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Descriptive Epidemiology of 2007 Homebuilt Aircraft Accidents and Accident and Fatality Rates

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Descriptive Epidemiology of 2007 Homebuilt Aircraft Accidents and Accident and Fatality Rates

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Dedication

I dedicate this work to those who have given their life in pursuit of their dreams. May we learn from them and be inspired by them. May we have their courage.

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Descriptive Epidemiology of 2007 Homebuilt Aircraft Accidents and Accident and Fatality Rates

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Abstract: Homebuilt aircraft are those that the builder has completed at least 51% of the construction themselves. From 1993 National Transportation and Safety Board data, homebuilt aircraft made up only 3% of the flying hours but were involved in 10% of the general aviation accidents in the United States. This research investigates if and how these rates have changed over the past 15 years. The National Transportation and Safety Board Aviation Accident Database and Synopses website was queried for all types of United States homebuilt accidents during 2007. Select variables were used to compare homebuilt accidents and fatality rates with non-homebuilt aircraft rates. Human and mechanical errors were implicated in homebuilt accidents similar to non-homebuilt general aviation accidents. Homebuilt accident rates per 100,000 flight hours are significantly higher than non-homebuilt accident rates (26.44 +3.36 vs. 4.89 ± 0.29

$p<0.001$) Homebuilt fatality rates per 100,000 flight hours are also significantly higher (8.67 ± 1.92 versus 1.56 ± 0.16, $p<0.001$). Safety efforts that focus on human and mechanical factors may reduce overall accident rates of both homebuilt and non-homebuilt aircraft.

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Chapter 1: Introduction

The Federal Aviation Administration (FAA) regulates commercial and general aviation and use of the national airspace. It is also developing regulations for commercial space travel in the United States. Aircraft require an FAA airworthiness certificate to demonstrate that an aircraft is airworthy. Air safety is explicit to the missions of the FAA, the Department of Transportation (DOT) and National Transportation and Safety Board (NTSB).[1,2,3]

Title 14, Code of Federal Regulations, part 21, section 21.191(g), defines experimental type certificates and amateur-built aircraft. Amateur-built aircraft are more commonly known as homebuilt aircraft. In 2007, the FAA estimated that approximately 19,000 homebuilt aircraft made up 84.11% of the experimental category.[4] The experimental type airworthiness certificate is given to aircraft to support research and development, to show compliance with the regulations, to compete in air racing, and to develop market surveys. An experimental airworthiness certificate is also given to homebuilt aircraft. A homebuilt aircraft is an aircraft that "the major portion of which has been fabricated and assembled by person(s) who undertook the construction project solely for their own education or recreation."[5] This is commonly called the "51% rule," where the major portion (at least 51%) of the aircraft construction has been completed by the homebuilder. Interpretation of what constitutes "the major portion" can be confusing, even to the FAA; for this law originated in 1964 when construction methods were much simpler.[6] The issue of fabrication and assembly is complicated by the use of sophisticated composite materials and techniques in the homebuilt industry over the last 30 years.

The Experimental Aircraft Association (EAA) was founded in 1953 to support homebuilders in all areas of their homebuilt aircraft.[7] The EAA's mission is "1) Promoting access to the dream of flight; 2) Protecting the right to fly; 3) Preserving the heritage of aviation; and 4) Preparing the future of aviation."[8] The EAA fulfills this mission with various opportunities for participation, such as the annual EAA Airventure Oshkosh airshow and the Young Eagles program. At the Airventure Oshkosh airshow there are many educational programs, safety lectures and homebuilder forums. The EAA also publishes several magazines dedicated to the support of homebuilt construction, maintenance and flight. The Young Eagles program, chaired by actor Harrison Ford, is dedicated to promoting aviation to children by having certified pilots give children rides in registered airplanes. Additionally, the EAA represents the interests of homebuilders in government and industry affairs; and develops website information resources and local educational programs**.**

The National Transportation and Safety Board (NTSB) is an "independent Federal agency charged by Congress with investigating every civil aviation accident in the United States … and issuing safety recommendations aimed at preventing future accidents."[9] Both the NTSB and the FAA use the following strict definition of accident:

> Accident means an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which

> any person suffers death or serious injury, or in which the aircraft receives substantial damage.[10]

An incident is an occurrence other than an accident that can affect the safety of an aircraft. There are many reasons why general aviation airplanes crash; and the FAA, the NTSB, AOPA and the EAA work to understand these reasons. These reasons can seem fairly obvious, like a pilot taking off on the wrong runway. However, the reasons airplanes crash can be quite complex; and showing the complexities of why the pilot took off on the wrong runway expose the intricacies of human behavior, aviation physiology and the interface of man and machine. One of the goals of aviation safety is to prevent such accidents from recurring by making recommendations that develop safer airplanes and pilots. Pilots also have a vested interest in making themselves safe pilots. They may attend safety seminars, obtain additional ratings, maintain their flight proficiency and learn about maintenance to keep themselves and their passengers from harm's way.

This research will examine the NTSB reports that describe the accidents encountered by homebuilts during 2007. This research will use the NTSB reports to compare homebuilt accidents to non-homebuilt general aviation accidents. The relevance of this work is to identify areas that are problematic for homebuilt pilots; and make suggestions for improving safety while encouraging flight. Also, this research compares rates of homebuilt accidents and fatalities from the past to the present. Hopefully, this work can help in the efforts toward building safer skies.

Chapter 2: NTSB Database

The public online NTSB Aviation Accident Database and Synopses website (http://ntsb.gov/ntsb/query.asp) contains over 140,000 aviation accidents. Its earliest reports are from 1962 and contain the records of most civil aviation accidents in the United States, its territories and possessions. Being online, the NTSB database is readily accessible compared to printed aviation accident databases as found in the International Civil Aviation Organization (ICAO) Circular Aircraft Accidents Digest. The NTSB database is searchable by multiple fields including date, location, injury severity, aircraft type, type of aircraft operation, and NTSB investigation status. This ability to search multiple fields is a distinct advantage over the Aviation Safety Network database (http://aviation-safety.net/index.php). The NTSB database was ultimately selected because of its attention to United States accidents and that it was specifically searchable for United States homebuilt versus non-homebuilt aircraft.

The NTSB database returned reports can be sorted by date, desired order and returns per page. The available types of reports include preliminary, factual and probable cause reports. Each of these relates to a different period of the accident investigation. Preliminary reports are usually available within days of an accident and are, therefore, the most subject to change. Factual reports are based on the collected series of facts surrounding the accident. This may include witness statements, weather conditions, pilot logbook hours, and pilot flight and medical certificates. The probable cause report is the synthesis of facts with NTSB interpretation defining the probable cause of the accident. This represents the completed investigation and supersedes the preliminary report.

Chapter 3: Literature Review

Commercial air travel on scheduled air carriers is much safer in terms of accident and fatality rates than other forms of transportation including general aviation and homebuilt flight. The incidence of accidents in 2007 for scheduled commercial air travel was 0.138 per 100,000 hours of flight time; roughly a factor of 70 times safer than the usual accident rates per 100,000 hours for general aviation.[11] Another way of comparing safety across different forms of travel is percentage of fatalities by mode of transportation. In 2007 passenger car and light truck occupants made up 67% of all transportation fatalities, pedestrians struck by vehicles 11%, motorcycles 12%, general aviation 1% and air carriers 0.00% (1 air carrier fatality).[12] Comparing fatalities per 100 million vehicle miles travelled is another way to show passengers the relative safety of each mode of transport. In 2007 airline travel had 0.012 fatalities per 100 million aircraft miles travelled versus 1.4 fatalities per 100 million motor vehicle miles travelled.[12(pp140,151)] Again, this reflects airline travel as roughly 100 times safer than motor vehicle travel.

There are published data on some of the factors behind general aviation aircraft accidents, such as pilot age, pilot experience, weather, day/night operations and geographical variations. Some of the earliest work by Li in 1994 found that most aircraft crash studies were based on case reports and case series; and few of those studies followed rigorous epidemiologic design. Li suggested that better methods of epidemiology could help describe the pilot related risk factors behind aircraft accidents.[13]

Li, Baker, Grabowski and Rebok in 2001 found that pilot error was more frequently encountered in general aviation accidents (85%) than in major airline accidents (38%).[14] Craig reasons that general aviation is riskier than commercial airlines because more time is spent taking off and landing per hour. Craig also finds that inexperience is the largest contributor to the general aviation accident rate. Fifty seven percent of accidents from 1983 to 2000 occurred when pilots had between 50 and 350 flight hours. The challenge of pilots at this point in their flight training and proficiency development is to survive this period of inexperience. He called this range of 50 to 350 flight hours “the Killing Zone.”[15]

Craig’s killing zone extends into many of the prime general aviation accident categories. Flying into bad weather is called continued Visual Flight Rules (VFR) flight into Instrument Flight Rules (IFR) conditions. Craig states that this accident category has the highest number general aviation aircraft deaths. The 2008 Nall Report Accident Trends and Factors For 2007 published by the AOPA Air Safety Foundation agrees: an accident in Instrument Meteorological Conditions (IMC) increases the fatality risk by a factor of five.[16]

Craig’s killing zone also applies to flying at night, where 59% of the night general aviation accidents between 1983 and 2000 involved inexperienced pilots. Night flying, like instrument flying obscures a pilot’s visual cues. What is left is the human sensory system that works well on the ground; but is easily fooled with motion around several axes. The 2008 Nall Report concurs; an accident at night doubles the risk of fatality.

Similarly, in 2001, Li, Baker, Grabowski and Rebok found that as a pilot's level of ratings and experience increased, the frequency of pilot error decreased. Baker, Lamb, Grabowski, Rebok and Li found gender differences in types of accidents; however overall they found that most general aviation accidents were due to mishandling of aircraft kinetics, poor decision making and inattention.[17] Li and Baker found the greatest correlates to general aviation crash fatalities were blunt force impact; and suggested better occupant protection equipment.[18] Kearney and Li report that general aviation crash rates and fatal crash rates are highest in mountainous terrain.[19]

Using 1993 NTSB data, Hasselquist and Baker were the first to publish specifically on homebuilt aircraft. They found that while homebuilt aircraft made up only an estimated 3% of the flying hours of the general aviation aircraft in 1993, they caused a disproportionate 10% of the accidents.[20] They proposed this disparity may be due to pilots having fewer type-specific flight hours. The higher homebuilt accident and fatality rates may also have been due to the higher mechanical failure in homebuilts during takeoff and landing. However, since Hasselquist's work, little has been published comparing the safety of homebuilts with other general aviation aircraft. Nothing has been published that updates the disparity in safety between homebuilts and other general aviation aircraft.

Chapter 4: Significance

By examining current data from the NTSB, can be discerned disparities in safety between homebuilts and other general aviation aircraft. These results may guide pilot education and development of safer homebuilt aircraft. Furthermore, comparing the 1993 and 2007 data may show general safety trends. This analysis may further help to define safety related policy. Additional descriptive epidemiology of the 2007 NTSB database may provide further direction for the safety efforts of organizations such as the FAA, the EAA, and the Aircraft Owners and Pilots Association (AOPA).

Chapter 5: Hypotheses

1) H0: NTSB homebuilt accident and fatality rates per 1000 aircraft and per 100,000 flight hours in 2007 are no different from 2007 general aviation accident and fatality rates

   H1: NTSB homebuilt accident and fatality rates per 1000 aircraft and per 100,000 flight hours in 2007 are greater or less than the 2007 general aviation accident and fatality rates

2) H0: NTSB homebuilt accident and fatality rates per 1000 aircraft and per 100,000 flight hours in 2007 are no different from homebuilt accident and fatality rates of 1993

   H1: NTSB homebuilt accident and fatality rates per 1000 aircraft and per 100,000 flight hours in 2007 are greater or less than the homebuilt accident and fatality rates of 1993

Chapter 6: Methods

An Institutional Review Board exemption was obtained January 2009 due to the publicly accessible nature of the NTSB accident reports. Data were collected to compare accident and fatality rates for homebuilt versus non-homebuilt general aviation aircraft. The preliminary, factual and probable cause accident reports were reviewed from the NTSB Aviation Accident Database and Synopses website (http://ntsb.gov/ntsb/query.asp). Search criteria for the descriptive epidemiology data were homebuilt aircraft in the United States under general aviation operations with preliminary, factual or probable cause types of accident reports between January 1, 2007 and December 31, 2007. (See Table 1) For the aircraft accident and fatality rates the search criteria was narrowed to include accidents only (no incidents) and airplanes only (no helicopters or gyrocopters) as this more closely mirrors the general aviation non-homebuilt database.

Table 1: Search Criteria for 2007 United States Homebuilt Accident Descriptive Epidemiology and Accident/Fatality Rate Data

Search Criteria	Number of accident reports returned	Number of Fatalities reported	Use of Data
1/1/2007-12/31/2007 United States: Accidents and Incidents Homebuilt Aircraft All aircraft types All reports General Aviation Operations	265	N/A	Descriptive Epidemiology
1/1/2007-12/31/2007 United States: Accidents Only Homebuilt Aircraft Airplanes Only All reports General Aviation Operations	238	78	Accident and Fatality rates

For comparison, the NTSB accident website was queried for the general aviation accident and fatality occurrences. The query included accidents only (no incidents) preliminary, factual and probable cause accident reports of general aviation operations for non-homebuilt built airplanes in the United States between January 1, 2007 and December 31, 2007. (See Table 2)

Table 2: Search Criteria for 2007 United States General Aviation Non-Homebuilt Accident Descriptive Epidemiology and Accident/Fatality Rate Data

Search Criteria	Number of accident reports returned	Number of Fatalities reported	Study Use
1/1/2007-12/31/2007 United States: No Homebuilts Airplanes Only All reports General Aviation Operations	1118	357	Accident and Fatality rates

The data from the NTSB reports, both descriptive and accident/fatality occurrences were tabulated using Microsoft Excel 2007 by the author, a 500 hour commercially rated Certified Flight Instructor Instrument.

Interpreting the causality of accidents is variable in nature depending on the available evidence and the experience of the investigators. Upon inspection of the NTSB database, accident causality was occasionally attributed to factors not normally considered as accident factors. For instance, one report listed the ground as a causal factor:

> Findings
> 1. (C) AIRCRAFT CONTROL - NOT MAINTAINED - PILOT IN COMMAND
> ----------
> Occurrence #2: IN FLIGHT COLLISION WITH TERRAIN/WATER
> Phase of Operation: DESCENT - UNCONTROLLED
> Findings
> 2. (C) TERRAIN CONDITION - GROUND
> Findings Legend: (C) = Cause, (F) = Factor

As no other NTSB reports list the ground as a separate causal factor; and neither the FAA nor the NTSB safety reports use ground as a separate category of cause, the final descriptive epidemiology data did not include ground as its own new causal category among human, mechanical, weather, undetermined and mixed.

Similarly, the NTSB database occasionally excluded what appeared a clear cause or factor in the accident. It is widely known among pilots and flight instructors that according to basic aerodynamics, exceeding a certain angle between the direction of the wing's travel and the oncoming wind causes the wings to lose lift; and the airplane may precipitously drop, or "stall." Stalls are a major cause of accidents. The 2004 NTSB Annual Review of Aircraft Accident Data reports stall and then collision with the ground as the most common string of events leading to an accident.[21] Another of the 2007 homebuilt accident reports listed the following:

> Witnesses stated that they observed the airplane in level flight, about 300 feet above the ground, when the engine quit. The airplane was then observed executing a left turn in an attempt to return to the airport. During the left turn, the airplane began to descend at a rapid rate, then impacted the ground.
>
> Findings
> 1. (C) INDUCTION AIR CONTROL, INTAKE MANIFOLD – BLOCKED (PARTIAL)
> 2. (C) FLUID, FUEL - CONTAMINATION, WATER
> \----------
> Occurrence #2: FORCED LANDING
> Phase of Operation: EMERGENCY DESCENT/LANDING
> \----------
> Occurrence #3: IN FLIGHT COLLISION WITH TERRAIN/WATER
> Phase of Operation: EMERGENCY LANDING AFTER TAKEOFF
> Findings
> 3. TERRAIN CONDITION - GROUND
> Findings Legend: (C) = Cause, (F) = Factor

In the findings of this case, there was no mention of the likely inadvertent stall and loss of control in flight. Therefore, there is no mention of pilot error as a causal factor. It is likely the plane experienced loss of power, the pilot attempted return to the airport and then experienced an inadvertent stall/loss of control. It is very likely that pilot error played an important factor in this accident. Therefore, human error was added to the descriptive epidemiological count. This interpretive procedure was performed for less than 2% of the NTSB accident reports.

Descriptive epidemiology variables were chosen to reflect the general causal elements of aircraft accidents in use by the FAA or the NTSB in previous safety reports. Accident and fatality rates were calculated using denominators from the NTSB accident reports and the FAA‘s General Aviation and Part 135 Activity Survey for 2007.[22]

Statistical Analysis:

All rates were reported using a 95% confidence interval based on a Poisson approximation. Since the number of accidents was large, the rates were compared using a z-test. Contingency tables variables were tested for independence using the chi-square test. Means were compared using confidence intervals and t-tests.

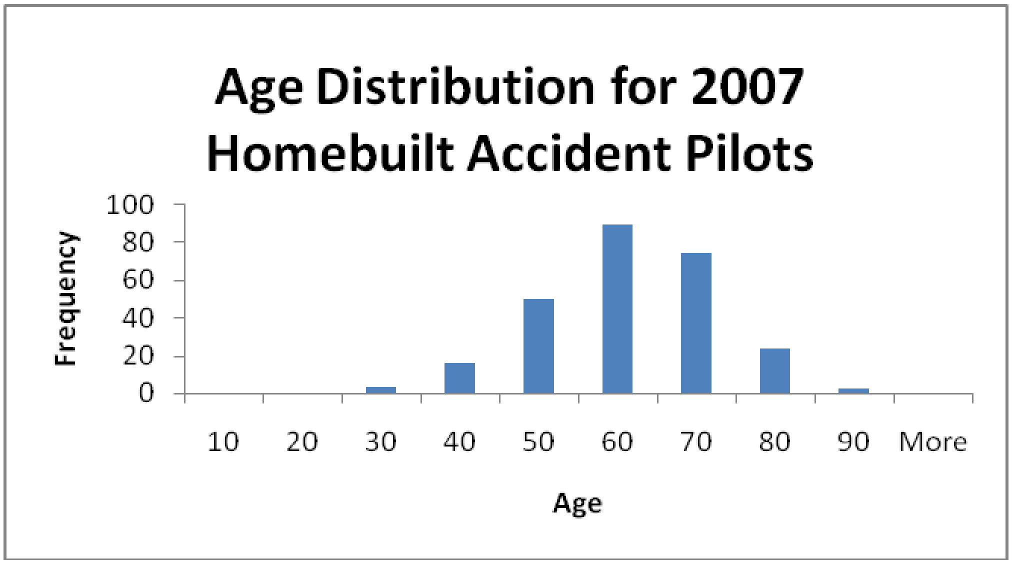
Chapter 7: Results

The mean age of pilots involved in a homebuilt accident in 2007 was 57, with an average of 3782 total flight hours and 43 flight hours in the 90 days preceding the accident. (See Table 3) The age of homebuilt accident pilots followed a normal distribution. (See Figure 1) The pilots of homebuilt accidents are significantly older than their non-homebuilt counterparts who averaged 50 years. (Mean age 56.81 ±1.38 95% CI by T-test, p<.001) The total percentage of homebuilt accident pilots who are over the age of 60 climbed from 36% in 1993 to 44% in 2007, however the change was not statistically significant. (Chi Square, p=0.08)

Table 3: Characteristics of 2007 Homebuilt Accident Pilots

Variable	Mean	Range
Age	57	19-87
Total Flight Hours	3782	0-34000
Flight Hours in the 90 Days Preceding Accident	43	0-400

Figure 1: Age Distribution for 2007 Homebuilt Accident Pilots



The distribution of total flight hours of the 2007 homebuilt accident pilots showed a right skew with the greatest frequency of accident pilots having less than 1000 hours of total flight time and less than 20 hours in the preceding 90 days. (See Figures 2 and 3)

Figure 2: Frequency of Total Flight Hours for 2007 Homebuilt Accident Pilots

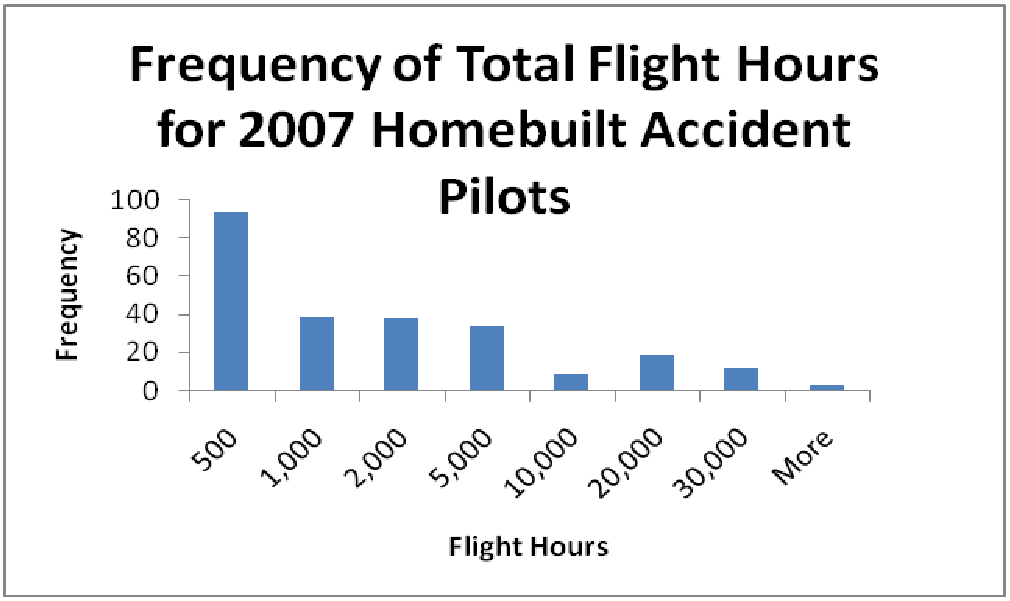
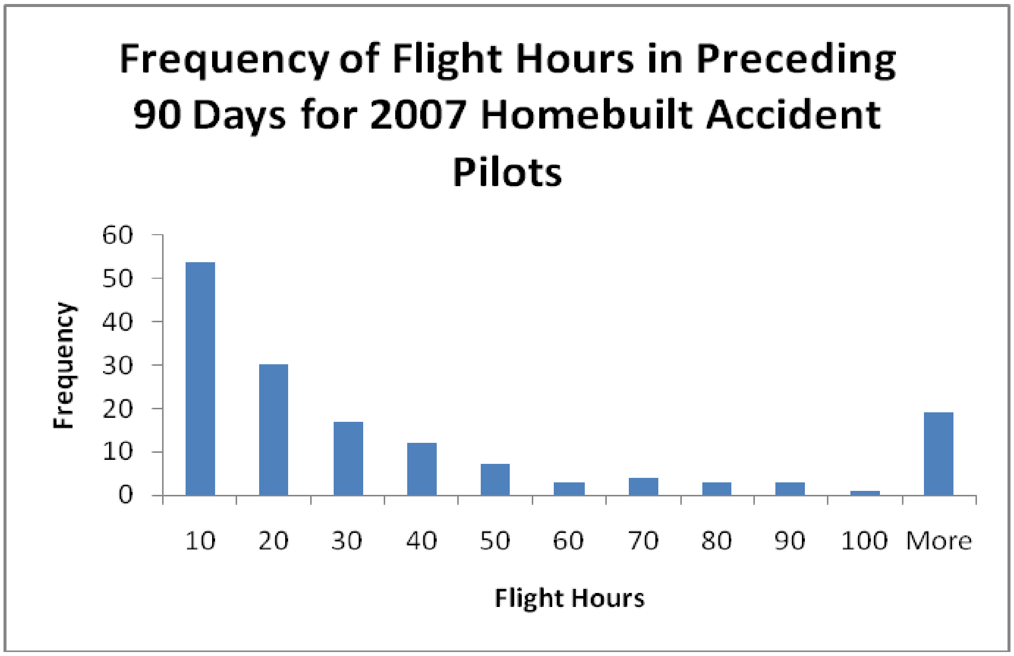


Figure 3: Frequency of Flight Hours in Preceding 90 Days for 2007 Homebuilt Accident Pilots



Nearly half (45%) of the homebuilt accident pilots in 2007 had a private pilot rating; almost a third (30%) had a commercial pilot rating. (See Table 4) Note that a single pilot could have several ratings among different aircraft. For instance, they could be an Airline Transport Pilot in airplanes but only a Private Pilot in helicopters.

Table 4: Proportion of Ratings Held by 2007 Homebuilt Accident Pilots

Rating	Number	Percent
No License	12	3.92%
Student	9	2.94%
Sport	15	4.90%
Private	138	45.10%
Commercial	91	29.74%
Airline Transport Pilot	41	13.40%
Total Recorded Ratings	306	100.00%

The NTSB categorizes injuries as fatal, severe or minor, with specific definitions for each. (See Table 5) The 2007 Homebuilt Accident Pilot Highest Rating Versus Accident Count by Injury Severity (See Table 6) includes pilots for whom NTSB officials could find no evidence of FAA pilot ratings or flight hours to Airline Transport Pilots with 34,000 flight hours. The Chi-Square test cannot prove independence of pilot rating versus injury severity variables at p=0.32.

Table 5: NTSB Categorization and Definition of Injury Severity for Aircraft Accidents[23]

Fatal	Any injury that results in death within 30 days of the accident.
Serious	Any injury that (1) requires the individual to be hospitalized for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5% of the body surface.
Minor	Any injury that is neither fatal nor serious.
None	No injury.

Table 6: 2007 Homebuilt Accident Pilot Highest Rating versus Accident Count by Injury Severity

	Fatal Accidents		Serious Accidents		Minor/ Uninjured Accidents	
Rating	Number	Percent	Number	Percent	Number	Percent
No License or Student	6	9.23%	7	14.00%	10	6.17%
Sport	5	7.69%	3	6.00%	6	3.70%
Private	31	47.69%	25	50.00%	81	50.00%
Commercial	17	26.15%	8	16.00%	33	20.37%
ATP	6	9.23%	7	14.00%	32	19.75%
Total Accident Count	65	100.00%	50	100.00%	162	100.00%

The causes and factors related to injury severity included those that were human, mechanical, weather, undetermined or mixed. (See Table 7) Human causes dominate across all injury severity ratings, ranging between 59% and 82%. Mechanical causes are second across all injury severity ratings except fatalities, where undetermined causes are second to human causes.

Weather was causal in only 2% of 2007 homebuilt accidents. Only 7% of the accidents occurred on days with a cloud ceiling of less than 5,000 feet; and only 2.3% of accident flights had a visibility less than 5 statute miles. Similarly, only 11% of the accident flights occurred with a wind speed of greater than 15 miles per hour.

Table 7: Causes Versus Accident Count by Injury Severity for 2007 Homebuilt Aircraft Accidents

	Fatal Accidents		Serious Accidents		Minor/ Uninjured Accidents	
	Number	Percent	Number	Percent	Number	Percent
Human	47	72.31%	41	82.00%	96	59.26%
Mechanical	9	13.85%	12	24.00%	64	39.51%
Weather	1	1.54%	0	0.00%	5	3.09%
Undetermined	12	18.46%	2	4.00%	6	3.70%
Mixed	6	9.23%	5	10.00%	11	6.79%
Total Accident Count	65	100.00%	50	100.00%	162	100.00%

The descriptive epidemiological breakdown of human factors (See Table 8) finds failure to maintain control/cause aircraft to stall as the most frequent cause of homebuilt aircraft accident. That, in combination with misjudged landings, makes up nearly half of the elements of pilot error. The order of the causes listed in Table 8 represents the order of cause as originally listed by Hasselquist regarding 1993 homebuilt accidents.[20] The numeric percentage reflects the current order obtained from the 2007 data. Misjudged fuel represented 6.75% of the human errors. Alcohol consumption was found to be causal in only one accident of homebuilt aircraft in 2007. Failure to maintain directional control on rollout was the third highest contributor to pilot error. NTSB accident reports typically have several causal factors listed as attributes to a single accident.

Table 8: Breakdown of Pilot Error as Attributable Causes or Factors of 2007 Homebuilt Accidents

Separate Cause or Factor	Number	Percent
Failure to maintain control/Caused aircraft to stall	76	30.16%
Poor handling of airport surface winds	7	2.78%
Misjudged landing	43	17.06%
Misjudged fuel available/landing requirements	17	6.75%
Failure to see and avoid	11	4.37%
Performing aerobatics/unable to recover	5	1.98%
Improper preflight	8	3.17%
Improper maintenance/construction	10	3.97%
Maneuvering at insufficient altitude	10	3.97%
Drugs medications	4	1.59%
Fuel selector set wrong	1	0.40%
Poor handling of hazardous runway conditions	0	0.00%
Failure to maintain directional control during landing rollout	21	8.33%
Improper use of flight controls	7	2.78%
Poor in-flight planning	14	5.56%
Misjudged weather and terrain	11	4.37%
Spatial disorientation	0	0.00%
Misjudged weight	0	0.00%
Misunderstood fuel system	1	0.40%
Poor handling of density altitude	1	0.40%
Flew into forecast or known icing	1	0.40%
Got lost	0	0.00%
Alcohol	1	0.40%
Unknown	3	1.19%
Total	252	100.00%

As listed, mechanical problems caused from approximately 14-40% of accidents. Total loss of power occurred in 72% of those. Most often, the cause of the loss of power was found, but often it was not. (See Table 9) Again, the order of causes listed in Table 9 is that as listed by Hasselquist regarding 1993 homebuilt accidents; the numeric percentage reflects the 2007 homebuilt data. The only exception to the Hasselquist listing is propeller failure, which was added as there were four cases of propeller failure among 2007 homebuilt accidents.

Table 9: Breakdown of Mechanical Problems as Attributable Causes or Factors of 2007 Homebuilt Accidents

Separate Cause or Factor	Number	Percent
Complete power loss-cause determined	42	39.62%
Complete power loss-cause unknown	34	32.08%
Flight control failure	2	1.89%
Propeller failure*	4	3.77%
Landing gear failure	12	11.32%
Airframe failure	6	5.66%
Spark plugs fouled	1	0.94%
Poor aircraft design or assembly	1	0.94%
Water in fuel line/contaminated fuel	1	0.94%
Throttle separated from carburetor	0	0.00%
Cooling system line separated	0	0.00%
Engine fire	3	2.83%
Total	106	100.00%

*New cause in 2007

Most accidents in homebuilt aircraft also occurred during the takeoff or landing phase of flight. (See Table 10) The proportion of homebuilt aircraft accidents in which the aircraft use was classified as personal use was very similar being 85.61% in 2007 and 88% in 1993.

Table 10: Breakdown of Phase of Flight of 2007 Homebuilt Accidents

Separate Phases of Flight	Number	Percent
Prior to Taxi	0	0.00%
Taxi	1	0.38%
Takeoff and Climbout	78	29.55%
Cruise/Maneuvering	85	32.20%
Descent	1	0.38%
Downwind leg	8	3.03%
Base Leg	2	0.76%
Final Approach	18	6.82%
Landing	60	22.73%
Go Around	11	4.17%
Unknown	0	0.00%
Total	264	100.00%

Comparing 2007 homebuilt aircraft to non-homebuilt aircraft, one sees a doubling of the accident and fatality rates per 1000 aircraft.[21] These differences are significant. (See Table 12) There is more than a 5 time difference between accident rate and fatality rate per 100,000 flight hours. These differences are also significant. Homebuilt aircraft make up only 9.47% of general aviation aircraft yet are involved in 17.55% of the general aviation accidents.

Table 11: Comparison between 2007 General Aviation Homebuilt and Non-Homebuilt Aircraft Accident and Fatality Rates

	Non-Homebuilt	Homebuilt	p value
Million Hours Flown	22.86	0.9	
Number of Aircraft	186,806	19,538	
Number of Accidents	1118	238	
Accident Rate per 1000 Aircraft	5.98 ± 0.35	12.18± 1.54	<0.001
Accident Rate per 100,000 Hours	4.89 ± 0.29	26.44 ± 3.36	<0.001
Number of Fatalities	357	78	
Fatality Rate per 1000 Aircraft	1.91±0.20	3.99 ± 0.89	<0.001
Fatality Rate per 100,000 Hours	1.56 ±0.16	8.67 ± 1.92	<0.001

A similar comparison between 1993 and 2007 data shows a statistically significant decrease in the homebuilt accident rate per 1000 aircraft and an increase in the homebuilt fatality rate per 100,000 hours. (See Table 12)

Table 12: Comparison between 1993 and 2007 General Aviation Non-Homebuilt and Homebuilt Aircraft Accident and Fatality Rates

	1993		2007		
	Non-Homebuilt	Homebuilt	Non-Homebuilt	Homebuilt	p value
Accident Rate per 1000 Aircraft	7.4	19±0.63	5.98	12.18±1.55	<0.001
Accident Rate per 100,000 Hours	7.8	28.8±0.70	4.89	26.44±3.36	0.18
Fatality Rate per 1000 Aircraft	N/A	N/A	1.91	3.99	
Fatality Rate per 100,000 Hours	1.8	3.4±0.24	1.56	8.67±1.02	<0.001

Chapter 8: Discussion

When examining data that describes accidents, injury and death there is an obligation to help prevent such unfortunate events from recurring. Descriptive epidemiology of the accidents helps aerospace specialists focus safety efforts.

In 2007, homebuilt aircraft made up almost one fifth of the general aviation accidents, and therefore deserve considerable attention. This high proportion of accidents skews the general aviation accident rate upward from 4.89 accidents per 100,000 hours (not including homebuilts) to 6.47 accidents per 100,000 hours (including homebuilts) as published in the 2008 Nall report.[16(p4)] Therefore, efforts aimed at reducing homebuilt accidents may effectively reduce the accident rate of general aviation aircraft.

2007 homebuilt accident pilots with more advanced pilot ratings had a smaller proportion of the fatal accidents. This result is similar to that found by Li, Baker, Grabowski and Rebok's finding in 2001.[14]

It is possible older pilots fly homebuilts because older pilots have the time required for building and maintaining a homebuilt. Age may have its advantages, however, as alcohol factored in only one 2007 homebuilt accident, alcohol has been implicated in 7% of general aviation fatalities from 1994-1998.[22]

Human and mechanical factors continue to make up the majority of the causes of 2007 homebuilt accidents. This is consistent with many previous general aviation studies including the 2008 Nall Report, where human factors by far continue to remain the greatest concern for aviation safety.[16(p5)]

Failure to maintain aircraft control remains the greatest threat to pilots, making up the majority of the human causes of accidents among general aviation.[23] In-flight loss of control continues to plague all general aviation aircraft. “Flying the plane” amidst simple distractions is taught to student pilots. However, it is unclear why inadvertent stalls and loss of control persist. Low level operations, high wing loading and lack of experience could all contribute to loss of control accidents in homebuilts. Could more specific training relieve this burden? Perhaps more attention needs to be given to flight with distractions. Maybe more training time committed to power off gliding and emergency landing procedures could help avert accidents.

Misjudged landing and fuel availability are the second and third causes of homebuilt accidents. This is similar to the Annual Review of Aircraft Accident Data: U.S. General Aviation, Calendar Year 2004. Could better instrumentation such as standardized fuel flow monitors help this constant challenge?

While there was a decrease in the total homebuilt mechanical failures as compared to Hasselquist in 1993, complete power loss occurred in 72% of the 2007 homebuilt accidents attributed to mechanical causes. This high proportion places an important burden on the pilot/operator/mechanic to ensure correct maintenance. Also, as one of the 2007 homebuilt accidents occurred because of the pilot’s ignorance of a manufacturers recall, attention to recalls and safety notices may play a part in decreasing future accidents.

The nearly negligible impact of weather on 2007 homebuilt accidents is in stark contrast to the typical non-homebuilt aircraft accident. According to the 2008 Nall report greater than 10% of the general aviation accidents and greater than 30% of the general aviation fatal accidents occur either at night and/or in Instrument Meteorological Conditions (IMC).[16(p12)] This is likely due to the fact that few homebuilt aircraft fly cross country or fly night operations. Most homebuilts fly short maneuvering trips taking off and landing at the same airport.

However, with the miniaturization of flight instruments capable of multiple functions, it is reasonable to expect more homebuilt aircraft to eventually fly under Instrument Flight Rules (IFR). Likewise, increased portable and miniature avionics capabilities may lull the Visual Flight Rules (VFR) pilot into a false sense of security, baiting them into unintentionally entering IFR conditions. Therefore, it would be reasonable to expect a future increase in homebuilt weather related and/or night accidents.

Eighteen percent of 2007 homebuilt accidents had an undetermined cause, whether that is an undetermined loss of power or an undetermined cause of accident completely. This is higher than the 12.3% of undetermined causes listed in the 2008 Nall report for general aviation.[16(p5)] Fatal accidents had a higher rate of undetermined causes, which would be expected given the difficult nature of an accident investigation without input from the pilots, occupants, or other witnesses.

That 8% of the 2007 homebuilt accidents listed multiple categories of causes (Human, Mechanical, Weather, etc.) is testament to the understanding that accidents are created from chains of events as opposed to a single discrete cause. As the ability to process data grows, so will our ability to understand the complexity of accident occurrence chains. Increasing pilot awareness to avoid factors that may lead to accidents should remain a focus of safety education.

Increased use of portable Global Positioning System (GPS) in homebuilts may also help to determine chains of events. GPS technology was used in the recreation of one of the 2007 homebuilt accident fatalities. Could future GPS systems become part of a flight instruction system and accident avoidance system, where GPS receivers integrated with other onboard computers and accelerometers could provide real time feedback when a plane was operating close to its operating limitations? Such a system would not limit GPS as a locator system; but could integrate with other data inputs to warn pilots of impending risks such as low altitude maneuvering and earlier stall warnings.

Most accidents occur during take-off and landing, with many also occurring during cruise flight and maneuvering. This data is similar to previous general aviation accident reports. Such findings are likely because the period during takeoffs and landings has the highest workload, the lowest altitude and greatest aircraft traffic.

Accident and fatality rates are significantly lower for non-homebuilt general aviation aircraft than homebuilts. There are many factors that may explain why homebuilt flight is more dangerous than non-homebuilt flight.

One possible reason for this disparity is that these craft are experimental in their construction. Many homebuilt aircraft have characteristics that make the integration of man and machine more complex and less forgiving than the standard production Cessna training airplane. Essentially, they can be harder to fly.

Figure 4: High Performance Lancair Homebuilt[24]

Homebuilts, like hot rods, are performance driven. Their owners are often trying to maximize power while reducing drag in every way possible. Flying faster, higher, and more efficiently are some of the benefits coming from the development of homebuilt aircraft. These benefits are seen in the composite structures on newer production aircraft and the technology that supports commercial spaceflight. However, pushing the limits comes at a price. For instance, some homebuilt airplanes are pressurized and capable of flight at over 20,000 feet. This far exceeds the performance capabilities of many standard general aviation aircraft; and therefore, requires a specific piloting and mechanical skill set to support that high performance. Several of the 2007 homebuilt accidents occurred in what would be considered high performance aircraft.

Also, modifications for high performance can bring about drastic changes in basic flight characteristics. For instance, increasing the engine size on a Rutan designed

Varieze, from the standard Continental O-200 170 pound 100hp engine to a Lycoming O-320 244 pound 150hp engine will increase cruise speed by about 40 mph. The tradeoff however, is that this will also increase the stall speed by approximately 10mph; and therefore increase the required landing speed to approximately 100 mph (R. Harris, Owner of EZ Jets, Inc.; oral communication; June 2009). On a long 10,000 foot runway this is not necessarily a problem. However, given the higher likelihood for complete power loss in homebuilts, a higher approach speed at an emergency off airport landing could create tragedy.

Figure 5: Rutan VariEze Homebuilt (Provided by the author. Photographed by Gregory Shaskan in July 2006)

Some homebuilts, such as the VariEze, have design characteristics that make them safer, such as more difficult to stall. However, due to a thin small front wheel, VariEzes will be prone to flipping over during landings on soft terrain. Other planes such as the Quickie and the Glassair are designed with high wing loading (a higher amount of weight carried per area of the wing) for high speed. This means less maneuverability, higher stall and landing speeds and greater effort and concentration to fly. Additionally, in high wing loaded homebuilts, the speed when an airplane stalls is much closer to the normal operating speed of the aircraft. This slim margin for error is reduced further when an airplane turns, because this increases the stall speed. Even in homebuilts with greater maneuverability, such as the Pitts, performing aerobatic maneuvers brings the pilot closer to the aerodynamic limits of the plane. Regardless, given any experimental plane, there are characteristics that are very different than previous planes a pilot has flown. Therefore, thorough familiarization of all flight, operational and mechanical characteristics is essential prior to first flight.

Figure 6: Rutan Quickie Homebuilt[25]

Figure 7: Glassair Homebuilt[26]

Figure 8: Pitts Aerobatic Homebuilt[27]

The John Denver Long-EZ crash is an example of how unfamiliarity with an aircraft can be the determining occurrence in an accident chain. A 2750 hour pilot, Denver had recently purchased a Long-EZ. On the day of the fatal flight, he had not completely fueled the plane, was flying at a low altitude, and had a fuel selector valve located in a difficult position to reach in the aircraft. The NTSB probable cause report surmises that his aircraft ran out of fuel; and as he attempted to switch fuel tanks he lost control of the plane at too low an altitude to recover. From this high profile accident, one can see that airplane familiarity is essential. When combined with the many varied flight characteristics of homebuilt aircraft; homebuilt flight can be especially unforgiving.

Figure 9: Long-EZ Homebuilt[28]

Chapter 9: Limitations

Limitations to this study include limitations inherent in the NTSB database, interpretation of that database, available denominators, and changes in how accidents are described over time.

Undoubtedly, the NTSB database is an invaluable resource. However, occasional errors or inconsistencies of accident interpretation are possible. While every effort to correctly interpret this database was made, the case can be made that further interpretation of an already interpretive database may only muddy the waters.

Using the correct denominators for accident and fatality rates is the greatest single limitation of the study. While the number of aircraft can be tracked relatively consistently through aircraft registrations, the use of flight hours has always been problematic. The hour denominator depends on the accuracy of the FAA’s yearly activity survey, which has been debated.[16(p33)]

And finally, the way we perceive the causes of accidents changes over time. This is reflected in the shift away from our focus on single attribute causes of accidents to understanding accidents as complex chains of events. Our understanding of these chains of occurrences is enhanced by our ability to record and analyze data with greater ease than in the past. However, it can be difficult to apply our new understanding to past accidents en masse when trying to make comparisons in general descriptive trends.

Chapter 10: Safety Recommendations

Based on the descriptive epidemiology of the 2007 homebuilt aircraft accidents there are several clear trends that direct the focus of safety efforts. First, pilots at all levels continue to inadvertently lose control of the plane. It would then make sense to further focus on the basics of “flying the airplane” amidst distractions. This skill is most often accomplished with the flight instructor having the student perform a fairly simple task, such as reaching for a pencil or folding a map, while flying. Perhaps, increasing the frequency and intensity of this training could prevent future accidents. This could be coupled with more contingency training; such as better familiarity with engine out procedures at lower altitudes. More work with engine out gliding skills may also help avoid accidents.

Landing accidents continue to burden the general aviation system. The FAA’s flight currency requirements for general aviation pilots carrying passengers include three take offs and landings in the last 90 days. These requirements include three landings to a full stop if flying passengers in an aircraft with a tailwheel; and three landings to a full stop at night if flying passengers at night.[29] Increasing these requirements may help decrease landing accidents. Similarly, increasing the required FAA pilot flight review from every two years to every year could also decrease accidents. However, any such changes would need to carefully balance the idea of encouraging instead of stifling general aviation flight experience

Homebuilts continue to have challenges with mechanical problems. Special attention to the continued concerns over proper maintenance may help save lives. Reinforcing to pilots that just because an aircraft has an experimental certificate does not relinquish the need for proper maintenance is an essential point for homebuilt pilots. Additional training to flight instructors so that they could educate pilots transitioning to homebuilt aircraft may also help reduce future accidents.

Chapter 11: Future Use of This Project

The best further use of this project would be to find ways to reinforce all of the above concepts in an effort to reduce accidents. This could be accomplished with the help of both the FAA and the EAA, as homebuilts continue to make up a large proportion of general aviation accidents. Distribution of pamphlets at aviation events such as Oshkosh and Sun and Fun could reach a wide variety of homebuilt pilots. Furthermore, specific safety seminars on homebuilt pilot and aircraft concerns could be given at these large events as well as in conjunction with local Flight Standards District Offices (FSDO).

Glossary

AOPA- Aircraft Owners and Pilots Association

ATP- Airline Transport Pilot

CFI- Certified Flight Instructor

DOT- Department of Transportation

EAA- Experimental Aircraft Association

FAA- Federal Aviation Administration

FSDO- Flight Standards District Offices

GPS- Global Positioning System

IFR- Instrument Flight Rules

IMC- Instrument Meteorological Conditions

ICAO-International Civil Aviation Organization

NASA- National Aeronautics and Space Administration

NTSB- National Transportation and Safety Board

VFR- Visual Flight Rules

VMC- Visual Meteorological Conditions

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Vita

Gregory Giancarlo Shaskan, son of Edward Gregory Shaskan and Kathleen Field Cobb, was born January 14, 1966 in Naples, Italy. He resided in Farmington, Connecticut through high school; and attended Pomona College in Claremont, California. He received a Master of Traditional Oriental Medicine from Pacific College of Oriental Medicine in San Diego, California. Interested in international medicine he attended Saint Matthew's School of Medicine, spending two years in Ambergris Caye, Belize and two years in Brighton, England. His Family Medicine Residency at Saint Joseph's Regional Medical Center in South Bend, Indiana included an International Health Track, where he provided Tsunami relief in Sri Lanka and primary care medicine during several trips to the Philippines. He completed a Sports Medicine Fellowship at Resurrection Medical Center in Chicago, Illinois; and worked briefly at as a Clinical Assistant professor for Loyola University in Chicago before being accepted into the University of Texas Medical Branch/ National Aeronautics and Space Administration Aerospace Medicine Residency in Galveston, Texas.

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