Prologue

This note was written on Aug. 4, 1989 as a bit of guidance for the two sons of a deceased friend of mine, Dudley A. Buck, the inventor of the Cryotron superconductive computer element. Dudley died before Douglas and David knew him, and for a short period in their life, I served as a surrogate father in certain technical matters. The boys were planning to go into the personal flying machine business and wondered what I would do. I probably answered their questions very successfully because one of them remained with Boeing Aircraft Company for many years after my letter arrived and the other one took off for Tahiti in a sailboat with a beautiful lady.

Although there have been many design improvements and attitude changes by me over the years, I have chosen to leave the writing unaltered. After all, there is no real truth in this business and an old opinion of mine is about as good as a new one. There are several other approaches briefly depicted only as drawings attached to this note, and not part of the letter to Douglas and David, to indicate that I am not stuck on only one thing. As time changes, the mind changes.

It is very easy to draw pictures and write words on flying machines. It is not so easy to build real ones that work. Bearing this in mind, I have entered these remarks on flying machine design here so that the reader can get a look at the problem from several vantage points, no one of which presents a total view.

I would like to be associated with the work indicated, but am very realistic about the inertia of this business. Violent changes are not allowed, and as normal as this design seems to me, it is radical to almost all others. The main body of this note describes what is possibly the ugliest flying machine I have ever been associated with, although it is pretty to me by virtue of its functionality. Make it fly first and make it pretty later.

THE LETTER (8/13/89)

This entire writing should be considered a primer to bring you up to speed on what the basics are in the field as seen through myopic inventors eyes. If after reading about the failure possibilities you still feel like going on with the proposal to someone else, we can pull together a proposal that has less negative stuff in it. At this initial juncture, however, I did want you to get as clear a view of the negatives as possible. Also, keep in mind that we do not want any Wussies in on the deal. Only men of courage need apply! If all of this sounds like I am trying to get you to back out -- you are right. This is a fun business, but it is also a serious one. Keep in mind that everybody else that has tried this has failed.

The vehicle presented here is an entry-level design and as such has many limitations that will not occur in a design for a mature industry. Many sacrifices have been made in the design just to secure a breath of life and allow the field to begin. Far better things are available, but with each step of goodness come the increased cost of getting there. Perhaps this design is enough for now.

FLYER THREE

Flyer 3 is the temporary name given to the third design in a series of personal transportation vehicles. The primary goal throughout the series of designs has been to use only common, everyday construction and maintenance techniques and still achieve a very high level of utility and dependability through redundant and integrated design. By doing this in the right way, it is possible to have even the first vehicle of a series be reliable without the limitations and expense of proven components.

There is nothing intrinsically different between flying a helicopter and driving a car but a gulf has been created between the two methods by some quirk of social and economic manipulation. In this writing, we will explore this gap and see if we have a chance of closing it and making the air our roadway of the future. This writing is not intended to be anything more than an expanded outline of the subject. It is intended to spark the reader's imagination and help to continue dialogue toward either bringing the project to fruition or to find the flaws in the arguments bringing about the demise of the project.

HOW MANY HAVE TRIED BEFORE?

The list of things tried to make aircraft practical for everyday use is absolutely astounding in length. There is no real technical breakthrough of a major sort being proposed here to make this trial possible where the others have failed. I have only used readily available devices in a particular way to achieve the results claimed. The one possible difference is that I have used a lot of different things in one design whereas most designers feel that one "trick" per design is about all the world will stand for. This is a mysticism that comes from both the engineering and business world whenever aircraft are considered. There is some deep-lying fear that only super small changes are allowed. I feel no such limitation and I will do anything needed to get the result I deem necessary.

HAVE THEY REALLY FAILED?

Airplanes are a monumental failure for individual use in commute service and I don't think they are much fun either. Airplanes only go to airports and they do that only when the weather is good. Helicopters are technically better for the commute service and for just plain fun, but they are incredibly expensive to buy and operate. Helicopters have fallen into some trap that is hard to define, rendering them useless. This I know because I cannot use one, and I very much want to do so. It is a fascinating exercise to ponder our failure to use the air for personal transportation but the subject is too long to be included here. For now, I will just state that existing aircraft and the companies that propagate them are not getting the job done. Good designs and people abound, but somehow they cannot get together. At times I think there is something sinister out there like the curse that struck at the Tower of Babel rendering the builders unable to communicate. There is room for a new approach.

WHAT IS MY INTERACTION?

I am a potential user. I am one of those who really like the efficiency and speed of flight as well as the view of the world it presents. I cannot get what I want through existing channels and so I have to do what I can about the problem using the talents I have. I am a designer and not a businessman. I recognize that any time and effort I put into this project will never be repaid unless there is a business basis to proceed on. At this point in time I cannot get involved with all of the details needed to complete a vehicle for my own use and so I seek a business connection to help me.

HOW DO WE GET OUR MONEY BACK?

An inventor, such as myself, usually resorts to royalties to recover the time invested in a particular whiz-bang he designs. That approach will not work very well in this field and so I have to use another approach. The problem with this field is that there is not anything really novel in this project that will end with a strong licensing position. Moneys taken out of this field will be by the time-honored method of making something and selling it. Standard business methods will prevail and I am not attuned to that method. There are some special cases where a "weed eater" patent worked well for an inventor but usually these things are mostly a lot of money spent on securing a strong patent position and that is not my bag either. Somebody is going to have to do the ordinary thing to mine the money in this field. That is out of my realm and so I turn to businessmen to help me. The design presented here will allow me to open the door for someone, but it will also get it slammed in my face unless I have a clever business partner. I would not start this endeavor without such a partner.

WHAT IS THE JOB TO BE DONE?

We are to supply a flying machine that will take an individual just about any place he wants to go. There is not much room for carrying big items with you, but some things can be accommodated both within the cocoon and attached to a backpack carrier on the outside of it. The hovering capability will let one land on a flagpole, if that is desirable, or scoot along at 300 mph on a cross-country journey of over 600 miles. There is absolutely no need for an airport. Fuel up at any gas station and eat anywhere that looks good.

For a short while, perhaps 3 years after the product is introduced, there will be a need to fly with a reasonable degree of forward visibility to keep from hitting objects and getting lost. After this time miniature millimeter wave radar will be available that can see for miles ahead regardless of the low visibility due to clouds and fog. The availability of such a flying machine as proposed here will drive the development of dual MM wave radar systems with high reliability. This is basically the only instrument needed except a fuel gauge. The radar is just a pair of eyes that sees hazards, like wires and other aircraft that the human eye cannot easily detect. Response to such objects can be automatic. The job to be done is personal transportation whether it be spotting fish, backpacking into the mountains, going to work or school or just about anything else that a person needs or wants to do.

WHAT IS THE PLAYING FIELD LIKE?

We want the easiest market penetration possible. It would be insane to supply the intensive capital necessary to go straight for the commute market. One should always pick on the lunatic fringe first. There are plenty of hot shots out there that can live with the limits of a one-man vehicle to just tool around the countryside. These guys will kill themselves and others flying into wires, poles, buildings, schoolyards and little old ladies. In general they will commit mayhem and the entire field as well as the company will get a bad name. I am afraid that is par for the course and there is almost no way around this fact in the beginning. The Sierra club will be out in force to keep from turning the sky black with flying machines and politicians will be stumping for some restrictive political issues we cannot even think of now. In the beginning the playing field will not be level. Of course there will be legitimate users and a host of careful people but they will not show. Time alone will produce the ingredients necessary for a stable business. In the meanwhile, there will be mistakes made and a price will be extracted from the pioneers.

WHAT ARE THE LAWS LIKE?

At present the laws are remarkably tolerant. The vehicle we are talking about is classed as a helicopter and as such is not subject to either altitude or unreasonable weather restrictions. The law suggests that if you have less than one mile visibility you slow down until you can see where you are going. Now that is what I call a reasonable law! The machine proposed here weighs less than 250 pounds and is foot launched. This qualifies it for the ultralight category that presently does not require licensing for either the machine or the pilot. There is a severe speed restriction on ultralights, operating without license, to go less than 60 mph. So just fly around at this speed until you either get licensed as a pilot or until no one is looking. The FAA is also about to allow certain classes of aircraft used in private service to have type certificates issued to them without the usual expense that goes into commercial aircraft. The FAA has not been the problem in this field for many years.

There is a source of evil in the legal operation of aircraft, however. It is the local township that often has laws excluding the landing and takeoff of aircraft without written consent of the city manager or other dignitaries unless they are done at a designated airport. I also believe that the entire state of New Jersey has such a restriction. How's that for forward thinking? The only immediate relief for this kind of mess is to use a designated heliport in large cities that become a kind of parking lot. There is not much room used in storing the vehicle introduced here so this is not a severe burden. In the long run the laws will decay or be modified to yield to public demand. God only knows where that will take us because this machine is such an invasive thing. There is no rooftop that is sacred or inaccessible. There is no military base or estate that is possible to close. Never before has there been a law passed against a particular species in such a wide class as aircraft, but this one poses some problems we have not had to face before.

At the present there is a large market without getting into the legal problems facing the commuter. For the time being, we have the lunatic fringe and other sportsmen that can play endlessly without any foreseeable legal limitations. There may even be a few business uses that are lawful. We can sure think of some illegal ones.

SOME PRELIMINARY TECHNICAL DETAILS

The attached drawings show this very strange bird in various flight modes. It is unusual in a variety of ways and these will be enumerated. First of all it has contrarotating propellers to largely eliminate the gyroscopic effects that are the bane of rotorcraft. These propellers are stiff like airplane propellers instead of floppy like helicopter rotors. The propellers are capable of changing pitch in flight but do not use the messy cyclic pitch control of helicopters.

There are 4 engines located in the forward or canard wings and the vehicle can fly on only two of them. The engines are basically cheap 2 stroke engines that are connected to the main gear drive by clutches and flexible couplings. Each winglet of the canard group contains an engine, liquid cooling heat exchanger, alternator, hydraulic pump, starter, reserve gas tank and muffler. This power unit is repeated 4 times and all units are completely separate and can function independently. These units can be detached quickly and tested separately. Exchanges can be made at home if necessary. The machine is designed to fly nicely on 3 engines and the loss of one should not even be a consideration.

The pilot gets into the machine by squatting down and strapping in. He then starts the engines and lets the lift of the propellers raise him to the standing position. It is at this point that the real peculiarity of the machine makes its appearance. The entire power head, composed of the engines, propellers and canard group, is tiltable by hydraulic action under the pilot's control. This tilting of the lift vector acts as a powerful control force when acting in conjunction with the aft wings. This kind of control is not as feasible in large vehicles as it is in small ones. It is a control technique that has been largely ignored and is surely controversial in most circles of aircraft design. The fact is, it takes only about 1 1/2 horsepower to give a very large amount of high-speed control power to the machine. It sure saves a lot of other bull pucky in the aircraft construction but transfers a lot of design to the hydraulic unit.

The hydraulic unit is where the real beauty is. The design uses ordinary pumps on each engine and they will feed into the various actuators used throughout the aircraft. Each power unit will only feed 1/4 of the total control power and it will feed only a binary actuator of the simplest possible sort. These actuators are not much more than rubber expansion chambers molded on top of each other. An engine or other hydraulic component failure will not result in more than 1/4 of the entire system failing. The control system is designed to operate sluggishly on only one unit and this gives a wide margin for multiple failures.

The cocoon housing the pilot has a large bubble in the top for good visibility in most directions. The upward view is restricted somewhat by the canards and connecting housing, but with this type of aircraft the pilot should be just as comfortable on his back as his stomach. He just has to roll the machine over to see the entire sky. There are doors on the front of the cocoon that would be closed after starting the engines and having them at idle while the vehicle sits on its trefoil wings. Once the propellers are turning at full speed and the vehicle is lifted from the ground the leg fairings come down from the upper portion of the cocoon and provide protection during high-speed flight. These fairings must be retracted anytime the aircraft is near the ground so that the pilot's legs can take the landing jounce.

The trefoil wings serve to support the pilot during high-speed flight and to provide roll control for the vehicle. They are also used to support the vehicle on the ground in both the at-ready vertical position and in the horizontal storage position. This horizontal position minimizes gust damage to the vehicle.

TABLE OF SPECIFICATIONS

Vehicle Empty Weight	200 lb.
Normal Gross Weight	500 lb.
Maximum Weight	720 lb.
Rotor Diameter	8 ft.
Stored Length	7 ft.
Disc Loading	10 lb./ft.
Power Loading	6 lb./hp.
Installed Horsepower	80 hp.
Fuel Capacity	12 gal.
Calculated Top Speed	300 mph
Normal Cruise Range	600 mi.

METHOD OF OPERATION

It is obvious from the drawings that the vehicle is a tail sitter with horizontal cruise characteristics. This configuration gives low drag in cruise and still allows hovering flight. There is a compromise needed in deciding which of these two modes is most important and the governing factors are the propeller diameter and the installed horsepower.

The takeoff and landing modes use vectored thrust from the tilting head for lateral control and both rpm change and pitch change for vertical control. The vectored thrust works in conjunction with the aft wings to affect a pitching moment for the entire aircraft as a means of gust alleviation. Roll control is accomplished by using pitch change in the aft vertical stabilizer or wings.

In dealing with gusts near the ground with this class of machine it is a very desirable maneuver to quickly rotate the machine to face the gust and thus avoid being struck from less controllable directions. Unusually high drift velocities over the ground should be dealt with by quickly rolling the aircraft about the vertical axis, a very high speed control axis, and face the prevailing wind or gust. This is the normal action of a bird and it is allowed in this class of machine and not in many others.

Upon landing it is best to immediately cut the power as soon as the trefoil supports contact the ground. This helps to avoid an inadvertent, uncontrolled lift-off. One of the most perilous moments in a landing is the spin-down time of the propellers and during this time the pilot must use his own physical power to help stabilize the aircraft against rollover. As far as I know, no one has done this kind of thing and it is still open for debate as to how good a scheme it is. The trefoil can be equipped with outriggers if necessary but that is a messy thing to do.

I believe the transition regime between take-off hover mode and horizontal cruise will be natural and peaceful. I am led to believe the speed governs the angle of attack and as the speed goes up, the vehicle just gets more horizontal. Preliminary tests on captive vehicles will be made to elucidate this point. As forward speed increases, so does propeller pitch.

There is a potentially treacherous regime in decelerating from high-speed horizontal flight to the hovering mode. In this maneuver the braking action of the large propellers, coupled with the reduced power and slipstream velocity, could destabilize the aircraft and produce a tendency to tumble or oscillate wildly. There are probably limitations to deceleration rates that must be observed. Under reasonable deceleration rates the transition should be a normal one.

WHAT WOULD THE EXPERTS SAY?

They would throw up their hands and run away screaming. Any mainline, conservative aircraft designer I have ever met would have very little good to say about the approach cited here. The entire industry believes that the only way to go is to build slowly on the results of previous cautious motions. This is the correct approach to use when unknown components are put in critical locations of the design but the approach used here cuts these critical spots to a minimum. The expert might also point out that if this would work, it would have been done before. There would probably be statements about the bad record of foot-launched aircraft, but actually, the times it was tried were with airplanes where the pilot was required to run over rugged ground at top speed. There were two rotorcraft designs I know of that used foot launching, and according to the engineers I personally interviewed, it was quite successful. In both of these cases some expert in the organization spooked and put a fixed landing gear on the final design. Perhaps it is time we asked ourselves what is really correct and ignore the experts.

SAFETY CONSIDERATIONS

No one can ever state on paper how overall safety is achieved but a list of factors bearing on the subject can be made. Each item on the following list represents a deviation from what would usually be done in conventional aircraft design and presumably represents a small step toward increased safety. The thing most noted about the overall design is that it is not made up of standard, separate, purchasable components so much as it is an integrated system designed to operate as a whole. This brings an initial burden to the designer and producer, but may pay off in the long run.

This class of aircraft will not glide to earth gently as an airplane if all power fails nor will it autorotate like a helicopter. Other methods have to be used to guard against a bad landing following such an event. The main deterrent against total power failure is the multiple and independent engine installation. The aircraft could make an emergency landing on just two of the four engines under most conditions. There are times when having only one operating engine would allow the pilot to walk away from the crash landing. Totally separate systems for fuel, hydraulics and electrical power on each engine should give the pilot plenty of warning that it is time to land. The nice part about this machine is that it can land almost anywhere.

The most critical components in this design are in the propeller assembly because a failure here can cascade into a total machine failure unless precautions are taken. In the event of sudden and catastrophic failure of the rotor system, such as loss of a blade, the entire power pod having rotors, engine and fuel detach from the cocoon and wings. The cocoon becomes a very fast glider, largely without control. It is more of a dart aimed in whichever way it was turned loose. The detachment mechanism is automatic and G operated. Such a violent event has plenty of energy to activate a detach switch even if the pilot is reluctant and dawdles a moment. After a brief delay a parachute is automatically deployed to decelerate the cocoon. The chute used here would be similar to the ones used successfully in ultralight aircraft.

Designing the rotor system to be reliable without the penalty of having a long manufacturing series with costly inspection methods is the job to be done. The first rotor out of the back door must be safe enough to do the job. We cannot wait for the customers to find our mistakes the hard way.

One blade design that recommends itself is the hollow, steel blade construction method used years ago on large airplane propellers. Welding can seal a thin shell of steel with a single spar down the center and this unit can be evacuated with a gauge sealed in the root. Should a crack occur, the vacuum integrity is broken and a visual and audible warning can be given. This is a very simple procedure that checks the blade and hub attachment for every failure mode possible. A crack always precedes a blade failure and usually by many operating hours.

The metal blade is also good for resisting the blow-up effect that composite blades suffer. Metal blades can successfully negotiate hail, tree limbs and many other hazards and foreign objects that composites cannot. This aircraft has to be tough enough to fly through a thunderstorm without concern. It would not be recommended practice, but it will happen and it should be uneventful.

It is necessary to have a gearbox connecting the engines to the contra-rotating propellers. All that can be done here is to design with adequate safety margin and choose good materials. This is one of the few compromises of this type that have to be made in the design. Surge loads can be prevented by using flexible couplings to the engines and by using a slip clutch between each propeller and the gears. In this way the blades are normally synchronized, but in the event of excessive loading from ground handling, or even bird strikes in the air, the full load is not passed on to the gears. A standard chip detector and over-temperature indicator can help warn of unusual events. Lubrication of the unit by using hydraulic pressure will help minimize one of those "lost grease fittings" that go unattended for years.

There will be no ball bearings, capable of producing sudden failure, in the entire rotor hub assembly. Oil jacked journal and thrust bearings will be used in all places requiring movement between two rotating members, including the propeller pitch bearings. The jacking pressure will be supplied to only 1 of 4 pads in each bearing from the hydraulic unit in each engine. Thus one engine only supplies 1/4 of the total required hydraulic boost power and multiple failures can be tolerated before the system becomes inoperative.

The attachment of the canard winglets, containing the engines, is a critical item. These units must be easily detached for quick servicing, but they must not come loose in flight where they could interact with the propellers. It is appropriate to use very good design and a self-checking safety device that prevents engine starting unless all is well. It should go without saying that the engines should be completely contained within the canard winglets by a scatter shield in the event of an engine blow-up.

GETTING STARTED

Unlike many projects that can get along by "smart buying and assembly", this project must fabricate many of its own parts and modify them. It is a very strong bias of the writer to structure a project this way. A machine shop and other fabrication facilities are required from the very beginning and there must be an initial commitment of capital to do this.

There is a modeling and test phase that precedes the initial full-scale work, but this requires reasonable tooling too. I will personally have to resist a tendency to do excessive modeling and get on with full-scale work. I keep thinking I can solve some problem at a reduced scale where construction and testing is easier, but there is a trade off that allows full-scale experience to add up to a higher value.

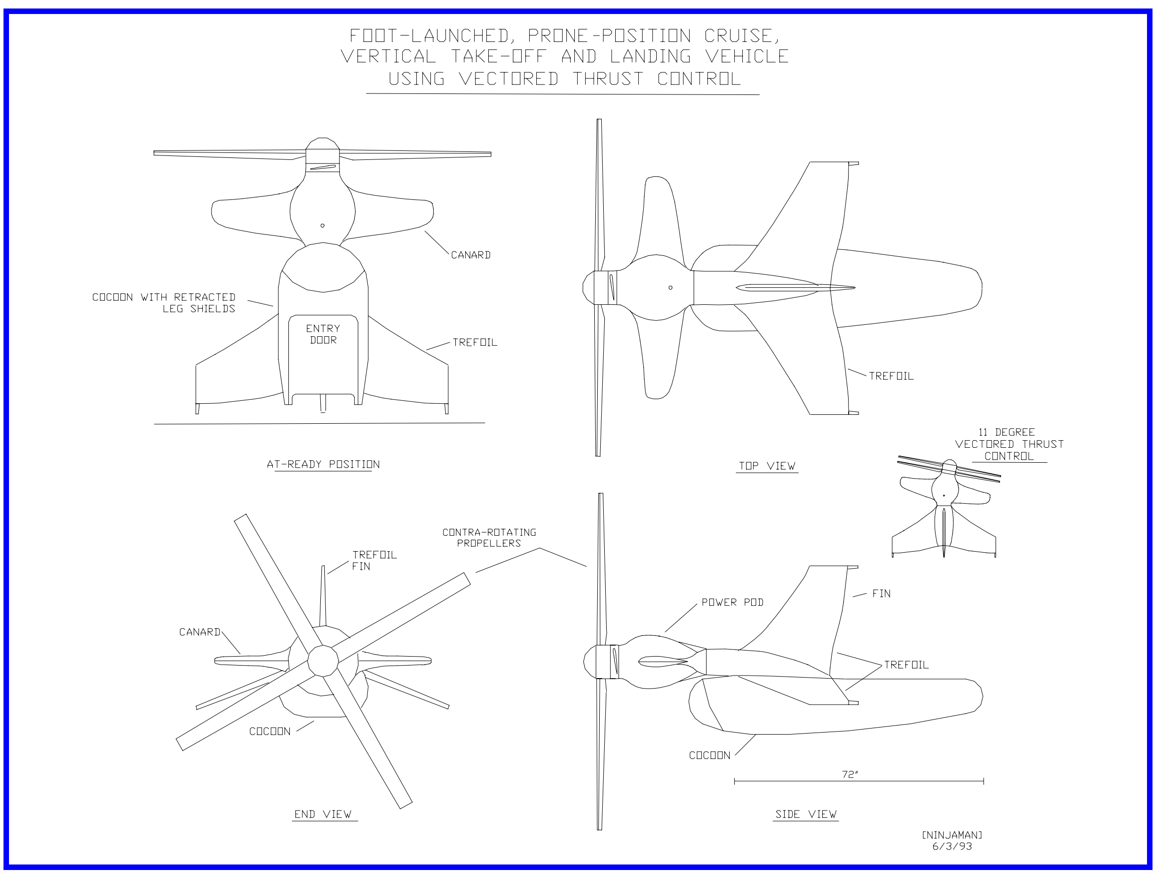
Before there are any flyable vehicles there will be a shop full of derelict test vehicles, each solving a part of the total problem. As the preliminary tests converge to produce a close to final shape there will be a very fun period of test we can call the "seven league boot" test. In this test phase the vehicle will be cobbled together out of anything that will work at all and the flying machine will be strapped on to do a little hopping around to see how it controls. A neat aspect of testing this class of vehicle is that you really don't have to fly very high to test a lot of things. The early stages of this testing mode can also help develop the training phase to come later where the vehicle is tethered to a mobile platform in such a way it is free to move on each axis within limits but restrained against wild action.

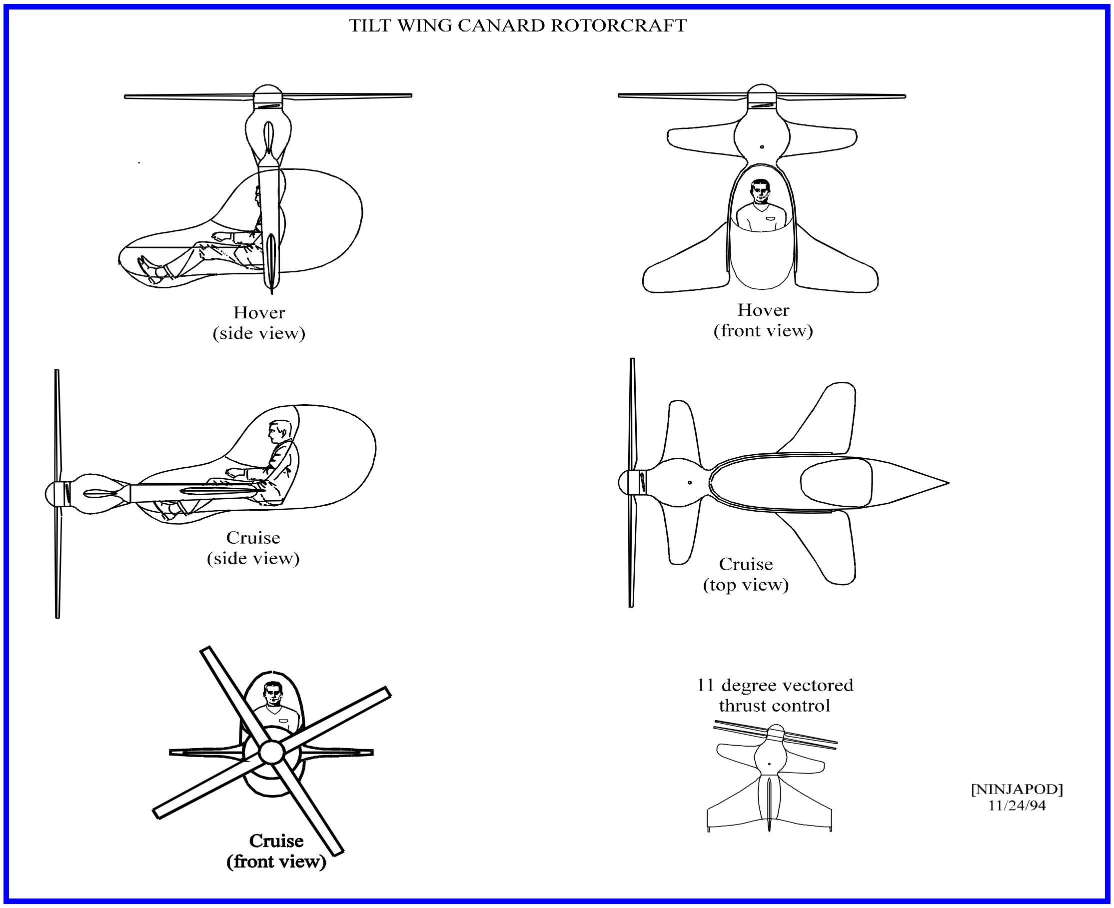
As each of the test devices are put into storage the final design will be coming together. It is probably prudent to consider a radio-controlled version of the machine to test the limits of what could be wild and dangerous maneuvers. It is better to know the answer to these questions and fix them instead of telling someone not to do such-and-such. They are going to do it anyway and probably get killed.

After a series of static reliability tests and tests to determine the effect of multiple failures, we will be ready to fly. At this point the machine will still be very primitive insofar as creature comforts are concerned. It will not be totally enclosed in the right way and I'll bet it will be either too hot or too cold for comfort. In principle, the noise and vibration will be low because that will be part of the basic design of the power system. It is possible there will be some kind of Mickey-mouse rotor blades in use to avoid the difficulty of fabricating the hollow metal blades. We will just have to keep inspecting these substitute blades after each flight until we get the good blades. This is a typical trade-off in prototype design.

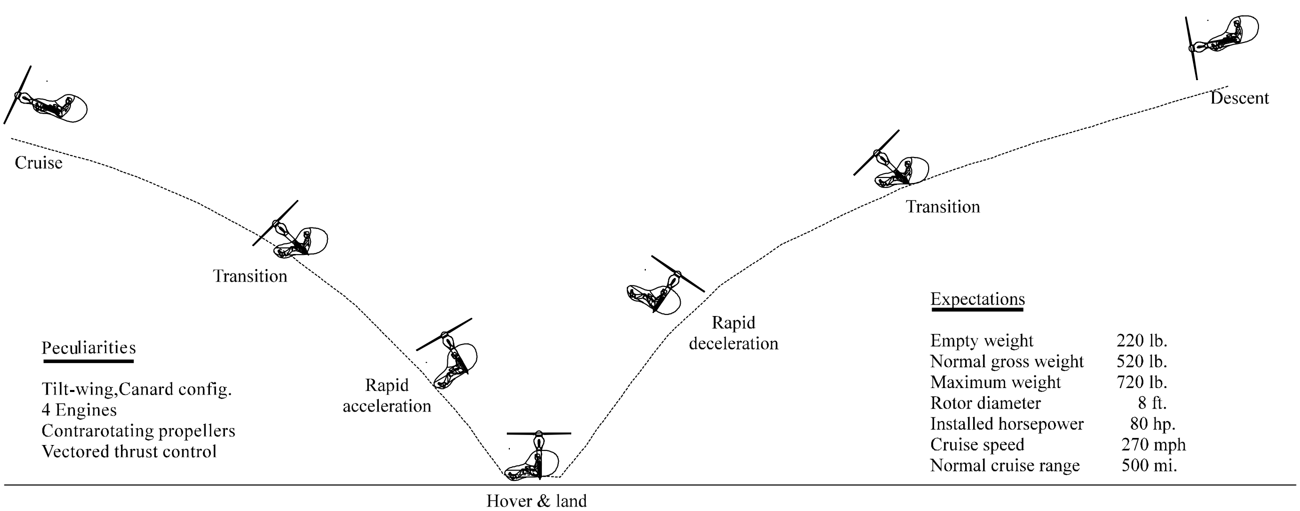
WHERE TO FROM HERE

If the technical part of the program is successful it will be business as usual from here on. I won't get into what that entails but there are some peculiar appearing aspects of the sales program worth mentioning. For one thing, there is something very personal about each vehicle and this may develop into a custom fit for the cocoon with detailing resembling the clothing business. There will be a never-ending list of comfort items to service. Some units will have air conditioning. As time goes on there may be a demand for two place machines that can be met and turbo superchargers will undoubtedly be introduced. I have no idea where all of these things go but a technical success could open Pandora's box.





TYPICAL FLIGHT TRAJECTORY FOR TILT WING VEHICLE



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