9-2016

2016 General Aviation Flight Training Metrics

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Scholarly Commons Citation
Hampton, S., Byrnes, K., & Techau, T. (2016). 2016 General Aviation Flight Training Metrics. , (). Retrieved from https://commons.erau.edu/publication/770

JNASA/CR—2016–000000

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September 2016

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Prepared under Contract T16-6500-ERAU

September 2016

Acknowledgments

This report is available in electronic form at

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PREFACE

This document is the final report and deliverable for Task Number NNL13AA08B, Contract No. T16-6500-ERAU, On-Demand Mobility Studies: Investigating Vehicle Platforms Able to Carry Small Packages to 9 Passengers, with Investigations of Their Enabling Component Technologies, which was awarded to Embry-Riddle Aeronautical University (ERAU). As such, this report documents accomplishment of the contract and provides information regarding flight training metrics at ERAU, which is conducted under 14 CFR § 141.

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EXECUTIVE SUMMARY

The study evaluates training at a collegiate flight training program (Embry-Riddle Aeronautical University) providing metrics for time and costs from zero time to a Commercial certificated Pilot with Instrument and Multi-Engine add-ons. Training times for flights and activities are pulled from a sophisticated database used at Embry-Riddle Aeronautical University (ERAU) and matched with flight and ground school lessons and then further subdivided to determine the amount of time spent training in areas of operation that are prescribed by the Federal Aviation Administration in the published Practical Test Standards and Airman Certification Standards for those seeking pilot licenses and ratings.

Provided are mean times and costs for a prospective pilot to attain Private, Instrument, Commercial and Multi-Engine licenses at Embry-Riddle. For example, the records of 286 students in the FAA approved Private pilot course were pulled, de-identified, and analyzed. Of more interest though is the mean time that each student spent in each course training to proficiency in required area of operation which in turn will provide insight into those areas requiring the most training and would perhaps benefit the Simplified Vehicle Operation program at NASA by helping to identify candidate technologies proposed to be developed by the program office.

1. OVERVIEW

1.1 Introduction

The National Aeronautics and Space Administration (NASA) On-Demand Mobility and Simplified Vehicle Operations(ODM/SVO) program requires a baseline metric against which training improvements can be measured. To develop the training metric, a large, detailed general aviation training database is required. Embry-Riddle Aeronautical University's (ERAU) Flight Department has compiled extensive aviation training records. A group of flight and programming specialists teamed to parse and analyzed these records for specific parameters. This study reports the detailed findings and presents the conclusions and recommendations of the team.

The report builds on work begun in support of NASA's Advanced General Aviation Transportation Experiments (AGATE) program in 1995 to estimate the cost of training a general aviation pilot. That work, "Baseline Metrics for General Aviation Aircraft", categorized the training by specific flight skill objectives identified by anticipated operational requirements for the AGATE program, then current Federal Aviation Administration (FAA) Practical Test Standards (PTS), and provided a framework to estimate the individual required training time and costs; those parameters were then used to identify areas where significant savings could be realized.

The present report updates the defined skills, training hours, and costs identified by the existing PTS (2012) for the Commercial certificate and Multi-Engine add-on rating and the recently released (June 2016) Airman Certification Standards (ACS) for the Private certificate and Instrument rating and is expanded to include those skill sets requiring additional training (extra training) over and above minimums for the FAA Part 141 approved curriculum. The time/costs for training were estimated during an 18-month period from a database (August 2014 – April 2016) which included over fifteen hundred students, seventy aircraft, and ten Flight Training Devices (FTD).

1.2 Objectives

a. To develop training metrics for students at a collegiate flight program that can be used as a baseline against which both time and costs to attain specific levels of training can be measured.

b. To provide recommendations, based on the data generated, on where to focus training that can take advantage of technology developments related to automation and/or an understanding of aeronautical decision-making (ADM).

2. REVIEW OF RELEVANT LITERATURE

2.1 Flight Training Requirements

The FAA's PTS and June 2016 release of several ACS, combined with FAR regulatory requirements under Part 141, 91 and 61, essentially provide guidelines for the development of flight training programs at university programs. At the conclusion of training, applicants for certificates and ratings are tested on the Area of Operations that are listed that pertain to the associated license or rating. Applicants are expected to perform at the prescribed performance standards (PTS/ACS) while meeting minimum training requirements (time and tasks) prescribed in the regulations (Part 61, 91, 141).

Applicants receive ground and flight training based on a traditional building block model approach which starts with a ground school to be followed by flight training. Besides an aircraft, flight training may include instruction in a Flight Training Device (FTD), a mechanism with varying levels of fidelity which simulates the aircraft environment and is used extensively at many institutions such as ERAU to introduce a task and build proficiency prior to validation of a given skill in an aircraft.

2.1.1 FAA Practical Test Standards

The FAA’s PTS provide testing criteria for applicants seeking a Commercial certificate and a Multi-Engine rating. The PTS essentially acts as a guide for the development of flight training programs since applicants for certificates and ratings are tested on those Area of Operation tasks that are listed in the PTS to the prescribed performance standards.

2.1.2 FAA Airman Certification Standards

The recent June 2016 release of the ACS provide the guide for the development of training programs in the same fashion as did their predecessor PTS. Applicants for certificates and ratings are tested on the Area of Operations that are listed to the prescribed performance standards. The standards were revised to accommodate the changes in design and use of the technology within the aircraft, as well as a training philosophy change that has focused more on special emphasis areas. To accommodate the changes, the FAA worked with industry to develop a systematic approach to:

- Provide clear standards for aeronautical knowledge
- List specific behaviors for risk management and ADM
- Consolidate overlapping tasks in the PTS
- Tie the many special items to knowledge and skill
- Connect the standards for knowledge, risk management, and skill to guidance (H-series Handbooks), to knowledge test questions, and the practical test (FAA, 2016).

Table 1 below shows the status of current PTS and ACS in effect at the time of this study.

Table 1

FAA PTS and ACS Replacement Matrix

Type	**Certificate or Rating**	**Publication Date (Change Date)**	**Number**	**Title**	**Status**
PTS	Private	11/1/2011 (Feb 2014)	FAA-S-8081-14B	Private Pilot Practical Test Standards for Airplane (SEL, MEL, SES, MES)	Superseded
ACS	Private	Jun 2016	FAA-S-ACS-6 (Change 1)	Private Pilot – Airplane Airman Certification Standards	In Effect
PTS	Instrument	1/1/2010 (Sep 2013)	FAA-S-8081-4E	Instrument Rating Practical Test Standards for Airplane, Helicopter, and Powered Lift	Superseded
ACS	Instrument	Jun 2016	FAA-S-ACS-8 (Change 1)	Instrument Rating – Airplane Airman Certification Standards	In Effect
PTS	Commercial	11/1/2011 (Sep 2012)	FAA-S-8081-12C (Changes 1-4)	Commercial Pilot Practical Test Standards for Airplane (SEL, MEL, SES, MES)	In Effect

Notes: The requirements to obtain a Multi-Engine rating are contained within PTS FAA-S-8081-12C (Changes 1-4). Table current as of Aug 30th, 2016.

2.1.3 Embry-Riddle Flight Training Curriculum

The ERAU flight and ground training curriculum (Appendices E, I, M, and Q) are based on the requirements set forth in the FAA's PTS and ACS (2016) and FAR Part's 61, 91 and 141. The program at the university is a FAA Part 141 certificate program. The university has two residential campuses, Daytona Beach, Florida and Prescott, Arizona. Data for this study comes from the Daytona Beach, Florida campus.

The ground school is conducted as part of the Aeronautical Science academic program for the Private Certificate, Instrument Rating, and Commercial Certificate programs. The Multi-Engine Rating Add-on Rating ground school is completed as an integral element of the flight course.

A full list and hourly cost of flight training equipment used for the courses in the study can be found in Appendix A. The aircraft used are; 1) Cessna 172 (Private, Instrument & Commercial), 2) Piper Arrow (Commercial Complex), and Diamond DA-42 (Multi-Engine). Each aircraft is fully instrumented, Cessna 172 and DA-42 are equipped with Garmin G1000 avionics. The DA-42 which is powered by diesel engines for the purpose of this study has a full authority (FADEC) for power and thrust control. Flight training devices used include Frasca AdvATD, Frasca DA42L, Frasca G1000.

2.2 Focus Group Research

The study used subject matter experts (SME) in a *focus group* environment to develop specific time criteria for each task within every training unit for each course. The term *focus groups* are typically used in qualitative research studies that use interviews as part of the research design. Vogt, Gardener, and Haeffele (2012) suggest that focus group interviews make sense when the “focus group participants will provide you with something that you could not obtain individually.” Focus groups were used in this project to evaluate ERAU flight training records and attribute flight activities to specific categories of instruction. As flight instructors with instructional and flight ratings gained through significant experience, the flight instructors utilized in the focus groups in this study qualify as subject matter experts (SME). Nelson, Magliaro, & Sherman (1988, p. 31) observed that “in comparison to novices, expert’s knowledge structures are more highly organized and well-integrated.”

SMEs are useful in focus groups to quickly identify issues relevant to the task at hand, and the focus group setting helps to facilitate expert discussion and formation of unified conclusions. Colvin and Goh (2005) used inter-rater agreement of SME ratings to assess the content validity of a theoretical model study related to police acceptance of technology, and in a study in the aviation domain, pilots were considered appropriate SMEs to evaluate a scale used to rate proficiency in aviation-related radio communications (Knoch, 2014). Knoch found that the use of focus groups facilitated SME interaction and was efficient as a research methodology, and found that the pilot SMEs were able to draw conclusions about audio speech samples that went beyond the criteria specified in the scale they were evaluating. A key finding was that the pilot’s aviation expertise was important in that the pilot’s ability to understand the audio samples from a technical perspective. Similarly, Knoch observed that the technical knowledge possessed by the SMEs allowed them to consider the technical knowledge of the speaker in addition to the speech provided.

In the present project, SMEs contributed to both the face and content validity of the project as they associated flight student training activities with aviation instructional requirements using their knowledge and experience. Babbie (2013) relates face validity as being related to the level of which an indicator seems to be reasonably related to an indicator variable, while content validity relates to whether a variable or measure encompasses all reasonable variations of a concept.

Kitzinger & Barbour (1999) view group interaction as a key part of focus group research, noting that the primary distinguisher of a focus group from other types of groups is that researchers actively encourage and attend to group interaction. Focus groups tap into participant’s experiences, insights, attitudes, and experiences, (Kress & Shoffner, 2007), and permit researchers to develop a deeper understanding of participant’s beliefs than would collection of data by survey or other research designs (Parker et al., 2012).

3. METHODOLOGY

The first requirement for the project is a definition of a trained collegiate general aviation pilot. For the purposes of this report, a trained collegiate general aviation pilot is defined as a student who has successfully completed both the training and a flight check through the Commercial certificate with a Multi-Engine add-on rating phase of flight training. For the Embry-Riddle curriculum, this corresponds to the completion of the fourth formal flight course (FA323). At this point, students with no prior flight time typically have approximately 190 hours of experience. While it may be argued that such students have not yet achieved requisite "judgment" levels, it must be recognized that this is the point at which the FAA allows the successful student to fly in all weather conditions in a Multi-Engine aircraft and, as such, represents a definitive limit for the use of this term.

The next requirement is a list of competencies required to achieve the Commercial certificate with an Instrument and Multi-Engine rating. Building on work completed for AGATE in 1995. Table 2 contains the list of competencies required by the FAA identified from the ACS for the Private certificate and Instrument rating, and the PTS for the Commercial certificate and Multi-Engine rating. Again, it could be argued that there are some specific competencies missing. However, most flight training experts would agree that the list is sufficiently comprehensive to contain the most critical skills; and, as pointed out in the introduction, the building block approach allows task specific costs to be shifted between competencies. Appendices E, I, M, and Q contain descriptions of the Embry-Riddle flight courses that are used in the calculation.

Table 2

Competencies for Private and Commercial Certificate / Instrument and Multi-Engine Rating

Area of Operation	Private	Instrument	Commercial	Multi-Engine
Preflight Preparation	x	x	x	x
Preflight Procedures	x	x	x	x
Airport Operations	x			x
Takeoffs, Landings, and Go-Arounds	x		x	x
Performance Maneuvers	x		x	x
Navigation	x	x	x	x
Slow Flight and Stalls	x		x	x
Basic Instrument Maneuvers	x			x
Emergency Operations	x	x	x	x
Night Operation	x			
Postflight Procedures	x	x	x	x
Air Traffic Control Clearances and Procedures		x		
Flight by Reference to Instruments		x		
Instrument Approach Procedures		x		
Airport and Seaplane Base Operations*			x	
High Altitude Operations			x	x
Multi-Engine Operations				x
Other (Other training not included above)	x		x	

Notes: Requirements collected from FAA and PTS. Table current as of Aug 28th, 2016.

Data for calculating times is pulled from Education & Training Administration (ETA), a commercial database software package from Talon Systems that ERAU uses for recordkeeping, billing, scheduling and other services. The time for each flight is input into to the ETA database based on when the Pilot in Command (PIC) begins and ends instruction. Both time and Hobbs values are kept to indicate when the flight or activity starts, and when the flight or activity has been completed. PIC notations of oral instruction both pre- and post-flight is also tracked, which modifies the cost calculations to reflect actual times spent in training. The instructor also has the option to adjust the flight time based on flight activity. For example, during a cross-country flight where a stop is made, the instructor may make a reduction in the Hobbs time. Oral and Flight Training Device (FTD) activity times are also provided by the instructor.

Appendix A provides a brief schematic representation of the cost calculations contained in the report. Specific costs for individual actions or parts are the original inputs at the bottom of the figure, and total costs and costs per mile are the final outputs. At appropriate points, the costs are modified by the type of cost or how these vary. For example, pre-flight inspection is an individual skill listed under the Area of Operation defined as Preflight Preparation. Students may take varying amounts of time to master the skill, but a mean time for each skill can be calculated. Each skill set within that Area of Competency is then calculated and added to derive a mean for that competency area which is then divided by the total training time for the course to find the percentage of course time devoted to that competency, in this case, Preflight Preparation. This mean can then be translated into a cost by using the appropriate charge for the type of instruction and the mean time devoted to it. The study was structured to account for possible shifts in skill mix across categories in the case that there was a change in the mix which could occur as a result of a new aircraft, different costs for flight and ground training, etc. The point is that the category of the cost can be easily changed if there is disagreement or a change in definition. The same is true for the skills listed under all the other competencies.

The main results of the report are contained in Appendices B,C, F, G, J, K, N, and O; these tables reflect aggregate flight hours, training device (FTD) hours, oral hours, and associated costs. A summary of data in reports and graphs is contained in the text and in the Appendices listed, while individual data are in the results of this report. A discussion of the individual costs with the methodology and the results follows.

3.1 Ground Training Competencies

Academic courses are used to teach the Private Pilot through Commercial Pilot based on Part 141 requirements. The Multi-Engine add-on is taught by the Flight Department at the beginning of the flight course. An approved FAA Part 141 training curriculum provides the course outline and specifies each line item for each lesson in each course. SME with extensive experience teaching each course provided the specific time breakdown which was then reviewed to ensure accuracy. The charts in the results below show the training time and percentage of total training time in each area of operation identified by the FAA's ACS/PTS for the Private Pilot, Instrument, Commercial, and Multi-Engine. One can clearly see where the greatest amount/percentage of time is spent.

Costs for the ground school's area of operation are calculated based on credit hours charged, which are $1,385 per hour. The Private ground course is 5 credit hours, Instrument and Commercial 3 hours, and Multi-Engine add-on 1 hour. The courses are split into lessons with each line item allocated a time which is then summarized for each course to provide the time spent in each area of operation in the associated ACS/PTS. Results are then summarized with total time and cost for each area of operation provided for training through the Multi-Engine add-on rating.

3.2 Flight Time Competencies

The Embry-Riddle flight curriculum is divided into lessons and units each of which bears a set of competencies which can be tracked to one of the Areas of Operation listed in Table 2 for the Private Pilot, Instrument Rating, Commercial Pilot and Multi-Engine Rating certificates. The

Areas of Operation are from the FAA’s Airman Certification Standards (2016) and Practical Test Standards (2012).

Because flight training is always taught in sequential lessons, and these often have multiple competency requirements, the competency components of the different lessons had to be identified. To accomplish this, Embry-Riddle flight training specialists tracked the lesson, and Area of Operation contained in Table 2. These competencies were further subdivided by the type of instruction, e.g., dual flight, oral briefing, ground simulation, or solo flight. The amount of time (by type of instruction) and the individual skills devoted to each competency was then reviewed by a group of experienced instructors using the Focus Group method with the results tabulated and recorded.

Because we were working backward from an existing curriculum, the approach used is more of an "inverse" elaboration analysis such as that described by Reigeluth and Stein (1983). The intent was to identify within the existing curriculum "clusters" of competencies which fall within each Area of Operation so that time and costs could be determined for each category. A classical task analysis approach, such as that described by Romisowski (1992), did not fit this phase of the study. Through the elaboration, the descriptions of competencies in this work are preserved so that future work to describe the links between overall flight competencies and specific hierarchies of objectives can be accomplished.

Individual student records are used to calculate a mean completion time for each Area of Operation within each lesson student lesson by type of instruction (Dual, Oral, FTD, etc.) to include additional training. The mean time for each lesson is provided by the ETA database and is then refined by the focus group SME’s for that course to determine the amount of time spent on each individual skill.

A simple example may help make this competency calculation clear. A lesson that is a dual instruction unit has Preflight Procedures, Takeoffs and Landings, High-Performance Maneuvers Slow Flight and Stalls, and Postflight Procedures associated with it. The total time from the ETA database is broken into one-tenth intervals by the focus groups SME’s and assigned to each Area of Operation identified by the associated ACS/PTS. In this case for a 1.3 Dual, .2 Oral hour lesson (generated by ETA). The time allocated by the focus group is:

Preflight Procedures	.3
Takeoffs and Landings	.4
High-Performance Maneuvers	.2
Slow Flight and Stalls	.2
Postflight Procedures	.2
Oral Debrief	.2

Thus, the result identifies the time in each lesson devoted to each Area of Operation, which can then be added by each lesson for a given flight course and then summarized as shown in Appendices B, F, J, and N to provide total times of training in a given area. The sum of these calculations over all the lessons for all the courses yields the grand mean for these competencies for each area of operation.

The specific skills in each area of operation for each flight course are contained in the summary tables in Section 4. Note that there is considerable similarity thus the overall times to develop proficiency across the entire curriculum can be derived. The standard deviation is also provided for the individual courses for all those students completing the training within the stated period of time.

4. RESULTS

4.1 Private Pilot Training

The Private Pilot course is the first academic ground school and flight course at ERAU. It is planned to be completed in the first academic year and consists of a ground school taught as part of the academic curriculum followed by flight. While flight training normally occurs concurrently although it is dependent on the availability of an instructor and is subject to weather delays and breaks in the academic calendar.

4.1.1 Private Pilot Ground Training

Ground instruction takes place in the academic curriculum as an approved FAR Part 141 ground school. Table 3 below identifies the time spent for each identified Area of Operation. As can be seen, the majority of the time (31.4 hours / 56%) is spent under Preflight Preparation. Instruction which includes systems, flight planning, weather, airspace, performance and limitations et.al. fall under Preflight Preparation thus the high percentage of time committed to that Area of Operation. Figure 1 provides a graphical representation.

Table 3

Summary of Ground Instruction (Classroom) by Area of Operation - Private Pilot

Type of Instruction	**Hours**	**Percentage**
Preflight Preparation	31.4	**56.5%**
Preflight Procedures	1.5	2.7%
Airport Operations	2.8	5.0%
Takeoffs, Landings, and Go-Arounds	0.1	0.2%
Performance Maneuvers	0.0	0.0%
Navigation	6.7	12.1%
Slow Flight and Stalls	0.9	1.6%
Basic Instrument Maneuvers	0.0	0.0%
Emergency Operations	0.2	1.1%
Night Operation	0.0	0.0%
Postflight Procedures	0.0	0.0%
Other (Other training not included above)	1.0	1.8%
Subtotal - Area of Operation Ground Instruction	**44.6**	**80.2%**
Review and Testing	11.0	19.8%
Total Ground Instruction	**55.6**	**100.0%**

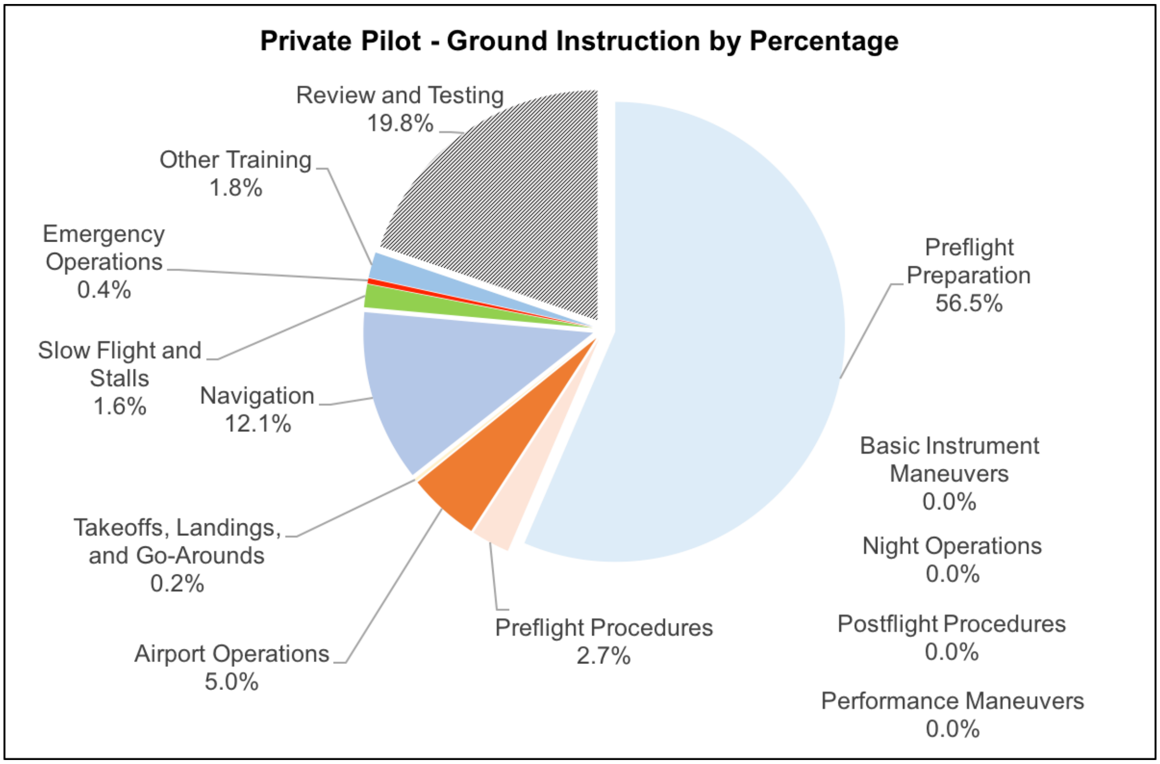

Figure 1: Ground instructional training for each ACS area of operation for the Private Pilot certificate.

4.1.2 Private Pilot Flight Training

Flight training consists of time with an instructor in a one-on-one (oral), time in a high fidelity training device (FTD level 6), dual instruction with an instructor in an aircraft (Cessna 172), and solo time (time spent by the student in the aircraft without an instructor). Considerable time in the Private pilot course is spent on Preflight Preparation in support of cross-country planning activities and during post-flight debrief by the instructor in a one-on-one environment. Among the various types of oral training for the Private Pilot, the greatest percentage of hours is spent between Preflight Preparation (26.1%) and Postflight Procedures (25.1%) while the time spent on all other phases of oral training are fairly evenly divided, as depicted in Table 4. Tables 4 – 6 show the time spent training in the other categories identified in the ACS as Areas of Operation. The highest percentage of time for in both the FTD and for Flight training are Takeoffs and Landings, Navigation (cross country) and Airport Operations. It should be noted that phase and final checks account for ten percent (9.3%) of the total time in the course.

Table 4

Oral Training - Instrument Pilot - Hours

Type of Training	Oral	
	Hours	Percentage
Preflight Preparation	16.6	26.1%
Preflight Procedures	4.5	7.1%
Airport Operations	4.8	7.5%
Takeoffs, Landings, and Go-Arounds	1.6	2.5%
Performance Maneuvers	0.0	0.0%
Navigation	1.6	2.5%
Slow Flight and Stalls	2.0	3.1%
Basic Instrument Maneuvers	1.1	1.7%
Emergency Operations	3.5	5.5%
Night Operation	0.9	1.4%
Postflight Procedures	16.0	25.1%
Other (Other training not included above)	5.2	8.2%
Total Training (less Phase Checks)	**57.8**	**90.7%**
Phase Checks	5.9	9.3%
Total Training (Dual, Solo, Phase Check)	**63.7**	**100.0%**

Table 5

Flight Training Device (FTD) Training - Private Pilot - Hours

Type of Training	FTD	
	Hours	Percentage
Preflight Preparation	0.1	0.6%
Preflight Procedures	0.5	3.0%
Airport Operations	1.2	7.2%
Takeoffs, Landings, and Go-Arounds	3.7	22.2%
Performance Maneuvers	1.7	10.2%
Navigation	1.5	9.0%
Slow Flight and Stalls	0.9	5.4%
Basic Instrument Maneuvers	0.5	3.0%
Emergency Operations	1.1	6.6%
Night Operation	0.4	2.4%
Postflight Procedures	0.0	0.0%
Other (Other training not included above)	3.8	22.8%
Total Training (less Phase Checks)	**15.4**	**92.2%**
Phase Checks	1.3	7.8%
Total Training (Dual, Solo, Phase Check)	**16.7**	**100.0%**

Table 6

Flight Training- Private Pilot - Hours

Type of Training	Flight	
	Hours	Percentage
Preflight Preparation	0.0	0.0%
Preflight Procedures	7.6	8.5%
Airport Operations	11.0	12.4%
Takeoffs, Landings, and Go-Arounds	19.1	21.5%
Performance Maneuvers	3.7	4.2%
Navigation	14.7	16.5%
Slow Flight and Stalls	6.1	6.9%
Basic Instrument Maneuvers	2.0	2.2%
Emergency Operations	3.2	3.6%
Night Operation	3.3	3.7%
Postflight Procedures	6.5	7.3%
Other (Other training not included above)	2.6	2.9%
Total Training (less Phase Checks)	**79.8**	**89.7%**
Phase Checks	9.2	10.3%
Total Training (Dual, Solo, Phase Check)	**89.0**	**100.0%**

4.1.3 Private Pilot Summary of Flight Training

In summary, Table 7 and Figure 2 provides a representation of the combined phases of training the student pilot takes to obtain a Private Pilot's certificate and the total amount of time spent on each type of training throughout the entirety of the Private Pilot course. The greatest amount of time is spent almost evenly between Takeoff, Landings, and Go-Arounds (14.2%) and Postflight Procedures (13.1%). The least amount of focus is spent on Basic Instrument Maneuvers (2.1%) and Night Operation (2.7%). Ultimately, time is allocated to provide particular attention to the most challenging and valuable phases of flight and/or post flight.

Table 7

Summary of Training by Area of Operation - Private Pilot - Hours

Type of Training	**Private**			
	Flight	**FTD**	**Oral**	**Total**
Preflight Preparation	0.0	0.1	16.6	16.7
Preflight Procedures	7.6	0.5	4.5	12.6
Airport Operations	11.0	1.2	4.8	17.0
Takeoffs, Landings, and Go-Arounds	19.1	3.7	1.6	24.4
Performance Maneuvers	3.7	1.7	0.0	5.4
Navigation	14.7	1.5	1.6	17.8
Slow Flight and Stalls	6.1	0.9	2.0	9.0
Basic Instrument Maneuvers	2.0	0.5	1.1	3.6
Emergency Operations	3.2	1.1	3.5	7.8
Night Operation	3.3	0.4	0.9	4.6
Postflight Procedures	6.5	0.0	16.0	22.5
Other (Other training not included above)	2.6	3.8	5.2	11.6
Total Training (less Phase Checks)	**79.8**	**15.4**	**57.8**	**153.0**
Phase Checks	9.2	1.3	7.7	18.2
Total Training (Dual, Solo, Phase Check)	**89.0**	**16.7**	**65.5**	**171.2**

Notes: Solo flight time is embedded in the Flight column

Not all types of training are common to Private, Instrument, Commercial, or Multi-Engine training

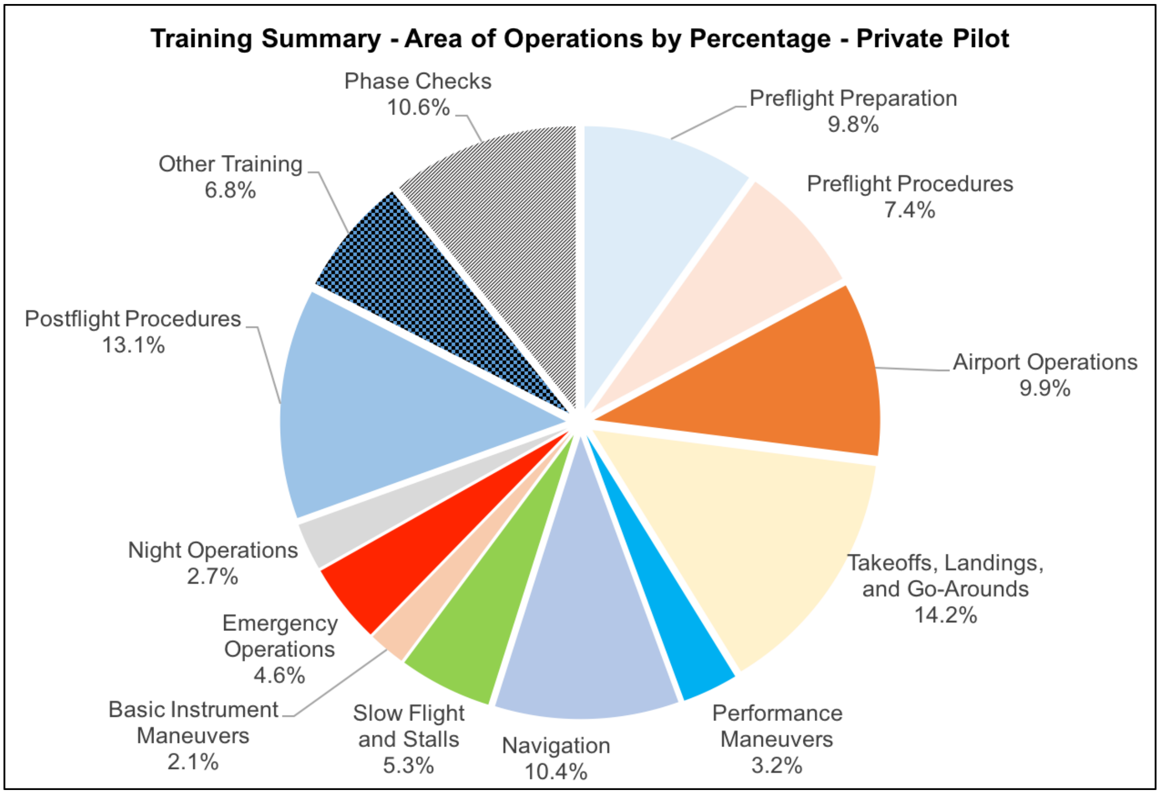

Figure 2: Summary chart of Private Pilot flight training viewed by area of operations as a percentage of total flight training (Oral, FTD, Flight).

As can be seen from Table 8 (descriptive statistics) times vary widely between students and the overall standard deviation is quite large, even after removal of outliers.De Veaux, Vellemen, and Bock (2012) describe outliers as “a value that doesn’t fit with the rest of the data” (p. 86), and advocate that dealing with outliers is a judgment call in which the researcher evaluates outliers in the context of the rest of the data. As a systematic place to define when a value is an outlier, De Veaux et al. point to the formula of John W. Tukey, who said that outliers are 1.5 x the Interquartile Range (IQR) beyond the values of Q1 and Q3. To graphically present how removal of the outlier values changes the descriptive statistics, histograms of the values of each variable are useful. Figure 3A shows Days to complete the training with outliers included, while Figure 3B shows the same histogram with the outliers removed.

Table 8

Descriptive Statistics - Private Pilot Training (Outliers Removed)

Type Training	Range	Minimum	Maximum	Mean	Standard Deviation
Dual	87.4	43.9	131.3	80.3	17.1
Solo	3.3	5.4	8.7	6.9	0.6
FTD	16.1	11.3	27.4	17.3	3.1
Oral	52.7	20.8	73.5	43.4	10.6
Days	758.0	45.0	803.0	355.2	155.6

Note: Data from ERAU course FA-121

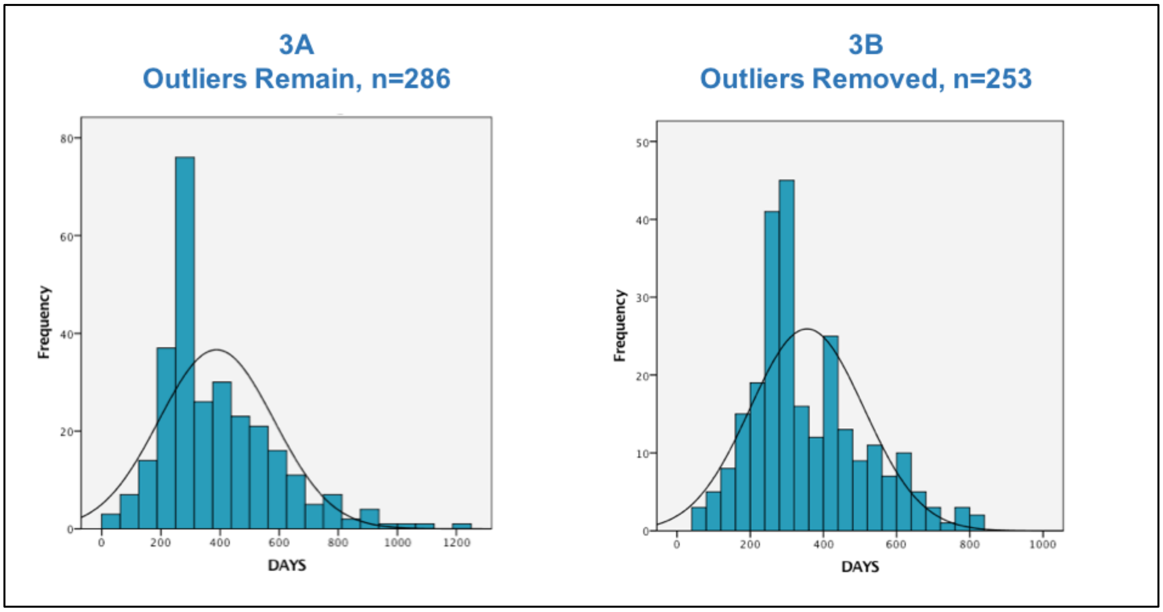

Figure 3: Histograms of Days in Private Pilot training with and without outliers.

4.5 Ground and Flight Training Costs

Below is a summary of the training costs at ERAU through the Commercial Certificate with Instrument and Multi-Engine Ratings. It should be noted that costs are based on flight and instructional hours at ERAU and will vary considerably nationally based on the location and type of equipment used.

Table 27
Summary of Flight Training Costs - Ab Initio to Multi-Engine Pilot by Certificate/Rating

Type of Training	Costs	Total Cost
Private Pilot Certificate		
Flight - Private	$19,486.96	
Oral - Private	$3,995.50	
FTD - Private	$2,371.40	
Total		**$25,853.86**

4.6 Summary of Training Results

Hours spent training have not changed significantly since 1995 even though there have been considerable increases in NAS complexity, NAS operating procedures/policy, training requirements, and aircraft systems. At the same time navigation technology (GPS, moving map displays, electronic flight bag (EFB), data link, weather in the cockpit, etc.) have provided increased situational awareness in the cockpit. However, these new technologies and associated complexity of the systems have increased the initial amount of knowledge that a student pilot must learn and develop confidence in the use of. Since knowledge is the foundation of a student's performance; students must have an understanding of the knowledge that is required prior to applying it to practice in the psychomotor domain. This increase in knowledge may be the source of the significant time spent in training during the pre-flight and post-flight phases.

Due to the increase in required knowledge, learning to apply this knowledge in the psychomotor domain could well be the cause of the increase in dual flight instruction. Basic psychomotor skills such as takeoff and landing remain both time to consuming and expensive for the student pilot to master. Specifically, for the Private Pilot, takeoff and landing are the most time-consuming task for students to learn and generate the proficiency to the level required by the ACS. For the Instrument rating, the challenge is gaining the vast amount of knowledge required to understand instrument operations as well as developing proficiency in instrument approach procedures. The increase in the automation and complexity of the avionics has reduced workload while increasing the required amount of technical and operational knowledge.

While overall total training time has not changed, costs have, due to an increase in dual instruction (reduction in Solo hours), increased aircraft/system costs, increased air traffic delays, and monetary inflation over the fifteen-year period. New aircraft costs, for example, are now in excess of $300,000 for a single engine trainer, an increase of approximately 350% in the past 15 years. At the same time, the fidelity of basic FTDs has increased significantly. Because an aircraft is not conducive to a good learning environment, especially during critical phases of flight, flight training has seen the increased use of FTD's which has resulted in both better training and a more efficient use of aircraft time while providing opportunities to focus on basic training, emergency training, CRM, ADM, and SRM.

5. DISCUSSION

5.1 General

Results of the study in general if looking at a comparison of total time are not surprising and provide some insight on perhaps where to focus attention for automation. Training requirements have not changed significantly for many activities, and pilots still need to develop specific motor skill sets for functions such as takeoff and landing and taxiing for example. However, the environment that they must operate in has become more complex and demanding of their attention. Rather surprisingly, the elimination of most of the considerable Solo flight requirements except for those activities required to meet Solo cross country time minimums in favor of time spent with an instructor and additional emphasis on ADM, CRM, and SRS has had minimal change on the overall flight time.

What has changed is the need for additional cognitive thinking when flying an aircraft as avionics have become more sophisticated and capable. This is particularly apparent when evaluating the Instrument rating, where NAS and technology modernization has eliminated the NDB and soon the VOR with the introduction of a Global Positioning System based on a satellite in orbit, which in turn has provided a real-time navigation and a moving map in the cockpit for the pilot which has greatly improved situation awareness. However, controlling and understanding how to use it has also increased the cognitive workload. Thus the pilot must now not only need to be able to perform the traditional stick and rudder skills to a prescribed performance level, but must also understand be fluent in programming the new technology for an activity such as an approach and thus be able to essentially operate a computer that performs similar functions on multiple platforms (aircraft that have different avionics suites with differing interfaces yet provide similar results). At the same time, applicant pilots must still learn the traditional systems and navigation techniques in the event of system failure.

The FAA’s Next Generation Air Transportation System (NextGen) will continue to provide additional areas that will require training on advanced navigation systems and to which the new ACS provides limited guidance. For example, Automated Dependent Surveillance-Broadcast (ADS-B) IN aids and improves situation awareness by providing real-time traffic information, and also provides the basis for Required Navigation Performance (RNP) instrument approaches. While RNP is generally not available for the GA community, awareness and understanding will still be needed in order for all to operate in the same airspace. As new capabilities are streamed to the cockpit, a new educational/training philosophy will need to accompany them. Of great concern is the transition period, or time from when a technology is introduced to when it is available across an entire fleet with associated training. Quite often in the past, technologists have introduced new capabilities without a thorough understanding of the training that will be need to be developed for safe and efficient operations; examples include the introduction of Loran-C, glass cockpits, GPS, etc. Other technologies and capabilities will soon follow and ensuring that GA and small business operators have the capabilities on board the aircraft and training is essential.

A further fear among many GA enthusiasts and commercial operators is the impact that UAS will have on everyday operations. Tools to identify and provide separation would be greatly appreciated, particularly in the airport environment and at altitudes where manned aircraft operate.

5.2 Private Pilot Certificate

Based on the results it is clear that student pilots (Private Pilot applicants) continue to spend the greatest amount of time, and thus cost, learning how to land an aircraft. However, what is of concern is that a considerable amount time within each flight activity .5hr or more is spent transitioning to and from the runway in preparation for takeoff and after landing (Preflight and Postflight procedures), a result of congested airspace at the airport that Embry-Riddle operates from.

In discussion with training managers and the flight administration, it is also apparent that the high rate of instructor turnover, 88% in the 2015/16 academic year, for example, has a detrimental element as well. This is also true on a national level as well; the flight instructor profession (and the regional pilot profession) is a transition job for the ultimate goal of a major airline job. Thurber and Epstein (2016) cite FAA estimates, which show that as of 2015 only about 19,000 of the approximate 101,000 certificated flight instructors in the U.S. are involved in part-time flight instruction. Moreover, of those 19,000, only about 6,000 instructors teach full-time, the authors note that multiple flight training businesses and universities have been unable to attract sufficient flight instructors to meet demand.

Much of the instructor turnover is caused by the regional airlines need to hire pilots, which is often the chosen career path of flight instructors that have graduated from ERAU. As a result, while the instructors are highly qualified, the experience level of the instructor core continues to be attacked by the high attrition rate, which in turn has a negative effect on training. This is evident predominantly at the Private Pilot level and can be seen by the excessive amount of training time leading up to stage and end of course checks which continues to be the case while the focus on additional training of the instructor core has resulted in an increase in the pass rate. Also of note is the large standard deviation (SD) in training time for those students completing the course within the study period, which is caused not only by the experience level of the instructors but also by the time in between flight activities (delays often caused by weather etc.) which results in a lack of continuity in the flight training process.

What is surprising, though, is that the reduction in required solo time from changes to required minimum flight times (FAA), has not resulted in a reduction in overall training time from 1995. Solo flight time requirements up through commercial were reduced considerably, a result of the notion that time with an instructor was more valuable than flight by the student alone. However, the anticipated reduction has to some extent been mitigated by special training areas that include a needed focus on such skills as Cockpit Resource Management (CRM) and Aeronautical Decision Making (ADM), and changes and the increased complexity of regulatory and NAS rules and regulations. Unfortunately, the result means that an increase in dual instruction time has resulted in an increase in total training costs. It should be noted that besides an increase in dual instruction, inflation, equipment and fuel surcharges account for a large percentage of the increased costs. On a positive note, the GA accident rate has begun to decline perhaps due in part to the increased attention being paid to ADM/risk management.

Aids to support approach and landing would be of great benefit to the student pilot and have the greatest impact on the time needed to introduce the operation to the student and for them to gain proficiency to a level that is safe and meets standards required by the ACS. Full automation for this task is unlikely to be achieved in the near term; however, tools could be developed beyond what is already available to provide flight path and drift guidance to help the students attain a consistent performance level with a high level of confidence.

Tablets/EFB's are a potential tool that with appropriate software could be used to improve and simplify the flight planning process; the tool could then be used for inflight flight following and if needed deviations, weather updates, re-routing of the aircraft, etc. The concept of using a tablet/EFB for these functions is a paradigm jump but not greater than moving from an E 6B or CR 3 to an electronic calculator as we did in the 1970's.

5.3 Instrument Rating

Changes to Part 141 have allowed college and training organizations similar to Embry-Riddle though to maximize the benefits associated with using FTD's to reduce overall training costs and time in the aircraft. At ERAU the FTD is used extensively to introduce each phase of instrument flight activity to develop and build proficiency in the Area of Operation before the task is validated in the aircraft, thus reducing flight time for the instrument rating. Also at ERAU required checking is performed in the FTD. Not surprisingly the Area of Operation requiring the most training time is focused on instrument approach procedures, with a significant element of this task focused on partial panel operations. Cross-country requirements (Navigation) are also a significant element.

One point to note is that the SD for Instrument rating training is considerably lower than for the Private pilot course due in large part to the reduced impact that weather has on flight operations and the increased emphasis on the use of FTD's. One recent reduction not fully reflected in the training time is the elimination of the requirement to learn and generate proficiency in the use of Non-Directional Radio Beacons (NDB) for navigation and approaches. NDB approaches have historically been a challenge for those seeking an instrument rating. The introduction of GPS and electronic Flight Management Systems (FMS) though have perhaps in turn compensated and added to the training time requirements. However, improvements in the technology, particularly the human/machine interface, have resulted in a higher level of situation awareness. As technology changes occur it will be important to take into account training requirements so that the benefits offered by improved systems are not lost in additional instructional costs.

EFB's and on-board navigation systems will need to be simplified and have improved industry standardized interfaces if we want to reduce training times and improve operational efficiencies. Garmin, Honeywell, Rockwell, all have systems that have somewhat similar capabilities but quite different approaches to achieving them, for the pilot this means understanding and knowing multiple systems to achieve the same result (e.g., an instrument approach to a landing). In the end, this increases the complexity and training time required to maintain both currency and the ability to move from one aircraft to another without additional instruction and proficiency time.

5.6 Summary of Discussion

There are opportunities for improvements in training with the introduction of technology at all levels of flight training. However, in general, it should be noted that one area identified by the SME's as critical that student pilots consistently lacked proficiency in and which caused considerable extra training was Aeronautical Decision Making (ADM). The concept being that the pilot is constantly making decisions which require a cognitive thought process and which at times may be in conflict with manual *stick and rudder* control of the aircraft thus acting as a distraction. Lack of good ADM becomes apparent during many phases of flight, especially those that occur during an emergency or one requiring a high level of precision such as the Power-Off 180 side approach. The result during the training process is a considerable increase in training time resulting in extra training (XT), and this is true especially when the student is preparing for a stage check or FAA certification/rating check. A review of the data showed up to a 500% increase of time over that which is identified by the approved curriculum, and whilst the argument that the excessive XT is caused in part by the lack of experience on the part of the instructors, it can be seen as an issue throughout the training process from the Private Pilot Certificate course through the Multi-Engine add-on.

A key concern to the writers is the issue of automation, without full automation at a 100% reliability level, applicant pilots will still need to develop the operational skills required to operate the aircraft in a similar manner to the training required today. Students, for the most part, are trained to the lowest common denominator and then left to build experience on their own. For example, if one were to have an automated landing tool, unless it was 100% reliable the applicant would still need to demonstrate proficiency at the certificate level required, thus the time needed to achieve the required level of proficiency may, or may not be affected, and may even increase because one now has to be able to accommodate and teach abnormalities in the system and be able to take over if needed.

As can be seen in Table 28, the greatest percentage of time is devoted to basic flying skills for the Private pilot and the mean time to reach the Commercial Pilot level with Instrument and Multi-Engine add-ons is significant. It is also likely that these time commitments as well as the cost act to deter prospective pilots from joining the community.

Table 28
Comparison of Flight Training Certification - Hours

Rating / Certification	**Hours by Type of Training**			
	Flight	**FTD**	**Oral**	**Total**
Private	89.0	16.7	65.5	171.2

6. RECOMMENDATIONS

It is apparent that several areas are candidates for a higher level of automation and that several skill sets need further evaluation, and so we offer the following. Table 29 identifies candidates for attention and following narrative provides the rationale.

Recommendation			Private
a.		Flight planning takes an excessive amount of time during both the ground school phase and the flight training pre-flight activity. Flight planning computer capability should be taken advantage of to minimize time and generate additional accuracy and reliability. Tools such as an EFB (ForeFlight is an example) are a capability that should be taken advantage of and used not only for planning the flight but also as a means to assist/guide/control the navigation system so that frequencies, routes, departure routes, and arrival routes are readily available with weather updates, etc. accounted for.	x
b.	i.	Routes planned should always be displayed and easy to read and understand with touch/or voice control.	x
	ii.	An EFB that can provide guidance for: 1) weather diversion; 2) mechanical; 3) pilot/passenger choice	x
c.		Auto-flight should be available from shortly after take-off to prior to landing.	x
d.		Take-off and landing while requiring considerable training and expertise would benefit by a tool that provides guidance for the flight path and drift information with automated correction/guidance initiating on the take-off roll and ends once the aircraft slows to a walking pace.	x
e.		Communications should be handled by the EFB negotiating with the ground controlling mechanism.	x
f.		Throttle should be a FADEC, one power lever that is nominally controlled in flight from the EFB/Auto-pilot, and providing simplicity for use during taxi/ground operations and inflight if needed by the pilot.	x
g.	i.	Electrical	x
	ii.	Fuel	x
	iii.	Environmental	x
	iv.	Landing gear	x
	i.	Decision-making aids that are reliable and simplify the selection of the optimal choice at critical moments.	x
	ii.	Tools to improve and simplify situational awareness.	x
	iii.	Tools that can reduce the workload in critical situations while maintaining a safe flight environment	X

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APPENDIX A: Rates and Cost Example

Resource Rates

Aircraft	Resource Rate	Instruction Rate	Fuel Surcharge
Cessna 172S Nav3	$118	$61	$29.58
Simulators			
Frasca AdvATD	$32	$61	
Frasca DA 42	$118	$61	
Frasca G1000	$81	$61	

Cost calculations example for a 1.3 hour Dual flight in Cessna 172 with .3 Oral:
Cessna 172 Time X (Hourly Rate + Instructor Rate + Fuel Surcharge)
1.3 X (118 + 61 + 29.58) = $271.15
Oral
.3 X 61 = $ 18.30
$289.45

Costs can also be broken down into tenths by Area of Operation for a given flight activity and then added accumulatively to provide cost for an Area of Operation for a course.