EAS2011 AERONAUTICS PROJECT

Honor Code: On my honor, I have neither given nor received unauthorized aid in doing this homework/quiz/report/exam.
Signed by:

Helen Thomas Daniella Burger

B Guaglardi Samuel Crabbendam

TEAM 18

Daniella Burger, Helen Thomas, Benjamin Guaglardi, Samuel Crabbendam

Avigator Consulting, Ltd.

Executive Summary

On March 24, 2025, the Avigator Consulting, Ltd firm secured a preliminary contract to evaluate the Cessna 172 (with subtypes Cessna 172R Skyhawk R, Cessna 172N Skyhawk N, and Cessna 172S Skyhawk S) and the Diamond DA40 Diamond Star NG. This contract was created with the end goal of selecting one addition for the contracted company's fleet.

On April 27, 2025, the Aircraft Performance Team at Avigator Consulting, Ltd. concluded that the aircraft with the best technical and economic performance out of those studied is the Diamond DA40 Diamond Star NG.

The team arrived at this conclusion after performing careful economic analysis, researching the fuel and safety of the Cessna 172 and Diamond DA40 aircraft types. Additionally, the team performed careful technical analysis, computing specific variables for comparison as well as generating flight envelopes by using MATLAB.

Due to the Diamond DA40 Diamond Star NG model's history of safety and ability to accept multiple fuel types, it is the most economically appealing. Though the Diamond DA40 does cost more than any of the Cessna 172 aircraft types mentioned in the report, the Aircraft Performance Team concludes that other economic benefits outweigh the higher initial upfront cost of the aircraft.

The Diamond DA40 Diamond Star NG outperforms the Cessna 172 models with its flight envelopes and other characteristic parameters. Therefore, the Aircraft Performance team has concluded that, overall, it is in the client's best interest to consider the Diamond DA40 Diamond Star NG as the best addition to their fleet.

Contents

List of Tables

List of Figures

1. Introduction

This report intends to generate a comparison of two different general aviation aircraft types, in addition to a selection of their subtypes, which will serve as an analysis of aircraft performance. In addition to the thorough examination of the two aircraft types, will outline a technical analysis through calculations generated by the Aircraft Performance Team.

The two types of aircraft that will be analyzed in this report include the Cessna 172 (with subtypes Cessna 172R Skyhawk R, Cessna 172N Skyhawk N, and Cessna 172S Skyhawk SP) and the Diamond DA40 Diamond Star NG. These aircraft types were chosen to compare against each other as they both feature one propeller (which in this report will be the same propeller for all aircraft, a 76'' diameter McCauley, with model number 1A170E/JHA7660), 4 seats, and are both light aircraft. (1) These specifications classify the two aircraft as competitors.

2. Economic Analysis

Though the aircraft flight performance is a valuable criterion by which to compare the Cessna 172 and its subtypes with the Diamond DA40 Diamond Star, other factors must be discussed. Aircraft operating costs as well as potential benefits differ according to several factors.

2.1 Fuel Types

In addition to the other similarities between the general aviation aircraft types, the two competitors use the same fuel type. The Cessna 172 varieties take 100LL (Low Lead) fuel types (2). As of April 6, 2025, the 100LL fuel type cost $5.96 per gallon. (3) The Diamond DA40 Diamond Star takes either 100LL or 130LL fuel. (4) Since the aircraft types both take the same types of fuel, this is not a major point of economic comparison.

However, since the Diamond DA40 Diamond Star accepts more than one fuel type, this can be highly beneficial to pilots when choosing their landing site. When operating an aircraft that accepts more than one fuel type, is more flexibility when choosing a location to refuel. Thus, the Diamond DA40 Diamond Star can be preferred when considering fuel-related factors.

2.2 Safety

Another significant factor to consider when discussing the economic benefits of the aircrafts being studied is safety. The safety of an aircraft can influence how much money is spent on repairs, maintenance, and insurance. Between the dates of April 14 and April 25, the FAA reports that Cessna aircraft types had 26 accidents or incidents while Diamond aircraft types only had 4 total accidents and incidents. (5)

When considering safety over a longer period, Genesis Flight College reports that per 1,000 aircraft, the mishap rate for the Diamond DA40 is 4.0 while the mishap rate for Cessna 172 Aircraft is 17.3. (6) This data suggests that over time, the Diamond aircraft types have consistently proven to be the safer aircraft when compared to the Cessna 172 aircraft types.

2.3 Aircraft Cost

Due to the variability in the market as well as dynamic pricing on aircraft, it is difficult to determine an exact cost for each aircraft. Additionally, based on the quantity that is being purchased, there is a potential for volume pricing as well as bulk discounting. Certain add-ons can increase the price of aircraft and depending on the status of the aircraft, there can be major price fluctuations. Therefore, the following figures for aircraft costs will be based on aircraft that are currently on the market and are found on an aircraft marketplace, and are not an official price from the company.

An estimated cost for the new standard version of the Cessna 172S Skyhawk SP is $419,620 USD. (7) Though this price may be different for the other Cessna 172 models that are mentioned in this report, this price serves as a good baseline for comparison to the Diamond DA40 Diamond Star NG.

An estimated cost for the new standard version of the Diamond DA40 Diamond Star NG is approximately $595,840 USD. (8) The price for this is more expensive than any of the Cessna 172 models mentioned in the report. Therefore, if the main concern of the client is to save money, it is recommended that they consider the Cessna 172 models instead.

3. Technical Analysis

3.1 Cessna 172R Skyhawk R

3.1.1 Manufacturer Specifications for Cessna 172R Skyhawk R

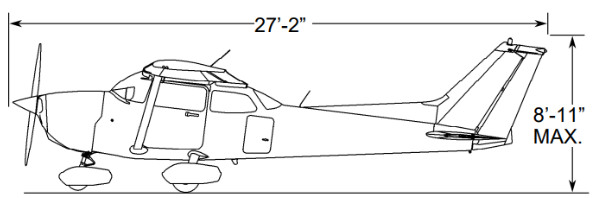


Figure 1: Cessna 172R Skyhawk R side view showing aircraft specifications. Image taken from source (9).

The Quantitative Manufacturing Specifications for the Cessna 172R Skyhawk R were taken from the Pilot's Operating Handbook (POH) for the Cessna 172R Skyhawk R and are as follows. (9)

Table 1: Quantitative Manufacturing Specifications for Cessna 172R Skyhawk R

Propeller Diameter	75"
Wing Area	174 ft^2
Total Capacity	56 U.S. gallons
Maximum Power	160 BHP rating
Max Engine Speed	2400 RPM
Max Takeoff Weight	2450 lbs
Max Velocity at Sea Level	123 knots

3.1.2 Aircraft Performance Team Calculations for Cessna 172R Skyhawk R

In order to perform technical analysis of the Cessna 172R Skyhawk R, the Aircraft Performance Team conducted calculations by hand as well as using MATLAB for computation of flight envelopes. Evidence of the hand calculations can be found in the Appendix (Items 1-3).

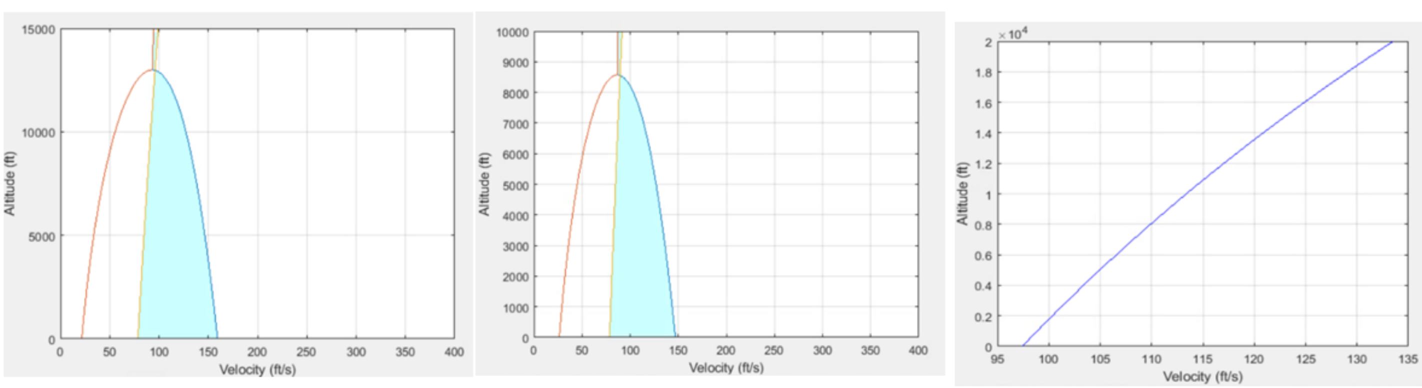
For the proper evaluation of aircraft performance, specific values will be used in the team's calculations. All calculations will occur at a standard temperature. The altitude for the specific scenario in which the following values will be computed is 6,000 ft., and the propeller will have an RPM of 2300. (9) The service ceiling value that will be used is 13,500 ft, with the best angle of climb at sea level occurring at a speed of 60 KIAS. (9) At 60% power, the aircraft will have a true airspeed of 104 knots, and a maximum range of 685 nautical miles. (9) Additional values needed for these calculations occur at an altitude of 2,000 ft. The maximum continuous power percentage is 79%. (9) The true airspeed will be 115 knots with a fuel consumption rate of 9 gallons/hour. (9)

Table 2: Team Computations for Cessna 172R Skyhawk R

Coefficient of Induced Drag (k)	0.0522
Coefficient of Parasitic Drag (C_{Do})	0.0722
Drag Coefficient (C_D)	0.427
(w/o flaps) Max Coefficient of Lift (C_{Lmax})	1.9131
Propeller Efficiency (η)	0.796
Engine Characteristic (m)	1.9131
(w/flaps) Max Coefficient of Lift (C_{Lmax})	2.253
$\gamma_{glide\ min}$	0.1222 rad

The figures for flight envelopes generated through MATLAB are pictured below. The MATLAB scripts for these computations can be found in the Appendix (Items 4-6).

3.1.3 Evaluation for Cessna 172R Skyhawk R



A B C

Figure 2: Flight Envelopes for Cessna 172R Skyhawk R. A) Graph of Steady Flight Envelope Generated by MATLAB. B) Graph of Climb Flight Envelope Generated by MATLAB. C) Graph of Glide Flight Envelope Generated by MATLAB.

The Cessna 172R Skyhawk R is reliable, efficient, and well-suited for training and general use. With a max takeoff weight of 2,450 lbs., it reaches up to 123 knots at sea level. At 6,000 ft and 60% power, it cruises at 104 knots. (9) Its aerodynamic design, with a drag coefficient of 0.427

and high lift capability (C_{Lmax} up to 2.253 with flaps), supports safe takeoff and landing. Fuel efficiency of the Cessna 172R is sufficient and long lasting with a fuel consumption rate of 9 gallons per hour at 2,000 ft. (9)

The plots of the flight envelopes illustrate the flight performance of the Cessna 172R Skyhawk. Graph A shows the aircraft operates safely between stalls and maximum speeds up to around 14,000 ft, with the speed range narrowing as altitude increases. Graph B highlights a more forgiving speed range at lower elevations. Graph C shows maximum gliding occurs at 133 ft/s.

3.2 Cessna 172S Skyhawk SP

3.2.1 Manufacturer Specifications for Cessna 172S Skyhawk SP

These specifications were found in the Pilot's Operating Handbook (POH) for the Cessna 172S Skyhawk SP. (2) These specific parameters are either used in the calculations done by the Aircraft Performance team or are used in the analysis in some other way.

Table 3: Quantitative Manufacturing Specifications for Cessna 172S Skyhawk S

Propeller Diameter	76"
Wing Area	174 ft^2
Total Capacity	56 U.S. gallons
Maximum Power	180 BHP rating
Max Engine Speed	2700 RPM
Max Takeoff Weight	2550 lbs.
Max Velocity at Sea Level	124 knots

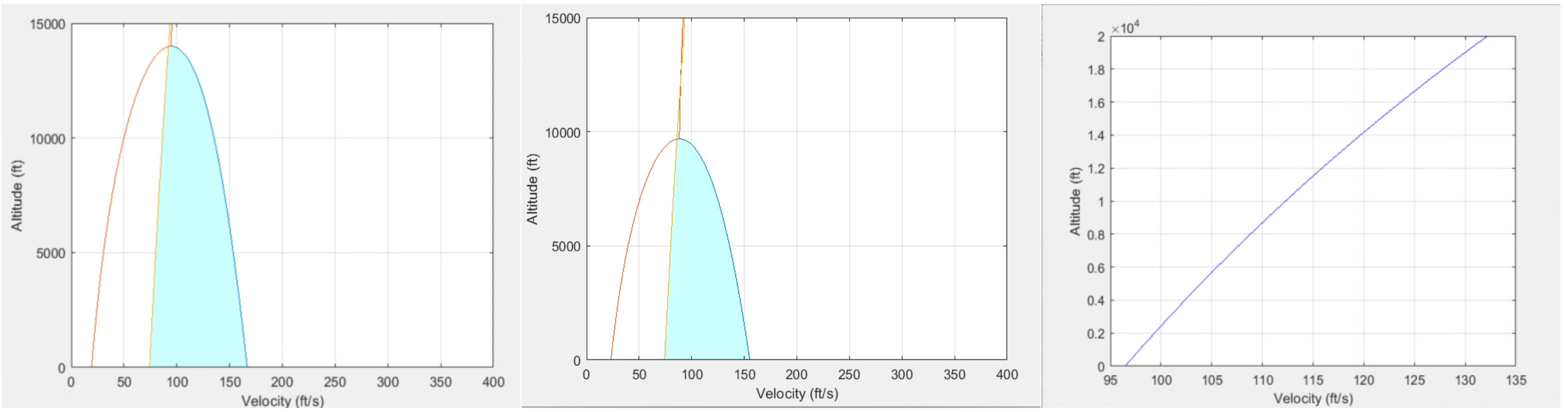
3.2.2 Aircraft Performance Team Calculations for Cessna 172S Skyhawk SP

For the proper evaluation of aircraft performance, specific values will be used in the team's calculations. All calculations will occur at a standard temperature. The altitude in which the following values will be computed is 6,000 ft. The propeller will have an RPM of 2300 and the service ceiling is 14,000 ft, with the best angle of climb at sea level occurring at a speed of 62 KIAS. (2) At 45% power, the aircraft will have a true airspeed of 94 knots, and a maximum range of 640 nautical miles. (2) Additional values that are needed for these calculations occur at an altitude of 2,000 ft. The maximum continuous power percentage is 77%. (2) The true airspeed will be118 knots and the fuel consumption rate will be 10.4 gallons per hour. (2) The following table outlines the team's calculations. The hand calculations can be found in the Appendix (Items 7-9).

Table 4: Team Calculations for Cessna 172S Skyhawk SP

Coefficient of Induced Drag (k)	0.0484
Coefficient of Parasitic Drag (C_{Do})	0.0727
Drag Coefficient (C_D)	0.4545
(w/o flaps) Max Coefficient of Lift (C_{Lmax})	2.24
Propeller Efficiency (η)	0.796
Engine Characteristic (m)	2.016
(w/flaps) Max Coefficient of Lift (C_{Lmax})	3.326
$\gamma_{glide\ min}$	0.119 rad

The figures for flight envelopes generated through MATLAB are pictured below. The MATLAB scripts for these computations can be found in the Appendix (Items 10-12).



A B C

Figure 3: Flight Envelopes for Cessna 172S Skyhawk SP. A) Graph of Steady Flight Envelope Generated by MATLAB. B) Graph of Climb Flight Envelope Generated by MATLAB. C) Graph of Glide Flight Envelope Generated by MATLAB.

3.2.3 Evaluation of Cessna 172S Skyhawk SP

The Cessna 172S Skyhawk SP is a 1998 model of the Cessna aircrafts and it is well-rounded, light and has strong performance and efficient design. This model delivers a top speed of 124 knots at sea level and a service ceiling of 14,000 ft. (2) Performance calculations at standard temperature show reliable cruise capabilities, reaching 118 knots true airspeed at 2,000 ft and 45% power. (2) The aircraft's drag and lift coefficients, combined with a propeller efficiency of 79.6%, highlight its aerodynamic efficiency.

The MATLAB plots of the flight envelopes illustrate the flight performance of the Cessna 172S Skyhawk. Graph A and Graph B show that altitude peaks at an optimal climb velocity, with a distinct operational envelope (shaded in blue) where the aircraft can safely perform with Graph A depicting a max altitude of roughly 14,000 and Graph B depicting a max altitude of 9000 ft. Graph C highlights the optimal climb speed region, and the max velocity in this graph is 132 ft/s. Although the 172S is a slightly newer model compared to the 172 R, their flight envelope data is similar. The team analyses confirm the 172S as a dependable aircraft for both training, general aviation use as well as a strong candidate for analysis.

3.3 Cessna 172N Skyhawk N

3.3.1 Manufacturer Specifications for Cessna 172N Skyhawk N

The following specifications are from the Cessna 172N Skyhawk N POH. (10)

Table 5: Quantitative Manufacturing Specifications for Cessna 172N Skyhawk N

Propeller Diameter	75”
Wing Area	174 ft^2
Total Capacity	43 U.S. gallons
Maximum Power	160 BHP rating
Max Engine Speed	2700 RPM
Max Takeoff Weight	2550 lbs
Max Velocity at Sea Level	122knots

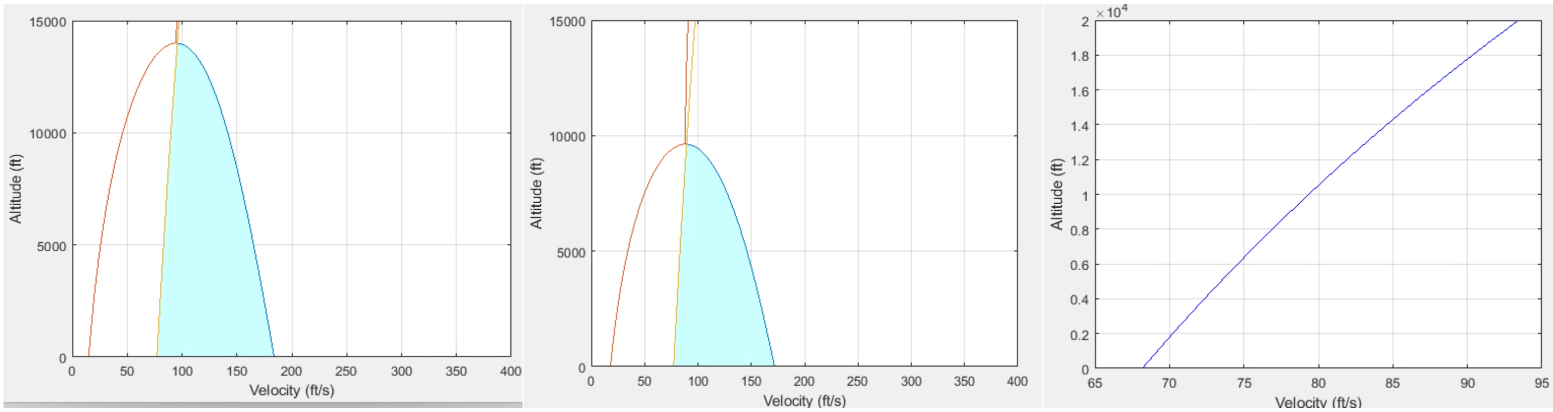
3.3.2 Aircraft Performance Team Calculations for Cessna 172N Skyhawk N

The following values will be used in the team’s calculations. All calculations will occur at a standard temperature. The total aircraft weight (with fuel included) is 2,300 pounds. (10) The altitude for this specific scenario is 6,000 ft. The propeller will have an RPM of 2300 and the service ceiling value is 14,200 ft, with the best angle of climb at sea level occurring at a speed of 65 KIAS. (10) At 45% power, the aircraft will have a true airspeed of 93 knots, and a maximum range of 750 nautical miles. (10) Additional values that are needed for these calculations occur at an altitude of 2,000 ft. The maximum continuous power percentage is 75%. (10) With these specific conditions, the true airspeed will have a value of 116 knots and the fuel consumption rate will be 8.4 gallons per hour. (10) The hand calculations for the following values may be found in the Appendix (Items 13-15).

Table 6: Team Calculations for Cessna 172N Skyhawk N

Coefficient of Induced Drag (k)	0.041
Coefficient of Parasitic Drag (C_{Do})	0.05
Drag Coefficient (C_D)	0.42
(w/o flaps) Max Coefficient of Lift (C_{Lmax})	1.8685
Propeller Efficiency (η)	0.796
Engine Characteristic (m)	2.608
(w/flaps) Max Coefficient of Lift (C_{Lmax})	2.412
$\gamma_{glide\ min}$	0.09055 rad

The figures for flight envelopes generated through MATLAB are pictured below. The MATLAB scripts for these computations can be found in the Appendix (Items 16-18)



A B C

Figure 4:Flight Envelopes for Cessna 172N Skyhawk N. A) Graph of Steady Flight Envelope Generated by MATLAB. B) Graph of Climb Flight Envelope Generated by MATLAB. C) Graph of Glide Flight Envelope Generated by MATLAB

3.3.3 Evaluation of Cessna 172N Skyhawk N

The Cessna 172N Skyhawk is a 1978 model of the Cessna aircrafts, which exhibits well-balanced performance characteristics, supported by its specifications and derived performance metrics. (10) The aircraft attains a maximum velocity of 122 knots at sea level and a service ceiling of 14,200 ft, confirming its capabilities for both training and recreational flight operations. (10) The leftmost flight envelope graph illustrates the relationship between airspeed and altitude, revealing the operational limits of the aircraft; the apex of the curve indicates the maximum attainable altitude at a specific velocity, which is critical for optimizing climb performance. Performance calculations at 6,000 ft, with a total weight of 2,300 lbs., demonstrate efficient operational parameters, including a propeller efficiency of 0.796. (10) With a maximum range of 750 nautical miles and given the aircraft's aerodynamic coefficients (C_{Lmax}) of 1.8685 without flaps and 2.412 with flaps), the Cessna 172N effectively balances lift and drag, contributing to its operational versatility.

Graph A and Graph B show that altitude peaks at an optimal climb velocity, with a distinct operational envelope (shaded in blue) where the aircraft can safely perform with Graph A depicting a max altitude of roughly 14,000 and Graph B depicting a max altitude of 9000 ft which demonstrates the Cessna’s ability to climb at altitude (ft) given its velocity (ft/s). This is similar to the flight envelope values for the 172R and 172S Graph C highlights the optimal climb speed region, revealing that small changes in velocity near this point can significantly affect altitude performance, the max velocity in this graph is 94 ft/s which differs from the Cessna 172R and 172S, likely because the Cessna 172N is the oldest of the aircrafts being evaluated.

3.4 Diamond DA40 Diamond Star NG

3.4.1 Manufacturer Specifications for Diamond DA40 Diamond Star NG

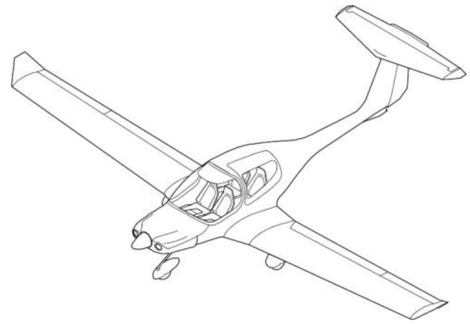


Figure 5: Diamond DA40 Diamond Star NG top view. Image taken from source (4).

The Quantitative Manufacturing Specifications for the Diamond DA40 Diamond Star NG are taken from the Diamond DA40 Diamond Star Flight Manual and are as follows. (4)

Table 7: Quantitative Manufacturing Specifications for Diamond DA40 Diamond Star NG

Wing Area	145.7 ft^2
Total Capacity	39 US gallons
Max Takeoff Weight	2,888 lbs.

3.4.2 Aircraft Performance Team Calculations for Diamond DA40 Diamond Star NG

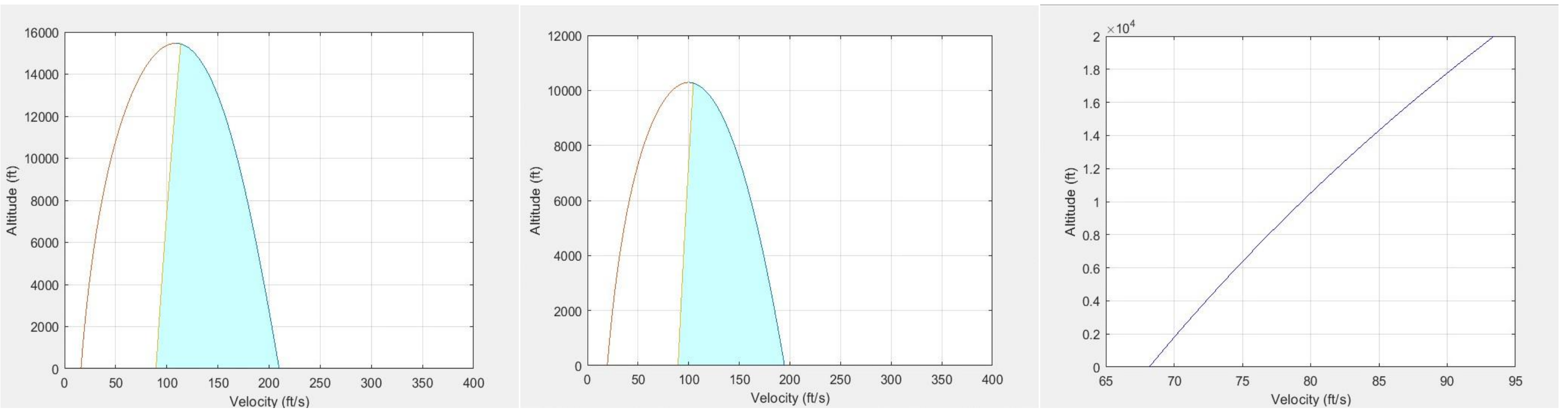
To evaluate aircraft performance, specific values will be used in the team's calculations. All calculations will occur at a standard temperature. All the following values were taken from the Diamond Star DA 40 NG Airplane Flight Manual. (4) The total aircraft weight is 2,535 pounds. (4) The altitude for the specific scenario in which the following values will be computed is 6,000ft. The propeller will have an RPM of 2300 and the service ceiling value that will be used is 16,400 ft, with the best angle of climb at sea level occurring at a speed of 65 KIAS. (4) At 65% power, the aircraft will have a true airspeed of 137 knots, and a maximum range of 934 nautical miles. (4)

Additional values that are needed for these calculations occur at an altitude of 2,000 ft. The maximum continuous power percentage is 65%. (4) With these specific conditions, the fuel consumption rate will be 8.5 gallons per hour.

Table 8: Team Calculations for Diamond DA40 Diamond Star NG

Coefficient of Induced Drag (k)	0.0303
Coefficient of Parasitic Drag (C_{Do})	0.0404
Drag Coefficient (C_D)	0.46
(w/o flaps) Max Coefficient of Lift (C_{Lmax})	1.8277
Propeller Efficiency (η)	0.796
Engine Characteristic (m)	2.392
$\gamma_{glide\ min}$	0.1332 rad

The figures for flight envelopes generated through MATLAB are pictured below. Additionally, the MATLAB scripts for these computations can be found in the Appendix (Items 20-22).



A B C

Figure 6:Flight Envelopes for Diamond DA40 Diamond Star NG. A) Graph of Steady Flight Envelope Generated by MATLAB. B) Graph of Climb Flight Envelope Generated by MATLAB. C) Graph of Glide Flight Envelope Generated by MATLAB

3.4.3 Evaluation of Diamond DA40 Diamond Star NG

The Diamond Star DA40 NG is a 2010 model of the Diamond Aircrafts which exhibits well-rounded performance characteristics. (4) The aircraft exhibits power and operational efficiency, achieving a maximum takeoff weight of 2,888 lbs. (4) The DA40 NG delivers strong thrust and good fuel economy. With a low parasitic drag coefficient (C_{Do}= 0.0404) and a high maximum lift coefficient (C_{Lmax}= 1.8277), it offers forgiving low-speed handling, short-field capability, and impressive glide performance (minimum glide angle of 0.1332 radians). (4)

Graph A depicts a max altitude of roughly 15,000 occurring at approximately 115 ft/s. Graph B depicts a maximum attainable altitude of approximately 10,300ft at 100ft/s, which demonstrates Diamond's ability to climb at altitude (ft) given its velocity(ft/s). These values are slightly higher than the flight envelope values for the Cessna Aircrafts. Graph C highlights the optimal climb speed region, revealing that small changes in velocity near this point can significantly affect altitude performance. Graph C displays a near linear increase in altitude as velocity increases from 66ft/s to a max velocity of 94ft/s which is the same as the oldest model of the Cessna.

The differences in these graphs in comparison to those of the Cessna may be because it's a newer model of aircraft and the manufacturer may have prioritized max altitude for the steady and climbing flight making these values higher versus the velocity for the glide. The climb and glide flight envelopes further demonstrate the aircraft's versatility, making it suitable for a variety of flight operations while maintaining operational capabilities. Overall, the Diamond is the newest of all the aircraft models evaluated, proving it to be a strong candidate for comparative analysis.

3.5 Technical Comparison of Aircraft

This technical comparison entails the following aircraft: Cessna 172S, Cessna 172R, Cessna 172N, and Diamond Star 40 NG. The purpose of the comparative analysis is to select the optimal aircraft providing the most benefits to add to the company's fleet.

All the aircrafts are four-seat, single-propeller light aircraft, featuring a 76'' diameter McCauley 1A170E/JHA7660 propeller. (1) The Cessna Aircrafts utilize 100LL fuel. (2) The Diamond DA40 utilizes both 100LL fuel and 130LL fuel, offering greater refueling flexibility. (4) Safety data indicate that Diamond aircraft have a significantly lower mishap rate compared to Cessna models. (6) From a cost perspective, however, Cessna 172 variants are more affordable than the Diamond DA40 Diamond Star NG, making them attractive to cost-conscious clients.

Technical analysis, supported by hand calculations and MATLAB-generated flight envelopes, was conducted for the Cessna 172N Skyhawk N, Cessna 172R Skyhawk R, Cessna 172S Skyhawk SP, and the Diamond DA40. The Cessna 172N achieves a cruise speed of approximately 104 knots at 6,000 ft, with a fuel consumption of 8.5 gallons per hour. (2) The Cessna 172R offers a similar performance, with a cruise speed of 104 knots at 6,000 ft and a fuel consumption of 8.5 gallons per hour. (9) The Cessna 172S, however, has a higher cruise speed of 118 knots at 2,000 ft and a slightly increased fuel consumption of 9.0 gallons per hour. (10) The Diamond DA40 stands out with a cruise speed of approximately 138 knots at 8,000 ft and a fuel consumption of 8.5 gallons per hour, offering the best performance in terms of both speed and fuel efficiency. (4) Overall, the 172S provides the highest cruise speed among the Cessna variants, while the DA40 outperforms all three Cessnas in both cruise speed and fuel efficiency.

4. Recommendations

After careful consideration, evaluation, and computation performed by the Aircraft Performance Team, it is our recommendation that the client prioritize the Diamond DA40 Diamond Star NG as an addition to their team. The Diamond DA40 Diamond Star has a long record of being safer with fewer mishaps than the Cessna 172 models (6). Additionally, its ability to accept multiple fuel types makes it a more economical option in terms of aircraft refueling.

The technical performance of the Diamond DA40 Diamond Star NG completely outperforms the Cessna 172 models and overall, has highly impressive parameters. Its low parasitic drag coefficient and high maximum lift coefficient optimize the lift to drag ratio.

The second recommendation that the Aircraft Performance Team gives is the Cessna 172S Skyhawk SP. While this model does not have the same reliable safety as the Diamond DA40 Diamond Star NG, it is the newest Cessna model that is evaluated in this report. (5) This model has the highest lift coefficient out of the Cessna models that were evaluated in this report.

Additionally, the Cessna 172S Skyhawk SP is less expensive than the Diamond DA40 Diamond Star NG. If the client is most concerned about the upfront initial costs for the aircraft, they should take this factor into consideration.

References

1 Rosenow K. Feasibility Study of Serial Hybrid-Electric Systems in Small Aircraft.

2 Cessna Aircraft Company. Skyhawk SP Information Manual. [Internet]. BEFA.org 2019 [cited 2025 Apr 8]. Available from: https://www.befa.org/wp-content/uploads/2019/12/POH-Cessna-172S.pdf

3 AOPA Airports [Internet]. Aopa.org. 2025 [cited 2025 Apr 8]. Available from: https://www.aopa.org/destinations/airports/KGNV/details#notams

4 Diamond Aircraft Industries. DA40-180 Airplane Flight Manual [Internet]. Diamond Air; 2021 [cited 2025 Apr 27]. Available from: http://support.diamond-air.at/fileadmin/uploads/files/after_sales_support/DA40-180/Airplane_Flight_Manual/Basic_Manual/60101e-r10-complete.pdf

5 Federal Aviation Administration. Preliminary accident and incident reports [Internet]. 2025 [cited 2025 Apr 27]. Available from: https://www.asias.faa.gov/apex/f?p=100%3A93%3A%3A%3ANO%3A%3A%3A

6 Genesis Flight College. Why diamond aircraft are the safest choice for aviation training: Genesis Flight College [Internet]. 2024 [cited 2025 Apr 27]. Available from: https://flygenesis.ca/flight-training-blog/why-diamond-aircraft-are-the-safest-choice-for-aviation-training/#:~:text=The%20Diamond%20aircraft%20have%20the,Diamond%20DA40%20has%204.0%20mishaps.

7 AOPA. Cessna 172s [Internet]. 2020 [cited 2025 Apr 27]. Available from: https://www.aopa.org/go-fly/aircraft-and-ownership/aircraft-guide/aircraft/cessna-172

8 Premier Aircraft. Premier aircraft [Internet]. 2025 [cited 2025 Apr 27]. Available from: https://www.premieraircraft.com/

9 Cessna Aircraft Company. Information Manual Model 172R [Internet]. 1997 [cited 2025 Apr 27]. Available from: https://wayman.edu/files/172R-POH.pdf

10 Cessna Aircraft Company. Cessna 172 Pilot's Operating Handbook [Internet]. 1978 [cited 2025 Apr 27]. Available from: https://wayman.edu/files/Cessna-172N-POH.pdf

Appendix

Item 1: Hand Calculations for Cessna 172R Skyhawk R Page 1

C172R Max Weight = 2450 lb $S = 174\ ft^2$

$V_{\gamma_{min}} = 65\ kts = 109.77\ ft/s = \sqrt{\frac{2W}{\rho S}\sqrt{\frac{k}{C_{D0}}}}$

$\rho @ 6000\ ft = 1.987E{-3}$

$\sqrt{\frac{k}{C_{D0}}} = 0.55$, $C_L = 1.1763$

V_{stall} : W flaps W/o flaps

47 knts $= 79.3\ ft/s$ 51 kts $= 86.07\ ft/s$

$V_{stall} = \sqrt{\frac{2W}{\rho S C_{L_{max}}}}$ $C_{L_{max}}$: W flaps W/o flaps

2.253 1.9131

3. $\eta = \frac{T_{min} V_{max}}{P_{max}}$ = (for study) $\frac{672(lb) \cdot 117.33 \left(\frac{ft}{s}\right)}{180\ hp \cdot 550 \frac{ft\ lb}{s\ hp}}$

$= 0.796$

4. Power specific fuel consumption

@ 2000 ft, 79% Bhp, 9.0 gph

$C_p = 9.0\ gph \cdot 6\ lb/g \cdot \frac{1}{\%Bhp} \cdot \frac{1}{160\ hp}$

$= 0.427$

Item 2: Hand Calculations for Cessna 172R Skyhawk R Page 2

Max Range: 687 nm = 4176960 ft

$$R = \frac{\eta}{C_p}\left(\frac{\sqrt{\frac{C_{D_0}}{k}}}{2C_{D_0}}\right)\ln\left|\frac{W_i}{W_f}\right|$$

, C_p: 2.156E-7

W_i: 2450 lb

↓ 53 gal · 6 $\frac{lb}{gal}$

W_f: 2132 lb

η: 0.796

$$\frac{C_L}{C_D} : 8.139 = \frac{\sqrt{\frac{C_{D_0}}{k}}}{2C_{D_0}}$$

$\sqrt{\frac{C_{D_0}}{k}}$: 1.1763, C_{D_0} : 0.0722, k : 0.0522

Flight Ceiling: 13500 ft → ρ: 1.5957E-3 slugs/ft^3

$$\eta\left(\frac{\rho_1}{\rho_s}\right)^n P_{max} = \frac{4}{3}\sqrt{\frac{2W^3}{\rho S}\sqrt{3k^3 C_{D_0}}}$$

n = 1.9389

Item 3: Hand Calculations for Cessna 172R Skyhawk R Page 3

C172R Variables

W_i = 2450 lb

W_f: 2132 lb

η: 0.796

C_p = 0.427 $\frac{lb}{hr\ hp}$

n: 1.9389

C_{D_0}: 0.0722

k: 0.0522

$C_{L_{max}}$: W Flaps: 2.253

W/o Flaps: 1.9131

S: 174 ft^2

γ_{max}: 1.222

Item 4: MATLAB Script for Cessna 172R Skyhawk R Steady

```
h=linspace (0,15000,500);
for k=1:size(h,2)
    [Vmax(k) VminTC(k) Vstall(k)]=SLFP(h(k));
end
Vmin=max (VminTC,Vstall);
fill([Vmin Vmax(end:-1:1)],[h h(end:-1:1)],[0.8 1 1], 'Linestyle','none');
hold on;
plot (Vmax,h,VminTC,h,Vstall,h);
grid on;
xlim ([0 400]);
xlabel ('Velocity (ft/s)');
ylabel ('Altitude (ft)');
function [Vmax VminPC Vstall]=SLFP(h);
%Input: altitude h (ft)
%Output: max air speed Vmax (ft/s), min air speed due to thrust
%constraint VminPC (ft/s),
% stall speed Vstall (ft/s)
W=2450; S=174; CD0=0.0722; K=0.0522; Psmax=160*550; m=1.9389;
CLmax=1.9131; eta=0.796;
[Ts ps rhos]=StdAtpUS (0);
[T p rho]=StdAtpUS (h);
tmp=sort (roots ([1/2*rho*S*CD0 0 0 -eta*Psmax* (rho/rhos)^m 2*K*W^2/rho/S]));
Vmax=tmp (2);
VminPC=tmp (1);
Vstall=sqrt (2*W/rho/S/CLmax);
end
function [T p rho]=StdAtpUS(h)
%Standard Atmosphere
%Input : h altitute (ft)
%Output : T temperature (F), p pressure (lbs/ft^2), rho density (slug/ft^3)
h1=3.6089e4; h2=6.5616e4; h3=9.0e4; a0=-3.567e-3;
a2=5.494e-4; g=32.2;
R=1716;
T0=518.67; p0=2116.2; rho0=2.3769e-3; T1=T0+a0*h1;
p1=p0*(T1/T0)^(-g/a0/R); rho1=rho0*(T1/T0)^(-g/a0/R-1);
T2=T1;
p2=p1*exp(-g/R/T2*(h2-h1)); rho2=rho1*exp(-g/R/T2*(h2-h1));
if h <=h1
    disp('Troposphere');
    T=T0+a0*h;
    p=p0*(T/T0)^(-g/a0/R);
    rho=rho0*(T/T0)^(-g/a0/R-1);
elseif h <= h2
    disp('Tropopause');
    T=T1;
    p=p1*exp(-g/R/T*(h-h1));
    rho=rho1*exp(-g/R/T*(h-h1));
elseif h <= h3
    disp('Stratosphere');
    T=T2+a2*(h-h2);
    p=p2*(T/T2)^(-g/a2/R);
    rho=rho2*(T/T2)^(-g/a2/R-1);
else
    disp('Error: the altitute should be less than 90000 ft' );
end
end
```

Item 5: MATLAB Script for Cessna 172R Skyhawk R Climb

```
 h=linspace(0,10000,500);

for k=1:size(h,2)
    [Vmax(k), VminTC(k) Vstall(k)]=SCFP(h(k),5);
end
Vmin=max(VminTC,Vstall);
fill([Vmin Vmax(end:-1:1)],[h h(end:-1:1)],[0.8 1 1], 'Linestyle','none');
hold on;
plot(Vmax,h,VminTC,h,Vstall,h);
grid on;
xlim([0 400]);
xlabel('Velocity (ft/s)');
ylabel('Altitude (ft)');
function [Vmax VminPC Vstall]=SCFP(h,Vclimb);
%Input: altitude h (ft)
%Output: max air speed Vmax (ft/s), min air speed due to thrust constraint VminPC (ft/s),
%stall speed Vstall (ft/s)
W=2450; S=174; CD0=0.0722; K=0.0522; Psmax=160*550; m=1.9389;
CLmax=1.9131; eta=0.796;
[Ts ps rhos]=StdAtpUS(0);
[T p rho]=StdAtpUS(h);
tmp=sort(roots([1/2*rho*S*CD0 0 0 W*Vclimb-eta*Psmax*(rho/rhos)^m ...
    2*K*W^2/rho/S]));
Vmax=tmp(2);
VminPC=tmp(1);
Vstall=sqrt(2*W/rho/S/CLmax);
end
function [T p rho]=StdAtpUS(h)
%Standard Atmosphere
%Input : h altitute (ft)
%Output : T temperature (F), p pressure (lbs/ft^2), rho density(slug/ft^3)
h1=3.6089e4; h2=6.5616e4; h3=9.0e4; a0=-3.567e-3;
a2=5.494e-4; g=32.2;
R=1716;
T0=518.67; p0=2116.2; rho0=2.3769e-3; T1=T0+a0*h1;
p1=p0*(T1/T0)^(-g/a0/R); rho1=rho0*(T1/T0)^(-g/a0/R-1);
T2=T1;
p2=p1*exp(-g/R/T2*(h2-h1)); rho2=rho1*exp(-g/R/T2*(h2-h1));
if h <=h1
    disp('Troposphere');
    T=T0+a0*h;
    p=p0*(T/T0)^(-g/a0/R);
    rho=rho0*(T/T0)^(-g/a0/R-1);
elseif h <= h2
    disp('Tropopause');
    T=T1;
    p=p1*exp(-g/R/T*(h-h1));
    rho=rho1*exp(-g/R/T*(h-h1));
elseif h <= h3
    disp('Stratosphere');
    T=T2+a2*(h-h2);
    p=p2*(T/T2)^(-g/a2/R);
    rho=rho2*(T/T2)^(-g/a2/R-1);
else
    disp('Error: the altitude should be less than 90000ft' );
end
end
```

Item 6: MATLAB Script for Cessna 172R Skyhawk R Glide

```
gangle=0.123;

h=linspace(0,20000,100);%Vector of altitudes
for k=1:size(h,2)
    [V(:,k) Vstall(k)]=SGFP(h(k),gangle);
end
plot(V(1,:),h,'b-');
grid on;
xlabel('Velocity (ft/s)');
ylabel('Altitude (ft)');
function [V Vstall]=SGFP(h,gangle);
%Input: altitude h (ft) glide angle gangle (rad)
%Output: gliding airspeed V (ft/s), stall speed Vstall (ft/s)
W=2450; S=174; CD0=0.0722; K=0.0522; CLmax=1.9131;
[T p rho]=StdAtpUS(h);
tmp=sort(roots([1/2*rho*S*CD0/W 0 -gangle 0 2*K*W/rho/S]));
V=tmp(3:4); Vstall=sqrt(2*W/rho/S/CLmax);
end
```

Item 7: Hand Calculations for Cessna 172S Skyhawk S Page 1

1. $V_{\gamma_{min}} = \sqrt{\frac{2W}{S\rho}\sqrt{\frac{k}{C_{D_0}}}} = 69.77\ ft/s$

$\boxed{\text{C172S}}$

$\sqrt{\frac{k}{C_{D_0}}} = 0.816$, $C_L = 1.22$

$\gamma_{min} = 2\sqrt{C_{D_0}K} =$

2. $V_{stall} = \sqrt{\frac{2W}{S\rho C_{L_{max}}}} = $ 81.014873 ft/s (w/o flaps)
67.512 ft/s (w flaps)

W/O Flaps $C_{L_{max}} = 2.24$

W Flaps $C_{L_{max}} = 3.236$

80 mph

3. $\eta = \frac{max\ T \cdot V}{P_{max}} = \frac{672 \cdot 117.33\ ft/s}{160\ hp \cdot 550 \frac{ft}{s} \cdot \frac{lb}{hp}} = \underline{0.796}$

4. $P = TV$, 160 hp @ sea level

Flight ceiling $= \underline{\eta} \left(\frac{\rho_h}{\rho_s}\right)^m \underline{P_{max}} = \frac{4}{3}\sqrt{\frac{2W^3}{\rho S}\sqrt{3K^3 C_{D_0}}}$

Flight ceiling: 14050 ft, $\rho = 1.545\ E\text{-}3$

Thrust

$\eta = 0.71$
$\delta_t = 0.77$

$m = 2.016$

$P_{av} = TV_{req}$

$\frac{TV}{P}$ $\epsilon\rho$

$P_{max} = 160 \cdot 550$
$V = 205.91$
$W = 2550\ lb$

Item 8: Hand Calculations for Cessna 172S Skyhawk S Page 2

Power specific fuel consumption:

@ 2000 ft, 77% power, GPH = 10.4

$10.4\,\text{gal} \cdot \frac{6\,(\text{lb})}{\text{gal}} \Big/ (180\,\text{hp} \cdot 0.77) = 0.4545$

$C_p = 0.4545\ \frac{\text{lb}}{\text{hp h}} =$

$$\text{Range} = \frac{\eta}{C_p}\left(\frac{\sqrt{\frac{C_{D_0}}{k}}}{2C_{D_0}}\right)\ln\left(\frac{W_i}{W_f}\right)$$

$W_i = 2550$

$W_f = 2232$

$$\frac{\sqrt{\frac{C_{D_0}}{k}}}{2C_{D_0}} = 8.42$$

$\eta = 0.71$

Max Range = 640 nm = 3,888,716.8 ft

$C_p = 0.4545\ \frac{\text{lb}}{\text{hr hp}} = 2.295E{-7}\ \frac{1}{\text{ft}}$

$$\frac{\left(\sqrt{\frac{k}{C_{D_0}}}\right)^{-1}}{2C_{D_0}} = 9.43618$$

$$\frac{(0.816)^{-1}}{2C_{D_0}} = 9.43618$$

$C_{D_0} = 0.0727 \quad k = 0.0484$

Item 9: Hand Calculations for Cessna 172S Skyhawk S Page 3

- Variables

$k = 0.0484$

$C_{D_0} = 0.0727$

$C_p = 0.4545\ \frac{\text{lb}}{\text{hr hp}}$

$W = 2550$ lbs

$S = 174\ \text{ft}^2$

W/O Flaps $C_{L_{max}} = 2.24$

W Flaps $C_{L_{max}} = 3.326$

$r = 2.016$

$\eta = 0.796$

$\gamma_{glide_{min}} = 0.119$

Item 10: MATLAB Script for Cessna 172S Skyhawk S Steady

```
h=linspace (0,15000,500);
for k=1:size(h,2)
    [Vmax(k) VminTC(k) Vstall(k)]=SLFP(h(k));
end
Vmin=max (VminTC,Vstall);
fill([Vmin Vmax(end:-1:1)],[h h(end:-1:1)],[0.8 1 1], 'Linestyle','none');
hold on;
plot (Vmax,h,VminTC,h,Vstall,h);
grid on;
xlim ([0 400]);
xlabel ('Velocity (ft/s)');
ylabel ('Altitude (ft)');
function [Vmax VminPC Vstall]=SLFP(h);
%Input: altitude h (ft)
%Output: max air speed Vmax (ft/s), min air speed due to thrust
%constraint VminPC (ft/s),
% stall speed Vstall (ft/s)
W=2550; S=174; CD0=0.0727; K=0.0484; Psmax=180*550; m=2.016;
CLmax=2.24; eta=0.796;
[Ts ps rhos]=StdAtpUS (0);
[T p rho]=StdAtpUS (h);
tmp=sort (roots ([1/2*rho*S*CD0 0 0 -eta*Psmax* (rho/rhos)^m 2*K*W^2/rho/S]));
Vmax=tmp (2);
VminPC=tmp (1);
Vstall=sqrt (2*W/rho/S/CLmax);
end
function [T p rho]=StdAtpUS(h)
%Standard Atmosphere
%Input : h altitute (ft)
%Output : T temperature (F), p pressure (lbs/ft^2), rho density (slug/ft^3)
h1=3.6089e4; h2=6.5616e4; h3=9.0e4; a0=-3.567e-3;
a2=5.494e-4; g=32.2;
R=1716;
T0=518.67; p0=2116.2; rho0=2.3769e-3; T1=T0+a0*h1;
p1=p0*(T1/T0)^(-g/a0/R); rho1=rho0*(T1/T0)^(-g/a0/R-1);
T2=T1;
p2=p1*exp(-g/R/T2*(h2-h1)); rho2=rho1*exp(-g/R/T2*(h2-h1));
if h <=h1
    disp('Troposphere');
    T=T0+a0*h;
    p=p0*(T/T0)^(-g/a0/R);
    rho=rho0*(T/T0)^(-g/a0/R-1);
elseif h <= h2
    disp('Tropopause');
    T=T1;
    p=p1*exp(-g/R/T*(h-h1));
    rho=rho1*exp(-g/R/T*(h-h1));
elseif h <= h3
    disp('Stratosphere');
    T=T2+a2*(h-h2);
    p=p2*(T/T2)^(-g/a2/R);
    rho=rho2*(T/T2)^(-g/a2/R-1);
else
    disp('Error: the altitute should be less than 90000 ft' );
end
end
```

Item 11: MATLAB Script for Cessna 172S Skyhawk S Climb

```
h=linspace(0,15000,500);
for k=1:size(h,2)
    [Vmax(k), VminTC(k) Vstall(k)]=SCFP(h(k),5);
end
Vmin=max(VminTC,Vstall);
fill([Vmin Vmax(end:-1:1)],[h h(end:-1:1)],[0.8 1 1], 'Linestyle','none');
hold on;
plot(Vmax,h,VminTC,h,Vstall,h);
grid on;
xlim([0 400]);
xlabel('Velocity (ft/s)');
ylabel('Altitude (ft)');
function [Vmax VminPC Vstall]=SCFP(h,Vclimb);
%Input: altitude h (ft)
%Output: max air speed Vmax (ft/s), min air speed due to thrust constraint VminPC
(ft/s),
%stall speed Vstall (ft/s)
W=2550; S=174; CD0=0.0727; K=0.0484; Psmax=180*550; m=2.016;
CLmax=2.24; eta=0.796;
[Ts ps rhos]=StdAtpUS(0);
[T p rho]=StdAtpUS(h);
tmp=sort(roots([1/2*rho*S*CD0 0 0 W*Vclimb-eta*Psmax*(rho/rhos)^m ...
    2*K*W^2/rho/S]));
Vmax=tmp(2);
VminPC=tmp(1);
Vstall=sqrt(2*W/rho/S/CLmax);
end
function [T p rho]=StdAtpUS(h)
%Standard Atmosphere
%Input : h altitute (ft)
%Output : T temperature (F), p pressure (lbs/ft^2), rho density(slug/ft^3)
h1=3.6089e4; h2=6.5616e4; h3=9.0e4; a0=-3.567e-3;
a2=5.494e-4; g=32.2;
R=1716;
T0=518.67; p0=2116.2; rho0=2.3769e-3; T1=T0+a0*h1;
p1=p0*(T1/T0)^(-g/a0/R); rho1=rho0*(T1/T0)^(-g/a0/R-1);
T2=T1;
p2=p1*exp(-g/R/T2*(h2-h1)); rho2=rho1*exp(-g/R/T2*(h2-h1));
if h <=h1
    disp('Troposphere');
    T=T0+a0*h;
    p=p0*(T/T0)^(-g/a0/R);
    rho=rho0*(T/T0)^(-g/a0/R-1);
elseif h <= h2
    disp('Tropopause');
    T=T1;
    p=p1*exp(-g/R/T*(h-h1));
    rho=rho1*exp(-g/R/T*(h-h1));
elseif h <= h3
    disp('Stratosphere');
    T=T2+a2*(h-h2);
    p=p2*(T/T2)^(-g/a2/R);
    rho=rho2*(T/T2)^(-g/a2/R-1);
else
    disp('Error: the altitute should be less then 90000ft' );
end
end
```

Item 12: MATLAB Script for Cessna 172S Skyhawk S Gliding

```
angle=0.119;
h=linspace(0,20000,100);%Vector of altitudes
for k=1:size(h,2)
    [V(:,k) Vstall(k)]=SGFP(h(k),gangle);
end
plot(V(1,:),h,'b-');
grid on;
xlabel('Velocity (ft/s)');
ylabel('Altitude (ft)');
function [V Vstall]=SGFP(h,gangle);
%Input: altitude h (ft) glide angle gangle (rad)
%Output: gliding airspeed V (ft/s), stall speed Vstall (ft/s)
W=2550; S=174; CD0=0.0727; K=0.0484; CLmax=2.24;
[T p rho]=StdAtpUS(h);
tmp=sort(roots([1/2*rho*S*CD0/W 0 -gangle 0 2*K*W/rho/S]));
V=tmp(3:4); Vstall=sqrt(2*W/rho/S/CLmax);
end
```

Item 13: Hand Calculations for Cessna 172N Skyhawk N Page 1

Cessna 172N $W = 2300\,lb$ $S = 174\,ft^2$

$V_{glide\,min} = 65\,knts = 109.77\,ft/s = \sqrt{\frac{2W}{\rho S}}\sqrt{\frac{k}{C_{D0}}}$

$\rho @ 6000 = 1.9867\,\frac{slugs}{ft^3}$ $\sqrt{\frac{k}{C_{D0}}} = 0.9055$, $C_L = 1.104$

V_{stall}

w/o Flaps: $50\,knts = 84.39\,ft/s$
w Flaps: $44\,knts = 74.263\,ft/s$
$= \sqrt{\frac{2W}{\rho S C_{L_{max}}}}$

· $C_{L_{max}}$

w Flaps: 2.412

w/o Flaps: 1.5605

3. $\eta = \frac{T_{max} \cdot V_{max}}{P} = \frac{672 \cdot 117.73\,\frac{ft\,lb}{s}}{160 \cdot 550\,\frac{ft\,lb}{s}} = 0.7964$

74" Aluminum Blade

4. Power specific Fuel: @ 2000 ft, 8.4 gph @ 75% BHP

$C_p = 8.4\,gph \cdot 6\,\frac{lb}{gal} \cdot \frac{1}{160\,hp} \cdot \frac{1}{0.75} = 0.42\,\frac{lb}{hr\,hp}$

Item 14: Hand Calculations for Cessna 172N Skyhawk N Page 2

Range: Max: 750 NM

$R = 750 \text{ NM} = 4{,}560{,}000 \text{ ft}$

$$= \frac{\eta}{C_p}\left(\frac{\sqrt{\frac{C_{D_0}}{k}}}{2C_{D_0}}\right)\ln\left(\frac{W_i}{W_f}\right)$$

$W_i = 2300 \text{ lb}$, $W_f = 2060 \text{ lb}$ } 40 gal

$\eta = 0.796$

$C_p = 2.121212E\text{-}7 \ \frac{1}{ft}$

$$\frac{\sqrt{\frac{C_{D_0}}{k}}}{2C_{D_0}} = 11.02$$

$$\frac{\left(\sqrt{\frac{k}{C_{D_0}}}\right)^{-1}}{2C_{D_0}} = 11.02$$

$C_{D_0} = 0.05$

$k = 0.041$

Flight ceiling: 14200 ft, ρ@14600 = 1.545E-3

$$\eta\left(\frac{\rho_h}{\rho_s}\right)^m \cdot P_{max} = \frac{4}{3}\sqrt{\frac{2W^3}{\rho S}\sqrt{3k^3 C_{D_0}}}$$

$m = 2.60824$

Item 15: Hand Calculations for Cessna 172N Skyhawk N Page 3

C172N

Variables:

- $S = 174 \text{ ft}^2$
- $m = 2.608$
- $W = 2300 \text{ lb}$
- $C_p = 0.42 \ \frac{lb}{hp \cdot h}$
- $\eta = 0.796$
- $C_{D_0} = 0.05$
- $k = 0.041$
- $C_{L_{max}}$:
  - w/ flaps: 2.412
  - w/o flaps: 1.8685

$\gamma_{glide\,min} = 0.09055$

Item 16: MATLAB Script for Cessna 172N Skyhawk N Steady

```
h=linspace (0,15000,500);
for k=1:size(h,2)
    [Vmax(k) VminTC(k) Vstall(k)]=SLFP(h(k));
end
Vmin=max (VminTC,Vstall);
fill([Vmin Vmax(end:-1:1)],[h h(end:-1:1)],[0.8 1 1], 'Linestyle','none');
hold on;
plot (Vmax,h,VminTC,h,Vstall,h);
grid on;
xlim ([0 400]);
xlabel ('Velocity (ft/s)');
ylabel ('Altitude (ft)');
function [Vmax VminPC Vstall]=SLFP(h);
%Input: altitude h (ft)
%Output: max air speed Vmax (ft/s), min air speed due to thrust
%constraint VminPC (ft/s),
% stall speed Vstall (ft/s)
W=2300; S=174; CD0=0.05; K=0.041; Psmax=160*550; m=2.608;
CLmax=1.8685; eta=0.796;
[Ts ps rhos]=StdAtpUS (0);
[T p rho]=StdAtpUS (h);
tmp=sort (roots ([1/2*rho*S*CD0 0 0 -eta*Psmax* (rho/rhos)^m 2*K*W^2/rho/S]));
Vmax=tmp (2);
VminPC=tmp (1);
Vstall=sqrt (2*W/rho/S/CLmax);
end
function [T p rho]=StdAtpUS(h)
%Standard Atmosphere
%Input : h altitute (ft)
%Output : T temperature (F)
h1=3.6089e4; h2=6.5616e4; h3=9.0e4; a0=-3.567e-3;
a2=5.494e-4; g=32.2;
R=1716;
T0=518.67; p0=2116.2; rho0=2.3769e-3; T1=T0+a0*h1;
p1=p0*(T1/T0)^(-g/a0/R); rho1=rho0*(T1/T0)^(-g/a0/R-1);
T2=T1;
p2=p1*exp(-g/R/T2*(h2-h1)); rho2=rho1*exp(-g/R/T2*(h2-h1));
if h <=h1
    disp('Troposphere');
    T=T0+a0*h;
    p=p0*(T/T0)^(-g/a0/R);
    rho=rho0*(T/T0)^(-g/a0/R-1);
elseif h <= h2
    disp('Tropopause');
    T=T1;
    p=p1*exp(-g/R/T*(h-h1));
    rho=rho1*exp(-g/R/T*(h-h1));
elseif h <= h3
    disp('Stratosphere');
    T=T2+a2*(h-h2);
    p=p2*(T/T2)^(-g/a2/R);
    rho=rho2*(T/T2)^(-g/a2/R-1);
else
    disp('Error: the altitute should be less then 90000 ft' );
end
end
```

Item 17: MATLAB Script for Cessna 172N Skyhawk N Climb

```
h=linspace(0,15000,500);
for k=1:size(h,2)
    [Vmax(k), VminTC(k) Vstall(k)]=SCFP(h(k),5);
end
Vmin=max(VminTC,Vstall);
fill([Vmin Vmax(end:-1:1)],[h h(end:-1:1)],[0.8 1 1], 'Linestyle','none');
hold on;
plot(Vmax,h,VminTC,h,Vstall,h);
grid on;
xlim([0 400]);
xlabel('Velocity (ft/s)');
ylabel('Altitude (ft)');
function [Vmax VminPC Vstall]=SCFP(h,Vclimb);
%Input: altitude h (ft)
%Output: max air speed Vmax (ft/s), min air speed due to thrust constraint VminPC (ft/s),
%stall speed Vstall (ft/s)
W=2300; S=174; CD0=0.05; K=0.041; Psmax=160*550; m=2.608;
CLmax=1.8685; eta=0.796;
[Ts ps rhos]=StdAtpUS(0);
[T p rho]=StdAtpUS(h);
tmp=sort(roots([1/2*rho*S*CD0 0 0 W*Vclimb-eta*Psmax*(rho/rhos)^m ...
    2*K*W^2/rho/S]));
Vmax=tmp(2);
VminPC=tmp(1);
Vstall=sqrt(2*W/rho/S/CLmax);
end
function [T p rho]=StdAtpUS(h)
%Standard Atmosphere
%Input : h altitute (ft)
%Output : T temperature (F), p pressure (lbs/ft^2), rho density(slug/ft^3)
h1=3.6089e4; h2=6.5616e4; h3=9.0e4; a0=-3.567e-3;
a2=5.494e-4; g=32.2;
R=1716;
T0=518.67; p0=2116.2; rho0=2.3769e-3; T1=T0+a0*h1;
p1=p0*(T1/T0)^(-g/a0/R); rho1=rho0*(T1/T0)^(-g/a0/R-1);
T2=T1;
p2=p1*exp(-g/R/T2*(h2-h1)); rho2=rho1*exp(-g/R/T2*(h2-h1));
if h <=h1
    disp('Troposphere');
    T=T0+a0*h;
    p=p0*(T/T0)^(-g/a0/R);
    rho=rho0*(T/T0)^(-g/a0/R-1);
elseif h <= h2
    disp('Tropopause');
    T=T1;
    p=p1*exp(-g/R/T*(h-h1));
    rho=rho1*exp(-g/R/T*(h-h1));
elseif h <= h3
    disp('Stratosphere');
    T=T2+a2*(h-h2);
    p=p2*(T/T2)^(-g/a2/R);
    rho=rho2*(T/T2)^(-g/a2/R-1);
else
    disp('Error: the altitute should be less then 90000ft' );
end
end
```

Item 18: MATLAB Script for Cessna 172N Skyhawk N Glide

```
gangle=0.119;

h=linspace(0,20000,100);%Vector of altitudes
for k=1:size(h,2)
    [V(:,k) Vstall(k)]=SGFP(h(k),gangle);
end
plot(V(1,:),h,'b-');
grid on;
xlabel('Velocity (ft/s)');
ylabel('Altitude (ft)');
function [V Vstall]=SGFP(h,gangle);
%Input: altitude h (ft) glide angle gangle (rad)
%Output: gliding airspeed V (ft/s), stall speed Vstall (ft/s)
W=2300; S=174; CD0=0.05; K=0.041; CLmax=1.8685;
[T p rho]=StdAtpUS(h);
tmp=sort(roots([1/2*rho*S*CD0/W 0 -gangle 0 2*K*W/rho/S]));
V=tmp(3:4); Vstall=sqrt(2*W/rho/S/CLmax);
end
```

Item 19: Hand Calculations for Diamond DA40 Diamond Star NG

Project Work

Variables

$\gamma_{glide} = 0.1332$ [rad]

$K = 0.0303$

$C_{D_0} = 0.0404$

$\eta = 0.796$

$m = 2.392$

$W = 2535$ lbs

$C_p = 0.46$ lb/hr/lb

$S = 145.7\ ft^2$

$C_{L_{max}}$ (w/o flaps) $= 1.8277$

$$\eta = \frac{T_{max} \cdot V}{P_{max}} = 0.796$$

Same prop as Cessnas

$$\text{Max Range} = \frac{\eta}{C_P}\left(\frac{\sqrt{\frac{C_{D_0}}{K}}}{2C_{D_0}}\right)\ln\left(\frac{W_i}{W_f}\right)$$

$$\Longrightarrow \frac{C_{D_0}}{K} = 812.695\, C_{D_0}^2$$

$$V_{\gamma glide_{min}} = \sqrt{\frac{2W}{\rho S}\sqrt{\frac{K}{C_{D_0}}}} = 123.21\ ft/s$$

$$\sqrt{\frac{K}{C_{D_0}}} = 0.8665$$

$K = 0.0303 \qquad C_{D_0} = 0.0404$

$$V_{stall} = \sqrt{\frac{2W}{\rho S C_{L_{max}}}} \qquad C_{L_{max}} = 1.8277$$

$$TV = P \Rightarrow \frac{P}{V} = T_{max} = 775$$

mt-propellers

$= 0.46$ lbfuel/hr/hp

$$\gamma_{glide} = \frac{1}{L/D} = 0.1332 \text{ [rad]}$$

$\underbrace{\text{Flight Ceiling}}_{16400\ ft}$ Eq. to solve for engine characteristic

$$m = \frac{\ln\left(\dfrac{\frac{4}{3}\sqrt{\frac{2W^3}{\rho S}\sqrt{3K^3 C_{D_0}}}}{\eta P_{max}}\right)}{\ln\left(\frac{\rho}{\rho_s}\right)} = 2.392$$

Item 20: MATLAB Script for Diamond DA40 Diamond Star NG Steady

```
h=linspace (0,15500,500);
for k=1:size(h,2)
    [Vmax(k) VminTC(k) Vstall(k)]=SLFP(h(k));
end
Vmin=max (VminTC,Vstall);
fill([Vmin Vmax(end:-1:1)],[h h(end:-1:1)],[0.8 1 1], 'Linestyle','none');
hold on;
plot (Vmax,h,VminTC,h,Vstall,h);
grid on;
xlim ([0 400]);
xlabel ('Velocity (ft/s)');
ylabel ('Altitude (ft)');

function [Vmax VminPC Vstall]=SLFP(h)
%Input: altitude h (ft)
%Output: max air speed Vmax (ft/s), min air speed due to thrust
%constraint VminPC (ft/s),
% stall speed Vstall (ft/s)
W=2535; S=145.7; CD0=0.0404; K=0.0303; Psmax=160*550; m=2.392;
CLmax=1.8277; eta=0.796;
[Ts ps rhos]=StdAtpUS (0);
[T p rho]=StdAtpUS (h);
tmp=sort (roots ([1/2*rho*S*CD0 0 0 -eta*Psmax* (rho/rhos)^m 2*K*W^2/rho/S]));
Vmax=tmp (2);
VminPC=tmp (1);
Vstall=sqrt (2*W/rho/S/CLmax);
end

function [T p rho]=StdAtpUS(h)
%Standard Atmosphere
%Input : h altitute (ft)
%Output : T temperature (F), p pressure (lbs/ft^2), rho density (slug/ft^3)
h1=3.6089e4; h2=6.5616e4; h3=9.0e4; a0=-3.567e-3;
a2=5.494e-4; g=32.2;
R=1716;
T0=518.67; p0=2116.2; rho0=2.3769e-3; T1=T0+a0*h1;
p1=p0*(T1/T0)^(-g/a0/R); rho1=rho0*(T1/T0)^(-g/a0/R-1);
T2=T1;
p2=p1*exp(-g/R/T2*(h2-h1)); rho2=rho1*exp(-g/R/T2*(h2-h1));
if h <=h1
    disp('Troposphere');
    T=T0+a0*h;
    p=p0*(T/T0)^(-g/a0/R);
    rho=rho0*(T/T0)^(-g/a0/R-1);
elseif h <= h2
    disp('Tropopause');
    T=T1;
    p=p1*exp(-g/R/T*(h-h1));
    rho=rho1*exp(-g/R/T*(h-h1));
elseif h <= h3
    disp('Stratosphere');
    T=T2+a2*(h-h2);
    p=p2*(T/T2)^(-g/a2/R);
    rho=rho2*(T/T2)^(-g/a2/R-1);
else
    disp('Error: the altitute should be less then 90000 ft' );
end
end
```

Item 21: MATLAB Script for Diamond DA40 Diamond Star NG Climb

```
h=linspace(0,10300,500);
for k=1:size(h,2)
    [Vmax(k), VminTC(k) Vstall(k)]=SCFP(h(k),5);
end
Vmin=max(VminTC,Vstall);
fill([Vmin Vmax(end:-1:1)],[h h(end:-1:1)],[0.8 1 1], 'Linestyle','none');
hold on;
plot(Vmax,h,VminTC,h,Vstall,h);
grid on;
xlim([0 400]);
xlabel('Velocity (ft/s)');
ylabel('Altitude (ft)');
function [Vmax VminPC Vstall]=SCFP(h,Vclimb);
%Input: altitude h (ft)
%Output: max air speed Vmax (ft/s), min air speed due to thrust constraint VminPC (ft/s),
%stall speed Vstall (ft/s)
W=2535; S=145.7; CD0=0.0404; K=0.0303; Psmax=160*550; m=2.392;
CLmax=1.8277; eta=0.796;
[Ts ps rhos]=StdAtpUS(0);
[T p rho]=StdAtpUS(h);
tmp=sort(roots([1/2*rho*S*CD0 0 0 W*Vclimb-eta*Psmax*(rho/rhos)^m ...
    2*K*W^2/rho/S]));
Vmax=tmp(2);
VminPC=tmp(1);
Vstall=sqrt(2*W/rho/S/CLmax);
end
function [T p rho]=StdAtpUS(h)
%Standard Atmosphere
%Input : h altitute (ft)
%Output : T temperature (F), p pressure (lbs/ft^2), rho density(slug/ft^3)
h1=3.6089e4; h2=6.5616e4; h3=9.0e4; a0=-3.567e-3;
a2=5.494e-4; g=32.2;
R=1716;
T0=518.67; p0=2116.2; rho0=2.3769e-3; T1=T0+a0*h1;
p1=p0*(T1/T0)^(-g/a0/R); rho1=rho0*(T1/T0)^(-g/a0/R-1);
T2=T1;
p2=p1*exp(-g/R/T2*(h2-h1)); rho2=rho1*exp(-g/R/T2*(h2-h1));
if h <=h1
    disp('Troposphere');
    T=T0+a0*h;
    p=p0*(T/T0)^(-g/a0/R);
    rho=rho0*(T/T0)^(-g/a0/R-1);
elseif h <= h2
    disp('Tropopause');
    T=T1;
    p=p1*exp(-g/R/T*(h-h1));
    rho=rho1*exp(-g/R/T*(h-h1));
elseif h <= h3
    disp('Stratosphere');
    T=T2+a2*(h-h2);
    p=p2*(T/T2)^(-g/a2/R);
    rho=rho2*(T/T2)^(-g/a2/R-1);
else
    disp('Error: the altitute should be less then 90000ft' );
end
end
```

Item 22: MATLAB Script for Diamond DA40 Diamond Star NG Glide

```
gangle = 0.119; % Glide angle (rad)
h = linspace(0,20000,100); % Vector of altitudes

for k = 1:length(h)
    [V(:,k), Vstall(k)] = SGFP(h(k), gangle);
end

plot(V(1,:), h, 'b-');
grid on;
xlabel('Velocity (ft/s)');
ylabel('Altitude (ft)');

% === Function Definitions ===

function [V, Vstall] = SGFP(h, gangle)
% Input: altitude h (ft), glide angle gangle (rad)
% Output: gliding airspeed V (ft/s), stall speed Vstall (ft/s)

W = 2300; S = 174; CD0 = 0.05; K = 0.041; CLmax = 1.8685;
[~, ~, rho] = StdAtpUS(h);

tmp = sort(roots([0.5*rho*S*CD0/W, 0, -gangle, 0, 2*K*W/(rho*S)]));
V = tmp(3:4); % Take the two positive real roots
Vstall = sqrt(2*W / (rho*S*CLmax));
end

function [T, p, rho] = StdAtpUS(h)
% Standard Atmosphere
% Input : h altitude (ft)
% Output : T temperature (F), p pressure (lbs/ft^2), rho density (slug/ft^3)
h1 = 3.6089e4; h2 = 6.5616e4; h3 = 9.0e4;
a0 = -3.567e-3; a2 = 5.494e-4; g = 32.2; R = 1716;
T0 = 518.67; p0 = 2116.2; rho0 = 2.3769e-3;
T1 = T0 + a0*h1;
p1 = p0 * (T1/T0)^(-g/(a0*R));
rho1 = rho0 * (T1/T0)^(-g/(a0*R) - 1);
T2 = T1;
p2 = p1 * exp(-g/(R*T2)*(h2 - h1));
rho2 = rho1 * exp(-g/(R*T2)*(h2 - h1));
if h <= h1
    disp('Troposphere');
    T = T0 + a0*h;
    p = p0 * (T/T0)^(-g/(a0*R));
    rho = rho0 * (T/T0)^(-g/(a0*R) - 1);
elseif h <= h2
    disp('Tropopause');
    T = T1;
    p = p1 * exp(-g/(R*T)*(h - h1));
    rho = rho1 * exp(-g/(R*T)*(h - h1));
elseif h <= h3
    disp('Stratosphere');
    T = T2 + a2*(h - h2);
    p = p2 * (T/T2)^(-g/(a2*R));
    rho = rho2 * (T/T2)^(-g/(a2*R) - 1);
else
    disp('Error: the altitude should be less than 90000 ft');
    T = NaN; p = NaN; rho = NaN;
end
end
```