Light Sport and General Aviation Airplane Comparison and Harloff Performance Factor

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About the author

Dr. Gary J. Harloff earned B.S., M.S., and Ph.D. degrees in Aerospace engineering at UT-Austin, UF-Gainesville, and UT-Arlington respectively, and has worked in research at Boeing, Pratt & Whitney Aircraft, LTV Aerospace, NASA, and others. He has developed aerodynamic and propulsion technology for flight and orbit. His current interest is in developing a new light sport aircraft with a new propulsion system and is looking for investors. He also is a fee-based money manager for Harloff Capital Management www.harloffcapital.com , a division of Harloff Inc., with new investment technology unavailable to Wall Street.

Introduction

A person who is unfamiliar with flight and interested in buying a Light Sport or General Aviation Airplane may face several years of discovery until they are happy with their airplane. Airplane size, performance, and flyability relationships are hard to quantify. This study characterizes current Light Sport (LSA) and General Aviation (GA) airplanes. About 93 airplanes are examined from manufacturer specification level information sheets and available information. The data for each airplane are presented in the appendix. From the manufacturer supplied information aerodynamic performance is computed, and is presented in terms of excess horsepower ratio, lift/drag, maximum lift coefficient, and zero lift drag. An airplane rating system, the Harloff Performance Factor, is employed to quantify airplane flyability for low-time to high-time pilots. A low number indicates an easy to fly airplane for low-time pilots. A high number indicates a harder to fly airplane for a higher skilled and higher-time pilot. The rating system can also be used to determine if a wing or engine change is desirable, and how one airplane compares to another in terms of overall performance.

Minimum horsepower require for flight

The horsepower required for level flight can be related to 0.0431 times the take off gross weight raised to the 1.5 power, all divided by wing span. Thus the minimum engine horsepower can be computed once the airplane weight and wing span are known. The actual airplane horsepower is divided by this minimum horsepower to provide a measure of excess power, and the horsepower ratio is employed in the Harloff Performance Factor presented below.

Aerodynamic performance

Zero lift drag coefficient

The airplane drag is the sum of: a) zero-lift drag, and b) lift-induced drag. From the manufacturer-supplied information a zero lift drag coefficient, Cd0, is computed. It can be shown that the airplane maximum lift to drag ratio varies inversely with the inverse of the square root of Cd0. Airplanes with lower Cd0 have higher lift to drag ratios, and subsequently have higher ranges compared to an airplanes with lower Cd0. Without the airplane drag coefficient, it is hard to evaluate the range differences between different airplanes due to differing amounts of fuel on board. The Cd0 coefficient usually varies between 0.02 and 0.03, although both lower and higher drag airplanes are reported here. Low drag airplanes are more fuel efficient than higher drag airplanes. Low drag airplanes usually have aerodynamic covers on wheels, no struts, have small surface area, and have a smooth composite finish over the body and wings. Of the airplanes examined, the amphibian Beaver has the highest Cd0 of 0.069 and a maximum L/D of 9.0. The airplane with the lowest Cd0 of 0.013 is the Glassair iii, with the 27-foot span wing, and it has a L/D of 19.7. Table 1 shows L/D, take-off lift coefficient, and zero lift drag for each of the airplanes examined.

Stall speed

The Light Sport Airplane maximum stall speed, the minimum controllable speed, is 45 kts. Lower stall speed aircraft are generally safer than high stall speed aircraft. And FAR 23 certified airplanes have an upper stall speed limit of 61 kts. A stall speed above 50 kts may require higher skill level than most low-time pilots have. Take off velocity is generally 1.15 times higher than stall speed. The airplane stall speed is mostly determined by wing loading (weight/wing area) and deployed flap geometry, if any. As a rule of thumb, Light Sport airplanes with a stall speed below 45 knots will have a wing span of about 30 ft. or higher and a span/chord ratio of 7.5 or less. One of the lowest LSA stall speeds is for the Sport Aircraft SportCruiser at 29 knots. Some airplanes have much higher stall speeds. Consider for example, the Lancair IV-P with a stall speed of 65. kts., and the dual boom twin-engine pusher/puller Adam A500 (also known as the Adam –360 designed by Burt Rutan) at 75 kts.

The take-off lift coefficient is a measure of airplane take-off capability and generally higher Clmax airplanes stall at lower speeds and lower take-off distances. These values are also tabulated for each of airplane in Table 1. The highest Clmax, 6.85, is for the amphibian Beaver airplane. Usually maximum Cl is below 2 without flaps, and increases up to 4 with simple flaps.

Harloff Performance Factor

The Harloff Performance Factor quantifies airplane performance by including several performance features into a single number. These are: computed take-off and landing distance, climb rate, cruise and stall speed, and excess horsepower. A low number airplane is good for a low time pilot. A high number airplane implies skill and a high time pilot is needed to fly the airplane. The index is computed by the following formula:

Harloff Performance Factor = climb rate (ft/sec)/100 – [computed roll take off (ft) +computed roll landing (ft)]/200+ 4 [Umax cruise/Ustall-1] + max L/D + 5 [HP/HP min required for level flight]

The climb rate, takeoff and landing distance, and speed ratio terms are similar to a rating system given in Design for Flying (D. Thurston 1995); new terms of max L/D and HP ratio are added here and computed take off and landing roll distances are used instead of manufacturer provided distances, to provide a consistent basis for comparison.

A few airplanes are listed below from lowest to highest Harloff Performance Factor to illustrate the rating system. One of the lowest and probably one of the easiest airplanes to fly in the list is the Stinson Station Wagon with a factor of 16. The lowest factor is 15 for the Adam A500 dual boom 2-engine airplane. The Cessna 172 has a factor of 19 and it is one of the most successful airplanes built for the general aviation market. In the LSA class for 1320 lb aircraft, factors range from 27 for the Air Elite Aviation Storm Rally airplane, to 43 for the Sport Aircraft Works Sport Cruiser. The low value of 31, for the Cessna LSA, indicates that this should be one of the easier airplanes to fly in the Light Sport Aircraft class. Two cub airplanes are compared and the American Legend AL3c-100 cub has a lower factor of 28 compared to the 31 for the Cubcrafters Sport Cub. The Legend Cub is a somewhat lower performance airplane compared to the Cubcrafter Sport cub in the following areas: cruise velocity, climb rate, take-off and landing roll distances, Lift/Drag ratio, and zero-lift drag, Cd0. Of the high value Harloff Performance Factor airplanes, for high-time pilots, are the racing Midget Mustang with a 160 hp engine with a factor of 53, the Berkut 540 with a factor of 57, and the Lancair Propjet with a factor of 73.

Airplane	Harloff Performance Factor
Adam A500 (dual boom 2 engine)	15
Stinson Station Wagon	16
Cessna 172	19
Piper Arrow Pa28	27
American Legend AL3c-100 Cub	28
Cessna Skymaster 337D (dual boom 2 engine)	30
Cessna LSA	31
Cubcrafters CC11-100 Sport Cub	31
Piper Seneca iV PA-220t	32
Sonex 80 hp Jabiru	32
Dehavillian Beaver amphibian	33
Beech Bonanza	36
Zodiac Ch601/Rotax 912S	37
Midget Mustang, O-320	53
Berkut 540	57
Lancair Propjet	73

Summary

Light Sport and General Aviation airplanes are reviewed and compared. For each airplane several aerodynamic characteristics are computed including lift/drag ratio, take-off lift coefficient, and zero lift drag coefficient. Take-off and landing roll distances are computed and compared. An airplane performance comparison factor is presented to compare different airplanes. Low factor airplanes are generally easier to fly than high factor airplanes. Low time pilots should consider flying low factor airplanes and high time pilots should consider flying high factor airplanes.

Appendix: Data for 93 airplanes

This appendix lists the LSA and GA airplanes examined and they are listed in increasing order of take off gross weight. The Light Sport Airplanes weigh up to 1320 lbs, have 100 HP or less, have a maximum cruise speed of 120 kts, have fixed landing gear, have fixed propeller pitch in flight, and have a stall speed of 45 kts or less. The amphibian LSA airplanes have a maximum gross weight of 1430 lbs., and retractable wheels are permitted.

		HPF	Weight lb.	HP	HP/HP-min flight ratio cmptd	Max cruise kts	stall speed kts	climb rate ft/min	Take off roll, ft cmptd	Landing roll, ft cmptd	L/D max cmptd	Cl max cmptd	Cd0 zero lift cmptd
Midget Mustang	O-200	36	950	100	1.5	152	52	1500	649	737	12.9	1.52	0.021
Midget Mustang	O-320	53	1000	160	2.2	187	54	2500	445	786	13.5	1.5	0.020
Zodiac	Ch701	34	1100	100	1.7	83	26	1100	178	184	7.5	3.92	0.072
Sonex	Sonex-80 hp Jabiru	32	1100	80	1.1	130	40	800	546	433	14.1	2.07	0.018
Sonex	Waitex-80 hp Jabiru	32	1100	80	1.1	130	40	800	546	433	14.1	2.07	0.018
Aerosport	C42 Ikarus	30	1144	100	1.9	83	35	1000	335	327	8.3	2.09	0.067
B &F Technik	FK-9 Mark IV	41	1146	100	1.9	104	35	1500	340	332	11.8	2.25	0.038
fantasy air	Allegro 2000	41	1147	80	1.7	119	35	984	432	333	17.1	2.24	0.021
Sonex	Sonex-120 hp Jabiru	40	1150	120	1.6	148	40	1200	373	433	13.3	2.17	0.020
Sonex	Waitex-120 hp Jabiru	40	1150	120	1.6	148	40	1200	373	433	13.3	2.17	0.020
Kappa	KP-5	42	1199	100	1.8	120	33	1100	316	295	14.7	2.54	0.024
Atec	Faeta	43	1212	100	1.7	120	34	1375	340	313	14.1	2.85	0.028
Evektor USA	SportStar	28	1212	100	1.6	105	43	850	570	511	11.0	1.68	0.039
Ct	LSA	32	1232	80	1.3	112	39	885	588	414	14.5	2.05	0.024
Fantasy Air	Allergro 2000	35	1232	100	1.9	97	35	1000	362	327	11.4	2.47	0.046
Rans-7LS	Courier	27	1232	100	1.6	96	43	1000	580	511	10.1	1.31	0.039
Rollison	EuroFox	33	1232	100	1.6	96	35	980	362	327	11.6	2.43	0.036
Skykits	Savannah	37	1234	100	1.6	83	24	1320	173	160	8.3	4.41	0.060
FK-Lightplanes USA	FK9 B Mark iv	39	1250	100	1.6	104	34	1500	351	313	11.3	2.85	0.040
Gryf Aircraft	SportRider MD-3	33	1270	100	1.6	109	43	1180	599	511	12.4	1.77	0.035
Indus aviation	Thopedo T-211	26	1270	120	1.5	104	45	1020	536	553	8.6	1.6	0.051
Sonex	Xenos-80 hp AeroVee	34	1275	80	1.6	104	38	800	581	396	15.9	1.63	0.023
Sonex	Xenos-120 hp Jabiru	45	1275	120	2.4	122	38	1200	378	396	15.9	1.63	0.023
Jihlavan Ap	KP5 Kappa	41	1278	100	1.7	120	33	1100	338	295	14.8	2.7	0.024
Ac Manuf & Dev	Ch601 XL	32	1300	100	1.3	115	38	900	468	396	12.4	1.99	0.025

Aerosport Ltd	Breezer	34	1320	100	1.4	109	36	1100	419	351	11.7	2.28	0.030
Air Elite Av	Storm Rally	27	1320	100	1.5	107	44	800	642	524	11.5	1.61	0.036
American Legend	Legnd. Al3c-100 Cub	28	1320	100	1.7	83	30	500	286	244	9.6	2.43	0.051
Cessna	LSA	31	1320	100	1.5	120	45	900	674	549	14.1	1.6	0.025
Cubcrafters CC11-100	Sport Cub	31	1320	100	1.7	91	31	800	312	265	10.1	2.26	0.044
Dova DV-1	Skylark	35	1320	100	1.3	117	37	1200	431	361	12.3	2.9	0.030
Flight design	Ct	31	1320	100	1.4	112	39	960	496	412	12.1	2.4	0.033
Hansen Air Group	Sky Arrow	30	1320	98	1.5	95	38	1100	479	391	10.2	1.86	0.044
Iniz Ind Ital	Sky Arrow 600 Sport	31	1320	98	1.5	95	38	1100	479	391	10.7	1.86	0.039
Jabiru	J250	30	1320	120	1.7	120	45	700	554	549	12.7	1.6	0.030
Just Aircraft	Highlander	35	1320	100	1.5	91	29	1100	261	223	9.8	3.93	0.054
LightSportflying	Festival	29	1320	100	1.5	101	38	770	476	396	11.4	1.78	0.032
New horizon		35	1320	100	1.7	120	38	600	462	386	16.0	1.76	0.020
Martin3		43	1320	100	2.0	109	27	984	237	203	13.7	4.02	0.037
Nexaer		38	1320	120	1.7	120	44	1500	528	524	12.6	1.62	0.029
RV	12	30	1320	100	1.3	120	45	950	674	549	13.0	1.6	0.024
Skyboy SLSA		25	1320	100	1.4	78	38	1050	476	396	7.8	1.93	0.071
Sport Aircraft Works	SportCruiser	43	1320	100	1.4	120	29	1200	261	223	13.9	3.35	0.021
Sportair USA	StingSport	33	1320	80	1.1	120	44	1200	818	524	15.5	1.66	0.018
Sportcruiser		30	1320	100	1.4	109	42	980	581	478	11.9	1.68	0.029
Storm A/C	Rally	27	1320	100	1.5	107	44	800	642	524	11.5	1.61	0.036
Tecnam	P92 Echo Super	30	1320	100	1.4	112	45	1067	674	549	12.4	1.49	0.028
Tecnam	P2004 Bravo	29	1320	100	1.3	116	45	900	674	549	12.7	1.63	0.027
Tecnam	P2002 Sierra	27	1320	100	1.4	116	45	750	674	549	12.9	1.55	0.026
The Champ	Model 7EC	35	1320	100	1.6	120	44	1299	642	524	12.9	1.22	0.027
TL Ultralight	Sting Sport	34	1320	100	1.4	120	44	1299	642	524	13.5	1.73	0.025
Zodiac CH601 XL	Jabiru 3300	34	1320	110	1.4	135	44	900	588	532	14.8	1.5	0.018
Zodiac CH601 XL	Rotax 912S	37	1320	100	1.3	139	44	1200	652	532	16.3	1.5	0.014
Zodiac CH601 XL	Lycomiing O-235	35	1320	116	1.5	139	45	930	579	553	15.0	1.45	0.017
Mermaid amphib	Retr gear	31	1430	100	1.4	96	31	800	339	265	11.2	3.21	0.042
Gannet	Amphib	42	1430	100	1.7	109	27	984	258	203	13.8	4.36	0.036
Freedom		42	1430	100	1.7	109	27	984	258	203	13.8	4.36	0.036
Sky Arrow	650	29	1433	98	1.3	101	40	1000	584	433	11.7	1.82	0.033
Rv-9	118 hp	36	1600	118	1.2	143	42	950	589	471	16.2	2.19	0.016
Rv-9	135 hp	38	1675	135	1.3	149	43	1100	560	491	16.1	2.2	0.016
Swift	CC1B	37	1710	145	1.4	126	42	1400	507	471	12.6	2.21	0.028
Citabria	Adventure	33	1750	160	1.7	117	45	1167	555	553	12.0	1.53	0.031
Rv-9	160 hp	43	1750	160	1.4	162	43	1400	511	511	16.4	2.21	0.016
Da-20		37	1754	125	1.4	138	45	1000	720	549	17.5	2.05	0.020
Cozy	Mk IV	29	1903	180	1.4	182	71	1200	1469	1381	18.3	0.96	0.014
Piper pa-18	Amphib	26	2000	160	1.5	90	37	830	419	371	8.8	2.35	0.058
Berkut	360	48	2000	180	1.2	208	59	2000	1010	943	21.5	1.54	0.009
Skyhawk Extra	300L aerob	53	2095	300	1.9	170	60	3200	631	975	12.1	1.49	0.028
Cessna	172	19	2200	145	1.1	108	54	660	1174	790	12.1	1.4	0.034
Berkut	540	57	2200	260	1.6	208	59	3000	748	943	17.7	1.7	0.014
Lancair	Legacy	50	2200	260	1.5	226	56	1950	681	864	18.7	2.49	0.014

		HPF	Weight	HP	HP/HP-min flight ratio	Max cruise	stall speed	climb rate	Take off roll, ft	Landing roll, ft	L/D max	Cl max	Cd0 zero lift
			lb.		cmptd	kts	kts	ft/min	cmptd	cmptd	cmptd	cmptd	cmptd
Lancair	Legacy FG	32	2200	180	1.0	182	56	1000	1019	864	17.2	2.49	0.017
Piper pa-28-161	Warrior ii	26	2325	160	1.2	127	49	710	889	643	14.6	1.7	0.022
Stinson	Station Wgn	16	2400	165	1.1	104	54	650	1119	790	9.9	1.57	0.049
Glassair iii	span=23.2917 ft	40	2400	300	1.4	232	76	1661	850	1120	18.2	1.95	0.013
Glassair iii	span=27 ft	46	2500	300	1.5	229	71	1798	739	946	19.7	2.17	0.013
Da	40-fp	30	2535	180	1.3	134	49	900	870	650	15.6	2.14	0.025
Mooney	M20J	38	2740	200	1.2	175	53	1030	1004	761	21.2	1.65	0.011
Piper	Arrow pa28	27	2750	200	1.1	145	55	831	1095	820	16.3	1.58	0.018
Velocity	Xl-Rg	39	2800	300	1.5	205	64	1500	1007	1120	18.4	1.63	0.015
Cirrus	Sr20-g2	30	3000	200	1.0	157	54	900	1159	790	17.8	2.25	0.018
Beech Bonanza	J35	36	3100	250	1.1	168	50	1120	774	664	16.8	2.1	0.015
Lancair	ES	43	3200	310	1.4	196	56	1550	845	864	19.0	2.12	0.015
Myers	200D	36	3300	300	1.1	200	62	1400	1115	1041	18.5	1.57	0.012
Cirrus	Sr22	38	3400	310	1.4	183	59	1400	995	943	18.3	1.99	0.018
Lancair	IV-P	42	3550	350	1.2	287	65	1550	1139	1151	18.4	2.52	0.017
Lancair	ES-P	41	3550	310	1.2	235	61	1550	1118	1002	18.7	2.05	0.016
Piper seminole	PA-44-180	34	3800	404	1.5	157	55	1340	721	820	13.3	2.02	0.029
Lancair	Propjet	73	3800	750	2.2	322	64	4000	519	1120	14.2	2.77	0.028
Cessna skymaster	337D dual boom	30	4400	420	1.3	170	61	1200	1003	994	14.6	1.76	0.022
Piper Seneca iv	Pa-220t	32	4750	440	1.2	178	64	1400	1173	1110	16.0	1.64	0.019
Dehavillian Beaver	Amphibian	33	5090	450	1.4	113	30	840	238	238	9.0	6.85	0.069
Adam	A500 dual boom	15	7050	700	1.2	230	75	227	1556	1524	13.8	2.18	0.034