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Very Light Aircraft: Revitalization Through Certification

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Abstract

As the future of the general aviation industry seems to be improving, a cultural paradigm shift may be imminent with the implementation of an advanced, revolutionary transportation system within the United States. By observing the support of government and industry for this idea, near and long term effects must be addressed if this change is going to occur. The high certification costs associated with general aviation aircraft must be reduced without compromising safety if a new transportation system is to be developed in the future. With the advent of new, streamlined rules recently issued for the certification of small aircraft, it seems as though new opportunities are now available to the general aviation industry. Not only will immediate benefits be realized with increased sales of certified small aircraft, but there would now be a way of introducing the advanced concepts of future aircraft at varying degrees of technology and cost as options to the customer.

1. Introduction

General aviation (GA) is usually defined as all of aviation except the military, air freight operators and commercial airlines. With this definition, general aviation industry provides more than 540,000 jobs, $40 billion in economic contributions, and serves 120 million people every year. There are currently 212,000 general aviation aircraft in domestic service, providing 62 percent of all flight hours, 37 percent of all flight miles, and 78 percent of all flight departures within the United States.[1] This is obviously a large market with many different missions and types of aircraft.

In the mid- to late-seventies, the GA market flourished with an all time record high sales of over 17,000 aircraft in 1978.[1] These airplanes were equipped with relatively unreliable navigation equipment, and the flying of these aircraft was generally considered a "hobby" to aviation enthusiasts. With the steadily increasing number of aircraft sales, the GA industry seemed to have a very bright future.

Unfortunately, this was not the case. Over the past 15 years, GA sales have plummeted to an all time low of just over 800 aircraft delivered last year. *This is a 95% decline in sales over a 15 year period.* This incredible drop in what seemed to be a thriving industry is usually credited to two very important issues.

As aircraft became more and more prevalent in the skies, the accident rate of the general aviation population began to increase as well. Although the Federal Aviation Administration (FAA) imposed numerous safety rules and regulations on the aircraft manufacturers, the victims of aircraft accidents sued the aircraft manufacturers with liability claims. As more court cases were brought against the manufacturers, insurance costs protecting against liability suits became increasingly expensive. Eventually, the insurance costs alone contributed to over 30% of the total airplane cost.

Although liability insurance was a problem, it is only half of the story. In today's faster paced society, the time and cost required to obtain and maintain a private pilot's license contributed even further to the decline in general aviation aircraft sales. As the basic cost of the aircraft became more expensive, so did the operational costs associated with flying the aircraft. General aviation aircraft were no longer affordable to the recreational aviation enthusiast.

To combat these problems, the government has set into motion a new revitalization effort for the general aviation industry. Last year, congress put into law the General Aviation Revitalization Act of 1994, limiting aircraft manufacturer liability to 18 years after the sale of an aircraft.[2] This was a tremendous achievement for the GA industry, as insurance costs began to drop to a more affordable level.

Although this first step was important, the technologies used in the general aviation field consist of technology dated over 20 years. Not only does the current aircraft fleet utilize old technology, but the Air Traffic Control (ATC) system has not had much improvement over the same number of years.

Today, we have seen a resurgence in the demand for a general aviation transportation system. Although not aimed at the recreational pilot, this new transportation system will enable a multitude of users to operate an aircraft at minimal cost, with improved safety, and at a high level of automation. This in turn will reduce the pilot workload and time required to maintain a current private pilots license. Leading this revolution is the Advanced General Aviation Transport Experiments (AGATE) Consortium, a partnership of government, industry, the FAA, and universities formed to improve and implement the technologies of today into the general aviation marketplace. With the combined effects of the tort reform and the AGATE program, the general aviation industry seems once again to have a very promising future.

2. A Revolutionary Transportation System

The word to emphasize in this title is transportation. As we have already seen, aircraft costs have become too high for the recreational aviator. Unless one is independently wealthy, purchasing an aircraft for fun becomes too large a financial burden for most people. There are then three main goals of this new transportation system:

- Capability
- Reliability
- Affordability

The key concept here is the user-friendly capability of this new aircraft. Much of the redundant burden placed on a pilot can be automated with today's technologies and computer systems. With these advanced systems, the ease of operating an aircraft will mimic as closely as possible the ease of operating an automobile. Although now the vehicle is in three dimensions, the pilot will eventually develop into a "flight systems manager", or some other derivative. This will enable the owner to operate the aircraft with a minimum amount of training and reduce by a great degree the workload during a flight operation.

Although this new automated aircraft would be in great demand if offering the capabilities aforementioned, the aircraft must also be safe to fly. The answer to most safety issues is redundancy. For instance, if one computer goes down, there is a backup to take its place. If the backup goes down, the backup to the backup takes its place. This redundancy ensures that should "any unforseeable" event occur, there is a minimum safety factor to account for a failure.

However, as more and more back-up systems are placed in the aircraft, the increase in cost associated with the redundant systems reaches a critical level. This is where the affordability issue is encountered. There must be a trade-off between safety and affordability, and this is known as the "accepted failure rate." In commercial and military applications, this number is 1 fatal accident in 1×10^9 flying hours. Although there are not set standards in general aviation, it has been found that this number is around 1×10^5 flying hours.[1] Because of the litigation problems, an effort should be made to increase this number closer to the acceptable rate of commercial and military operations, which would reduce the costs associated with liability insurance. Though more concentrated effort is needed early on in the critical design and testing phase, costs associated with the implementation of redundant systems should also be reduced without compromising safety and capability for this new future aircraft.

3. How Will This Work?

Many studies have been conducted by the human factors discipline on the interaction of the "pilot" and the aircraft cockpit for this new automated system. The envisioned concept is one with complete removal of the analog instruments used in current cockpits, all being replaced by two flat panel displays and possibly a Heads-Up Display (HUD) for navigational aid. The touch screen concept has also been considered, but turbulence effects on pilot interaction create problems that have yet to be resolved.

Another main difference in this new cockpit will be the operation of the controls. In today's aircraft, the yoke, throttle, and rudder pedals must be manipulated together to coordinate a maneuver. This is a difficult process to learn, and is not intuitive to the user. The envisioned new system will automate by computer the control inputs to command rates as opposed to headings, (i.e., a rate of turn as opposed to a bank angle), which will be more like driving a car. With the technology available today, this system would not be difficult to design. However, we once again face the redundancy issue, and must take into account safety and affordability.

To implement this new system, an air and ground infrastructure, termed "free-flight", will enable the aircraft operator to more easily navigate their aircraft and ensure collision avoidance with other aircraft. The Radio Technical Commission for Aeronautics (RTCA), an organization that is working with the FAA and recommends standards for aeronautical electronics and telecommunications, defines the concept as one that would allow pilots "to operate the flight without specific route, speed or altitude clearances."[3] Although still in the preliminary stage, the FAA already recognizes the importance of developing this infrastructure, "Even if we don't know where free flight will be in 2010, we know enough to tell which direction to go in 1995."[4]

Specifically, this new system would accept electronically transmitted flight plans, re-route aircraft to avoid collision and/or imposing weather conditions, and submit real-time weather and position data via satellite-based data-links and the Global Positioning System (GPS). Of course, this new infrastructure must also be proven reliable and not require the purchase of unaffordable equipment from the aircraft owner.

4. The Problems

As previously mentioned, one of the main problems with the development of this new transportation system is cost. The aircraft alone can be a major investment for some people, and with the addition of new avionics and hardware requirements, we may be "shooting ourselves in the foot." The main goal of this new renaissance is the revitalization of the general aviation industry. Therefore, the market to be targeted for these aircraft must be defined before a cost standard can be set. One of the most probable markets would be for relatively small corporations ($1M to $100M annual income) or traveling businessmen. This type of transportation would save the owner the cost of hiring a pilot and/or reduce the cost and time associated with his/her own training. Thus, the market must be defined to ensure that an achievable cost standard is met.

There must also be a shift in the cultural paradigm for this system to be successful. The general population is either comfortable with travel via commercial airlines or piloting their own aircraft. To implement such a radical change in the way people travel might not be readily accepted by the community. The FAA and ATC systems must also improve current procedures to meet the future needs of this system. Furthermore, experienced pilots are concerned with the ability of the "untrained" pilots to safely manage emergency situations. People's minds must be put to rest that the future GA aircraft will be safe and beneficial to the overall community. Although seemingly an insignificant problem, I believe this will be one of the hardest to overcome.

One final problem would be the issue of certification. The FAA has set strict standards on the design and testing of all types of aircraft. Particularly, the Federal Aviation Regulation's (FAR's) were created as a guideline for aircraft manufacturers to follow for aircraft certification. Although necessary for safety, these guidelines have proven to add the greatest overhead cost to the aircraft sale price. First, the aircraft design must be certified as flight worthy through numerous testing procedures, then the manufacturing facilities must be certified to ensure that the every aircraft produced will meet the standards achieved by the prototype aircraft. As flight testing is one of the major contributors to the certification cost, Figure 1 shows the increasing trend of flight hours required for certification over the past 30 years.[5]

The fact that only three new airplanes have been certified to FAR 23 rules over the past 10 years shows the tremendous problems with this certification process.[6] Furthermore, for modified aircraft there is an increase in the total program cost and engineering cost per pound of new weight due to the certification requirements. These cost trends have been rising substantially over the years, and can be seen in Figures 2 & 3.[5]

5. The Solutions

By implementing the "free-flight" mode, it has been found that a 2-3% savings in fuel efficiency can be achieved on an average flight of 500 nm.[7] Furthermore, domestic airlines could save an average of two minutes on en route flights.[8] Not only is there a time and workload savings involved with this new system, but it is evident there is a cost savings as well. Concerning the avionics issue, there is a tendency for hardware to remain at a fixed price over time with increased capabilities. The best example of this would be the home computer. Every year new models are introduced to the market, and these computers generally stay the same price as computers introduced the year before. It would therefore seem that avionics costs associated with the implementation of this new system would be relatively insignificant. As long as the target market and net worth of this new aircraft is identified, a fixed allowable cost to the manufacturer could then be set.

The AGATE program is the driving force in developing the technologies for the revitalization of the general aviation industry. As industry continues to become more aware and involved in the AGATE program, the attitude of the aviation industry is also starting to shift. New products are being developed, future problems are being addressed, and public access to useful information is becoming more readily available. This fact in itself will help to achieve public acceptance of the new general aviation transportation system idea simply through education. Once people understand the system, they are more apt to listen to the pros and cons thereof and make an informed decision on the validity of the idea. Through this program, and perhaps by implementing the transportation system in "steps", people will become more encouraged by the advantages than discouraged by the challenges.

As has been seen, the cost issue tends to dominate the problem area of creating the new automated aircraft. Directly related to this problem is the tremendous cost and frustration involved in the certification process. Furthermore, some vehicle for first implementation of these new technologies must be identified. In the past, the certification requirements for any aircraft under 12,500 pounds were the same. This basically means the certification process of a large twin engine aircraft (usually quite extensive and expensive) would be the same for a small homebuilt aircraft. Fortunately, in the last couple of years, the FAA has established new guidelines for certifying smaller aircraft. These new certification rules open the door for a vast number of aircraft companies to certify their aircraft at a greatly reduced cost. Hence, with the certification of new airplanes, there is now an opportunity to implement a new integrated transportation system.

6. The New Certification Rules

On December 31, 1992, the Primary Aircraft rule became effective as Advisory Circular (AC) 21-37.[9] This rule supplied new certification options to the small aircraft industry. In general, the Primary Category allows a multitude of different certification procedures to be used to certify small aircraft, providing that the procedures are accepted by the FAA. There have already been four different methods observed as adequate by the FAA:

- TP101-41: Transport Canada's ultralight design standards for certification of "sportplane" aircraft.[10]
- AC 21.17-3: Type certification of Very Light Airplanes (VLA) under FAR 21.17(b).[6]
- AC 23-11: Type certification of Very Light Airplanes (VLA) with powerplants and propellers certified to FAR parts 33 and 35, respectively.[11]
- Traditional certification standards under FAR part 23 and FAR part 27 for aircraft and rotorcraft, respectively.[12]

The Primary Category limits aircraft to being a single engine, naturally aspirated, unpressurized, four seat, 2,700 pound, 61 knot stall speed airplane operated only for personal use. These provisions can be deemed a "shell" with which to work. Any aircraft exceeding these limits are not allowed to be certified with the simplified procedures outlined in AC 21-37.

The Sportplane Category is the most streamlined option available, and the limits for certification are the same as above except for the weight being limited to 1,058 pounds and the stall speed to 39 knots. These standards are reduced in complexity, and can greatly reduce the cost of certification if the aircraft limits are met.

AC 21.17-3 allows the use of the Joint Aviation Requirements for Very Light Aeroplanes (JAR-VLA) as issued by the Joint Aviation Authorities (JAA) of Europe as an acceptable means of certifying aircraft under the Primary Aircraft rule. This new category simplifies the certification process and sets new limits on the aircraft to be certified to a single engine, naturally aspirated, two seat, 1654 pound, 45 knot stall speed airplane operated only for personal use. There are four different ways this rule can be applied for certification of VLA:

- May obtain a "Primary" category type certificate, provided the manufacturing of the aircraft is supervised or manufactured by a Production Certificate holder.
- May obtain an experimental kit-built airworthiness certificate provided the kit components were manufactured under an FAA approved quality assurance system.
- May be applied to obtain a "VLA-Special Class" certification, which restricts use to day/VFR operations.
- May be used in conjunction with other FAR part 23 requirements (AC 23-11, which is described below) to certify the aircraft in the "normal" category.

The first two applications basically state that the aircraft may be sold as a kit, without limitation on assembly or fabrication proportion to the builder, or the assembly of the kit by the customer may be supervised to allow the obtainment of a Primary airworthiness certificate. The third application allows the actual certification of the aircraft under this rule, but restricts the use thereof to day or Visual Flight Rules (VFR) operation. Finally, the last application gives the manufacturer an opportunity to certify the aircraft to the FAR part 23 "normal" category when incorporating the use of additional certification rules. The normal category of aircraft allows greater flexibility of operation, including night or Instrument Flight Rules (IFR) when applied. The additional certification requirements to achieve this category are outlined in AC 23-11.

AC 23-11 was formed as a supplement to the JAR-VLA rules outlined above. After examination by the FAA, it was found that 225 of the sections in the FAR part 23 certification procedures (the traditional aircraft standards) were applicable to the new Primary Aircraft rule. Upon further examination of the JAR-VLA rules, it was found that 204 of the sections in the FAR part 23 regulations were addressed in these new rules. Therefore, AC 23-11 was formed to allow aircraft manufacturers to use the JAR-VLA rules along with the AC 23-11 rules to certify an aircraft to the normal category of airplanes. This category differs from the Primary category in that it allows greater flexibility of use of the airplane.

Of course, if an aircraft manufacturer chooses to utilize the original FAR part 23 requirements to certify the aircraft, they would be eligible to obtain the Primary Category flight certification as well.

Although somewhat confusing, these rules basically do two things: reduce the level of FAA involvement and reduce the cost of certification. With the increased number of very light aircraft in the United States, it would seem that we now have a method by which to certify these aircraft and achieve a near term benefit by increasing their marketing potential.

7. Very Light Aircraft (VLA)

As the general aviation industry as a whole has been declining over the past 15 years, the demand for aircraft in this category has not. These aircraft are usually unconventional in design and make wider use of composite materials than either the GA aircraft of the past or the current larger commercial aircraft. To by-pass the high insurance costs associated with the liability issue discussed earlier, these airplanes are not sold as a completed unit. Instead, up to 49% of the aircraft is manufactured by the company selling the kit, and the remaining majority of the manufacturing is left to the purchaser.

When the aircraft owner builds the 51% of the aircraft, he essentially becomes the "aircraft manufacturer". Therefore, if an accident should occur while in operation, the only person liable is the one who is flying the aircraft.* Currently, there are around 17,000 homebuilt aircraft in operation, with over twice this amount still in the building stage.[13] Furthermore, there are around 1,000 homebuilts aircraft sold and around 1,500 aircraft experimentally certified each year.[14] It is interesting to note the adaptation of industry when a demand is present but the supply is not by the success of the homebuilt industry. These aircraft are affordable to the customer, mainly because of the reduction in cost of manufacturing and certification to the designing company. There are many different kinds of homebuilts: monoplane low-wing, high-wing, biplanes, amphibians, acrobatic, etc., which all vary in cost and time required for fabrication.

8. Why Certify Homebuilts?

As society continues to become more time conscious, the hours associated with building these aircraft are becoming more of an issue to the aircraft owner. It is for this reason that a majority of the "homebuilt" aircraft will no longer be built in the home. With the new certification rules available, it could be more cost effective for the manufacturer to build these aircraft. One other possibility is that aircraft could be certified under the new experimental rules, which allows any portion of the kit to be assembled by the purchaser of the aircraft.[6] This would enable the company to compromise with the customer on what portion he/she is willing to buy already assembled.

As the GA industry is predicted to grow well into the year 2000, the homebuilt market needs to capture a significant percentage of this GA growth. Without certifying these airplanes, the homebuilt market will probably lose a significant share of sales once production of the larger certified GA aircraft begins. Another option the new certification rules make available is the level of certification of the aircraft. For instance, if a customer does not require near all-weather operation, a lower level of certification may be issued, and hence the customer is given the option of a lower cost aircraft. On the other hand, if the customer wants the same airplane, but also wants near-all weather operation, a higher level of certification can be issued at a proportionately higher cost to the customer. This would help the marketing possibility of the smaller companies.

Figures 4 and 5 show the percentage of a sample database of existing aircraft that would be able to achieve certification under the new rules by meeting the weight and stall speed limits. It can be seen that *90% of the current homebuilt aircraft would be certifiable under the new Primary Category rules*. Keep in mind, however, that this graph represents only a small portion of the total

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* These aircraft are also required to prominently display the words "experimental" in plain view of anyone who may be operating the vehicle.

homebuilt aircraft types available, but is representative of the overall homebuilt market. It is therefore evident that the certification rules available to the kit aircraft manufacturers are a possible means of increasing market at lower cost to the majority of these companies. Furthermore, the variety of aircraft available to the general aviation customer would increase tremendously, with the addition of 509 different homebuilt manufacturers currently producing kit aircraft.[13]

As was discussed earlier, the technology for a new transportation system requires some testing and vehicle integration before large scale implementation can occur. It would seem, with the certification of a low cost, small aircraft, the new technologies for this arena might be a viable option to the customer. Relating to the cultural paradigm shift problem, a step such as this might be the answer to getting public acceptance of such a system as well. With the available options of day/VFR and night/IFR operations, why not make it an option for "near-all weather, minimal training operations"? Although the near-term issues may make the certification issue important to the homebuilt manufacturers, the long-term benefits, which may prove more beneficial than the short term, must be taken into account as well.

9. Example Applications

As a result of the FAA issuing the new Primary Certification rules and the derivatives thereof, three different homebuilt aircraft have been certified. In July of 1993, the Quicksilver GT-500 became the first aircraft certified under the Sportplane Category. Then, in May of 1995, this same aircraft received the first Production Certificate under the Primary Category regulations.[15] The certification of this aircraft was done at a fraction of the usual $25 to $30 million associated with certification costs. Although some changes were necessary to the original design, the final ready-to-fly selling price of these airplanes is $30,000.[15] This was a great first step for the certification of homebuilt aircraft.

As of July 1995, the CH-2000 of Zenair Aircraft became the second homebuilt aircraft to be certified.[16] This aircraft was certified utilizing the JAR-VLA regulations and the additional AC 23-11, because of the higher aircraft weight and stall speed. Also certified under these rules is the Katana Diamond, which utilized composite structures as opposed to aluminum.

It is evident that with the certification of these aircraft, the majority of homebuilts currently in production could be certified in a similar fashion. Although different aircraft will have specific configuration modifications necessary for certification, the overall process of certification has been shown to work and be cost effective.

10. Other Aspects of VLA Certification Needing Examination

As more and more small aircraft become certified, there will be a need for improved certification processes. For one, the noise constraints associated with any aircraft in the FAR part 23 category are the same, and there have been no reductions or streamlining of the certification process for VLA. Secondly, there should be an analysis done on the cost and time associated with certification of aircraft at various weights, perhaps in a cost per pound versus certification method used. Also, specific VLA certification rules for composite aircraft must be examined in greater detail. Finally, a new certification method must be developed for the implementation of the new transportation system discussed earlier. By examining those needs now, the future distribution of this new automated aircraft may be realized in a more timely fashion.

11. Conclusions

After examining the plight of the general aviation industry and the revitalization attempts thereof, it seems as though a new general aviation transportation system will inevitably be incorporated into the way people travel in the future. Furthermore, the FAA has established new certification rules that make it easier to certify the small aircraft that make up a majority of the United State's homebuilt market today. By implementing these new certification procedures, the Very Light Aircraft of today might not only dramatically increase their market share with the current aircraft configurations, but might also be the first to implement the new automated aircraft system into the market. This would not only help the small aircraft market, but would also help to revolutionize the entire general aviation industry as well. Although further examination of the noise and cost issues associated with certification are needed, the homebuilt manufacturer's of today should take better advantage of the new rules that have been made available. Possibly, by developing a certification methodology for small aircraft that is relatively inexpensive and time effective, more small aircraft companies will attempt to certify their aircraft.

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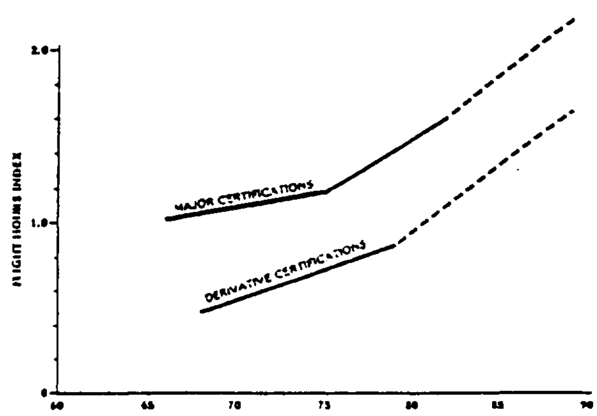

Figure 1. Flight Hours Required for Certification
(Copied From Reference 5)

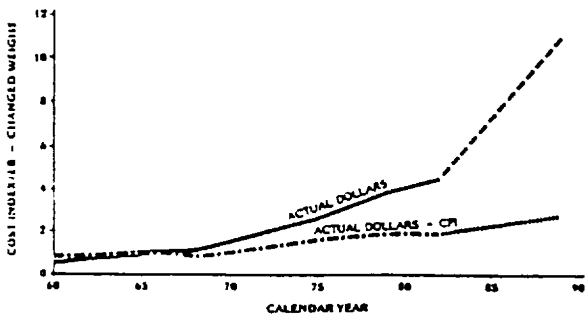

Figure 2. Total Program Cost per Pound for Certification
(Copied from Reference 5)

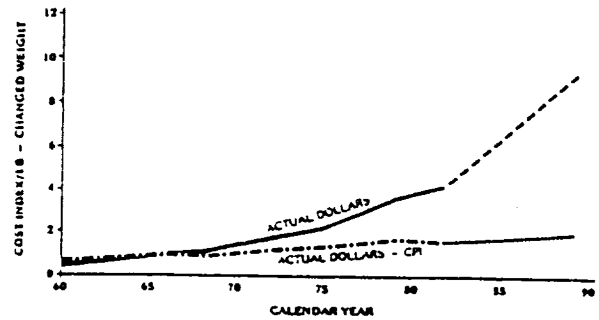

Figure 3. Total Engineering Cost per Pound for Certification
(Copied from Reference 5)

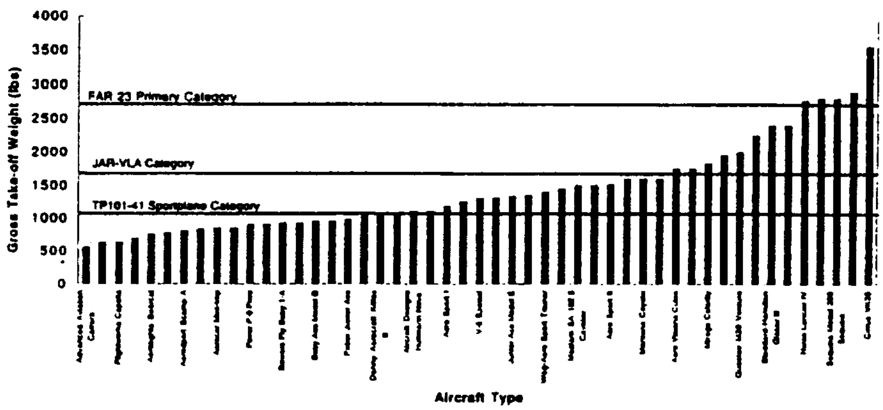

Figure 4. Very Light Aircraft Weights

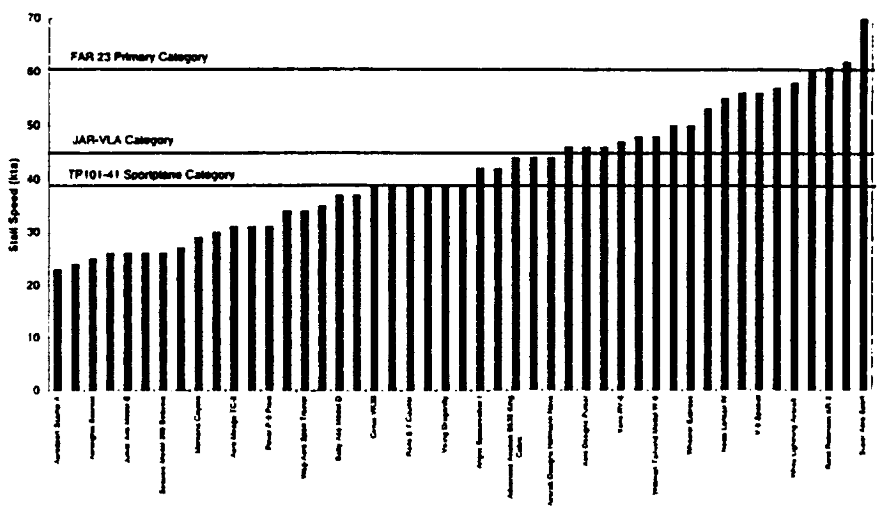

Figure 5. Very Light Aircraft Stall Speeds