Technical Report Documentation Page

1. REPORT No.
CA/TL-91/03

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE
Personal Air Transport
State of the Art

5. REPORT DATE
April 1991

6. PERFORMING ORGANIZATION

7. AUTHOR(S)
David D. Little

8. PERFORMING ORGANIZATION REPORT No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
California Air Transportation Technology Center
Naval Architecture Building
University of California, Berkeley Campus

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

12. SPONSORING AGENCY NAME AND ADDRESS
California Department of Transportation
Sacramento, CA 95807

13. TYPE OF REPORT & PERIOD COVERED
Final

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

As congestion on roadways and at airports continues to increase and the cost of capacity expansion becomes prohibitive, new ways of addressing personal transportation needs have to be considered. This report attempts to address the state of the art in Personal Air Transport (PAT), commonly referred to as the "flying automobile".

The report concludes that the PAT technology faces a number of technical, mechanical, regulatory, cost, and perception obstacles in its attempt to become economically feasible. No one of these obstacles appear to be insurmountable but the combination of which could keep the PAT from significantly impacting the personal transportation market.

17. KEYWORDS
Personal Air Transport, flying automobile, vertical takeoff/ landing technology, airport congestion, highway congestion

18. No. OF PAGES:
48

19. DRI WEBSITE LINK
http://www.dot.ca.gov/hq/research/researchreports/1989-1996/91-03.pdf

20. FILE NAME
91-03.pdf

This page was created to provide searchable keywords and abstract text for older scanned research reports.
November 2005, Division of Research and Innovation

PERSONAL AIR TRANSPORT

STATE OF THE ART

91-03

Research Report by:

David D. Little
Graduate Research Assistant
for
California Department of Transportation

April 1991

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
CA/TL-91/03		

4. TITLE AND SUBTITLE	5. REPORT DATE
Personal Air Transport State of the Art	April 1991
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) David D. Little	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS California Air Transportation Technology Center Naval Architecture Building University of California, Berkeley Campus	10. WORK UNIT NO.
	11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS California Department of Transportation Sacramento, CA 95807	13. TYPE OF REPORT & PERIOD COVERED Final
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

As congestion on roadways and at airports continues to increase and the cost of capacity expansion becomes prohibitive, new ways of addressing personal transportation needs have to be considered. This report attempts to address the state of the art in Personal Air Transport (PAT), commonly referred to as the "flying automobile".

The report concludes that the PAT technology faces a number of technical, mechanical, regulatory, cost, and perception obstacles in its attempt to become economically feasible. No one of these obstacles appear to be insurmountable but the combination of which could keep the PAT from significantly impacting the personal transportation market.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Personal Air Transport, flying automobile, vertical takeoff/landing technology, airport congestion, highway congestion	No. Restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified		

DS-TL-1242 (Rev.6/76)

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

NOTICE

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

Table of Contents

Introduction

1. Objective: Report Goals and "PAT" Concept

2. History
   - Curtiss Autoplane
   - Bureau of Air Commerce
   - Convaircar
   - Taylor Aerocar

3. State of the Art
   Flying Automobile PAT
   - Taylor Aerocar

   Vertical TakeOff/Landing PAT
   - Moller International
   - Flight Innovation

4. Constraints

5. Government Involvement and Support
   - FAA Certification Process

6. Conclusions

7. Future Research

8. Bibliography

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

INTRODUCTION

As congestion on roadways and at airports continues to increase and the cost of capacity expansion becomes prohibitive, new ways of addressing personal transportation needs have to be considered.

The "flying automobile", as it has been termed in the past, is such a way. The concept of a vehicle able to traverse acceptably well in both the air and on the road is, however, far from a new idea. Public interest and industry enthusiasm peaked during the late 1940s and early 1950s, but the technology suffered from mechanical problems as well as a lack of government support and consumer confidence.

In today's congestion environment, there is a renewed interest in a technology which combines the two modes of transportation, allowing for increased mobility in numbers and distance while reducing congestion on existing infrastructure.

There are currently three companies actively pursuing development of this technology. For lack of a better description (and the need for additional aviation acronyms) this general concept in transportation will be referred to as Personal Air Transport or PAT. Only craft with a seating capacity of four or less will be included in this category thereby eliminating the larger class of vertical takeoff/landing craft such as tilt wing and tilt rotor technologies.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

1. OBJECTIVE - REPORT GOALS AND THE "PAT" CONCEPT

This report attempts to address the State-of-the-Art in the general category of Personal Air Transport (PAT). This category can be divided into two distinct areas; the more traditional "flying auto" and the newer vertical takeoff/landing (VTOL) technology. The major firms in the field are identified and their craft characteristics are described. For each company, the respective stage of the development/production process and most recent progress are then covered. The goal of the study is to accurately describe the State of the Art in PAT and to determine if further research/involvement is warranted. If such research is warranted, then the specific areas of involvement will be identified.

Concept

The thought of leaving for work in the morning in a vehicle which can maneuver equally well on the highways as the skyways has been one that has intrigued mankind for almost as long as there have been airplanes. Since 1936 the US Patent Office has seen filings for more than 30 designs for such craft. Several prototypes were in daily use in the 1950's but the flying auto has yet to take flight with the buying public. The reasons have been both technical and bureaucratic. Federal agencies have resisted the idea of tens of thousands of amateur pilots daily filling the skies to converge over major cities. Technically, the design of a good airplane, light weight and high powered, contrasted with that of a good auto, which was sturdy, cheap and spacious. However with increasing congestion problems, the concept is again capturing public and industry interest. In the words of Dr. John Zuk, Chief of Civil Technology at NASA Ames Research, "traffic congestion won't quit but we still want personal mobility. We only have one place to go, and its up."

While designs of the 1940s and 1950s resembled more of an auto than a plane, the newer designs, pursued by two of the three active companies, tend to be more of a cross between a helicopter and an airplane. For this vertical takeoff/landing PAT the concept is somewhat different. This craft is not intended for integration into the mainstream of automobile traffic. In concept the vehicle is driven to or located at the nearest vertiport (launch facility) where the operator would punch in the appropriate origin, and destination codes, and the vehicle's on-board computers would check all systems. When both the vehicle and traffic control system are ready, the craft would take off vertically, climb to its designated altitude, make the transition to horizontal flight, cruise at 250 - 300 mph on a preset flight path to its destination, where it would vertically descend and land. A satellite based microwave guidance system would control the flight.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

2. HISTORY

The flying automobile concept followed soon after Orville Wright touched down in Kitty Hawk. In 1917 the Curtiss Autoplane, an aluminum-framed car with three wings, appeared at the Pan-American Aeronautical Exposition in New York City. The vehicle was aimed toward the upscale market with the pilot to be more of a chauffeur and the two passengers able to relax in a velvet curtained, leather lined compartment. The vehicle did fly but the venture ended when the United States entered World War I.

During the 1920s, Henry Ford backed a vehicle called the Sky Car. Ford, however, lost interest after a friend was killed and no other manufacturers stepped forward to advance the project. In the 1930s the Roosevelt Administration appointed Eugene Vidal, a former Olympic athlete and military pilot (and father of author Gore Vidal), to head the Bureau of Air Commerce. Vidal planned to have the government build the planes but federal lawyers blocked the idea. Vidal would later sponsor a contest for private sector designers to design an inexpensive "safety plane". Five groups of designers were eventually named to produce prototypes for government consideration. Most of the resulting craft are now in aviation museums. In general they were sturdy, if not aesthetically pleasing, designs. None of the designs, however, made it to mass production.

Following World War II the time seemed ripe again for flying autos. The family airplane was predicted to become almost as common as the family car. Drafts of the 1944 Highway Construction Act called for roadside landing strips along all major highways. Private plane sales rose to 30,000 in 1946 and Consolidated Vultee, a warplane manufacturer, began producing the Convaircar, a fiberglass auto that had a wing and tail attachment for flight. The attachment was to be rented and dropped off at the destination airport. The Convaircar first flew in 1947 and performed better in the air than on the road. The prototype crashed, however, during flight testing and one year later the project was abandoned as it became obvious that the expected post-war flying boom was not taking place (plane sales had dropped 75% from 1946).

Another designer who also felt that the wings should remain at the airport was Robert Fulton. A successful manufacturer of gunner-training devices during WWII, Fulton pursued the flying auto soon after the war ended. His small company went public in 1946 with the Airphibian which received enthusiastic media coverage. The wings and tail formed a single unit which, along with the propeller, were left at the airport when highway use began. Fulton received FAA approval to manufacture the Airphibian but the vehicle never made it to market, and Fulton would soon sell his company and the Airphibian was a memory.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

Taylor Aerocar

The manufacturer that came closest to commercial success was Moulton Taylor of Longview, Washington. Seven of Taylor's Aerocars (Figure 1.) were built during the 1950s and its design seemed to solve some of the flying automobiles inherent problems. Taylor insisted early on that the propeller be tail-mounted for easy conversion to highway operation and because it kept the wings free of the swirling airflow caused by the propeller.

The transition from plane to auto was simple and quick. A hand crank and five minutes were all that one needed for the conversion. The wings, tail, and propeller could be stored at an airport or towed in a trailer by the vehicle. This freed the owner from airport hangers. Mechanically, the same 143 H.P. engine served the propeller and the wheels. The craft first flew in 1950 and as an aircraft, the Aerocar received good reviews from the aviation officials who approved it for sale in 1956. Five Aerocars were built in the late 1950s and interest peaked in 1961 with its use in a hit television comedy and by a Portland radio station for traffic reports. Taylor entered into negotiations with a Texas manufacturer for mass production which would allow the price of an Aerocar to drop to $14,000.

Events quickly turned against Taylor's flying auto. CBS canceled the television show and the radio station went with a regular plane for its traffic reports. Negotiations with the Texas manufacturer soon collapsed. Taylor would not give up and ten years later produced an Aerocar III (Model #II was a plane) which top executives at Ford Motor Company considered for manufacture. Meetings with the U.S. Department of Transportation did not proceed well and in effect killed the partnership by requiring an excessively expensive vehicle license according to Taylor. Ford soon lost interest and financing disappeared shortly thereafter.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

THE CAR WITH THE BUILT-IN FREEWAY

AEROCAR is the all-purpose vehicle the traveling public has dreamed of. The powerful little coupe with its fluid drive and unencumbered by wings is ideal for driving in traffic—fast on the get-away and easy to park—a full fledged automobile in every respect. AEROCARS comply with all highway vehicle codes.

As an airplane, the AEROCAR is a roomy, fast means of travel above the snarls of highways, crossing mountains and rivers as though they didn't exist. If bad weather makes flying impractical, you merely land at the nearest airport, fold the wings and they **become a trailer.** With your trailer in tow, you can then continue on to your destination by highway. It is not necessary to leave the wings at the airport and then have to return for them. The change-over requires no more effort than changing a tire and can be done by one person.

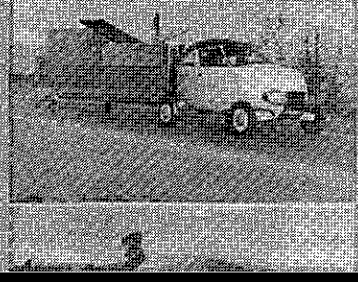
The entire AEROCAR may be kept at your home in your own garage, eliminating hangar rent and inconvenience. If your trip does not require flying, the AEROCAR is always ready for instant use, day and night, just like any conventional automobile. When you desire to fly, you can tow the flight unit to the nearest airport, spread the wings, and the unlimited highways of the air are yours.

AEROCARS have been proven by years of test and use. They have been driven thousands of miles in city and highway traffic. The trailers have been towed under all kinds of weather conditions, and AEROCARS have amassed many thousands of hours of flight experience and perform like any other modern light plane of similar weight and power. They are stable, easy to fly, and exceptionally easy to land. AEROCARS are fully approved by the C.A.A. (Type Cert. No. 4A16)

AEROCARS are **now available** in limited production. Public acceptance and the availability of financing will determine how quickly mass production will enable us to deliver AEROCARS at our goal price of ***LESS THAN $10,000.00.***

PERFORMANCE

Top Speed	Over 110 MPH
Cruising Speed	Over 100 MPH
Rate of Climb (1st Min @ full load)	Over 550 FPM
Service Ceiling @ full load	Over 12,000 Ft.
Cruise Range	Over 300 Miles
Landing Speed	50 MPH
Landing Run (with normal braking)	300 Ft.
Take-off Run	650 Ft.
Distance to Clear 50 ft. Obstacle	1225 Ft.
Designed Road Speed (Engine red line)	67 MPH



SPECIFICATIONS

Wing Span	34 Ft.
Wing Area	190 Sq. Ft.
Wing Loading	11-lb/Sq. Ft.
Power Loading	14.7-lb/HP
Car Empty Weight	1100 Lbs.
Trailer Weight	400 Lbs.
Design Useful Load	600 Lbs.
Allowed Baggage Weight	100 Lbs.
Pilot and Passenger Weight	340 Lbs.
Fuel Weight (24 Gals.)	144 Lbs.
Maximum Gross Weight	2100 Lbs.
Auto Road Tread	5'2"
Auto Wheel Base	6'8"
Trailer Wheel Tread	5'2"
Car-Trailer Length	26'
Baggage Space	14 Cu. Ft.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

3. STATE OF THE ART

3A. FLYING AUTOMOBILE PAT

TAYLOR ASSOCIATES

Following a fifteen year hiatus, Taylor began working on a new design for Aerocar IV or Aerocar CRX (Figure 2.) in the late 1980s. This time a separate turbine engine would be used to drive the propeller. This engine would be mounted in the rear and, as with previous designs, the tail, propeller and wings would detach. To eliminate manufacturer's liability problems, builders would be the buyers, under federal rules which allows "home-built" experimental aircraft. The Honda CRX has been envisioned as the type of vehicle to be used for the Aerocar IV prototype and negotiation for manufacture of the craft have been proceeding with a Chinese firm, thereby eliminating many of the regulatory roadblocks Taylor has encountered in the past.

Vehicle characteristics include an estimated air speed of 150 mph and an operating ceiling of 10,000 feet. The 15 gallon tank would provide an operational range of 700 miles. A further breakdown of the Aerocar features and characteristics can be found in Table 1.

3B. VERTICAL TAKEOFF / LANDING PAT

History

In the 1950s and 1960s, military programs developed several VTOL and powered-lift aircraft. With extension of these programs expected to occur in civil aviation, the FAA drafted tentative standards for powered-lift aircraft in 1967. However, in the early 1970s, U.S. military efforts in these areas were significantly reduced. Some research did continue on short takeoff/landing (STOL) aircraft and the FAA published several joint reports with NASA through 1977 on airworthiness criteria development for powered-lift aircraft but no direct-rule making action was taken.

MOLLER INTERNATIONAL

History

The flying automobile or "volantor" has been almost a life long pursuit for Paul Moller. In 1963, he earned his Ph.D. in mechanical and aeronautical engineering, and went on to teach at U.C. Davis for four years before leaving to pursue his flying-auto dream. He first flew a VTOL craft for the press in 1967, though the craft never got more than three feet off the ground.

In the mid 1970s Moller started a motorcycle muffler manufacturing company which he eventually sold to help finance the volantor. All told, Moller estimates he and other investors have put more than $20 million into his dream.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

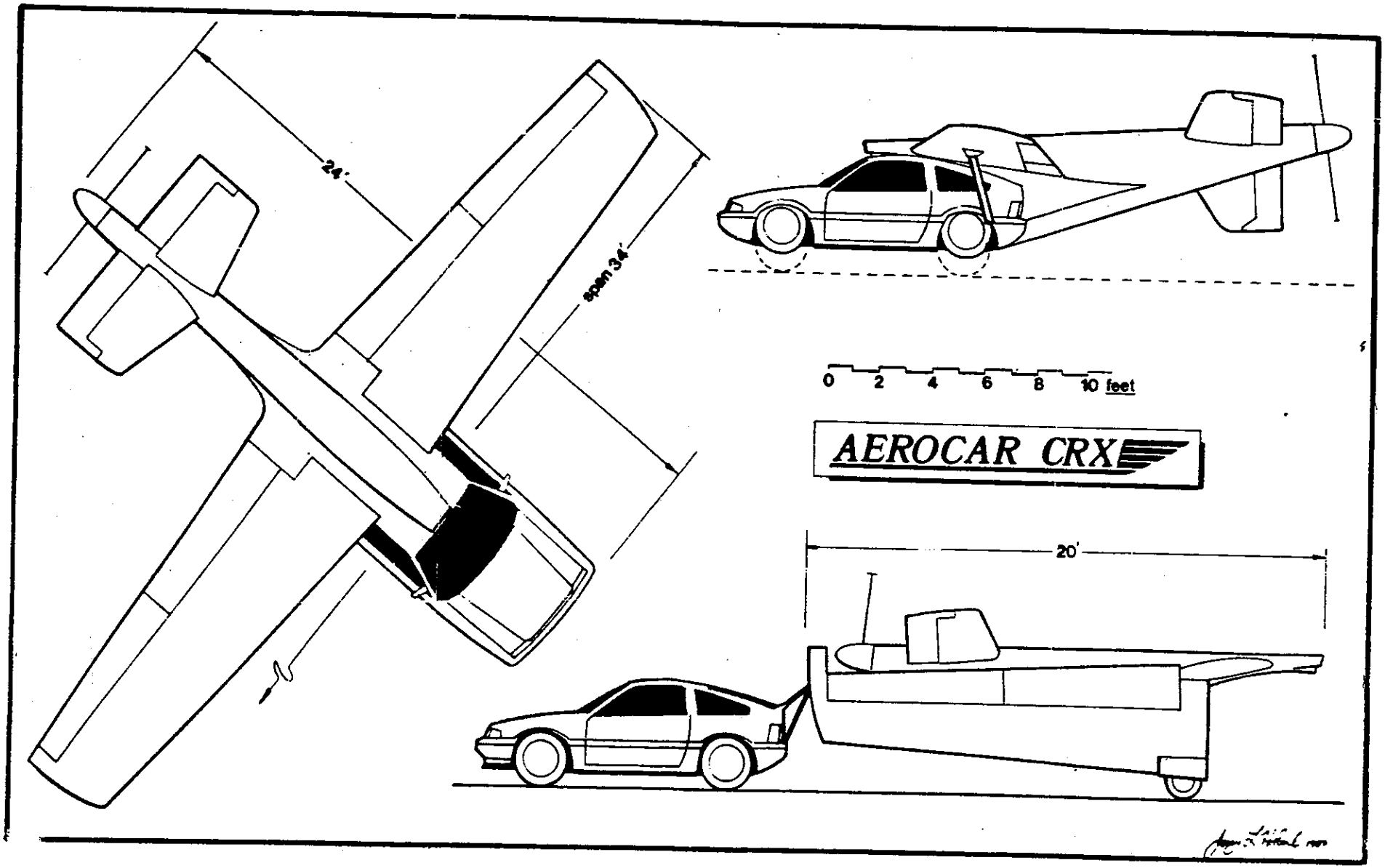


FIGURE 2

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

Currently, Moller International is strongly supported by NASA and the Defence Department for which the company is developing several types of remote controlled, unmanned flying vehicles. Some are large enough to carry payloads long distances, while others are small enough to enter enemy territories undetected. The "aerobots" can be as small as 2 feet in diameter and 1.5 feet tall, equipped to carry surveillance and reconnaissance (mine detection, chemical detection, etc.) missions with extreme speed over long distances, even transmitting video images. Their high speed and small size make detection very difficult. These Defence Department contracts help keep the company afloat (or aloft) financially. Possible industrial applications include security surveillance, fire spotting and suppression, pipeline and transmission line inspection, as well as inspection and surveying of remote or hazardous areas.

State of the Art

Moller has three volantors of varying specifications, all of which are still in the research and design stage. The M400 (Figure 3.) is being designed as a personal transport craft for four passengers having a range of roughly 850 miles and a cruising speed of 250 - 300 mph (see Table 1). The M200X is for a single passenger or can be operated by remote control, and is intended for military or industrial applications.

According to Moller, the key to the volantor's efficiency is its specially designed rotary engines which provide four times as much power per pound of engine weight as piston engines. Multiple thrust generating ducted fans, powered by the rotary engines, will provide the volantor its vertical lift in the hover stage and horizontal thrust in the cruise stage. In the M400 and M200, the fans are mounted horizontally and redirect their thrust vertically for take-off and hover while the M200X has its ducted fans oriented vertically. The volantor's design and propulsion are supposed to optimize both flight stability and safety. The short wing span reduces the turbulence effects of wind gusts as with fighter planes. The redundant safety system, such as eight engines reportedly improves the volantor's safety relative to other VTOL aircraft. With eight engines the craft can recover and land safely from a loss of up to two engines in flight.

Recent Progress (1985-1990)

It is the opinion of the author that from a technical standpoint progress over the last five years from a technical standpoint has not been substantial. The unmanned and one-man saucer shaped volanters have achieved hover stage but do not appear to be close to the next big step of horizontal flight. For the personal transport volanters (M400 & M200), hover stage has not yet been achieved. Company officials hope to attain hover in two years and horizontal flight by 1993 but others in the field are skeptical of this schedule.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

JANUARY 1991 $1.95

Popular Mechanics

ANNOUNCING PM'S 1991 DESIGN & ENGINEERING AWARD WINNERS

ANYONE CAN FLY THE SKYCAR

Take Off From Your Driveway, Land Anywhere

ENERGY CRISIS SPECIAL

How To Buy A New Furnace That Gives You The Most For Your Energy Dollar

AMERICA'S FASTEST 4-DOOR SEDANS

Head-To-Head Test

- Dodge Spirit R/T
- Ford Taurus SHO
- Pontiac Grand Prix STE

FIELD-TESTING THE NEW PALM-SIZED CAMCORDERS

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

Future Schedules and Markets

Moller's schedule for research and development, and eventual production of its vehicles varies by model and the targeted market of that model. The three main markets being targeted are military/industrial, uncertified users, and the general public.

The uncertified market would include foreign countries, most likely countries with a multitude of islands, where such a technology could provide a vast improvement in the nation's transportation system. Other users would include qualified pilots for the experimental or "home built" market. The M400 and M200 are envisioned to fill these markets for personal and cargo transport. Construction of the engineering prototype for the M400 is complete and all on-board components are at the pre-production phase.

The general public market would be dependant upon certification by the FAA. The schedule for FAA approval, covered in detail under section 4, is probably a minimum of three years away.

FLIGHT INNOVATION

History and State of the Art

The flying principle behind Fred Barker's "Sky Commuter" (Figure 4.) is also the ducted fan. Located at Arlington Airport in Arlington Washington, Barker has been working on his version of the flying automobile since 1984.

Like the Moller volantor, Flight Innovations first design used a rotary (Mazda) engine. Citing problems with drive shafts, flex couplings, and 90 degree transmissions, Barker changed to an electric motor weighing eighteen pounds and delivering 140 horse power. Three engines drive the ducted fans. Electricity for the engines comes from three alternators driven by a Tessler Flat-Blade turbine. According to Barker, this engine is based on cutting edge technology.

The advantage of this new engine is the Tessler Blade design. Using flat plates instead of conventional fan blades, the Tessler is less expensive in both composition and manufacture. But as with any vertical take-off craft, high powered engines are only half the battle. The other, and somewhat conflicting half, is designing a small, light and aerodynamic aircraft. The Sky Commuter airframe is made of graphite and Kelvar. These fibrous materials, according to Barker, provide the vehicle with the high strength and light weight airframe needed for hover and horizontal flight. The body itself weighs just over two hundred pounds. The craft empty, with engines, weighs 750 pounds. The two seat craft is estimated to have a cruise speed of 85 mph, operating at 9,500 feet with a range of 250 miles (see Table 1).

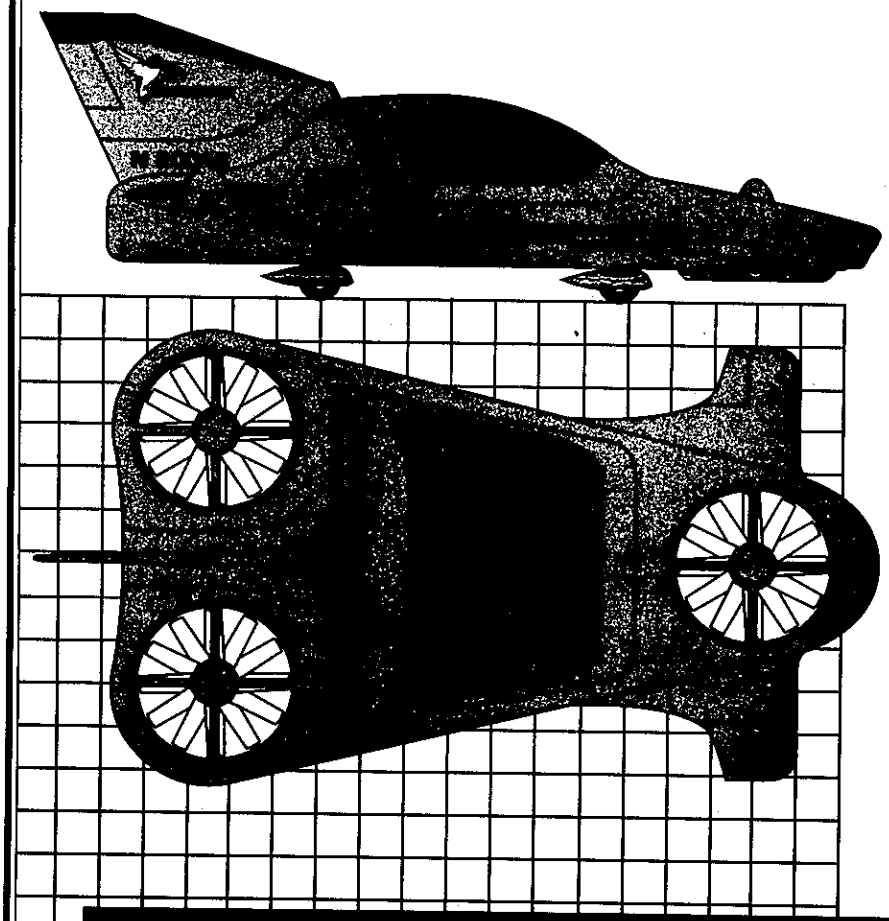
ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

FLIGHT INNOVATIONS INC.

SKY COMMUTER

VTOL AIRCRAFT – Technical Specifications



The SKY COMMUTER is a two passenger, vertical take-off and landing (VTOL) aircraft, constructed primarily of composite materials. The aircraft will be sold under the home built category and will be the most complete kit-built aircraft on the market. After FAA certification a fully assembled aircraft will be offered. Control is fly-by-wire, microprocessor based, with three axis attitude stabilization.

The SKY COMMUTER is powered by a newly developed flat blade turbine which drives two alternators. The rotors are powered by Fisher Industries 125 HP electric motors.

Safety Features

- Redundancy in all control systems.
- A rocket deployed chute that lowers air craft to earth in case of any malfunction.
- Lands on or takes off from water.
- Computer assisted landings.

OVERALL DIMENSIONS AND WEIGHT		PERFORMANCE (standard day, SL)	
Width	8 ft	Cruise speed	85 mph
Length	14 ft	Service ceiling	9500 ft MSL
Height	74 in	Take-Off	0 ft
Disc.Loading	40 #/sq ft	Landing	0 ft
Gross weight	1350 lbs	Range	250 miles
Empty weight	750 lbs		
Useful load	600 lbs		

FIGURE 4

FLIGHT INNOVATIONS,INC.
19132 - 59th Drive N.E.
Arlington Airport
Arlington, WA 98223
(206) 435-0751

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

Flight control of the Sky Commuter uses the "Fly-By-Wire" control. In this system the pilot has a minimum of control. In Barker's words, "the whole flight parameters are in the computer. You give a command to the control system, the computer decides what must be done to achieve it. If it is not in the parameters, it won't do it."

Recent Progress

Hover flight by the Sky Commuter was achieved in 1988 according to Barker. In the November 1990 issue of Popular Science, the craft was described in the "What's New" section as a personal-commuter aircraft currently undergoing tethered flight tests, buildable kits of which might be available as soon as 1992.

A demonstration of conversion from vertical to horizontal flight had been planned for November 1990. This schedule was delayed when the engine manufacturer went bankrupt. In an effort to raise funds for further development, Barker reportedly sold 25 percent of Flight Innovations to a group from Hong Kong for roughly $ 2 million. Efforts are currently going toward raising money from the public sector so development can continue without further loss of ownership by Barker.

Future Schedule

The current schedule Flight Innovations hopes to achieve is to have the vertical to horizontal flight demonstration in spring/summer of 1991 and FAA certification sometime in 1993. This appears to be quite ambitious and assumes the Experimental Aircraft category certification as opposed to the Small Power Lift category (see Section 5).

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

4. CONSTRAINTS

The main constraints to the actual production and marketing of the VTOL personal aircraft can be categorized under regulatory, technological and psychological.

Regulatory constraints are the Federal Aviation Administration (FAA) certifications and approvals needed before production can proceed. Moller is currently working with the FAA in drafting their Air Worthiness Criteria Manual for the Power Lift Normal category. No such category currently exists but is estimated by FAA official to be completed by 1994 (see section 5; Government Involvement and Support). From there the volantors will have to meet the established criteria in order to become FAA certified. This process is expected to take another four to six years.

Technical constraints on VTOL PAT's include the integration of these craft into controlled airspace and in flight mastering of the transition from hover to horizontal flight. The Sky Commuter has successfully performed the take-off, hover and landing stages of flight but still has yet to make the transition from hover to horizontal flight.

Airspace integration depends on the accurate determination and control of a craft's position in congested airspace. Through Global Positioning System (GPS), a reference framework can be provided by generating airways through the use of electronic beams and positioning satellites. Using on-board computers, position control of the vehicle would require potentially no pilot assistance following the input of origin and destination information.

The ability of Air Traffic Control (ATC) computers to route PATs around other aircraft (and each other) would require a substantial increase in both equipment (hardware and software) and personnel. The FAA's eagerness to take on this responsibility for the safety of potentially hundreds of thousands of daily commuters is unknown. Likewise, the federal governmental willingness to allocate the necessary resources to properly equip the FAA for this venture is also unknown but potentially a formidable obstacle for the technology's development.

Psychological constraints are a third hurdle for these vehicles to overcome. As John Zuk stated, "the biggest obstacle to building a system like this are not technical but psychological. People have to get comfortable with the idea, get used to giving up the wheel and allow the computer to do the flying. There was a time when elevators frightened people, but with experience comes trust."

Other operational considerations, if not constraints, are noise, cost, and safety. According to Moller company literature hover tests have demonstrated a noise level of 85 dBA at 50 feet which "compares favorably to that of general aviation planes" for the volantor and 70 dBA for the Sky Commuter. Favorable comparisons to

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

G.A. aircraft in terms of noise does not mean PAT's will not have noise problems. G.A. airports regularly have to deal with noise complaints from adjacent neighbors and situation with PAT's would conceivably be worse with the craft taking off from a driveway within the neighborhood. If takeoffs directly from one's residence were restricted or banned due to noise problems the convenience and time savings of the PAT would be greatly diminished.

Operating costs of a volantor are supposed to be less than that of a conventional helicopter because the use of multiple lift fans eliminates the need for the cyclic blade pitch control, transmissions and clutches, and anti-torque tail rotor. As with noise comparisons to G.A. aircraft, this comparison does not mean PATs will necessarily to the masses. Direct operating costs of small helicopters typically average $25 - 30 per hour[1]. Assuming a one way daily commute time of one hour, annual operating costs would range from $12,500 to $15,000. Additional costs for maintenance, component replacement, repair, insurance, and depreciation could more than double the total operating costs of a PAT.

As for safety, the Moller's hover phase can be maintained with the loss of one engine. Even with the loss of two engines, a safe landing can occur. The backup safety system is a ballistically ejected parachute for both Moller and Flight Innovation's craft. While this may of may not be reassuring to the owner/operator of a PAT, to the property owner who "receives" the aborted craft, this would be of small consolation. At this point in time, with conversion from vertical to horizontal flight still unattained, it is impossible to estimate the flight reliability of PATs. Hence, the general public's perception of the technology's reliability in flight could be another obstacle in PAT's development. Clearly the issue of safety is an important one and could act as a major constraint on the technology's acceptance but until flight conversion is achieved it is an issue that can not yet be addressed.

---

[1] Robinson Helicopter: R22 Beta Estimated Operating Costs (9/90)

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

5. GOVERNMENT INVOLVEMENT AND SUPPORT

FAA Certification Process

In response to the resurgence of development efforts in VTOL aircraft in recent years, the FAA completed the criteria for powered-lift transport category aircraft in the mid 1980s. The updated transport criteria were published in 1988. With technology improvements allowing for lighter engines to vertically lift aircraft, the FAA's most recent efforts have been in establishing criteria for these normal (less than transport) category aircraft.

The FAA is currently developing the draft for the manual of criteria for Air Worthiness Certification for the Small Power Lift category of aircraft. Such a manual exists (finished in 1988) for the Large Powered Lift category of aircraft. The threshold weights for different types of aircraft are the following:

A/C Type	Weight (lbs)
Helicopter	6,000
Aircraft	12,500
Powered Lift	20,000

On October 23 and 24, 1990, the FAA held a conference on Normal Category Powered Lift Air Worthiness Certification Issues in Fort Worth, Texas. The second half of the conference had four panels of FAA and industry experts, who worked on different technical areas. These areas were propulsion, systems, airframe, and flight. The panels continued to work on revising the existing draft of the Criteria Manual over the following three to four months. The public comment period for the existing draft will end in March of 1991 and the FAA hopes to have the final draft complete by the following December. The next step for the final draft toward becoming official FAA Certification Regulations is a legal review by FAA legal department and an internal economic analysis. This process is estimated to take between two and four years (1994 - 1996).

A powered lift technology aircraft can become FAA certified in this category prior to the legal review and economic analysis being finished. The applying company would use the final draft as a certification basis. For the intervening months until the current draft is finalized, companies cannot use it as a basis for certification, but according to officials at the FAA, there is no firm in the normal category that is ready to apply for certification.

Another avenue for companies is the Experimental Aircraft category, where the actual assembly is done by the buyer of the craft. This is the route that Flight Innovations is currently pursuing.

The regular process for certification following an application is as follows. For normal aircraft the applying company has three

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

years to pass all the FAA certification tests. For a large aircraft a five year period is allocated to pass these tests. The certification tests include some of the following:

- Structural strength
- Gear box testing
- Positive flight stability
- Flight handling quality
- Complete documentation of all design

Once a company applies for certification the rules in place at that time apply over the certification period (3 to 5 years). Any rules enacted after the application do not have to be adhered to. If the time required to complete the testing extends beyond the allotted period, the date of rule application shifts accordingly. For example, if company X were to apply under the small aircraft category on 1/1/95 and did not complete the process until 4/1/98, three months after the allotted period, company X's aircraft would have to conform to any certification rules enacted by 4/1/95, three months after their application.

Opinions of Professionals in Related Fields

FAA

A top official at the FAA Powered Lift Department gave the following comments on Moller and Flight Innovation.

Moller - The FAA official feels the company is still "a far ways off" from producing a prototype, achieving hover, and finally horizontal flight. One official has been quoted as saying the personal volantor is 25 years away from being a force in the personal transport market, with public acceptance being a major hurdle.

The engineering concept is not realistic and its emphasis on safety (eight engines) is delaying its progress. Eight engines are prohibitive from the stand points of cost, weight, and mechanical complexity.

Flight Innovation - The FAA official was admittedly less knowledgeable regarding the company and was surprised they did not attend the FAA conference in Fort Worth. The company has achieved hover, however, and has roughly ten kits out to builders, thereby confirming a market (or demand) for their product.

FAA officials spoken to were not aware of any international efforts in this market.

NASA-Ames

In talking with officials at NASA-Ames, their stances on the two VTOL companies pursuing this market were publicly enthusiastic while privately more skeptical.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

Moller - The NASA-Ames official stated that "the company is moving incrementally and realistically given their situation of limited resources. The company's current emphasis on the unmanned military volantor is wise and the personal transport volantor still has a long way to go." The achievement of hover and then horizontal flight are two great hurdles to be overcome from both a power/weight/aerodynamic and vehicle control (software) standpoint. Over the last three years "no major progress" has been made and the eventual FAA criteria it will be required to meet will be formidable.

Still, the company is respected for its work and efforts given the difficult technical and institutional environments it exists in.

Flight Innovation - Officials talked to at NASA Ames were not familiar with the Sky Commuter.

Experimental Aircraft Association

The president of this Wisconsin based association was skeptical of any potential for progress by Moller over the next few years and was not aware of efforts by Flight Innovation. He also did not know of any international efforts in this field.

Moulton Taylor and the Aerocar drew more enthusiasm, being "the only one to ever get type certified by the FAA." The EAA president also felt the main constraint on the flying auto is that of consumer interest and that Taylor had proven that it was mechanically feasible. He felt consumer interest is hampered by negative safety perceptions and the inconvenience of the plane to auto conversion. He also speculated that the turbo-prop may be the design to make real gains in this market.

Emerson Electric Company

A program manager at this St. Louis engine manufacturer had the following observations and concerns after reviewing Moller's technical data:

- excessive capital and maintenance cost of eight engines.
- improvements in piston and turbine engines that could negate advantages of the rotary engine.
- noise levels from the multiple engine configuration could be excessive.

Unfortunately the program manager had not been able to review Flight Innovation technical literature.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

6. CONCLUSIONS

The development of the flying automobile has had conflicting forces at work since its beginning. Mechanically, there is the inherent conflict in designing a craft that is to operate in the air and on the road. To overcome this mechanical problem, a large amount of research and development effort is required. Due to economies of scale, large production runs are also needed to reduce production costs.

The companies which are pursuing this venture, however, are relatively small in size. One reason for this, besides this technical obstacle, might be the liability issues that are involved with development of such a transport vehicle. These companies are all pursuing both the home-built and international builder/buyer markets. The net effect of this will be a much longer development time period.

So while these conflicting forces combine to slow the development of the PAT, the question arises of what role the government might play to promote this technology and ,more importantly, is it worthy of promotion. This report has not attempted to answer this question but concludes that it should be addressed if further research on the technology is to be pursued. The following section of this report covers areas of possible future research which could help to answer the question of PAT worthiness.

The overall conclusion of this report is that the PAT is close (5 to 10 years) to being a technically feasible technology in terms of vertical and horizontal flight. Automated control of the craft once airborne also would seem to be technically feasible in the that time frame (though regulatory responsibility may not be). There are, however, a number of factors and constraints combining to keep the PAT from becoming economically feasible. None of these factors alone appear to be dominant but the combination of which could keep the technology from ever reaching the commuter market.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

7. FUTURE RESEARCH

With highway congestion and its resulting costs in terms of delay and pollution being regarded as one of society's biggest problems, any technology which offers potential congestion relief immediately attracts attention to itself. This report has attempted to describe the current state of the art of PATs. In doing so, no fatal flaws were found with the technology which would seem to prevent it from someday entering the marketplace and helping to reduce highway congestion. The next step is to identify area of future research which will help clarify and quantify its potential in congestion reduction and answer the central question of; is the PAT technology worthy of governmental promotion and if so, what form should that promotion take?

Some possible areas of future research would include feasibility studies, both technical and economic of the technology and its airspace integration, and research on the transportation policy issue of regulatory responsibility of PATs.

Technological feasibility
- the likelihood and time frame of FAA certification
- requirements for the PAT's airspace management in terms of personnel and hardware

Economic feasibility
- projections on capital and operating costs for different levels of production and governmental involvement.
- market potential studies for the PAT (consumer demand analysis)
- quantifying potential externalities of the technology (ie. noise, safety, pollution) and under what mechanism and by who these costs would be bore as well as quantifying the societal benefits of the PAT

Transportation policy
- who should be responsible for the aircraft control and the management of the airspace/airport system, ie. the federal government (FAA) or a new three dimensional highway system with operators responsible for their craft?

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

BIBLIOGRAPHY

1. Smithsonian, "Flying Cars Were a Dream That Never Took Off the Ground", Vol. 19, no.11, February 1989

2. Popular Science, "What"s New", November 1990, pp.10-11

3. Sport Aviation, "Private Flying in 2000 - Roadable Aircraft", December 1983, pp.91-93

4. Sport Aviation, "Taylor Aerocar Design in Logic", September 1962, pp.20-21

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com