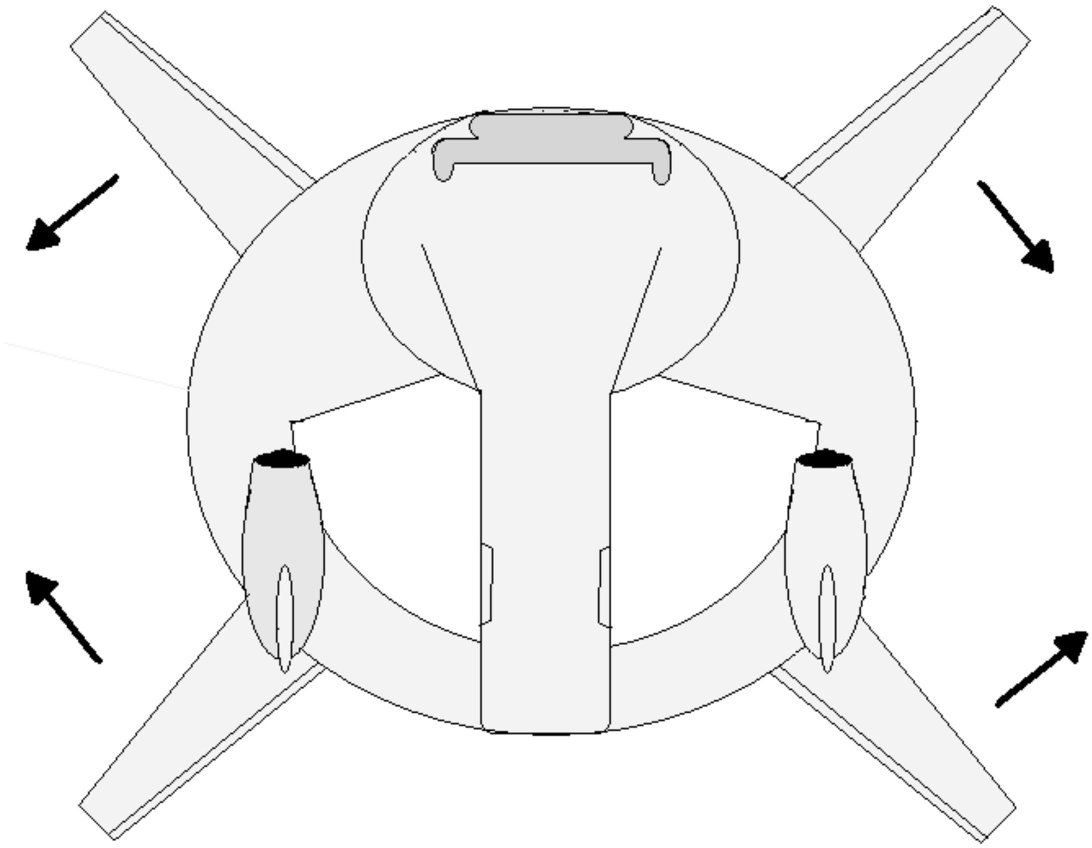
Next Generation VTOL

Search and Rescue/ Firefighting Aircraft



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Introduction

Extreme weather has always been one of the greatest fears of sailors. On July 10, 2007, in the waters just off the shores of Guam, the typhoon Man-Yi caused high winds and enormous swells to form. Many large ships had retreated to the safety of bays and harbors dotting the region, but others were caught dead in the storm. The Chinese cargo ship Hai Tong no. 7 was one of those ships. The combination of high seas and roaring winds proved too much for the rugged ship. The load of goods it was carrying became unstable, and the ship capsized, throwing its crew into the abyss during the climax of the storm. [24]

The U.S coast guard dispatched two C-130 search and rescue aircraft to the scene in hopes of finding survivors. After locating most of the crew of the Hai Tong, they could do little more than drop rafts to assist them. They shut down two of their four engines, and remained in orbit until a passing cargo ship could divert and pick them up. The entire rescue took days; meanwhile crewmembers of the ship began to perish amongst the waves. Had one of the rescue planes been able to pluck the crew out of the water upon the initial sighting, the ordeal for the crew would be short, and more lives would have been saved.

During the Second World War, US navy crews had perfected the art of distant sea rescues by using flying boats like the PBY-3 Catalina and Neptune[20]. But in the post war years, those aircraft became outdated, and were subsequently replaced with slower, shorter-range helicopters. The long range and rapid response previously offered by the seaplanes was lost[13]. As a result, coast guard crews relied on merchant ships and cutters to provide assistance in distant rescues while they helplessly circled overhead. The time for change has come, where coast guard crews will be able to perform rescues independent of other agencies and ships[24].

Mission

A practical vertical takeoff and landing (VTOL) aircraft is hard to design by any standards. Helicopters are limited by speed and range, while conventional tilt rotor designs are overly complex in design. The early V-22 Osprey test flights were plagued by problems and crashes, resulting in many deaths[13]. Moving two engines, their controls, and rotors 90 degrees represents a huge design challenge. Although they succeeded, this configuration is expensive and is not feasible while operating on floats. Any rotorcraft can be cumbersome to fly, but that difficultly is increased when operating off water[12]. they are inherently difficult to fly, especially in windy conditions that would be persistent on open water.

Tilt rotor aircraft have proven to be the most effective Vertical takeoff and landing configurations to date[13]. They are also the most complex and expensive configurations on the market. The V-22 osprey and Bell Aircraft have been the only two companies to enter the market, which is dominated by government and defense agencies[25]. If the complexity and expense issues could be solved, such an aircraft would be ideal for extensive use in diverse markets. This would mean designing an aircraft that could perform VTOL operations, then transition to forward flight without substantial reconfiguration of its components. Such an aircraft must be able to undertake multiple roles, such as firefighting, surveillance and rescue operations to justify the development and operations costs.

Another important consideration, especially in today's world, is environmental concerns. The foremost issue in this category is efficiency. This is challenging because it is difficult to be fuel-efficient when hovering. The extreme amounts of thrust and energy required to lift a fully loaded aircraft vertically require large engines that have high fuel burn rates. But as a hybrid

VTOL aircraft, transitioning to conventional flight will allow the power to be reduced significantly, thereby improving efficiency.

Another environmental issue that must be considered is noise. It is important to keep sound pollution down to minimize disturbances to the ground. Noise abatement issues have lead to the closure of many airports due to public disapproval[22]. It is important, especially for future generations, to preserve these airports and maintain the freedom to fly.

The Airframe

The most successful and proven method of VTOL flight over the years has been helicopters. Ever since their advent, they have been very successful at performing VTOL operations. Helicopters have significant shortcomings however. Their speed is greatly limited because the effect forward airspeed has on their flimsy rotor blades, resulting in loses with range and efficiency[26]. The rotor blades and anti-torque blade are also very complex, requiring difficult and frequent maintenance. Any failure of these components almost guarantees the destruction of the aircraft.

On a conventional helicopter, the blades are located above the helicopter, with a drive shaft attaching it to the airframe. This is a source of significant drag. For this concept aircraft to operate at high speeds, it is essential to reduce and or eliminate any and all sources of drag. To do this, the concept aircraft will have the rotor blades spinning midway around the fuselage, encircling the entire airframe. The problem with this is obvious: it would require you to have a circular shaped airframe.

A flying disk is considered an ideal shape aerodynamically, as it has very little drag. The problem is its constant airfoil shape and how it reacts to the center of gravity. As a flying disc increases its speed, its center of gravity has to move forward to maintain its stability[19]. Other problems exist with the placement of essential components to flight (i.e. Engines, passengers and fuel) and how it will affect the center of gravity. It is hard to actively adjust these loads to stabilize the aircraft throughout the flight envelope[19].

To try and solve this problem, designers have cut out the center of the disc to form a ring. A flying ring provides marginally better stability, but still has stability problems at different angles of attack[19]. This is attributable to equally sized and positioned airfoils around the aircraft. It would be like having an airplane where the horizontal stabilizer is the same size as the wing. There is also no place to store fuel, people or engines in a flying ring.

The solution to this problem is adding additional wing area to the forward airfoil. This concept has be thoroughly developed and tested by inventor Jack Jones, who named his concept the "Geobat"[19]. In remote control flight tests, the Geobat proved to have desirable speed and maneuverability, yet still maintain superb slow speed handling and stability. The circular shape of the aircraft also gives it a stronger structure than a conventional aircraft.

For my concept aircraft, I will incorporate the basic shape of the Geobat concept with rotor blades attached mid way around the fuselage. The rotor blades will be built with composite materials and be anchored to the aircraft by a two ring shaped hubs, which will encircle the entire airframe, and are buried just inside the leading edges of the airfoil. The rotor blades themselves will be counter rotating, eliminating the need for an anti torque blade. The two sets of blades will be stacked on each other, but separated enough to protect against blade flap. This means the two rings that the blades will be attached to are practically on top of each other. Being this close, the ring hubs will have magnets that will act as a brushless motor, slowing and positioning the rotor blades.

Each rotor blade disc will have two blades each. This is to ensure maximum efficiency by reducing the blade turbulence encountered by the second blade. Although additional blades may reduce the sound and provide more “bite”, the least number of blades is most efficient[10, 11, and 26]. When the aircraft transitions to forward flight, the blades will lock in position and provide addition lift for the aircraft. The electro magnets in the ring hubs can also be reversed to slow and position the rotors by applying a charge to the coils (similar to a brushless motor or regenerating brakes) [21]. A mechanical lock will then hold them in place. They will be positioned so that the top blades are perpendicular to the lower blade. While in flight, pitching movements and the roll can be controlled by changing the pitch of the blades. Yaw will be controlled by vertical stabilizers positioned beside the engine cowlings toward the rear of the aircraft.

Using the blades as additional sources of lift will require the blades to change their airfoil shape. With counter rotating blades, airfoil of the two of the blades will be the opposite shape of the other two when in forward flight. This will translate into drastic loses if not addressed. To prevent these loses; the shape of the airfoil would need to be changed. This seems impossible by today’s means, but should be possible in the near future with wing morphing technology.

Wing morphing is a concept was initially intended to be used to change the shapes of wing to adapt to different aspects and levels of the flight envelope. It allows for dramatic manipulation of the wing to allow for maximum efficiency at different airspeeds. Design concepts use electro based polymer actuators controlled by sensors hooked up to a computer [23]. The sensors record pressure data, which the data interprets and transmits a command to the nano actuators [23]. The actuator will then respond and adjust the shape of the surface as required. The same concept could be adapted to rotor blades by using computers to manipulate the actuators to change the airfoil to the desired airfoil shape[23]. This would give the aircraft four proper lifting surfaces, rather than the initial two and the two backwards airfoils.

The cabin and cockpit

The cabin and cockpit section of the aircraft will be centered on the flying ring, extending from the forward most airfoil to the rear. The cockpit will be blended into the forward airfoil to improve aerodynamics, ascetics, and double as a lifting body, thereby decreasing the wing loading[11, 26]. The rear fuselage will have a side door on each side, and a loading ramp to the rear. The fuselage may also be sectioned off by bulkheads. This would allow a rescue crew to put a small inflatable boat in the rear loading dock at the expense of cabin space. This adaptation simplifies rescues, and the bulkhead would prevent rough water from swamping the fuselage when the rescue boat is deployed. The bulkheads could be removed if desired for land-based operations.

The fuselage structure itself will be constructed of composite materials. Composites benefit from corrosion resistance and superior strength to comparable weight aluminum alloys[5]. Conventional aluminum alloy structures are praised for durability in rough conditions, but are subject to fatigue cracks[3]. Fatigue occurs when minute vibrations flex the metal seemingly insignificant amounts. Over time however, a large number of these “cycles” will cause a crack to form. These cracks can result in a major airframe failure, almost certainly causing a fatal in air break apart[3].

Composites do not have this problem. They can go countless cycles without showing any of the affects of fatigue[5]. They are however affected by UV deterioration and have a critical failing point. The UV light will break down the composite structure, slowly deteriorating its strength and causing delamination[5]. New advancements in paint (light, mirror like colors) solve this problem by reflecting heat and preventing UV exposure. Unlike aluminum alloys, composites have a critical failure point, the point at which the structure will cease to flex and fail completely[1]. Aluminum will bend when failing, but will not entirely fail at one initial point[3]. To solve this problem, the structure will be imbedded with carbon nano tubes. They, along with providing additional strength, will have an electric charge passed through them. If any damage occurs to the structure, the tubes will be broken[17]. This will disrupt the charge by breaking the connection. This will be interpreted by flight computers that will in turn alert the pilot to the potential problem, providing details to its location and severity. This will act as an advance warning system for damage that could compromise the safety of flight if left unattended.

The use of a composite structure will also reduce the complexity of the design, and reduce the cost and time needed to build the aircraft. The primary structure will be uni-modular in construction. To ease maintenance on the aircraft, a minimal amount of strategically placed access panels will provide a way to quickly inspect critical flight components without major disassembly. Composite construction will also reduce the drag of the aircraft. Metal airframes require the use of rivets, which become a major source of parasite drag[3]. The glass like finishes of composite aircraft greatly reduce this problem, contributing additional airspeed and efficiency to the design. Metal cannot always be shaped in the best aerodynamic configuration to ensure efficiency and retain its strength. Composite materials allow you to make complex curves that improve the drag reduction of the aircraft with out compromising its strength[1].

The cabin itself will seat 50 people in folding seats around the walls of the aircraft. When the seats are not in use, they can be folded against the wall much like the seats found in cargo planes like the C-130[13]. The seats when folded down will double as stretchers if the aircraft is performing rescue operations. Basket rescues will be able to be carried out from all three doors. The fuselage will also have lifting hard points. This would allow it to perform logging or heavy lifting operations if such a task is desired.

<u>Avionics</u>

A major problem with modern glass cockpit systems is the amount of time pilots spend with their eyes inside the cockpit looking at the monitors[2]. A pilot should have his “head outside the cockpit” 90% of the time, scanning for traffic and potential flight hazards[2, 6]. The avionics and navigation platform will be incorporated into a visor type head-up display, very similar to military systems. This system would allow the pilot to access all essential flight data while still looking outside the cockpit. It would also allow for an opportunity to incorporate infrared and thermal cameras into the system for search and rescue operations. Such a system could locate heat signatures in water or terrain and relate that data to the flight crew. The “target” would be projected in the heads up display, allowing the pilots and crew to quickly locate and rescue survivors. This setup would offer situational awareness superior to any other aircraft or flight system on the market.

Redundancy is essential to safe operations while flying[6]. To back up the overhead flight display, an independent conventioned “steam gauge” cluster panel will be incorporated into the cockpit. To improve in-flight visibility, a wrap around windshield will be used, extending from the floor up to the ceiling. The cockpit area will also be equipped with a rest area (lavatory, sleeping cot, and food) for longer flights to ensure crew comfort and vigilance.

Amphibious operations

One of the important design aspects of this concept is its ability to operate on land and water. Seaplanes inherently suffer from compromises with aerodynamics because of their shape and additional weight of equipment required for water operations. The rotor location on this concept aircraft provides special challenges to VTOL operations off of water, especially in rough water. The spinning rotor blades would impact waves, potentially causing damage to the blades, clutch, engines and ring hubs.

In order to cope with this problem, the concept aircraft will be equipped with skis to allow the aircraft to rise out of the water and become airborne quicker. The unconventional idea of using skis for water operations was pioneered just after World War Two. Initial tests were conducted with a Grumman Goose, which tested the benefits of ski and hydroplane assisted takeoffs. The ski concept proved superior to hydroplanes, and allowed for the aircraft to almost immediately be raised out of the water, allowing for a faster transition to takeoff[20]. On a conventional floatplane, the drag created by the water causes the aircraft to require more room to build up speed before it can become airborne[20]. This concept was incorporated into the sea dart supersonic jet fighter. The Sea dart had problems with vibrations at higher speeds, but that will not be a problem with the concept aircraft, which will become airborne at significantly slower speeds[20].

The skis will be retractable to minimize drag while cruising. When the concept aircraft takes off, the skis will be extended. As the throttle is pushed forward, the aircraft will rise out of the water. Immediately when the rotor blades are out of the water, the clutch for them will be engaged, and they begin to produce lift. Although this will not be true VTOL while in the water, it will allow for an extremely short takeoff.

Landing will be similar to take off where the rotor blades will be used to position the aircraft above the water with a minimal amount of forward airspeed, then un-clutched. Immediately after contact with the water, the blades will be locked, and the aircraft will come to rest on the water. The skies will be able to keep the rotor out of the waves long enough for the electro magnets to position and lock them in place. The aircraft's blended fuselage/airfoil will rest directly on the water much like the Russian Beriev Be-103[13]. This will provide superior seaworthiness and stability on the water.

The Power Package

The power requirements for any VTOL are usually significant. Comparably sized rotorcraft usually require around 10,000 to 15,000 SHP (Horse power measured from the shaft) total in order to maintain flight (Chinook, Mil Mi 12)[13]. This is achievable by using a large jet engine, which will be clutched to turn the rotor blades. To ensure redundancy, two engines will be used. The clutch and drive shaft configuration will allow one engine to power both rotors in the event of an engine failure.

The engines will need to be run at higher speeds to maintain a hover. When the aircraft transitions to forward flight, the engines are un-clutched from the rotor discs, and provide power like a conventional jet engine set up. The design of the engine intakes is critical when designing an amphibious aircraft. Rough water operation could allow for a wave to swamp and shut down an un-protected engine. To prevent this the inlets will be raised above the wing and have quick drains deep in the intake chamber.

Another problem that may arise with the engines during a hover is a lack of airflow for cooling. This is a problem that has plagued other VTOL aircraft, like the Harrier, initially restricting its hover to 90 seconds[13, 25 and 7]. To allow a greater intake of air, the inlets will be equipped will auxiliary air intakes that open when the engine requires more cooling during the hover phase of flight. The use of ceramic embedded composites for the engine cowling will also assist in cooling[1]. Although ceramics compromise strength for heat absorption, the cowling is not a structurally significant part, and therefore ceramics will not be detrimental to its reliability[1]. The ceramics will significantly raise the structures ability to withstand heat.

Another benefit that arises from locating the engines above the wing on pylons is reduced noise[22]. The wing will act as a physical sound barrier, and make sounds more tolerable for people on the ground. Metallic foam mesh will also be used around the engine cowlings to further reduce the noise. Developed by NASA's Glenn Research center, the "open cell foam" boosted noise reduction by almost 50% in early tests[18]. This will significantly reduce the noise the aircraft makes when operating in densely populated residential areas, making the aircraft more environmentally friendly and publicly excepted.

Fire Fighting

The ability for this aircraft to be able to adapt to different roles is essential to the success of this concept. Many airplanes and helicopters are frequently modified to combat forest fires in southwestern parts of the United States. Most helicopters use baskets or pumps slung beneath the aircraft to pick up water from ponds[13, 25]. The problem with helicopters is they are limited with their endurance, carrying capability, and the speed required to perform this job. Conventional aircraft require the water to be pumped onboard at the airport or siphoned out of lakes as they make a touch and goes[13, 25]. That means they need immediate access to a lake or airport in order to be effective.

The concept aircraft could solve both of these problems. It has a high cruise speed, allowing it to respond quickly, and the ability to hover, allowing it to use small lakes and ponds as a water source. The concept will make use of an on board pumping system that will extend a hose to the water then pump it up to the aircraft. The pump will be powered by a power takeoff system connected to the rotor clutch. The water itself will be stored two different ways. A limited amount will be stored in the ring structure of the aircraft. When it becomes necessary to carry larger amounts of water, large rubber bladders will be used. These bladders will be stored in the cabin floors at all times. When they need to be used, the seats are folded up against the wall and the bladders will be pulled out.

Landing Gear

The Concept aircraft will operate on and off land using its skis. The skis will be able to double as skids, similar to a conventional helicopter. For water operations, the skis are positioned so the forward part of the ski is at a high angle of attack[20]. This is to keep the skis from "nosing under" when landing on water[20]. This however would make the aircraft squat down on it's nose if landed this way on land.

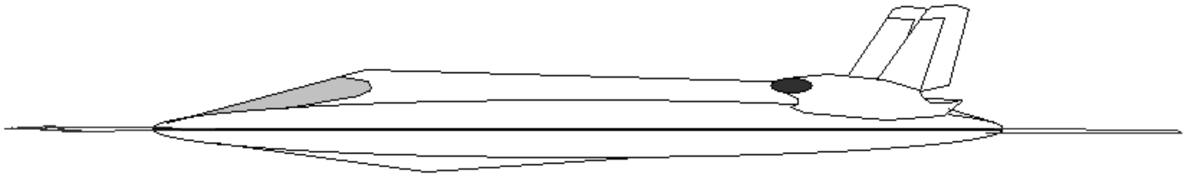
To raise the nose to a level configuration, the retractable oleo struts will extend further than they do for water operations when landing on solid ground. This will level the aircraft out, making landings more comfortable for the crew. To move the aircraft around on the ground, small retractable casters will be positioned in the skis. This will allow ground crews to easily move the aircraft about without needing the assistance of a platform. When it comes time to park the aircraft for the night, the casters will retract back into the skis. The skis will act as parking brakes while the aircraft is not in use.

Conclusion

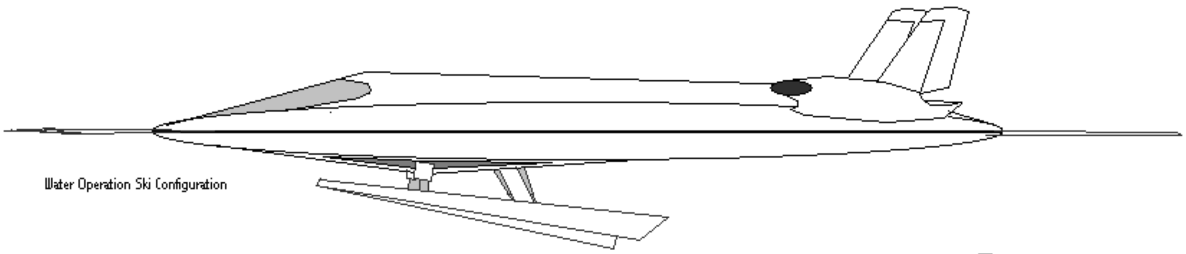
The need for a versatile VTOL aircraft is ever increasing in our world were natural and man-made disasters are a seemingly everyday occurrence. The capabilities of a rapid response, long-range aircraft could save thousands more lives than is possible with today's means. The need for such an aircraft will only continue to rise, as fishing boats travel further for their catches, more commercial vessels cross the seas, and more pleasure boats set out to explore the open ocean.

Further advancements of this design could be explored as well. Smaller versions may be adaptable to the general aviation market. Such aircraft could truly usher-in the era of "flying cars". Not only would such an aircraft revive the general aviation community, it would also improve the domestic economy if all manufacturing was to be done at one of the current U.S light plane manufacturers (i.e. Piper, Beechcraft and Cessna). All branches of aviation could explore the benefits of this aircraft. Civil, commercial, and military aviation could all make use of an aircraft capable of heavy lifting, forest fighting, and operating out of any open field. In hindsight, an aircraft with these capabilities could have been used to save lives in many recent disasters. In the collapse of the World Trade Centers, they could have preformed roof top rescues, they could have quickly responded to victims in distress during hurricane Katrina, or they could have provided immediate aid to earthquake victims in Haiti or Chile. An aircraft with these capabilities could change the way search and rescues are carried out worldwide.

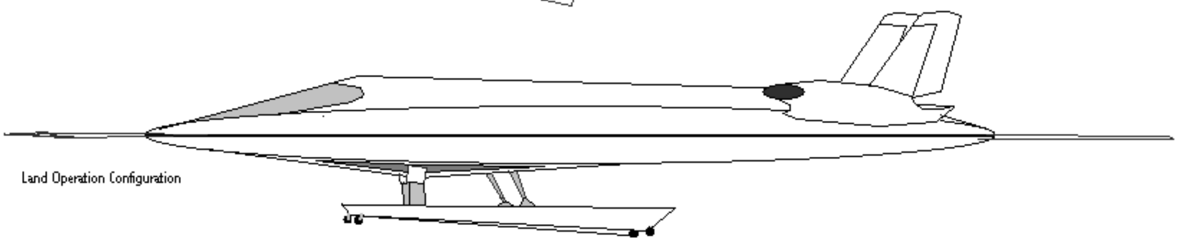
All drawings drawn by author.



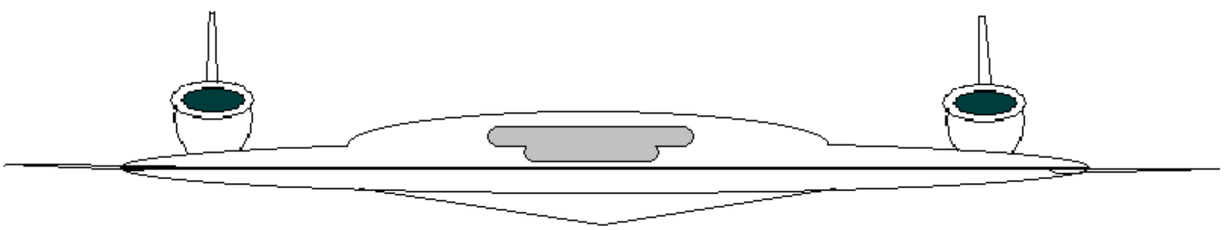
Flight Configuration

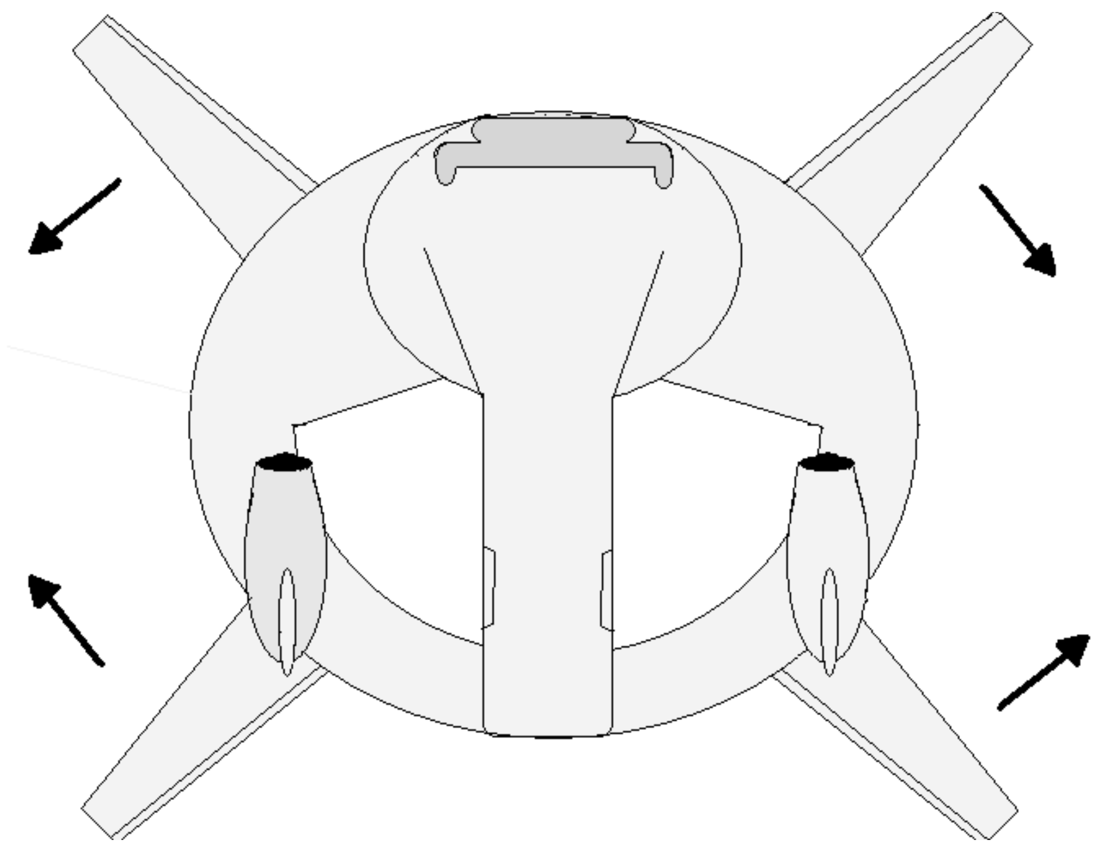


Water Operation Ski Configuration



Land Operation Configuration





Bibliography

1. Spangler, Scott M. "Composite Construction Sport Avaition August 2006, Vol. 55, NO.8

2. Wilhemlmsen, George R. "Cockpit Resource Management" Sport Avaition March 2006, VOL. 55, NO.3

3. Spangler, Scott M. "Metals Enduring Strength" Sport Avaition March 2007, Vol. 56, NO.3
4. Palmar, Bruce "Electric Flight" Sport Avaition March 2007, Vol. 56, NO. 3

5. Willford, Neal "Those Plastic Planes" Sport Avaition November 2005, Vol. 54, NO. 11

6. Devries, Douglas. "Risky Business." Sport Avaition Apr. 2008.

7. Laboda, Amy. "Speed Jacket." Sport Avaition Nov. 2005.

8. Lert, Peter. "Size Matters: Light Jets." Kit Planes Oct. 2001.

9. Purdy, Don. "EAA's Aerocrafter Edition 8." Oshkosh, WI, 2001. Experimental Aircraft Association
10. Bingelis, Tony. "Firewall Forward" Oshkosh, WI, 1998. EAA Aviation Foundation Inc.

11. Bingelis, Tony. "Sport Plane Techniques". Oshkosh, WI, 1998. EAA Aviation Foundation Inc.

12. FAA "Flight Training Hand Book." Washington, D.C, 1980. U.S Government Printing Office.

13. Chant, Christopher. The worlds greatest Aircraft. Edison, New Jersey: Chartwell Books Inc, 2006.

14. Black, Ian. "On target." Fly Past Mar. 1989: 8-9.

15. "Avaition Technology." Century of Flight. <http://www.century-of-flight.net/new%20site/frames2/technology_frame.htm>.

16. O'Donell, Sarah. "Nanotechnology Trends in Avaition." Mitre. <http://www.mitre.org/news/events/tech04/briefings/1495.pdf>.

17. "Cabon Nano Tubes and Self Healing Composites." PlastleMart.com. <http://www.plastemart.com/upload/Literature/Carbon-nanotubes-in-epoxy-to-promote-self-healing-prevent-micro-cracks-in-plastic-composites.asp>.

18. “Meatlic Foam Reduces Airplane Noise”NASA Tech Breifs. March 2010, Vol. 34 No. 3, Pg. 10.
19. Jones, Jack. “The Geobat Concept Explained”. Nawnan, GA. <www.geobat.com/nrl.htm>

20. “The Martin Seamaster and Covair Seat Dart”. Public Domain <ww.vestorsite.net/avmast.html>

21. Hewitt, Bob. “what is an Alternator”. 1997.<www.misterfixit.com/alternatr.htm>

22. Wolters, Richard A. “The World of Silent Flight.” Copyright 1979. McGraw-Hill Book Company.

23. O'Donell, Sarah. "Nanotechnology Trends in Avaition." Mitre. <http://www.mitre.org/news/events/tech04/briefings/1495.pdf>.

24. “Search for Crew Suspended”“Search for Crew Suspended”. Siapon tribune. Tuesday july 17,2007. <saipontribune.com/newsstory.aspx?newsID=70428&cat=1>

25. Taylor, John. “Janes: All the Aircraft of the World”.New York City, NY: Mallard Press, 1991.

26. Fike, W.J. “Practical Lightplane Design and Construction for the Amateur”. Anchorage, Alaska: 1955. W.J Fike, P.O box 683.