OMS flapper facts

SUMMER 1993

Newsletter of the Ornithopter Modelers' Society

OMS news

Big Ornithopter Information Directory:
In order to make ornithopter information more available to all OMS members, I am compiling a list of information sources. This directory will list books and magazine articles which contain information on ornithopters and natural flight, making it possible for members to get them through interlibrary loan. It will also list members who have copies of magazine articles, patents, plans, etc., who are willing to send copies of these for the cost of copying and postage.

In our last issue, I introduced a list of Model Airplane News articles and patents which P.J. Ernst, Sr. is offering, as well as a partial list of my own articles on ornithopters. If you have any information which you are willing to copy for other members, or if you know of any books, please send a list which can be added to the directory.

If you would like a copy of the directory, please send an SASE and, to cover copying costs, an extra unattached stamp.

Elections:
There will be no elections because no one wanted to run. However, I will continue as editor of the newsletter and may organize some contests later on. Suggestions for OMS postal contests, as well as prize donations, are welcome.

Design Manual and Back-issues:
The set of back-issues offered last time is no longer available, and further requests will not be filled. The set may be offered again someday, but for now copies of individual articles are available upon request, by topic, for the cost of copying and postage. The design manual is still available for $3.

Membership dues:
It has become necessary to increase dues to $9 per year ($14 overseas), to cover higher-than-expected costs and to provide additional services. Write checks to Nathan Chronister <u>not</u> OMS.

New format:
This issue of Flapper Facts looks different from previous issues for two reasons. First is that I am now working on an IBM instead of a Macintosh, something which may or may not become a habit. Second, I have decided to send the newsletter out in envelopes to prevent damage in the mail. This also frees up the back page for actual information rather than just a big logo.

Member news

This summer I built a new electric ornithopter. Unlike the first one, this one was flown with a modified version of the HLH731 gearbox, allowing the use of four cells instead of three. With this arrangement, good climbing flight was achieved. Unfortunately, the modification required scavenged parts, making it difficult for others to duplicate this ornithopter.

Roy White has been setting records again. This time it is a Cat III record set May 2, 1993 at Burton, Michigan, with a time of 12:52. Congratulations! Some data on the ornithopter follow.

Projected wing area = 146.3 sq. in.
Stab area = 71.8 sq. in.

Weight:	Flapping wing	420 mg
	Motor stick	170 mg
	Stab	210 mg
	Total	800 mg

In recent indoor flying at Akron, Ohio, Roy set a new personal best of 15:50. The blimp hangar there has a cat 4 ceiling of 186 feet. The record, held by Frank Kieser, is 17:01.

Richard Stonecipher recently built an indoor ornithopter from plans in "Winning Indoor Designs" by NFFS. The model was designed by Frank Kieser. Richard rented the High School Gym for a few hours and got flight times around two minutes. When he wrote, he was building another model, this time trying to make it lighter. The .042 wing spars and other delicate parts make it a tricky process.

After I published an article on the Flapping Flyer kit by Indoor Model Supply, a number of our members decided to give it a try. Thomas Hill writes: "I immediately ordered one and built it, as you said, in a weekend. I used the same glue as I use for indoor models: .25 Ambroid, .25 Duco, .50 Acetone, applied with needle style bottle. I found the kit enjoyable, although trimming has been a lesson in patience. The wood for the stab was weak and continually breaking [though not all of the kits have this problem. ed.]. I finally gave up and dedicated the stab to an 'experiment.' I shrunk the condenser paper with water. Insant 7x7 indoor propeller!! What a warp!! Lessons are fun. New stab on the board of stronger wood."

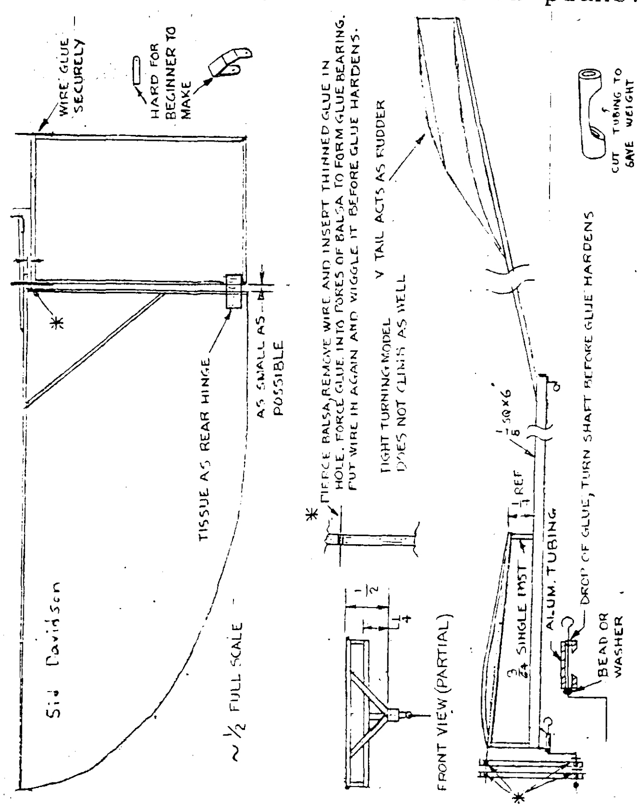
Sidney Castle had less luck with his first Flapping Flyer; something (he didn't say what) was dreadfully wrong. Learning from his mistakes, he is now building a second one. Although the Flapping Flyer is a good kit for someone with enough indoor model experience, being capable of pretty good flight times, Sidney's experience shows that it is not the ideal first ornithopter for everyone. A simpler, just-for-beginners ornithopter is greatly needed, and is the subject of the following article.

Flappers made easy

Ironically, getting ahold of a high-performance ornithopter is as easy as grabbing one near the porch light at night, while building a relatively incapable rubber-powered ornithopter requires far more time and effort. In an effort to change this state of affairs, Sid Davidson has been working on ways of simplifying the ornithopter. His letter follows:

"I am sending some ideas for beginners in ornithopters. Shorter solid motorsticks since they are unused to building hollow sticks and also because they may be more clumbsy than experts. Also as a stick gets longer it either has to be braced or it flexes more. Better for a beginner to have a short flight than none at all. Most problems are had with friction, since extreme simplicity in building can be done by anyone ... I believe a kit can be made in China for about $.15 with all wire parts cut and formed, leaving construction of wings, cabane, and tail to builder."

My own thinking is similar to Sid's, except that I have sacrificed even more performance for simplicity. A heavy yet durable ornithopter I have designed for beginners will appear in the next issue, with detailed plans.



The availability of simple ornithopter plans is crucial to the growth of ornithopter modeling. Growth will cause improvements to this newsletter and more product offerings from kit manufacturers. Please send in any ideas or plans you have which would make it easier for first-time builders of ornithopters.

PERSONAL TRANSPORTATION: A LUCRATIVE AERONAUTICAL BUSINESS OPPORTUNITY

Paul W. Herrick, P.E.*
Consulting Engineer
5705 Holly Lane
Jupiter, Florida 33458
(407) 746 5687

Abstract

This paper makes the case for utilizing America's hi-tech aerospace industrial capability to design, develop, produce, and market an airborne successor to the automobile. The motivating factors include the huge market worldwide, the problems with our current personal transportation system, and the fact that aerospace is our largest positive industrial trade balance contributor. Further, the paper examines the seven potential aircraft concepts to fill this role and arrives at the conclusion that, until we develop an efficient non-aerodynamic method of producing lift, a vertical takeoff and landing (VTOL) capable ornithopter (wing-flapping airplane) will be the optimum solution to the problem. The paper concludes by delving into some of the operational concerns and strong points of this type of personal transportation vehicle.

Introduction

As one reads the many editorials, articles, etc. in the current aviation and business periodicals it becomes obvious that U.S economic leadership is heavily connected to our aerospace industry. Over the past few years, while many of our other manufacturing disciplines have been in the areas of our trade deficits, U.S. aerospace has accounted for our single largest positive industrial trade balance with from 10 to 30 billion dollars per year in trade surpluses. These same articles rightly emphasize the need for us to remain aggressive in the aerospace business to retain and improve our current lead in these critical industries. They point out the state of the world markets for large subsonic passenger and cargo aircraft, supersonic and hypersonic transports, intercity STOL transports, and commercial/ business/ government operated helicopters. Understandably, the military markets have been de-emphasized of late (but that's another story). One thing that is obvious from these essays, but does not seem to have been imaginatively explored, is that a new, highly lucrative market area for our hi-tech U.S. aerospace expertise would be tremendously desirable for the economic future of this country.

Philosophically, in dealing with worldly prosperity, "Success requires not only devotion to one's work, but also that one should function as part of some one of the channels of material wealth." (ref. 1). Or, as bank robber Willy Sutton said when asked why he robbed banks, "Because that's where the money is!" Figure 1 shows us "where the money is" (ref. 2). Next to food and shelter, personal transportation vehicles (automobiles) are responsible for the largest percentage of consumer expenditures (about 13%). With a worldwide production of nearly 36 million cars per year (ref. 3), this one commodity type is responsible for about a half TRILLION dollars of yearly expenditures in initial outlays alone. It is well known that this particular industry area (automobiles) has been the source of a yearly deficit of from 35 to over 40 billion dollars per year for this country for the past several years. Could this be the market we are looking for? Could we use our hi-tech aerospace "strong suit" to take the car market? We can't pave every acre of land and bridge every mile of river. And we can't continue with a system in which we waste two billion gallons of fuel every year stuck in traffic jams, and, in which 60% of our drivers on interstates average less than 35 mph due to the congestion (ref. 4). Surely, someday, man will use the atmosphere as his medium of personal transportation. Let's look at it.

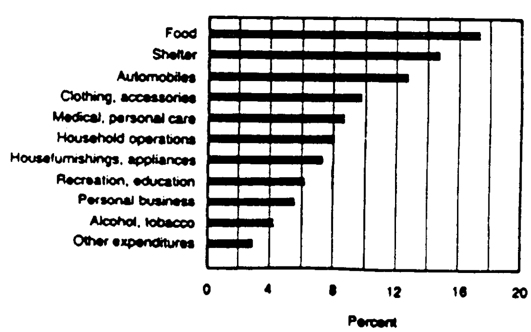


Fig. 1. Distribution of Consumer Expenditures

* Professional Engineer, Associate Fellow, AIAA

Current Situation

If one examines the current status of personal air vehicles (light planes and light helicopters) vis-a-vis personal land vehicles (cars and motorcycles) the picture does not look good. We have nearly one thousand PLV's (personal land vehicles) for each PAV (personal air vehicle) at the present time in this country. Specifically, the numbers are about as follows: 123 million cars, 4.4 million motorcycles, 130 thousand light planes, 1.3 thousand helicopters (ref.3,5). Looking at it another way; we have 66% of our population licensed to drive, while only 0.2% are licensed pilots. That amounts to 1.3 drivers per PLV and 5.3 pilots per PAV. In yet another way, that's nearly 300 drivers for every pilot. As figure 2 and table 1 illustrate, even in our most recent general aviation heyday of 1977, when a forty year peak of seventeen thousand general aviation aircraft were delivered, family travel by air was trivial for trips of less than 400 miles (ref.6). (For a good discussion on why the drastic drop in deliveries shortly after 1977, also see reference 6.).

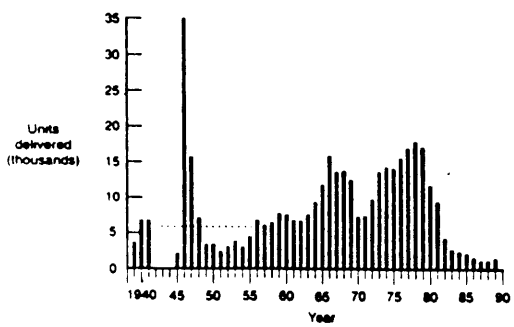


Fig. 2. Domestic General Aviation Deliveries

Round trip length, mi	Percent of trips	Percent by travel mode: Auto	Bus	Train	Air	Other
200-299	34	93	4	1	1	1
300-399	17	90	4	1	3	1
400-599	17	82	5	1	9	3
600-799	8	70	4	1	21	4
800-999	5	62	4	1	29	4
1000-1999	10	48	3	1	42	6
2000 and over	9	25	2	1	67	5
Total	100	76	4	1	16	3

Table 1. Household Trips in the U.S.A.

Why aren't we flying more on a personal basis? It's not because we don't have the right. The Federal Aviation Act of 1958 gave us the "Public Right of Transit" (Sec 104---"There is hereby recognized and declared to exist in behalf of any citizen of the United States a public right of freedom of transit through the navigable airspace of the United States"). The reasons for the success or failure of any concept are generally related to the following: safety, convenience, cost, user acceptance, and, more recently, environmental impact. From a safety standpoint cars look good compared to general aviation aircraft. Personal flying results in over eleven times as many fatalities per passenger mile as car travel does (but car fatality rates are about 35 times higher than airline rates on a "per passenger mile" basis). A look at general aviation accident statistics can be helpful to us here. They show the following typical characteristics: 50% of the accidents occur during approach and landing, 20% occur during take-off, 20% are weather related enroute, and 10% "other" (midair collision, mechanical, structural failure, fire, etc.). A clue as to how to attack these problems is shown in figure 3 . Statistics show that the landing accident rate (50% of all accidents) varies as approximately the square of approach speed (ref. 7). Even a small reduction in approach speed brings a large reduction in landing accidents.

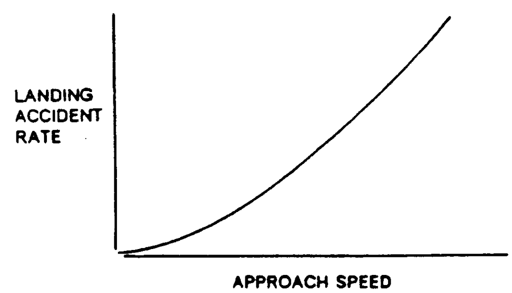


Fig. 3. Relationship Between Landing Accidents and Approach Speed

Concerning convenience, except for helicopters, aircraft require airports (or at least runways) which most people don't have nearby their home (or most driving destinations). Even helicopters require approved helipads due to their noise, downwash, and other safety factors. For airplanes with relatively high power-to-weight ratios, the length of runway required for landing is longer than that required for takeoff, therefore, required landing distance determines required runway length. As figure 4 illustrates, landing distance also varies with approximately the square of approach speed (ref. 7). Further, as reference 8 indicates, number of potential landing sites varies inversely with required landing distance (figure 5), therefore, not only does the reduction of approach speed increase safety but it also increases convenience, i.e., availability of suitable operating sites.

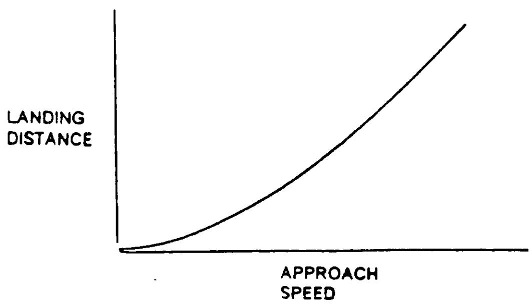


Fig. 4. Relationship Between Landing Distance and Approach Speed

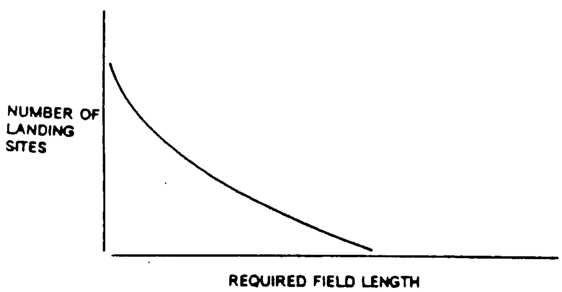


Fig. 5. Relationship Between Available Landing Sites and Required Field Length

The "Flying Car" or "roadable airplane" has been the subject of much activity, on an intermittent basis, for many years. Cessna announced in 1942 that they were designing a "Family car of the air which you'll learn to fly as quickly as you learn to drive--as easy and as safe only you'll be covering three times the distance." This never materialized. The Taylor Aerocar concept has had many forms, many of which flew, and the latest of which is shown in figure 6 (ref. 6). With this idea, you towed the wings, tail, and flight propulsion system behind your highly modified car (Honda CRX, in this case), and assembled the combination at the airport. After landing at another airport you disassembled the system and towed the flight components as you drove away. Since you still need an airport to operate it, the increasing availability of rental planes and rental cars (at most airports) tends to reduce the attractiveness of this idea.

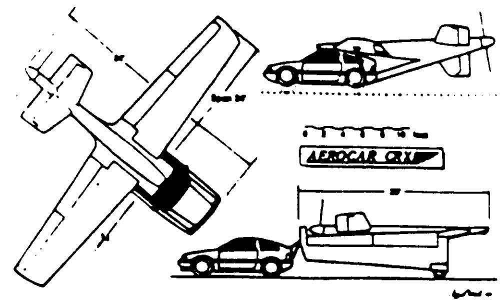


Fig. 6. Aerocar CRX Proposed by M. Taylor

The Answer

Because of the above discussed safety and convenience drawbacks of aircraft that land at significant approach speeds and require a runway, any PAV that will be a serious candidate to replace the car will at least have to have very short takeoff and landing requirements, and very probably, true VTOL capability. Currently there are two PAV candidate concepts which fit this latter requirement: the helicopter and the ducted fan. Figure 7 depicts the very successful Robinson R22 light helicopter, certainly the most promising PAV currently in production. Figure 8 shows one of the several approaches to a ducted fan PAV, the Flight Innovations Sky Commuter concept. Both of these ideas for personal air vehicles will be discussed below but suffice it to say that it is the author's opinion that neither one (helicopter or ducted fan) will prove satisfactory for the PAV market.

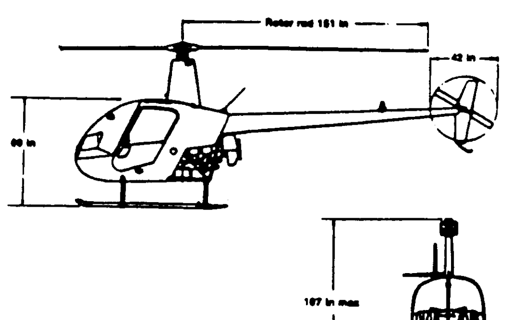


Fig. 7. Robinson R22 Beta

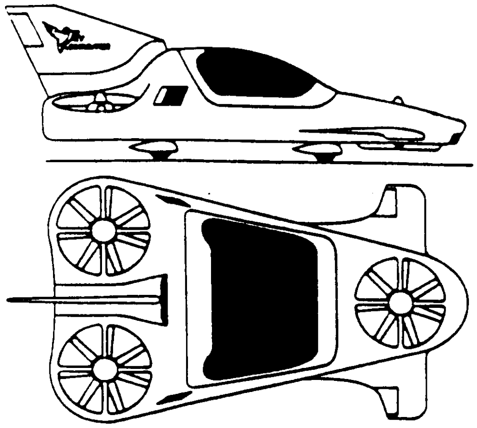


Fig. 8. Flight Innovations, Inc. Sky Commuter Concept

This is where the writer risks losing the reader but he is dead serious. The ultimate answer to the PAV problem is---the ORNITHOPTER (figure 9, taken from ref. 9). Engine power and advanced technology can turn this pre-20th century aspiration of our ancestors (to some), and "silly idea" (to others), into the most significant, practical, and money-making aircraft concept since the jet transport.

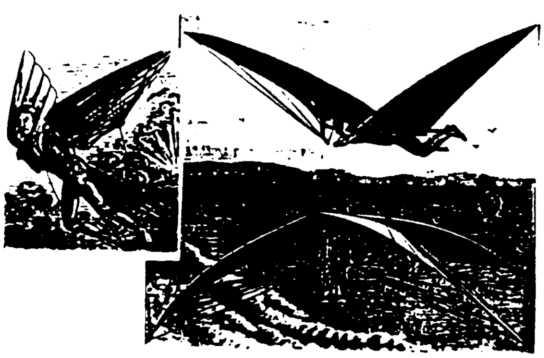


Fig. 9. 19th Century Ornithopter Concepts

Several research activities in the area of wing flapping flight have occurred in recent months and years (ref. 10 and 11, for example). Many serious and competent engineers and scientists worldwide are attacking various aspects of the problem but J. Harris and J. DeLaurier, of Battelle and U. of Toronto, respectively, have probably made the single most important advance with their September 1991 flights of the world's first remotely piloted, large scale, engine powered model ornithopter (figure 10). This 8.6 pound, 10 foot wing span, one horsepower engined model employed a scotch yoke drive with a 55-to-1 belt reduction to flap the kevlar aero-elastically twisting wings 3.5 times per second. Although it was hand launched and not capable of vertical takeoff or vertical landing, work being conducted by the author indicates that VTOL ornithopters are feasible and are literally "waiting in the wings".

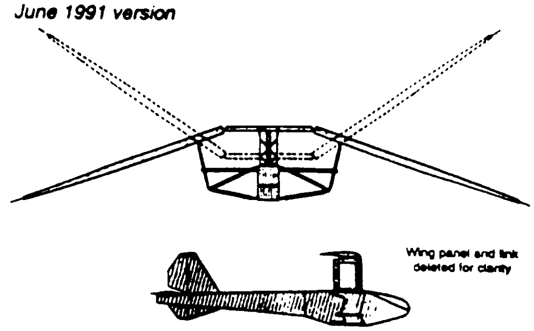


Fig. 10. Harris/DeLaurier Ornithopter Concept

Why An Ornithopter?

Seven concepts come to mind as candidate PAV's. These are: light planes, ultralights, autogyros, paraplanes, helicopters, ducted fans, and ornithopters. Although all of these aircraft can be designed to have very short takeoff and landing capabilities, only the last three can be truly VTOL. The criteria for evaluation of these aircraft, along with the best candidates in each category, include:

1) Lowest takeoff and landing distance --ornithopter, helicopter, and ducted fan (ability to generate vertical lift at zero air speed).
2) Highest safety -- ornithopter (high glide ratio and low landing speed at engine-out conditions).
3) Highest efficiency--ornithopter, light plane (high cruise and loiter lift-to-drag ratio).
4) Highest cruise speed -- ornithopter, light plane (high lift-to-drag ratio, no retreating blade to stall).
5) Lowest noise -- ornithopter (low tip speed).
6) Most compact (on ground) -- paraplane ("wing" stuffed into bag). Note: the ornithopter can be a close second (by folding its wings like a bird).
7) Most comfort -- light plane (highest wing loading for smooth ride, minimal vibration). Note: vibration (fuselage motion) is one of the two most challenging aspects of the ornithopter and may dictate two sets of wings flapping 180 degrees out of phase.

8) Lowest cost -- ultralight, autogyro, paraplane (simplicity). Note: complexity is the other primary ornithopter challenge.
9) Ease of operation -- paraplane (pendulum stability, only "rudder" and throttle controls).

These estimates are based on the author's analyses and his 35 years of experience piloting a wide variety of aircraft including light planes, ultralights, helicopters, autogyros, and paraplanes.

A comparison of the three VTOL concepts shows that when its wings are flapping in the horizontal plane (VTOL and hover flight), the ornithopter excels in safety, efficiency, and noise due to its very low values of hover disk loading (about a half pound/ sq. ft.) and tip speed (about 65 ft/sec.). Its downwash velocity (important for neighborhood acceptability) and hover fuel consumption are both very low while vertical thrust per HP is very high. Up and away flight speed, efficiency, and safety are high with the ornithopter (wings now flapping in the vertical plane) because it has a high, airplane-like wing aspect ratio (as opposed to a helicopter's rotor disk aspect ratio of 1.27) for high cruise, loiter and engine-out glide lift-to-drag ratios. Because there is no helicopter like retreating blade, or high flapping tip speed, there is no retreating blade stall speed limit or rotor/propeller sonic tip speed limit (or shock noise). Like the current ultralights and the proposed ducted fans, the ornithopter could use a ballistic parachute for vehicle letdown during hover engine-out or other non-glideable situations.

Some critical values predicted for two-place versions of the three VTOL concepts are (ducted fan and helicopter values from ref. 6):

VALUE	DUCTED FAN	HELICOPTER	ORNITHOPTER
TOGW	1350 pounds	1370	1200
Hover HP	212 to 300HP	92	50
Downwash vel	88 to 125mph	33	14
Fuel mileage	5mpg @ 85mph	14.7 @ 110	32.5 @ 100
Noise	buzz saw (very annoying)	wop wop wop (annoying)	swoosh swoosh (acceptable)

Operational Concerns

Autonomous operation will be absolutely essential for the ornithopter concept to be commercially viable. Engine driven wing folding and powered wheels will be needed for short ground trips and compact parking, and sophisticated onboard avionics will be required for simplified piloting and navigation as well as night/all weather operations and collision avoidance. The economies of scale will be relied upon to bring the cost of this hi-tech machine and its associated avionics down to consumer levels much as has been the case with modern consumer electronics such as calculators and computers.

Specifically, forward looking infrared (FLIR), millimeter wave radar, beam sharpened X band weather radar, Global Positioning Systems (GPS), and proximity warning equipment now being used by the military and airlines will be highly desirable for the mass usage of personal VTOL ornithopters. Again, with the current worldwide yearly automobile production rate as a yardstick, these hi-tech devices should succumb to the economies of scale. Some of them already have.

The fact that the ornithopter can fly, and fly efficiently, at very low airspeeds (including zero) without fear of stalling, allows "slowing down to a crawl", or stopping, to be a tactic for dealing with emergencies, traffic congestion, or inclement weather, just as it is in driving a car. Low speed and/or hover flight plus right-of-way rules and traffic signs/signals/cops will also facilitate many ornithopters converging on a point destination on the ground, such as employment, shopping, entertainment facilities,etc. The movement of the nearly thirty foot semi-span wings (especially if brightly colored) flapping once every two or three seconds will provide a prominent visual cue which pilots flying aircraft on a collision course do not currently enjoy. This present lack of observed relative motion is a major contributor to "midairs".

The low disk/wing loading of the ornithopter PAV's will cause gusty wind conditions to be one of the most limiting factors in flight operations. Fortunately, these conditions are usually of short duration, as with a passing thunderstorm. If the gusts are occurring at the destination, the ornithopter "driver" will have the option to wait in the air (loiter), divert to another destination, or make a precautionary "out" landing nearby (because of his "good neighborly" VTOL capabilities) and wait on the ground for conditions at his destination to improve. If the winds at his point of origin are gusting beyond acceptable limits, he'll have to wait it out or possibly ground taxi to a better location to initiate vertical takeoff. While rain, snow, fog, and clouds may not be a problem, icing could be more serious than it is for an airplane or helicopter due the complexity of the ornithopter's wings.

Environmentally, the ornithopter will excel due to its low downwash velocity and noise during vertical flight and hover operations. People and property will suffer little hardship by nearby takeoffs and landings, while the high fuel efficiency during both hover and cruise will minimize fuel consumption and, therefore, exhaust emissions.

Concluding Remarks

There is a huge market for personal transportation systems worldwide. Studies consistently show that given a choice between mass transit and personal transit, humans prefer the personal freedom, mobility, and privacy of personal vehicles. The earth's atmosphere must eventually become the medium of operation for these personal transportation vehicles. High technology can deliver a VTOL personal air vehicle that is safe, convenient, efficient, quiet, easy to fly, and environmentally acceptable. Economies of scale can bring the cost to acceptable levels. If any country is suited to make it happen it is the United States, with it's current hi-tech aerospace economic leadership position. It may not happen tomorrow, and it won't happen here first without a dedicated effort, but it WILL happen. And when it does, the most ideal concept will be the ornithopter. As William Stout, the father of the Ford Trimotor and many other innovative concepts, said in 1952 (ref. 12), "Whoever achieves flapping-wing flight first will dominate the air."

References

1. Anonymous: THE URANTIA BOOK, Urantia Foundation, Chicago, 1955.

2. "NATO Committee on the Challenges of Modern Society-Document No. 48", Symposium on Low Pollution Power Systems Development; Rome, Italy; December 1975.

3. Hoffman, M.S.: THE WORLD ALMANAC AND BOOK OF FACTS-1992, Pharos Books, 1991.

4. Berardinis, L.A.: "Smart Highways Get the Green Light", Machine Design, August 6, 1992.

5. AEROSPACE FACTS AND FIGURES 1991/1992, Aerospace Industries Association of America, Inc., 1991.

6. Crow, S.C.: "Back to the Future of Personal Aviation", SAE 901990, 1990.

7. Kohlman, D.L.: INTRODUCTION TO V/STOL AIRPLANES, Iowa State University Press, 1981.

8. McNally, D.J. and D.M. Brown: "Requirements for Future RALS/STOVL Operating Concepts", SAE 851840, 1985.

9. Harter, J.: TRANSPORTATION; A PICTORIAL ARCHIVE FROM 19th-CENTURY SOURCES, Dover Publications, New York, 1984.

10. Herrick, P.W.: "Air Combat Agility Flight Research: A Novel Approach", Society of Experimental Test Pilots, Cockpit, June 1990.

11. Herrick, P.W.: "Manned Flight: From Fandors to FANDORS (Flapping Aerial Navigation Designed Ornithological Replicas)", Scientific Symposium II, Oklahoma City, Oklahoma, May 1991.

12. Stocker, J.: "Flapping Wings for the Future?", The Rotarian, September 1952.

USIC results

The United States Indoor Championships last month included the ornithopter event, #210. Contestants were:

1	White	13:01
2	Krush	9:13
3	Williams, W.	8:33
4	Stonecipher	3:27
	Mc Ilrath, Sr.	0:00
	Coslick	0:00

Appropriately, five out of six are OMS members.

NATHAN CHRONISTER
3140 RT. 209 #2A
KINGSTON, NY 12401