Y-FUSELAGE CONFIGURATION TO ENHANCE SUBORBITAL PAYLOAD CAPACITY, SEAWORTHINESS SAFETY AND AERODYNAMICS

Norul Ridzuan Zakaria[(1)], Anas Md Yusof[(1)], Mohamad Rafi Shahzada[(2)], Manar Abd Latif[(3)], Norul Rafidi Zakaria[(3)], Saharudin Zakaria[(3)], Sutan Amzari Abas[(3)], Muhamad Ferdous Mohdshariff[(3)], Norul Muhammad Norulridzuan[(4)], Norul Aini Norulridzuan[(5)]

[(1)]University Sultan Azlan Shah (USAS), 33000 Kuala Kangsar, Perak, Malaysia, Email: norul@usas.edu.my
[(2)]MARA Corporation, MARA Tower, 50100 Kuala Lumpur, Malaysia, Email: rafi@maracorporation.com.my
[(3)]Spaceport Malaysia, 34000 Taiping, Perak, Malaysia, Email: manar@spaceportmalaysia.com
[(4)]University Kuala Lumpur Malaysian Institute of Marine Engineering Technology (UniKL-MIMET), 32200 Lumut, Perak, Malaysia, Email: stahnlze@gmail.com
[(5)]University College MAIWP International (UCMI), 68100 Kuala Lumpur, Malaysia, Email: norulaini99@gmail.com

ABSTRACT

The conventional aircraft fuselage is generally a straight tube or I-shape tube. Imagine a fuselage of Y-shape where the front single tube fuselage branches out towards the rear into 2 fuselages of symmetrical tubes resembling the alphabet “Y” and these 2 fuselages bend towards the centerline and align themselves parallel as twin rear fuselages, as if the Y-fuselage aircraft has 3 fuselages; 1 fuselage at the front and 2 parallel fuselages at the rear and 2 more fuselages connecting the single front fuselage and the 2 rear fuselages. Comparing a Y-fuselage aircraft to a conventional I-fuselage aircraft of the same fuselage diameter, the Y-fuselage aircraft will be able to carry more payloads because it has the larger volume. The conventional I-fuselage wide body passenger jets typically have their turbofans installed below the wing, which usually the wing roots are attached to the lower part of the fuselage. These turbofans often become the culprit to cause the wings to be ripped off from the fuselage or broken during emergency crash-landing on the ground or on water. When this happens during crash-landing on the ground, often the turbofans catch fire and may explode. When this happens during crash-landing on water, most of the time the turbofans caused the wings to be ripped off from the fuselage and the wingless fuselage becomes more vulnerable to be sinking. In Y-fuselage configuration, the turbofans can be installed above the empennage between the twin rear fuselages, resulting in a clean wing design and eliminating the risk of the turbofans becomes the cause for the wings to be ripped off from the fuselage or broken during emergency crash-landing. In the case of crash-landing on water, Y-fuselage configuration makes an aircraft more seaworthiness because the turbofans are not installed conventionally under the wing. Having the turbofans above the empennage between the rear fuselages of a Y-fuselage aircraft will also increase the aerodynamics and reduce the noise because the turbofans are “hidden” and the noise is deflected upwards by the empennage. In the conventional I-fuselage configuration, the turbofans below the wing are exposed and therefore reduce the aerodynamics and cause the aircraft to be noisier. Interestingly, with Y-fuselage configuration, it is possible to increase the payload capacity of an aircraft without increasing its length and wing span which is very significant if size of the aircraft is the most important limitation as in the design of suborbital aircraft or spaceplane. It is generally accepted that suborbital aircraft may resemble the designs of aircraft as in space shuttle resembling delta wing single fin aircraft, therefore Y-fuselage configuration may be applicable in the design of suborbital aircraft for better payload capacity, safety and aerodynamic too especially if the suborbital aircraft is to perform point-to-point suborbital flight across seas and oceans as in intercontinental hypersonic flight where there is risk of emergency crash-landing on water. This paper explores the idea of Y-fuselage configuration by visually and technically comparing it to the conventional I-fuselage configuration and describes the advantages of Y-fuselage in enhancing payload capacity, safety particularly enhances seaworthiness during emergency clash-landing on water and aerodynamics. The paper also illustrates a possible Y-fuselage suborbital aircraft configuration drawn using AutoCAD.

INTRODUCTION

Many have flown aboard the largest passenger jets ever built, the Boeing 747 and Airbus A380. After both passenger jets have successfully carried hundred thousands or millions of passengers, both Boeing and Airbus started to develop smaller passenger jets. We can see the reasons were both technical and economic, not only pertaining to the aircrafts, but also the airports.

Some airports are not capable of providing services to the 2 largest aircrafts without upgrades in their facilities including runways, aprons and bridges. If larger aircrafts are to be able to use these facilities, they need to be further upgraded, and if the upgrading has reached the maximum possibility, new airports have to be built to cater for the larger aircrafts.

Airports are very expensive infrastructure. Their economics do not only depend on the size of the aircrafts, but also the number of aircrafts or number of flights available and also not only the number passengers, but also number of visitors available, as modern airports now have become “cities with shopping malls and offices”. With such complexities, safety is now a very major issue.

The solution to these complexities is not larger aircrafts, but smaller more sophisticated and more efficient aircrafts such as Airbus A350 and Boeing 777. A380 and 747 were seen as the maximum limit in size of the aircrafts. Any larger aircraft is seen not to be practical and not cost effective both for the aircraft and airports.

However, in term of the very basic design of fixed wing aircrafts over the past 50 years there was no significant evolution. All the designs consist of a single tube fuselage with symmetrical wings on both sides of the fuselage. For effective understanding of the subject being discussed in this paper, the single tube fuselage is called “I-fuselage” because the single tube resembles the alphabet “I”.

INCREASING PAYLOAD CAPACITY

Airbus A350, A380, Boeing 747 and 777 and other modern late 20th and 21st century passenger jets are all of I-fuselage configuration that is they all have a single tube and symmetrical wings on both sides of the tube. The tube is where the passengers and other payloads are accommodated. To increase the number of passengers or the quantity of the payloads, the volume of the tube need to be increase; either the tube has to be lengthened or widened, or both.

Lengthening or widening the fuselage meaning generally increasing the wingspan of the aircraft, hence the size of the aircraft which may result into something like A380 or 747. We wish to avoid that because we want to increase the number of passengers or enhance the payload capacity without increasing the size of the aircraft. Therefore we came up with a new fuselage configuration called, “Y-fuselage” as a solution.

As in “I-fuselage resembles the alphabet I”, Y-fuselage resembles the alphabet “Y”. Aircrafts of Y-fuselage configuration have their fuselages resembling the alphabet “Y” in such a way that they have a single tube fuselage at the front, which branches out towards the rear into 2 fuselages of symmetrical tubes resembling the alphabet “Y” and these 2 fuselages bend towards the centerline and align themselves parallel as twin rear fuselages, as if the Y-fuselage aircraft has 3 fuselages; 1 fuselage at the front and 2 parallel fuselages at the rear and 2 more fuselages connecting the single front fuselage and the 2 rear fuselages. They have a single fuselage at the front and a twin fuselage at the rear for the sake of aerodynamics.

In doing so, we have increased the volume of the fuselage. This is so because for 3 dimensional alphabets of the same size, the volume of alphabet “Y” is greater than the volume of alphabet “I”. By increasing the volume of the fuselage, the payload capacity is increased if the power of the propulsion can be increased accordingly to provide the extra power and safety needed by the increment in the payload capacity.

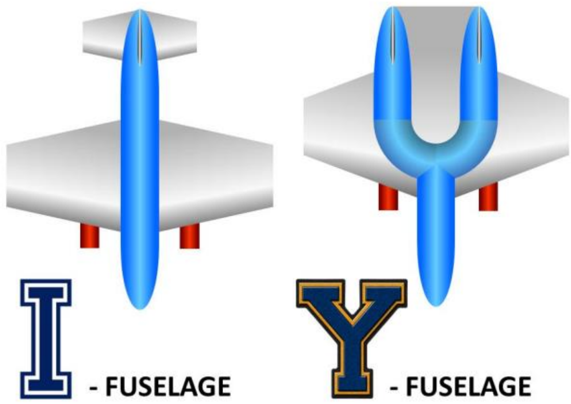

Figure 1. I-fuselage and Y-fuselage aircraft configurations.

INCREASING THE SEA WORTHINESS

Airbus A350, A380, Boeing 777 and 747 are long haul flights passenger jets, meaning they fly for long hours between 6 and 12 hours or more. Their flights may be of ultra-long haul too, which according to IATA (International Air Transport Association), ICAO (International Civil Aviation Organization) and IFALPA (International Federation of Air Line Pilots’ Association), ultra-long haul flights are defined as, any flights lasting more than 16 hours. They fly very long distance and intercontinental across seas and oceans. In fact most of their flights are above the oceans. For example, flights between Kuala Lumpur and Los Angeles spend almost all their flying time above Pacific Ocean.

These aircrafts are designed to be seaworthiness, meaning they can land on the water and survive that landing and remain afloat and able to move on the water. The more seaworthiness the aircrafts the safer they are, the better the aircrafts.

Typically these long haul flights passenger jets have low wing design with their turbofans installed below the wing and below the fuselage level. Typically either a pair or 2 pairs of turbofans are installed in such configuration. If these aircraft perform emergency landing on the water, the momentum causes them to skid on the surface of the water. However, their turbofans become the obstacle for the skid and cause the aircrafts to be stopped abruptly by the water. The higher speed they had during landing, the stronger this force.

The force is often strong enough to cause not the turbofans to be ripped off from the wings, but the wings to be ripped off from the fuselage or at lease very serious damage to the wing root. When this happens either the wings become detached from the fuselage or bended toward the fuselage. In both cases, it will reduce the seaworthiness of the aircraft, or make the aircraft more prone to be sunk. Worst case scenario would be water pouring into the fuselage due to the damage at the wing root.

Figure 2. A Boeing 767 crash-landed on the sea in 23 November 1996 demontrating how "below the wing" turbofans may cause an aircraft to be less seaworthiness.

Unlike I-fuselage configuration that typically had the turbofans installed below the wings and below the fuselage level, Y-fuselage configurations will allow more suitable installation of turbofans above the fuselage level. The turbofans in the Y-fuselage configuration can be installed above the empennage or rear section control surface between the twin rear fuselages. By having the turbofans installed in such a configuration, there will be no obstacle under the wings for the aircraft to skid on sea surface if it performs an emergency landing in the sea. This will only increase the smoothness of the skidding because there are no turbofans under the wings. If the skidding is smooth enough, the wings may not be ripped off from the fuselage or even the wing root may remain intact without serious damage.

Aerodynamically, there can be "a wing" or empennage or rear section control surface installed horizontally between the twin rear fuselages of the Y-fuselage aircraft. The turbofans will be suitable to be mounted above this structure. This wing together with the symmetrical main wings on both sides of the front fuselage and the rear fuselages will only tremendously increase the seaworthiness of Y-fuselage aircrafts compared to I-fuselage aircrafts. Better seaworthiness is better safety for these long haul and ultra-long haul flight aircrafts that fly mostly over oceans and seas.

Emergency landing on land will also benefit from Y-fuselage configuration due to the clean wing design. Similar to the emergency landing in the sea, the aircraft may skid on its belly when crash-landing on the ground. As in the case of landing on water, the turbofans typically being installed below the wings will be the most vulnerable part where they may explode and catch fire. Similarly too they may cause the wings to be ripped off from the fuselage and damage the wing roots and the fuselage. Y-fuselage configuration may avoid this mishap and tragedy.

Figure 3. A Boeing 777 crash-landed on a runway in 17 January 2008 demonstrating the impact and damage mostly on the "below the wing" turbofans.

INCREASING AERODYNAMICS

Moving the turbofans from below the wings to above the empennage between the rear fuselages makes Y-fuselage aircrafts embody clean wing design, and clean wing design only increases aerodynamics. Increasing the aerodynamics not only enable the aircrafts to reach higher speed, but also to be more economic or carrying more payload with less fuel.

There will be more aerodynamics factor in having the turbofans closer to the rear as in Y-fuselage aircrafts compared to as in the I-fuselage aircrafts because generally aircrafts with turbofans at the rear can be designed more aerodynamic than aircrafts with turbofans near the middle section of their fuselage. This is the same case as positioning engine at the rear of supercars and Formula 1 cars to reduce the drag coefficient (C_d) of those cars; the reason modern supercars and Formula 1 cars had their engine at the rear of their chassis.

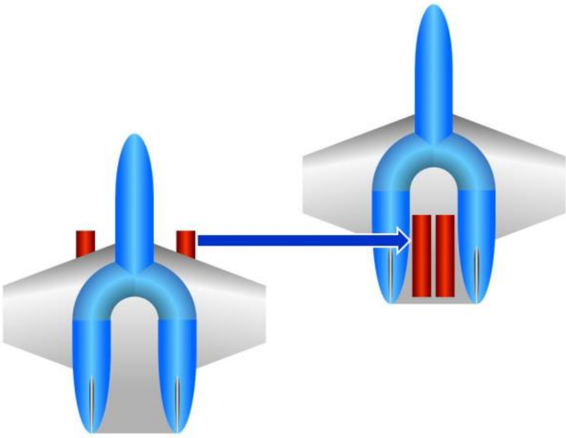

Figure 4. Removing the turbofans from under the wing and installing them above the empennage between the rear fuselages not only increase seaworthiness, but also increase the aerodynamics of Y-fuselage aircraft.

More aerodynamics factor is there when the turbofans are to be installed below the fuselage rooftop level or in “hidden configuration” between the rear fuselages because the turbofans will not contribute to any frontal cross section area. The turbofans can be installed in such a way that they become invisible when viewed from the front and the sides, and only visible when viewed from the rear.

Yet more aerodynamics occurs by having the turbofans installed closer to the centerline as in Y-fuselage aircrafts compared to that as in I-fuselage aircraft. Not only mass becomes more concentrated nearer the centerline, but more massive and more powerful turbofans can be installed if they are closer to the centerline. Having the twin turbofans closer to the centerline also minimize the effect of the loss of symmetry if one turbofan fails.

MINIMUM NOISE POLLUTION

Installing turbofans outside the fuselage of Y-fuselage aircrafts will have the same effect of doing the same to the I-fuselage aircrafts; reducing the noise that may leak into the cabin. In the case of the Y-fuselage, the effect of minimum noise leak into the cabin will be obvious to the first class passengers at the front because the turbofans are outside the fuselage and at the rear of the fuselage.

Installing the turbofans above the empennage will enable the empennage to deflect the noise from the turbofans upward. This will reduce the noise to people on the ground.

Noise pollution is measured by the amount of noise leak to listeners that suppose not to hear that particular noise. The magnitude of noise pollution is not only depending on the magnitude of the noise, but also the direction of the noise, a vector quantity. Y-fuselage configuration enables the positioning of turbofans that will minimize the noise pollution.

A PROPOSED CONCEPT

The authors proposed a concept of a Y-fuselage aircraft. It is a double trapezoidal wing design with the smaller wing slightly at the front of the middle section of the fuselage and the bigger wing at the rear of the fuselage.

There are 4 doors, 2 on each side of the fuselage. 2 front doors are right at the front of the middle section wing and 2 rear doors are between the middle section wing and the rear wing. The front doors are on the front single fuselage where the business class is, while the rear doors are on the twin rear fuselages where the economy class is.

It has double fins. Twin turbofans are installed above the empennage between the rear fuselages, resulting in clean wing high seaworthiness low noise aircraft.

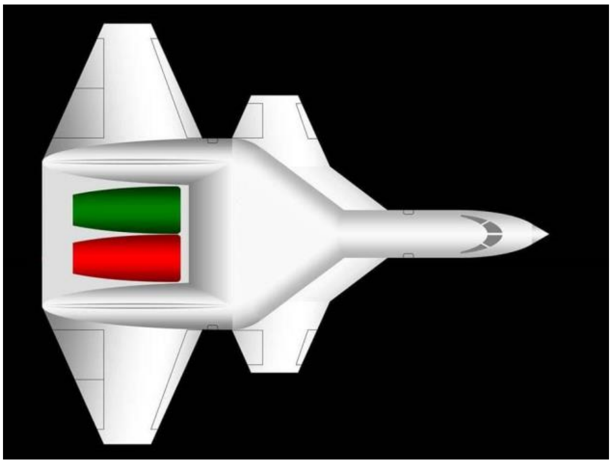

Figure 5. The Y-fuselage aircraft concept proposed by the authors.

The Y-fuselage aircraft is the size of Airbus A320neo, but able to carry 50% more passengers than the A320neo does. A320neo may carry the maximum number of 190 single class economy passengers, while the Y-fuselage aircraft is designed to carry 250 economy class passengers and 24 business class passengers or 280 single class economy passengers.

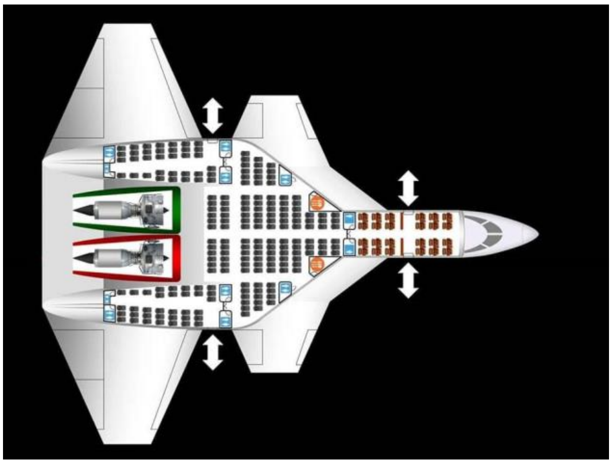

Figure 6. The proposed Y-fuselage aircraft concept is the size of Airbus A320neo but can carry 50% more passengers than the A320neo does.

OTHER ADVANTAGES OF Y-FUSELAGE

Y-fuselage aircrafts will have high seaworthiness. Automatically they will be favored as seaplanes. Y-fuselage seaplanes will have their engines well protected from the water because the engines can be position above the empennage between the twin rear fuselages. In the case of Y-fuselage seaplane the horizontal empennage between the twin rear fuselages also acts as part of the float.

The clean low wing design of Y-fuselage aircraft will be a significant advantage for seaplane because it provides "wing in the water" effect, which increases lateral stability on the water and maximizes the benefits of ground effect during take off and landing. Such wing design also prevents the seaplane from rolling on water. There will also be no extra weight and drag caused by the floats as in the conventional I-fuselage seaplanes.

An issue in the design of VTOL (Vertical Take Off and Landing) aircrafts is the enclosed positioning of the VTOL fans. Often conventional I-fuselages do not have enough space to accommodate VTOL fans, resulting in the VTOL fans to be placed outside the fuselage and actively reduce the aerodynamics of the aircraft. Y-fuselage aircrafts will have space for the installation of VTOL fans inside their fuselages, making Y-fuselage to be potential configuration for VTOL aircrafts.

The leading author has wrote that when the suborbital tourism industry matured, the main attraction will be where can suborbital flight be offered because of the quality of the views of Earth's surface to be made available to the passengers. At this time, VTOL capability for suborbital aircrafts may be important because with VTOL capability the aircraft can be more flexible to operate in destinations which will provide high quality Earth's surface view. Y-fuselage configuration may be favored for suborbital aircraft design as will be explained later.

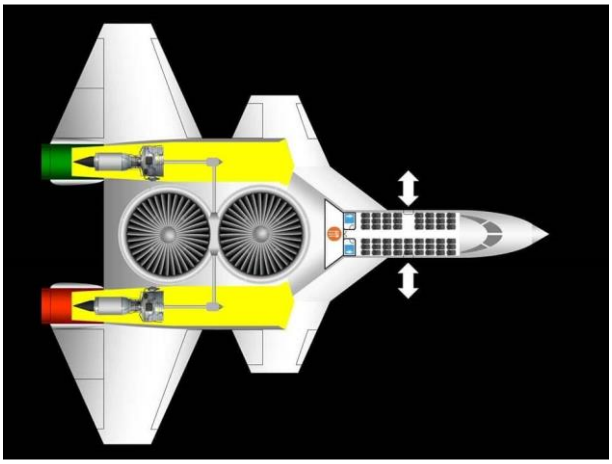

Figure 7. A concept of VTOL Y-fuselage aircraft, which is from a further study of the proposed Y-fuselage aircraft concept by the authors.

As explained earlier, the turbofans of Y-fuselage aircrafts can be installed in "hidden configuration" above the empennage between the twin rear fuselages. This configuration is very useful for military applications because such configuration can also hide or reduce the sonic and IR (infra-red) signatures of the turbofans. Low visual, sonic and IR signatures means more stealthy, a character needed by combat aircrafts, particularly for both tactical and strategic enemy territory penetration.

Another fundamental element of stealth in military applications is having all the missiles and bombs installed inside the fuselage instead of having them installed below the wings. For small conventional I-fuselage combat aircrafts, this capability is very limited, while Y-fuselage configuration will be able to provide that capability even for small aircrafts. Carrying all the missiles and bombs internal of the fuselage of course contribute to better aerodynamics too.

Therefore, Y-fuselage configuration has great potential in military applications. It is a potential configuration for future stealth bombers and attack aircrafts.

COMPARISON WITH BLENDED WING BODY

An aircraft configuration that has a similarity to the Y-fuselage configuration considering the widening or additional volume of fuselage is blended wing body. Blended wing body aircraft is a concept where the wing of the aircraft is blended seamlessly into the fuselage of the aircraft, enabling the aircraft to have wider fuselage and becomes more aerodynamic.

Unlike Y-fuselage concept where the fuselage remains the same shape and size along the length of the aircraft, the fuselage of blended wing body aircraft changes in shape and size along the length of the aircraft. Variation in the shape and size of the fuselage avoid standardization, universality and modularity in design. The luggage compartment shape and size and the design of seats and their legroom and headroom may vary accordingly. Different luggage compartment and seats will require different pricing too.

As for Y-fuselage aircraft, the same shape and size of its fuselage along the length of the aircraft is just like that of the conventional I-fuselage aircrafts. The usage of the same luggage compartment and seats will be more economic and more manageable in term of pricing for each passenger. That will also be a very positive human factors engineering of the cabin which will be very significant for the safety and comfort of the passengers.

Y-FUSELAGE FOR SUBORBITAL AIRCRAFT

Suborbital aircrafts were developed based on the design, engineering and operation of both aircrafts and rockets. However, the elements from rockets were mostly on the propulsion side, while the overall design and engineering were generally from high aerodynamic fixed wing aircrafts. An obvious example is the Space Shuttle; its propulsions are from rocketry, but its aerodynamics, winged structure, horizontal fuselage, landing operations and cabins for crews and payloads were from aviation although it flew orbital.

Suborbital aircrafts are more towards aviation than rocketry because most of their flights are below the Von Karman Line or less than 100km from the sea level, mostly from the conventional fixed wing aircrafts flight region to the near space region, where control surfaces such as wings, fins and flaps are effective. For this reason, some suborbital aircraft concepts were designed that they are to be powered by turbofans or other advanced air-breathing engines besides rockets. For this reason too, Y-fuselage configuration is proposed for both fixed wing aircraft and suborbital aircraft designs.

For suborbital flight applications, Y-fuselage configuration maintains all the advantages it is capable of providing to aviation, both civil and military. A very significant advantage will be high seaworthiness because such advantage will be useful for suborbital aircrafts to perform emergency landing or intentional landing on water.

Traditionally capsules were landed in the sea, since the Apollo program. Capsules from the Artemis missions too are to be landed in the sea. Y-fuselage configuration provides a path for suborbital aircrafts or spaceplanes with capability to be landed in the sea too with high seaworthiness and safety features.

The authors propose a general design of Y-fuselage suborbital aircraft or spaceplane. It is a concept of twin turbofans and twin rockets delta wing double fins y-fuselage suborbital aircraft capable of carrying 50 passengers.

The Y-fuselage suborbital aircraft has a large delta wing resembling Concorde and Space Shuttle. This resemblance enables the flight data of both Concorde and Space Shuttle to be useful for the design of the suborbital aircraft.

The suborbital aircraft is planned to take off and land horizontally at airports. Therefore it will use turbofans for the conventional take off and landing. Twin turbofans are the choice of design to match the twin rear fuselages. Turbofans are to be used for cruising after take off and landing too. The intakes for the turbofans are to be active. They will be fully opened to the maximum (100%) during low speed flight for take off and landing, partly close (50%) during high speed turbofans powered flight, and totally close (0%) during rocket powered near hypersonic flight. When the intakes are fully closed, the turbofans will not be in use because at this time rockets are to provide the thrust at high altitude and in space. The intakes are to be fully close for better aerodynamics and to protect the turbofans blades when the suborbital aircraft flying at near hypersonic speed.

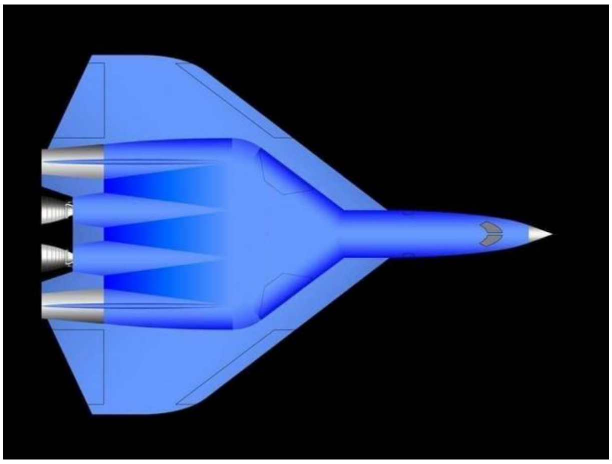

Figure 8. The Y-fuselage suborbital aircraft concept proposed by the authors.

The rocket thrust of the suborbital aircraft is to be provided by a twin liquid-propellant rockets. They are installed parallel to and between the twin rear fuselages closer to the centerline than the turbofans are to be. The rockets are to enable the suborbital aircraft to fly high altitude and into space above the Karman Line of 100km from sea level for few minutes.

The suborbital aircraft can carry up to 50 passengers or astronauts or spaceflight participants. They will be seated as in the standard aviation seating in the single fuselage at the front. The suborbital aircraft will be piloted by 2 pilots.

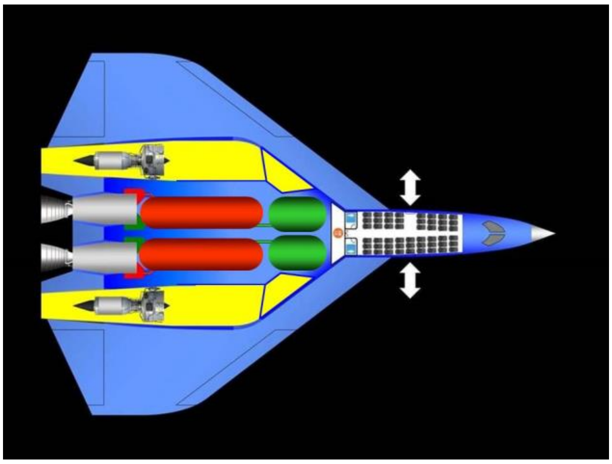

Figure 9. The proposed Y-fuselage suborbital aircraft concept can carry 50 passengers and powered by twin rockets and twin turbofans.

This suborbital aircraft is meant for regional distance point-to-point suborbital flights. Each passenger will not only eligible for an astronaut wing but also able to travel regionally. For such exclusive travel, this suborbital aircraft is equipped with lavatories and foods and beverages storage and delivery system. The lavatories and foods and beverages system however will only be effective during turbofan powered cruise flight.

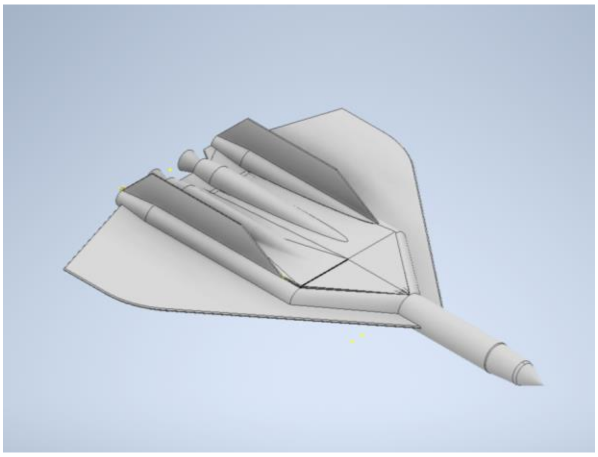

Figure 10. A 3-dimensional rendering of the proposed Y-fuselage suborbital aircraft by the presenting author.

As Y-fuselage configuration is to have high seaworthiness, this suborbital aircraft will be able to perform emergency landing on water. For higher rate of seaworthiness safety, all the nozzles of the turbofans and rockets can be closed to prevent water penetration into them.
If smaller propulsion system is to be used, there will be spaces available for VTOL fans as previously explained. Suborbital aircrafts with VTOL capability will enjoy the advantage of being more flexible in operation at destinations without runways. However smaller propulsion will decrease the operation radius.

With VTOL capability suborbital aircrafts can operate at destinations which will be able to offer very high quality view of Earth's surface to the passengers even at destinations without runway facilities. These suborbital aircrafts will be able to offer better suborbital tourism package.

As explained earlier, Y-fuselage configuration has potential to be favored for VTOL aircraft design. This will include VTOL suborbital aircraft design.

A further study of the concept has produced a more aerodynamic design which has switched the position of the rockets and turbofans. In the new configuration, each of the rockets is installed at each rear end of the twin rear fuselages and the number of turbofans was increased from 2 to 5 and they are installed between the rockets.

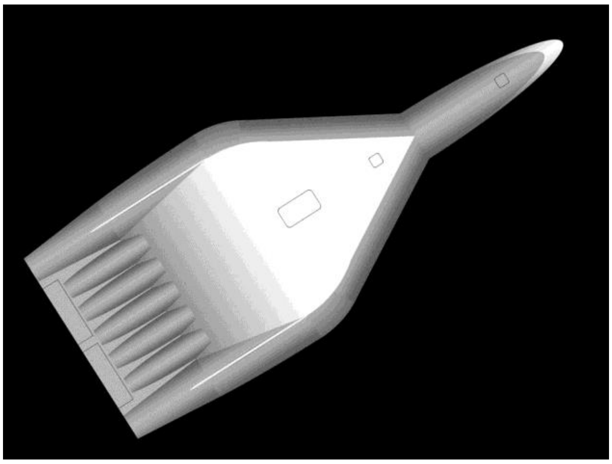

Figure 11. A further study concept Y-fuselage spaceplane with twin rockets at the rear end of the fuselages and 5 turbofans between them.

The new design uses retractable wings and canards, where the wings and canards are to be retracted into the fuselage during hypersonic near space and space flight when the control surfaces will not be effective. The new design is meant to be a concept for hypersonic intercontinental point-to-point suborbital spaceplane. The well separated rockets will be useful for the spaceplane to power-launch itself from the rooftop of a conventional single fin large passenger jet functioning as its first stage carrier.

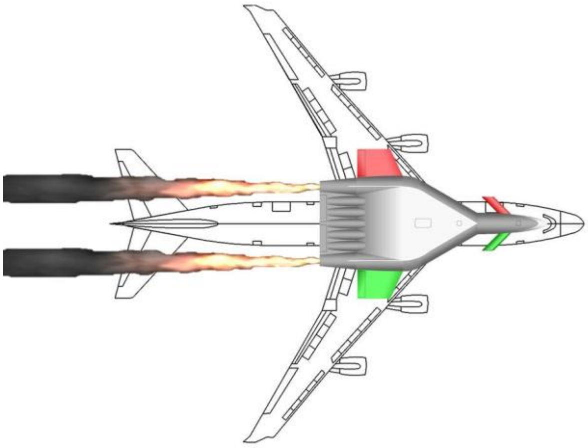

Figure 12. The Y-fuselage spaceplane is meant to be power-launched from the roof top of a conventional single fin large passenger jet.

The usage of the first stage "universal carrier" is to increase universality and reduce the cost of launching and make use of existing airport facilities. The spaceplane will use its 5 turbofans for cruising and landing. The intake and nozzle of the turbofans can be closed to maximize aerodynamics and protect the blades of the turbofans.

FUTURE PLANS

The authors and several others plan to conduct further study on Y-fuselage aircraft configuration. Among the activities planned after the 13th IAASS Conference in Prague are:

1. To produce more detailed technical drawings including AutoCAD drawings of Y-fuselage aircraft and suborbital aircraft.
2. To write to major aircraft manufacturers (Airbus, Boeing, Embraer, Bombardier, etc.), proposing them to consider developing Y-fuselage aircrafts.
3. To write and publish a book on Y-fuselage aircraft configuration.
4. To fabricate scaled models of Y-fuselage aircraft and suborbital aircraft.

CONCLUSIONS

The authors have summarized their conclusions as the following 16 statements:

1. A Y-fuselage aircraft can carry more passengers and more payloads than a conventional I-fuselage aircraft of the same length and wingspan.
2. Y-fuselage aircrafts increases their payload capacity by increasing the volume of the fuselage by having the fuselage in the shape of "Y" instead of "I".
3. Y-fuselage aircrafts can have clean wing design because they can have their turbofans installed above the empennage between the twin rear fuselages.
4. Clean wing design of Y-fuselage aircrafts will be able to make Y-fuselage aircrafts more seaworthiness than the conventional I-fuselage aircrafts with turbofans typically under their wing.
5. Clean wing design of Y-fuselage aircrafts will make them more aerodynamic than the conventional I-fuselage aircrafts.
6. Installing the turbofans between the twin rear fuselages will be able to make Y-fuselage aircraft more seaworthiness than the conventional I-fuselage aircrafts which typically have the turbofans installed under the wing, making Y-fuselage the more favored configuration for seaplane.
7. Installing the turbofans between the twin rear fuselages will be able to make Y-fuselage aircraft more aerodynamic than the conventional I-fuselage aircrafts which typically have the turbofans installed under the wing.
8. Installing the turbofans between the twin rear fuselages closer to the centerline will enable Y-fuselage aircrafts to be equipped with more massive and more powerful turbofans and minimize the effect of loss of symmetry if one turbofan fails.
9. The turbofans can be installed in "hidden configuration" above the empennage between the twin rear fuselages of Y-fuselage aircraft. By doing so, the optical, sonic and infra-red signatures of the turbofans can be minimized which will be useful for military applications.
10. The fuselage of Y-fuselage military aircrafts will have large enough volume for storage of all missiles and bombs.
11. The fuselage of Y-fuselage aircraft will be large enough for internal installation of VTOL (Vertical Take Off and Landing) fans, where often the conventional I-fuselage aircraft is too narrow for such and the external installation of VTOL fans becomes a handicap in aerodynamics. Therefore Y-fuselage VTOL aircrafts can be made more aerodynamic than I-fuselage VTOL aircrafts.
12. When compared to blended wing body aircraft, Y-fuselage aircraft enjoys more modularity and universality in fuselage design.
13. With higher payload capacity and better aerodynamics, Y-fuselage aircrafts can be made to be more economic for operation than the conventional I-fuselage aircrafts.
14. With higher and better seaworthiness, Y-fuselage aircrafts can be made to have higher and better safety standards than the conventional I-fuselage aircrafts.

15. Since suborbital aircraft can be made similar to fixed wing aircraft, the concept of Y-fuselage is applicable in the design of suborbital aircraft. Y-fuselage suborbital aircraft enjoys all the advantages of Y-fuselage aircraft when compared to the conventional I-fuselage configuration.
16. Y-fuselage configuration have potentials to be favored for development of:
    1. Medium and large passenger jets
    2. Seaplanes
    3. VTOL fixed wing aircrafts
    4. Stealth combat aircrafts
    5. Suborbital aircrafts

BIBLIOGRAPHY

1. Norul Ridzuan Zakaria, Anas Md Yusof, Md Sayuti Ishak. (2024). *Ring of Earth*, USAS Press, Universiti Sultan Azlan Shah, Malaysia.
2. Norul Ridzuan Zakaria. (2021). *Space Naval Architecture*, ISBN 9789672613404, USAS Space Center, Universiti Sultan Azlan Shah, Malaysia.
3. David Ashford. (2002). *Spaceflight Revolution*, ISBN 9781860943256, Imperial College Press, UK.
4. David Oliver. (1999). *Wings over Water: A Chronicle of the Flying Boats and Amphibians of the 20th Century*, ISBN 0785810439, Chartwell Books, USA.
5. Barry Schiff. (2004). *Beriev 103 From Russia With Love*, AOPA Pilot October 2004, Aircraft Owners and Pilots Association, USA.
6. David Ashford. (2009). *An Aviation Approach to Space Transportation*, The Aeronautical Journal, Volume 113, No. 1146, page 504.
7. Norul Ridzuan Zakaria, Nasri Nasrun, Jalaluddin Abu, Asmadi Jusoh, Liayana Azim, Md Azlin Said, Md Sayuti Ishak, Norul Rafidi Zakaria. (2012). *The Advantages, Potentials and Safety of VTOL Suborbital Operations*, Proceedings of the 5th IAASS Conference, Ouwehand, L. ISBN: 978-92-9092-263-6, Noordwijk, Netherlands: ESA, 2012, id.43.
8. Norul Ridzuan Zakaria, Adrian Mettauer, Jalaluddin Abu, Mohd Roshdi Hassan, Anwar Taufeek Ismail, Jamaluddin Othman, Che Zhuhaida Shaari, Nasri Nasrun. (2010). *Human Factors Engineering in Designing Passengers' Cockpit of the Malaysian Commercial Suborbital Spaceplane*, Proceedings of the 4th IAASS Conference, H. Lacoste-Francis, ESA-SP Vol. 680, 2010, id.90.
9. Norul Muhammad Norul Ridzuan. (2024). *An AutoCAD Rendering of Y-Fuselage Suborbital Aircraft*, Spaceport Malaysia Publication.
10. Malaysian Space Board Act 2022, Malaysian Space Agency (MYSA), Ministry of Science, Technology and Innovation (MOSTI).