Florida experienced a collapse of the right main landing gear and subsequent runway excursion. The airplane sustained minor damage and the two occupants onboard were not injured during the incident (Aviation Safety Network, 2020). Accidents involving the gear has been featured in accident reports from NTSB (United States), AAIB (United Kingdom), BEA (France), and many more.

Figure 8. Fire and Rescue tending to Diamond DA42 after running off the runway at Flagler Executive airport (Left) from Daytona News Journal (2020). Twisted left landing gear brace (NTSB Incident AIDS 2020)

There is a large number of accidents involving the landing gear of the Diamond DA42, and in 4 of 5 accidents or incidents involving this aircraft there has been a gear collapse. (NTSB and ASIAS Database). The pictures shown below show another crash after a training accident, which resulted in a main gear collapse, damage to wings and composite structure after crash landing. This picture not only continues to prove the delicate landing gear featured in the DA42, but also the fragile yet complex structure found on the DA42. Any damage to the composite structure, discussed in the maintenance section of this report, results in incredibly complex and expensive maintenance, often leading to the planes' retirement.

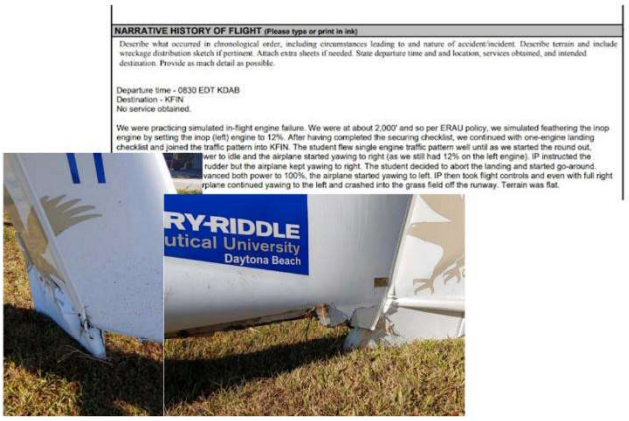

Figure 9. View of rudder damage (left), view of empennage damage (right), Pilot testimony (above) from FAA NTSB Docket ERA20CA143

Potential Safety Risks and Concerns

Considering the safety records, accident history, and the known issues with the Diamond DA42's engines and landing gear, there are several potential safety risks and concerns that should be addressed to ensure the safe operation of these aircraft at Embry-Riddle Aeronautical University.

1. Engine Reliability: As mentioned earlier, some accidents involving the DA42 are attributed to mechanical failures, particularly with the engines. It is crucial to address these known issues by following the latest maintenance guidelines and safety bulletins issued by Diamond Aircraft. Ensuring that all necessary modifications and updates are made to the engines can significantly reduce the risk of engine-related incidents.
2. Landing Gear Issues: The high number of accidents involving landing gear collapse in the DA42 indicates a potential design flaw or maintenance concern. To mitigate this risk, it is essential to conduct thorough inspections and maintenance of the landing gear components, as well as provide comprehensive training for pilots on proper landing techniques and how to handle gear-related emergencies.
3. Advanced Avionics and Safety Systems: Incorporating modern avionics and safety systems, such as terrain awareness and warning systems (TAWS) and traffic collision avoidance systems (TCAS), can further enhance the safety of the DA42. Ensuring that pilots are well-trained in the use of these systems can contribute to a safer flight environment.

Summary of Findings

The comprehensive analysis of the Piper PA-44 Seminole and Diamond DA42 aircraft as potential contenders for the Embry-Riddle Aeronautical University (ERAU) fleet has provided valuable insights into their respective performance, cost, and maintenance factors. In terms of performance, the Diamond DA42 exhibits superior fuel efficiency, high-altitude capabilities, and advanced avionics, which could be advantageous for ERAU's training program. However, the Piper Seminole's Lycoming engines generate greater horsepower, and the aircraft has a more

conventional design, which may be more familiar to maintenance personnel and flight students alike.

When evaluating the cost and maintenance factors of both aircraft, the Piper Seminole is the more cost-effective option, due to its simpler design, proven reliability, and lower overall maintenance costs. Although the Diamond DA42 has an innovative and aerodynamically efficient design with a composite single-monocoque fuselage, it presents higher scheduled and unscheduled maintenance requirements, longer maintenance times, and higher costs for engine overhauls. Furthermore, the Diamond DA42's reputation for unreliability among ERAU flight students, along with challenges faced by the institution in terms of unscheduled maintenance and safety bulletins, further supports the Piper Seminole as a more viable choice for the ERAU fleet.

The accident and incident records of both aircraft are impeccable, averaging 2.5 and 2.8 crashers per year for the DA42 and Piper Seminole, respectively. A figure that is considerably less than the NTSB average for civil aircraft. Both aircraft have been associated with accidents with Embry-Riddle, however the Piper Archer accident is notably worse.

Financial Feasibility

As explored throughout this report, the focus of this analysis is to determine which aircraft is more financially viable for both students and the flight department. While the Diamond DA42 TwinStar offers heightened performance, it does not offset the increased cost to operate. Therefore, the Piper Seminole the more financial friendly option for both students and the University based on the following metrics:

1. Cost of Multi-Engine Rating: A significant difference in rental pricing between the two aircraft was identified. The Piper Seminole's lower rental cost could result in a savings of over $5,000 for students seeking a multi-engine rating, making it a more cost-effective option for this purpose.

2. Aircraft Material Costs: The costs of materials for the Piper Seminole are found to be substantially lower than those for the Diamond Twin Star. Given that these are training aircraft and subjected to heavy usage and occasional mishandling, it is crucial to consider the affordability of replacement parts.

3. Regular Maintenance and Unplanned Expenses: The Piper Seminole's regular maintenance, such as oil changes, is typically more affordable by $100 or more compared to the Diamond Twin Star. Additionally, one of the largest expenses in aircraft maintenance, engine replacements, is 2.5 times more expensive in the Diamond Twin Star than in the Piper Seminole.

All of this makes it easy to conclude that the Piper Seminole is far more economical for students and the flight department than the Diamond Twin Star.

Conclusion and Recommendations

The Piper Seminole is the more feasible overall to replace the Diamond DA42 in the Embry-Riddle fleet. The financial benefits along with the ease of maintenance make it a superior choice. It is our recommendation that Embry-Riddle places the Diamond aircraft with the Piper Seminole to better benefit the students and the school. The simple design of the aircraft means less maintenance and less cost for repairs and material. It will also cost less for the students to receive flight training at ERAU which over time could lead to more students wanting to attend the university. This would give more money to the school while costing less for individual students.

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