Flight of the ‘Salvager-7 Pelican’

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1. Abstract:

Rotorcrafts have been key role players in almost every rescue or relief mission carried out in times of natural or man-

made disasters. Be it hurricane Katrina of 2005, South-East Asian Tsunami of 2004 or the Haiti earthquake of 2010[1]. Rotorcrafts, specifically helicopters have proved their support to be of significant importance in times of calamities. Tiltrotor aircraft, a relatively newer specification of rotorcraft, is a potential candidate for delivering these humanitarian services, a responsibility traditionally borne by helicopters. With its quality of hovering like a bee and flying like a bird, a tiltrotor aircraft puts forward many advantages over helicopters for search and rescue or relief missions. Such an aircraft can cruise at speeds way higher than that of helicopters, while retaining the ability to land and take off vertically. A higher speed implies that a tiltrotor aircraft would cover a much longer range on the same amount of fuel as a helicopter would. This fuel-efficient quality of a tiltrotor aircraft makes it a more viable option than a helicopter. There might come a time when tiltrotor aircrafts will take over helicopters and airplanes. In the current scenario, while the very idea of tiltrotors has been made feasible by decades of experimentations and improvements, there still exists a need for a faster, larger and versatile tiltrotor aircraft capable of fire-fighting and landing and taking off from water. Intrinsically, my design of the 'Salvager-7 Pelican' would be one of the few stepping stones towards building such a versatile tiltrotor aircraft. I propose that this aircraft would be able to meet at least the following criteria once put into the production.

Cruise Speed	: about 350 knots with minimum payload about 300 knots with maximum payload
Range	: more than 800 nautical miles
Passenger Capacity	:51 (seats) + 2 (beds)
Special Capabilities	:fire-fighting, landing and taking off from water/land

In brief, the S-7 Pelican would be a fire-fighting amphibious tiltrotor suited for humanitarian missions. After prototyping, test flights and mock rescue or relief missions, the S-7 Pelican would become feasible for being put into production. During the testing, possible adjustments or modifications to the proposed design would be welcomed, given that they improve the performance of the aircraft or assist in fulfilling the tasks purported to be carried out by the aircraft.

2. Background and Introduction:

The idea of a tiltrotor aircraft originated in the 1930s when George Lehberger patented the very first design of an aircraft based on the tiltrotor concept in May 1930[2]. Despite innumerable failures due to the problematic transition from helicopter to airplane mode, this innovative idea saw some degree of success with the flights of Transcendental 1-G, Bell XV-3, XV-15 and the V-22 Osprey, in chronological order[3]. Each of these models provided researchers and developers with plenty of data and information to make room for technical improvements in the future. The only commercially successful, but also controversial tiltrotor till date has been the V-22 Osprey.

My design of the S-7 Pelican resembles the V-22 Osprey in some aspects while differs in others. The most basic similarity between the two existing designs is the placement of the two circumvolving rotors at the wingtips. Having said that, the S-7 Pelican's design is based on a plethora of innovations and modifications. As a result, The S-7 would turn out to be a better option than the V-22. It will have a greater payload capacity, better stability, greater speed and range, better fuel efficiency and some additional abilities like landing and taking off from water and fire-fighting. These features, explained in further sections, would make the S-7 a practical and viable design to be invested in. It would thus turn be an exemplary model of an aircraft meant for rescue and relief missions. An elaborated comparison of the proposed aircraft and the V-22 will be done while discussing the design and structure of the S-7 Pelican.

[1] EADS aircraft, services provide relief as Haiti recovery continues, Eadsnorthamerica, Reference 1

[2] Tiltrotor, Globalsecurity, Reference 2

[3] Tiltrotor, WikiPedia, Reference 3

3. Structure and Design:

3.1. Basic:

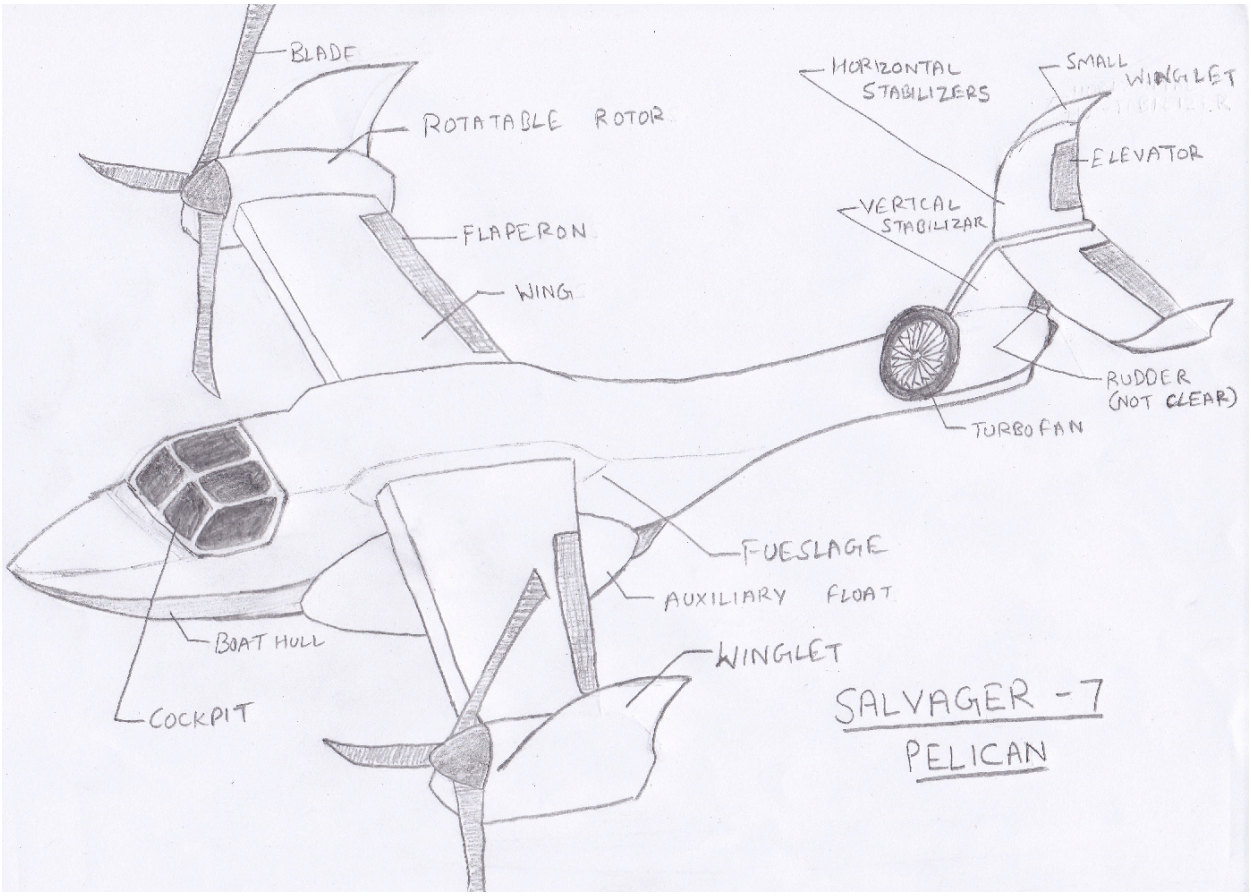

Figure 1

The proposed aircraft would look similar to what is shown in figure 1. As compared to the V-22 Osprey, the S-7 Pelican would be roughly 40% longer and 25% wider and 30% higher. Accurate dimensions of the size of S-7 cannot be suggested unless computer simulations of a virtual S-7 are carried out. Even though the S-7 would be a significantly larger vehicle than the V-22, it would be able to fly faster. Discussed below are some of the capabilities of the S-7 Pelican.

The S-7 would be capable of VTOL (vertical takeoff and landing) along with STOL (short take off and landing) on land and water. VTOL would be achieved with the two rotors tilted perpendicular to the ground while STOL on the other hand, would be made possible by rotating the rotor nacelles to an angle of about 60 degrees from horizontal. Landing and taking off from water would be made possible through the boat hull design at the base of the S-7 Pelican. A detailed elaboration on the boat hull is given in section 3.3. Lastly, landing and taking off from ground would be accomplished through a retractable landing gear. The gear would have a total of 3 wheels, 2 of which would be placed inside the auxiliary floats and one inside section 1 of the boat hull.

Moving on to passenger capacity, the S-7 would be able to carry 53 passengers. Since the S-7 is meant for rescue and relief missions, the seating space for the passengers could be compromised. As such, an individual on the S-7

would occupy lesser space as compared to someone on board the V-22. Also, given that the S-7 has a wider and longer body as compared to V-22, the S-7 will have 3 rows of 17 seats each as compared to the 2 rows of 12 seats each in the V-22. Additionally, there would be 2 beds in the front part of passenger cabin for carrying those who might be critically injured (useful in a rescue mission). The 51 seats and the two beds would be crashworthy just like the seats in a V-22 osprey[4].

Compared to the V-22 osprey, the S-7 Pelican will have a larger and heavier body, amphibious characteristics, fire-fighting abilities and greater payload capacity. As such, its much stronger engines would require more fuel than the V-22. Even though effective solutions to reduce the drag force on the S-7 and hence lower the load on the propulsion system have been proposed later in the essay, the S-7 would still have greater fuel requirements than the V-22. As such, the fuel tanks of the S-7 Pelican would be strategically placed in order to minimize the space they take up. One of the apt sites for placing the fuel tanks would be inside the thick main wings of the S-7. A side advantage for placing some fuel tanks inside the wings would be their proximity to the rotor engines located at the wingtips. This would eliminate the need of long fuel feeder pipes running all over the aircraft's body. These fuel tanks, having limited capacity, would be connected to other fuel tanks mounted onto the cabin roof. All these tanks would feed the two engines of the proprotors. To feed the auxiliary turbofan placed at the rear of the aircraft's body, there would be a separate fuel tank placed inside the tail of the aircraft. A rough placement of these tanks is shown in figure 2.

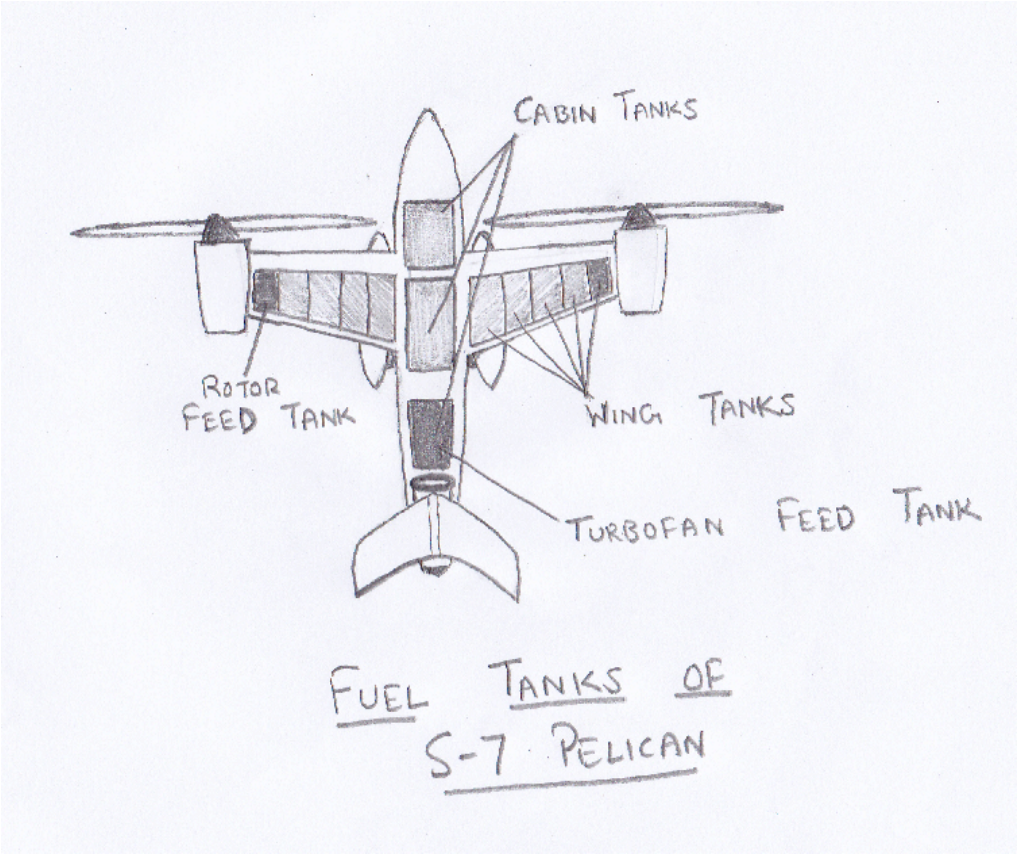

Figure 2

3. 2. The Wings:

3.2.1. Main wings

For an airplane in forward flight, the wings function as Lift-generators in for countering the weight of the aircraft and

[4] V-22 Osprey, WikiPedia, Reference 4

maintaining it at a certain height. For a Tiltrotor aircraft flying forward, the wings serve a similar purpose. After the rotors are completely tilted forward, the only source to produce vertical lift is the twin-wings. Hence the wings form an integral component of a tiltrotor aircraft.

For the S-7 Pelican, I propose a slightly forward swept wing design, similar to the V-22 Osprey. However, the wings of the V-22 apparently have parallel leading and trailing edges. In contrast, the S-7 will have a tapering trailing edge. The leading edge of an S-7's wing has not been swept back and has been kept pretty much perpendicular to the fuselage, to make sure that the rotor blades do not come in contact with the wings when they are tilted forward. Also, the wings of S-7 will have a larger span as well as a larger chord length as compared to the wings of V-22.

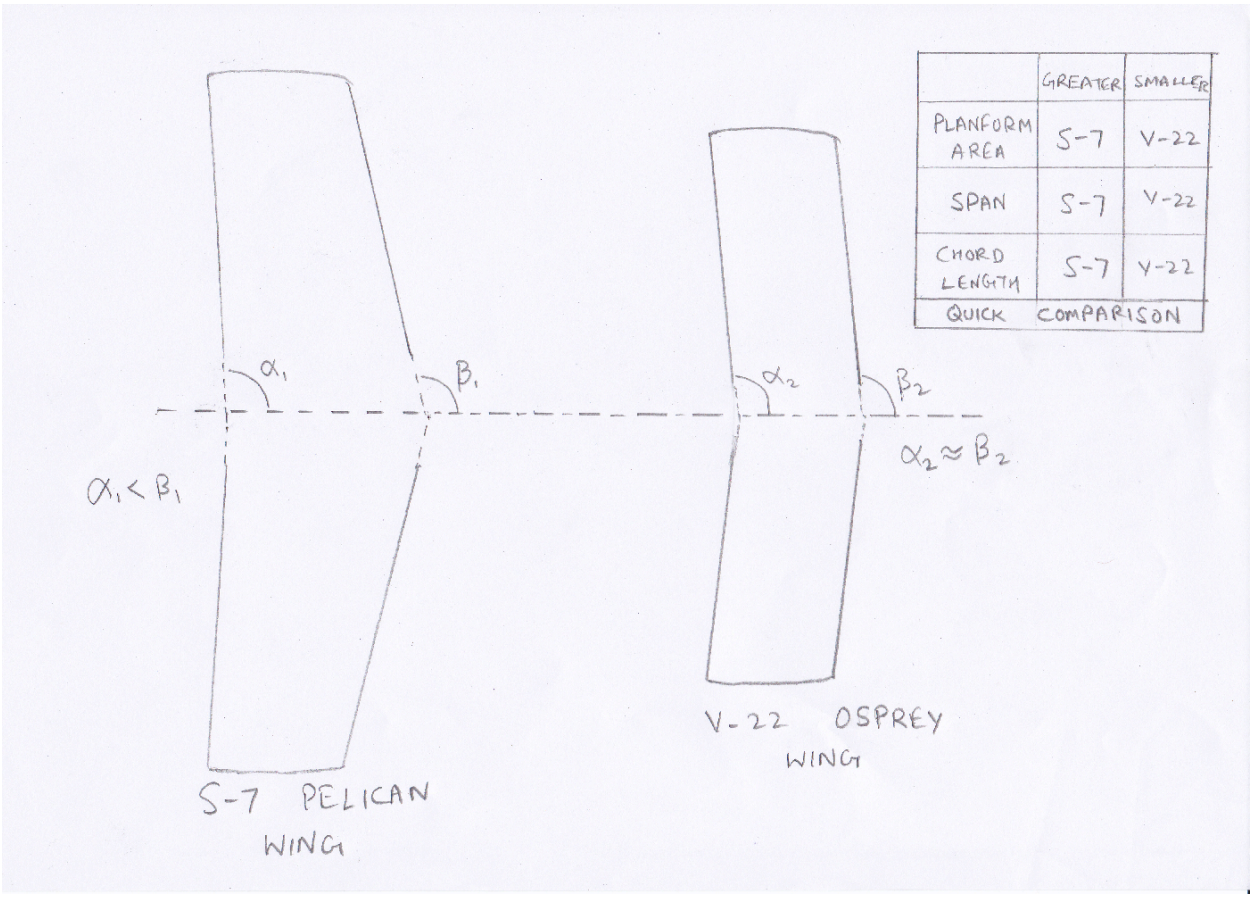

Figure 3

The intention behind having longer and wider wings than those of the v-22 is to significantly increase the planform area and hence boost Lift-generation. Since the S-7 is larger, heavier and has greater payload capacity than the V-22, it would inevitably require a greater Lift force as compared to the V-22. Secondly, the main reason why wings of the S-7 are tapered unlike the V-22 osprey's wings is that tapered wings are structurally and aerodynamically more efficient than wings with a constant chord[5]. Moreover, an increasing wing chord length from the wingtip to the fuselage would mean that the aircraft would have a larger planform area for a given wing span as compared to parallel-edged wings, evident from figure 3. An even larger planform area would generate a greater lift on the aircraft. Below is the qualitative explanation of generating greater lift through a larger planform area.

[5] What is This, Flight, Flightglobal, Reference 5

$$L = \frac{1}{2}\rho v^2 A C_L$$ [6]

L = lift force,
ρ = air density
v = true airspeed
A = planform area and
C_L= the lift coefficient at the desired angle of attack

It is clear from the lift equation that lift is directly proportional to the area of the planform which is in turn proportional to the length and the breadth of the wings. Hence the proposed wing design with a larger planform area would yield a higher lift force.

Moving on to the length-width ratio of the wing, or more specifically the aspect ratio, wings of the S-7 will have a moderate aspect ratio, slightly more than that of the wings of a V-22 Osprey. Aspect Ratio is calculated by taking the ratio of the square of wingspan to the planform area[7]. Given that the wingspan of V-22 is approximately 43 feet, its chord length about 8 feet 4 inches[8], and that the leading and trailing edges of a V-22 wing are almost parallel, the aspect ratio of the V-22 comes out to be 5.18. The predicted aspect ratio for the wings of S-7 would be about 6.

Theoretically, the higher the aspect ratio of the wing, the higher is the Lift-to-Drag Ratio. This is evident from the mathematical approximation of the maximum Lift-to-Drag ratio.

$$(L/D)_{max} = \frac{1}{2}\sqrt{\frac{\pi A \epsilon}{C_{D,0}}}$$ [9]

A = aspect ratio
ε = aircraft's efficiency factor
$C_{D,0}$ =zero-lift drag coefficient

Hence, a higher aspect ratio of the wings of an aircraft would yield a greater Lift-to-Drag ratio. However, there are limitations on increasing the aspect ratio of tiltrotor aircraft's wings. Most significantly, the limitation is due to the placement of heavy proprotors at the wingtips of a tiltrotor aircraft. The wing has to be wider, thicker and hence stronger to support the extra weight of the proprotors. Moreover, the positioning of the rotors at the wingtips calls for increased support from the wings. A longer wing would mean the proprotors would be further away from the fuselage and hence would require firmer wings. The wings can be strengthened by increasing their thickness, but only to a small extent. As a result, the aspect ratio of a tiltrotor aircraft's wing cannot be high. This accounts for choosing an aspect ratio of roughly 6 for the wings of the S-7 Pelican. Compared to the aspect ratio 5.18 of the wings of V-22, it would still yield a much higher Lift-to-Drag ratio.

Another strategy to boost the Lift-Drag ratio would be the diminution of Induced Drag acting on the aircraft. Induced Drag is produced due to the creation of wingtip vortices when the air flows from the lower to the upper surface of the wing, going around the wingtip[10]. The larger these wingtip vortices, the greater is the induced drag. A very effective and pragmatic solution to reduce induced drag is the inclusion of winglets (near vertical wingtip extensions) in the wing design. A winglet would decrease the size of wingtip vortices generated. As such, it would make these vortices contribute lesser to the induced drag[11] acting on the wings of the S-7. This would improve the Lift-to-Drag ratio and hence reduce the load on the propulsion system of the aircraft.

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[6] Lift (force), WikiPedia, Reference 6

[7] Aspect Ratio (wing), WikiPedia, Reference 7

[8] Bell/Boeing V-22A Osprey, Ausairpower, Reference 8

[9] Lift-to-Drag Ratio, WikiPedia, Reference 9

[10] Induced Drag, WikiPedia, Referene 10

[11] Winglets, Nasa & Wingtip Devices, WikiPedia, Reference 11

Since the wingtip devices of S-7 Pelican's wings are the proprotors, winglets are strategically attached to the rotors. Shown in figure 4 is the proposed approach of the placement of winglets and the resulting airflow pattern on the wings.

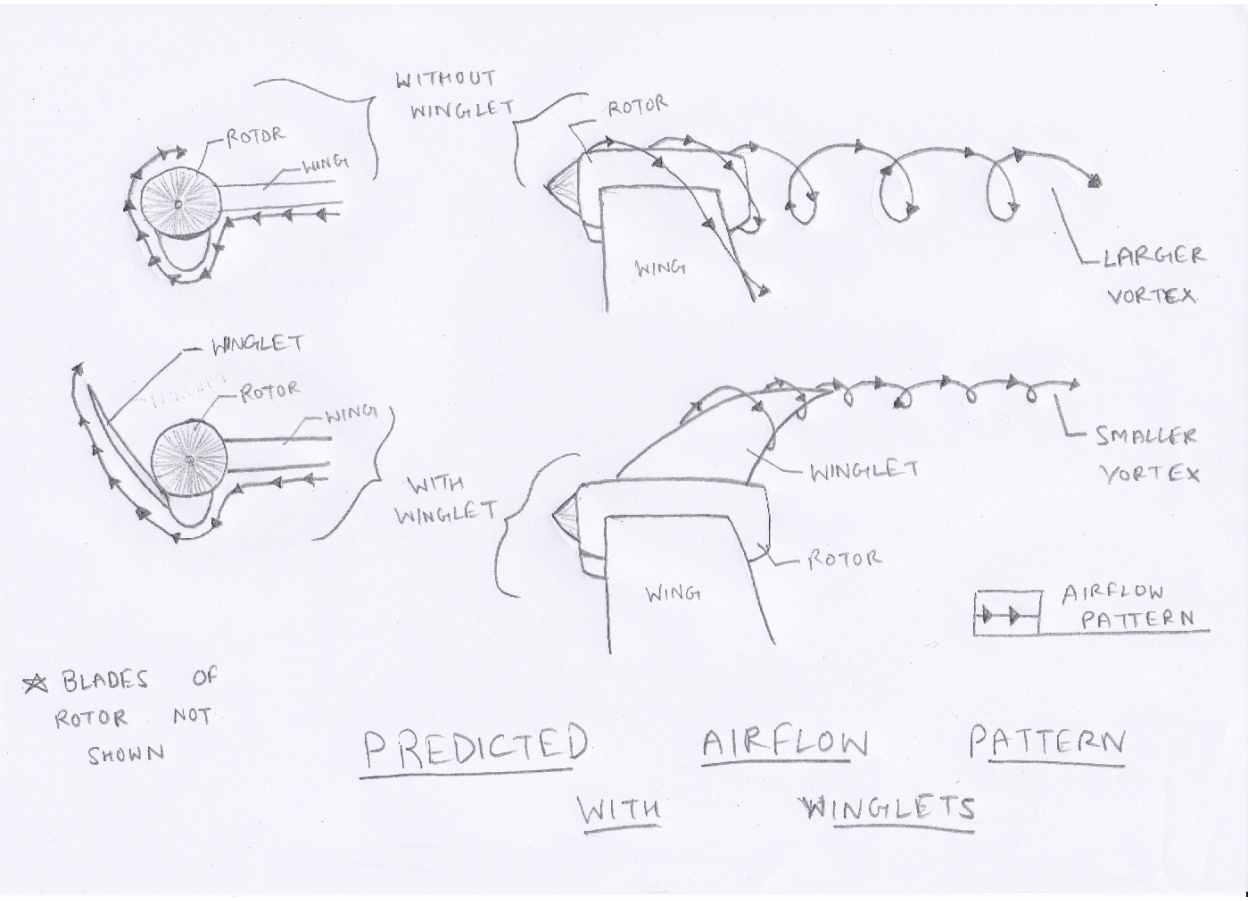

Figure 4

The depicted airflow pattern is an approximate assumption. Quite possibly, different wingtip vortices might get created, given the high-speed backward airflow though the rotor.

The gradual rotation of the rotors from vertical to horizontal direction would put the winglets in upright position. These vertical extensions would then reduce Induced Drag by affecting wingtip vortices, and hence serving their purpose of increasing the Lift-to-Drag ratio. Lower drag would mean a lesser load on the propulsion system. As such, for a given amount of thrust generated, there would be a greater net forward force on the aircraft. This would make the S-7 a more fuel-efficient aircraft.

Overall, the proposed design for the main wings of the S-7 Pelican is apt for generating greater Lift and decreasing the drag force on the aircraft.

3.2.2. Stabilizers and Yaw Control:

To prevent pitching and side to side movement of the aircraft nose, the aircraft needs horizontal and vertical stabilizers[12]. The horizontal and vertical stabilizers on the S-7 Pelican would be integrated into a T-tail design. Intrinsically, the two horizontal stabilizers would be mounted over the vertical stabilizers.

[12] Airplane, Nasa, Reference 12

The benefits of choosing a T-tail design over the conventional tail design are numerous[13]. First and foremost, using a T-tail design, the horizontal stabilizers are kept well out from the airflow behind the main wings, thereby giving a smoother airflow and thus a better pitch control through the elevators. This is important for a subsonic flight, which requires a cleaner airflow. Moreover, a T-tail design increases the effective distance between the tailplane and the wing without a significant increment in the length of the aircraft's body. A greater wing-to-elevator distance would generate a greater moment on the wing-axis of the aircraft. Moment and changes in moment about the wing-axis is what is utilized by elevators to pitch the aircraft up or down. Thus, with a greater wing-to-elevator distance, smaller and lighter tailplanes and elevators can be used.

For side-to-side yaw, pitch, drag and roll, the S-7 makes use of rudder, elevators and flaperons similar to the V-22[14]. As is evident from figure 1, the flaperons on the wings of S-7 would be attached at the trailing edge of the main wings, the rudder at the rear of the main vertical stabilizer and the elevators on the trailing edges of the horizontal stabilizers. The flaperons and elevators would work by changing their angle of attack and hence changing the respectively generated lift. On the other hand, the rudder would help control the yaw and to counter adverse yaw[15], if produced on the aircraft. These mechanisms utilize very basic and pragmatic concepts of changing lift or drag on both or one of the sides of an aircraft, and hence altering the moment about its center of gravity. As such these mechanisms would not be discussed in any further detail.

There would be a minor modification to the T-tail of the S-7 Pelican. The terminals of the horizontal stabilizers would be slightly curved vertical. These curvatures would act as mini-winglets to the horizontal stabilizers. They would serve the same purpose as the winglets on the rotors suggested earlier. The mini-winglets would modify the airflow pattern at the rear of the aircraft by shrinking the size of tip-vortices. Thus, they would minimize the induced drag on the rear of the aircraft. The phenomenon of reducing the induced drag for the mini-winglets would be same as that of the main winglets attached to the two rotors. Reference to figure 4 can be made for better understanding.

3.3. Amphibious Aspect:

To make an aircraft amphibious, there is a basic and obvious need of sufficient hydrostatic force (buoyancy) in order to balance the weight of the aircraft while it rests/floats on water. For the S-7 Pelican, I suggest a boat-hull design at the base of the aircraft's body. Primarily, it would be this hull which would provide the required buoyancy. In addition, there would be 2 auxiliary floats by the sides of the main body. Both the main hull and the auxiliary floats would be elaborated upon separately.

3.3.1. Boat Hull:

The hull at the base of the proposed aircraft would look like what is shown in figure 5. I propose that there be two sections inside the hull, namely section 1 and section 2 as depicted in figure 5. The Boat Hull is designed to serve two purposes. In the first place, it would enable the aircraft to float on water. This would be made possible by section 1 (lower section) of the hull. According to Archimedes' Principle, an object of density less than the density of a certain liquid would partially float on that liquid[16]. To make the density of the hull lesser than water, section 1 of the hull would

[13] T-Tail, WikiPedia, Reference 13

[14] Bell-Boeing, Fighter-planes, Reference 14

[15] Adverse Yaw, AbsoluteAstronomy, Reference 15

[16] Archimedes' Principle

be largely filled with air except for a retractable wheel and its retraction machinery, which would occupy an insignificant amount of space inside the hull. As such, section 1 of the hull would provide the required buoyancy when the S-7 would be floating on water.

Secondly, the boat hull would incorporate a water storage system for fire-fighting. The water storage tank would be section 2 (upper section) of the hull. A detailed explanation of the water siphoning, storage and expulsion system is given in the section 3.4.

3.3.2. Auxiliary Floats:

Similar to the boat-hull, the auxiliary floats will also serve two functions. Firstly, they would assist the boat-hull for enabling a stable floatation of the aircraft on water. The floats would be attached to the fuselage in such a way that when the is resting on water, the hull and the two floats would be simultaneously in contact with water. This would lead to a greater stability of the aircraft on water. The stability of an aircraft in water crucial in order to prevent the aircraft from toppling due to water waves.

Secondly, the floats would incorporate a retractable system for two side wheels of the aircraft. As proposed earlier, the S-7 Pelican has a total of 3 wheels for landing and taking off from ground. As such, there would be three retractable wheel systems in the aircraft's body, two of them in each of the auxiliary floats and one inside the main hull. The pilot would be able to control the retraction and extension of the wheels after takeoff and before landing respectively. The incorporation of two side wheels into the auxiliary floats would save space inside the main body of the aircraft, which could then be utilized for other purposes. Also, the two side wheels should be placed at a considerable distance from each other, so that the aircraft would be more stable while resting on its landing gear. Hence the placement of the wheels at the auxiliary floats is justified.

As far as the feasibility of the amphibious design of the S-7 is concerned, the flying boat design (boat hull at the bottom of the aircraft body) has proved to be successful for many large and heavy seaplanes. This is evident from the design of some exemplars like the Beriev A-40, Boeing 314, Canadair CL-415, Grumman HU-16 Albatross and many more[17]. An obvious reason for their success is that the hull of a flying boat is capable of countervailing its weight effectively.

Almost all of the previously mentioned seaplanes make use of auxiliary floats for better stability. Generally these floats are attached near the wingtips so as to make sure that the wings do not come in contact with water in case the aircraft starts to topple. However, for the S-7 Pelican, the auxiliary floats will not placed near the wingtips as such an arrangement would inevitably increase the load on the wingtips. Most Likely the wingtips would not be able to sustain the additional weight of the floats given that they already support the heavy rotatable proprotors. Hence, the floats will be placed by the sides of the fuselage and connected to it, thus not being attached to the wings. Moreover, they would be shaped in such a way that they create the minimum drag possible. Their shape can be roughly estimated by referring to figure 1.

3.4. Fire Fighting Flair:

To enable an aircraft fight fire, we basically need to make sure that it can fill up water in its water tanks and then discharge the stored water onto a fire site. To make sure that fire suppression is more effective, it can make use of fire retardants along with the stored water to mitigate the extent of a fire. For the S-7, there is an effective water intake, storage and expulsion system. These three mechanisms would be elaborated upon separately.

[17] Historical Seaplanes, Aviationtrivia, Reference 17

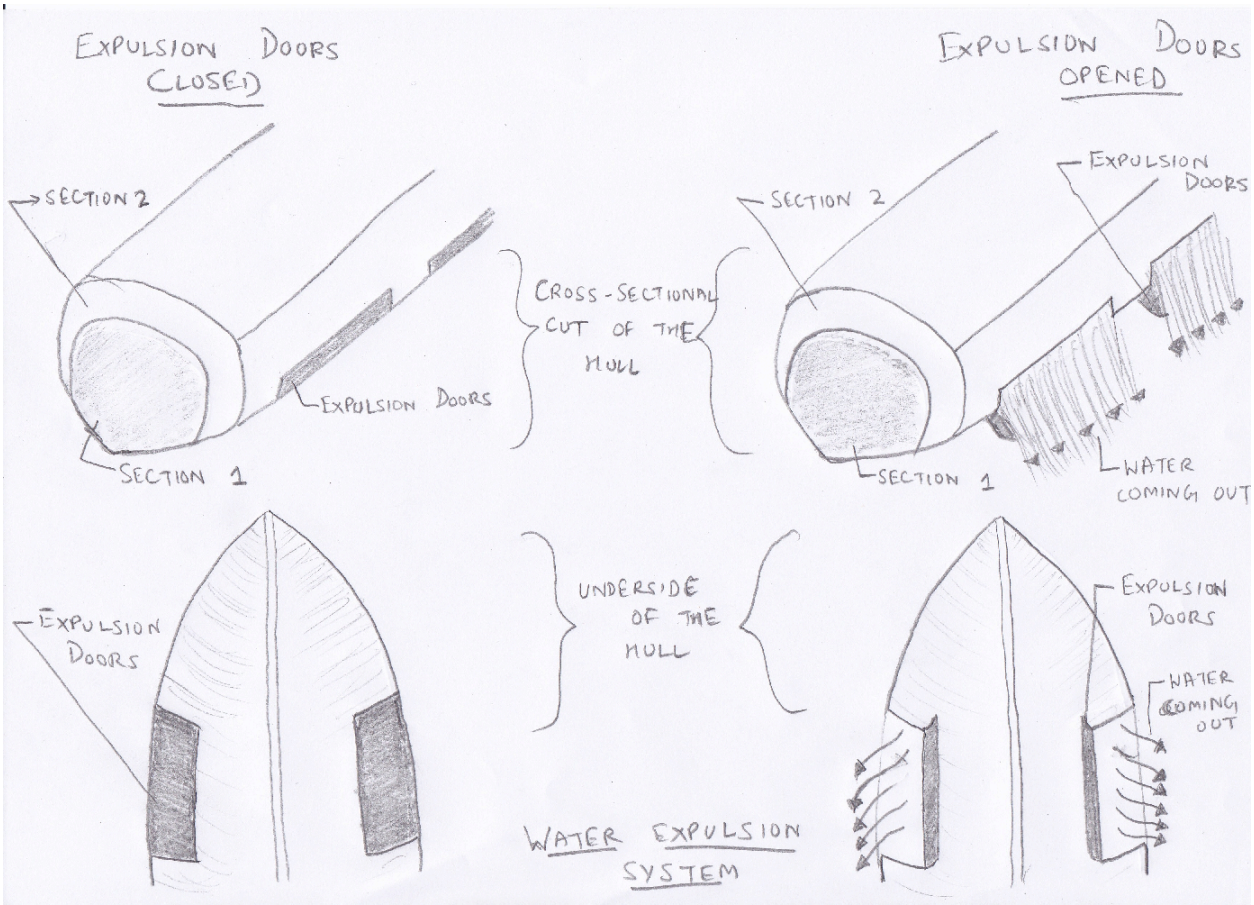

Figure 5

3.4.1. Water Storage:

Section 2 of the boat hull would be used for storing water for fire-fighting. The idea can be understood more clearly from figure 5. As such, this section would act like a water tank. Initially, it would be filled with air. As water would start filling in, there would be a need to remove the air inside the tank in order to make space for inflowing water. For removing the air inside Section 2, there would be air channels linking the inside of the section to outside atmosphere. These channels would be opened and closed at the will of the pilot. While filling up the water tank, they would be opened so that the influent water can push out the air inside the tank. After the tank gets filled, these channels would be closed by the pilot. Moreover, these channels would have openings at a height greater than that of the boat hull. This would make sure that only air is expelled out and that inflowing water is not leaked out through the channels.

3.4.2. Water intake:

The water siphoning arrangement would be placed inside the main body of the aircraft. This arrangement would consist of a vacuum pump and a "snorkel", which would be a long draft hose, to be used for sucking water from a water resource. One end of the hose would be connected to section 2 of the boat hull (storage tank) via a vacuum pump. The other end of the hose pipe would be lowered down to a water resource whenever the aircraft would need to fill up its water tank. The end of the draft hose, supposed to be dropped into a water reservoir would be made heavier with a metallic terminal so as to make sure that the water-drawing opening of the hose remains submerged in water while the tank fills up. The length of this hose would be kept about 30 feet so that the S-7 could refill its tanks even while flying over a water resource. The hose would be made of such a material which would allow it to withstand very low pressure inside it, created by the vacuum pump. One of the possible options for the draft hose could be the Draftex suction hose which is made of a lightweight woven fabric[18].

[18] Water Suction Hoses, Reference 18

3.4.3. Water expulsion:

Once water is filled into section 2 of the hull, the water could be expelled to any desirable site. This would be made possible by expulsion doors located at the underside of section 2. While flying or hovering over a fire site, the pilot would open these doors through a control transmission system and water would be shed onto the fire. The placement and the opening of expulsion doors can be understood better by referring to figure 5.

The fire-fighting system of the S-7 Pelican is sound and effective to fight any sorts of fire. The S-7 would be able to fill up water while flying, hovering or resting. This ability of the S-7 widens the options of water resources which the S-7 can utilize to fill up its water tank. Also, the water tank capacity of the S-7 would be appreciably great, given that the water tank or section 2 of the hull occupies almost half the volume of the boat-hull. Hence, it would be able to store enough water to fight severe fires. To fight very sever fires, some amount of a fire retardant could be mixed with the stored water and then expelled onto a fire along with the stored water. Moreover, when section 2 of the hull would be filled with water, the aircraft would still be able to land on water. In such a case, section 1 of the hull would create the required buoyancy for balancing the weight of the aircraft. This ability of the S-7 is a result of the strategic interior design of the boat hull. Besides, while landing with a filled-up water tank, section 1 would have a constant support from the auxiliary floats.

3.5. Propulsion, Takeoff and Landing:

The S-7 Pelican would have a sound take-off and propulsion system. This system would be fit for a VTOL (vertical take- off and landing) as well as for an STOL (short take off and landing). The S-7 would incorporate a total of 3 engines, two of them being rotatable rotors conventionally mounted on the wingtips, while one of them being the auxiliary turbofan, placed at the base of the rear vertical stabilizer. Being fixed, the turbofan would work as a supplement to the propulsion system. It would not assist the aircraft in generating lift while hovering, taking off, or landing. A third engine might seem redundant mainly because of the weight considerations and increased fuel requirement. However, the S-7 has been proposed to cruise at a speed not less than 300 knots. Also, it would be heavier and larger than the V-22 due to its greater payload capacity, firefighting abilities and amphibious characteristics. Hence, to achieve the required cruise speed, the inclusion of a third engine becomes inevitable.

It might be argued as to why would a turbofan be selected instead of another rotatable rotor, as a third rotor could also help the aircraft in generating extra lift. The main reason why such an approach was not adopted is that the primary requirement is a higher cruise speed and not a greater rate of climb. And as far as propulsion engines are concerned, turbofans have been proved to be highly fuel efficient and relatively noiseless propellers at subsonic speeds of an aircraft[19]. Also, as compared to a proprotor, a turbofan is much lighter (given the significantly smaller blade size). Hence, it would be wiser to choose a turbofan over a proprotor for a higher thrust-weight ratio and better fuel efficiency of the former.

A side benifit of having a turbofan solely meant for forward propulsion would be that it could be used to avoid the dangerous Vortex Ring State (VRS). Some details are provided in section 3.6.

As mentioned earlier, the turbofan would be an auxiliary engine for the S-7. This implies that the aircraft would still be able to fly without the turbofan turned on. In fact, the turbofan would only be powered when the aircraft reaches at least two-thirds of its cruise speed (about 200 knots) solely with its two rotors tilted forward. Once the turbofan is

[19] Turbofan, Wapedia, Reference 19

turned on, the S-7 would be able to cruise at speeds greater than 300 knots. Lastly, since the turbofan is an auxiliary engine, the input power to the turbofan can be compensated and thus its fuel requirements would be lower than normal turbofans used by commercial airplanes.

As far as the range of S-7 is concerned, it would be able to sweep a range of more than 800 nautical miles without refueling in between. Even though the S-7 would have higher fuel requirements than the V-22, it would also have a larger fuel capacity given the strategic placement of fuel tanks inside the S-7's body. On the other hand, given that the S-7 has a more fuel-efficient propulsion system as compared to the V-22 (solutions to reduce drag, section 3.2), it would be able to cover a longer range on the same amount of fuel as other normal aircrafts would do.

3.6. Anti-Crash Potency:

While designing an aircraft, safety issues should always be given special attention. A tiltrotor aircraft has greater safety issues to be considered than a normal helicopter or an airplane. The V-22 has a history of criticisms for its safety, given the innumerable V-22 accidents which have occurred in the past. Reportedly, there were four significant accidents involving the V-22, from 1990-2000[20]. The respective reasons as identified were, a mis-wired flight control system, a leaking gearbox, entering into the Vortex Ring State (VRS) and a hydraulic leak accompanied with a software failure.

It seems true that a tiltrotor aircraft becomes more vulnerable to gearbox or hydraulics damage since it has a much complex transmission system as compared to a helicopter or an airplane. However, the power-by-wire control system installed in the S-7 would significantly eliminate major hydraulic circuits and thus lower the chances of a hydraulic failure.

Moving on to the VRS, the S-7 incorporates an anti-VRS system as well. The hazardous VRS occurs when three things happen simultaneously. There is a high rate of descent, the forward speed is low and the rotors are using a large portion of their available power[21]. This jeopardy is common to helicopters and tiltrotors. However, the danger VRS poses to tiltrotors is higher than that posed to helicopters. This is because a tiltrotor entering a vortex ring state may experience one of its rotors entering the state before the other. Hence, one of the rotors would lose lift and would lead to an uncontrollable roll of the aircraft, most probably resulting in a crash[22]. To avoid entering into the vortex ring state, the S-7 would be equipped with an automated anti-VRS program installed on the computers controlling its flight, take-off and landing. After proper testing of the S-7, the VRS trigger values for speed, descent rate and applied power would be calculated. These 3 values would then be fed into the anti-VRS software. The anti-VRS system would consistently monitor the rate of descent, forward speed and the power applied to the rotors of the S-7 and thus persistently analyze the aircraft's proximity from VRS. As soon as the software would identify a possible entry into the VRS, it would auto-start the turbofan mounted at the rear of the aircraft (which would otherwise be unpowered while landing). The turbofan would give forward propulsion to the S-7, thereby making sure that it attains a forward speed greater than the VRS trigger speed. Hence, using the automated anti-VRS system, the S-7 would be able to avoid the VRS successfully.

The S-7 also inspires some of its anti-crash tactics from the V-22. Continuous critique of the V-22 being a safe aircraft has pushed its developers to come up with some efficient anti-crash techniques. In case one of the two rotor engine fails, the V-22 can still power both rotors with the remaining engine. This is made possible by a drive shaft running

[20] Accidents and Incidents involving V-22, Reference 20

[21] Helicopter Vortex Ring State, Aerospaceplanes, Reference 21

[22] V-22 Vortex Ring State, Globalsecurity, Reference 22

through the wings, which connects the two nacelles of the proprotors. A same approach would be used for connecting the two turboshaft engines of the S-7 Pelican.

Last but not the least, as highlighted earlier, the S-7 would use a power-by-wire control system for its flight controls, which is an improved version of the digital fly-by-wire control system[23]. Such a control system would not only eliminate mechanical transmission circuits, but would also avoid most of the of heavy and bulky hydraulics circuits. Along with the efficient pilot-cum-computer controlling of the aircraft, a power-by-wire system would also require lower maintenance cost than the conventional hydraulic circuit systems.

Henceforth, the S-7 Pelican would have some unique anti-crash characteristics, along with in intelligent flight control system run with power-by-wire controls. Overall, it would be a much safer aircraft.

4. Conclusion:

In conclusion, the Salvager-7 Pelican would turn out to be an efficient, versatile and pragmatic tiltrotor aircraft. The S-7 has been carefully designed with numerous innovations and modifications to the conventional tiltrotor aircraft design. It would be an exemplary model, specifically suited for humanitarian missions. With its characteristics of landing and taking-off from ground and water, higher speed, longer range, greater payload capacity and fire-fighting ability, the S-7 would become a more viable option for search-and-rescue or relief missions in times of natural or man-made disasters. As far as the costs are concerned, the S-7 would be no doubt be costlier than the existing V-22 tiltrotor aircraft due to its enhanced abilities. However, given that the S-7 is a more versatile and thus a much useful and handy aircraft, its monetary value is justified. Moreover, on a long term basis, the S-7 would be easier to maintain than any other rotorcraft because of its power-by-wire controls as mentioned previously. As such it might seem costly to produce an S-7 but considering the long term benefits of using an S-7 over the V-22, S-7 would still stand out as a more feasible option. It is quite possible that the S-7 becomes the leader of humanitarian by overtaking helicopters, once it is put into large-scale production.

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