THE CONCEPT OF ANTIPODAL EQUATORIAL SPACEPORT AND ANTIPODAL EQUATORIAL SPACEPLANE

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ABSTRACT

The farthest possible distance between 2 points on a sphere is half the circumference of the sphere. Therefore for any planet the farthest possible distance between 2 points on the surface of the planet is half the circumference of the planet. For planet Earth with the circumference of 40,000km, the farthest possible distance between 2 points on the surface of Earth is 20,000km (half of 40,000km). These 2 points are called antipodal points. Each point is antipode of each other or on the opposite side of each other on the surface of Earth. However since 70 percent of the surface of Earth is covered by oceans and seas, most of the antipodal points are either both in the water or one of them is in the water. Therefore it is more practical to look for landed antipodal regions rather than antipodal cities when antipodal spaceports are considered. Antipodal spaceports are 2 spaceports at landed antipodal regions on the opposite side of the Earth. They are to take advantage of the farthest possible distance to be economically and safely flown using antipodal spaceplane or spaceplane specially designed to be capable of flying a distance equal to half the circumference of Earth or 20,000km. A very important safety factor to be emphasized is the seaworthiness of the spaceplene because mostly the spaceplane will fly above oceans and seas. Since the rotational plane of Earth is the Equator where the rotational momentum is maximum to be exploited for providing extra momentum to the momentum provided by the propulsion of the spaceplane, the antipodal regions are chosen to be at or near the Equator. The 2 regions identified are Southern Caribbean and South East Asia. Therefore the 2 antipodal spaceports are to be located one in Southern Caribbean and the other one in South East Asia. Each region is also located at the center of a larger region where each can become the effective hub for air transportation for its respective larger region. This is very important because the antipodal spaceplane must be fed by conventional airlines to ensure its economics. Southern Caribbean is surrounded by North America and South America, therefore it can effectively become the hub for airlines from the countries in North America and South America. South East Asia is surrounded by Far East (China, Japan and Korea), Oceania (Australia and New Zealand) and the Gulf Countries, therefore it can effectively become the hub for airlines from those countries. The operational objective of equatorial antipodal spaceports is to provide "spaceline services" between the regions surrounding the spaceports so that passengers can fly between the 2 antipodal regions and be back home within 24 hours since the flight time of the antipodal spaceplane between the Southern Caribbean spaceport and the South East Asian spaceport can economically and safely be executed within 4 hours. This paper discusses with texts and illustrations the viability in terms of economics and safety of Antipodal Equatorial Spaceports and Antipodal Equatorial Spaceplane.

INTRODUCTION

For any sphere including a planet, there are antipodal points. These are 2 points which are diametrically opposite, meaning they are the endpoints of a diameter projected between any 2 points on a sphere or planet passing through the center of the sphere or planet. A unique and significant character of antipodal points is they are separated the greatest distance either measured intrinsically over the great circle distance on the surface of the sphere or planet or extrinsically, the chordal distance through the interior of the sphere or the planet.

If the 2 antipodal points on the surface of the sphere or planet are marked “A” and “B”, an imaginary straight tunnel can be constructed between them which go through the center point of the sphere or planet.

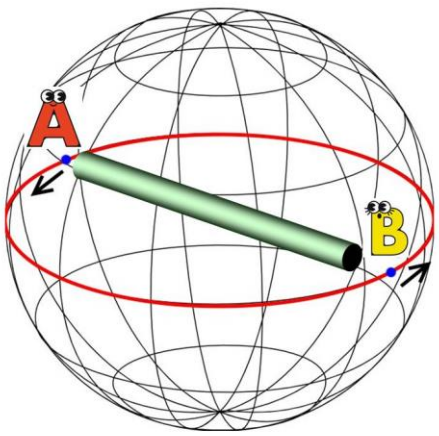

Figure 1. If "A" and "B" are antipodal points, an imaginary tunnel that goes through the center point of the sphere connecting point A and B can be constructed.

Being a planet, Earth has antipodal points. Therefore flying between its antipodal points is the farthest possible distance to travel on the surface of Earth. The circumference of the Earth at the Equator is 40,075km, therefore half the circumference of the Earth at the Equator is 20,037.5km, which is the distance between 2 antipodal points at the Equator, or 20,037.5km is the antipodal distance at the Equator. Since the rotational plane of the Earth is at the Equator and due to the maximum rotational momentum there, the circumference of the Earth there is a little bit greater than the circumference of the Earth at the Poles or anywhere else between the Equator and the Poles, after the Earth have been rotating on the Equatorial plane for billions of years.

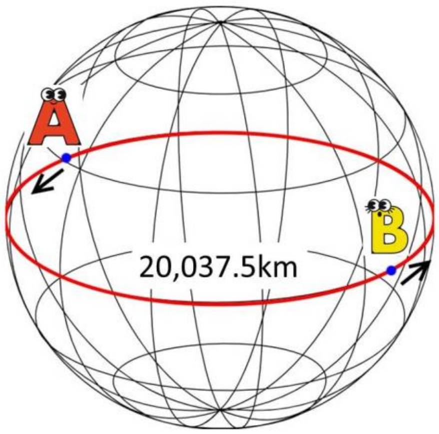

Figure 2. The antipodal distance at the Equator is 20,037.5km equals to half the circumference of Earth at the Equator.

The rotational momentum also causes the launch of rockets and launch vehicles to be more economic at the Equator. Due to that, rockets and launch vehicles can carry more payloads with less fuel if they are launched from a spaceport near the Equator compared to if they are to be launched from a spaceport far away from the Equator.

Being at the Equator is also very significant for lunar and interplanetary space flights because the Moon and planets orbital plane is most of the time parallel or near parallel to the Earth rotational plane, which is the Equator. This is why the Moon and the planets are always nearer to the Equator and never near the Poles. Therefore lunar and interplanetary missions are always launched from spaceports at or near the Equator and monitored from ground stations at or near the Equator too.

These are the 2 reasons the authors chose to study antipodal spaceports at the Equator. The authors are to locate an effective 2 spaceports which are antipodal to each other. If the spaceports can be located, the authors will propose a concept of spaceplane that is going to be most effective to fly between the spaceports.

THE ANTIPODAL EQUATORIAL SPACEPORTS

Most of the equatorial points on the surface of Earth are either both in the sea or ocean or one of them is in the sea or ocean simply because most of the Earth's surface is either seas or oceans. That is true for antipodal points on or along the Equator too. However, the authors strongly believe that spaceports should be developed on landed regions for the same reason airports were built on landed regions.

If we look for antipodal landed regions along the Equator, the regions are Southern Caribbean and South East Asia. We can safely say that the distance over the great circle on the Earth's surface between Southern Caribbean and South East Asia is 20,000km. Therefore the antipodal equatorial spaceports should be one in the Southern Caribbean and another one in South East Asia.

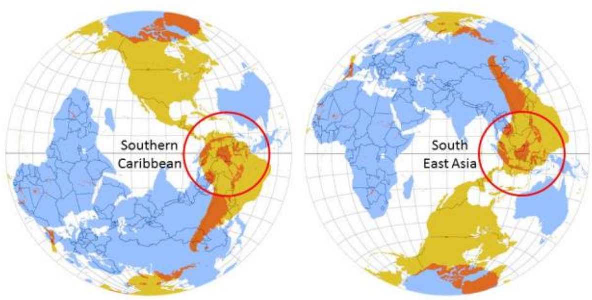

Figure 3. The antipodal landed regions along the Equator are Southern Caribbean and South East Asia. Therefore the antipodal equatorial spaceports should be in the regions.

The authors have marked each region with a red circle. The area within the red circles is where the authors believe should be the antipodal spaceports. Potential spaceports within the red circle in Southern Caribbean are Spaceport Puerto Rico, Spaceport Curacao and Guiana Space Center.

There was a plan to develop a spaceport in Puerto Rico in collaboration with Spaceport Malaysia in 2014. A delegation of the planners of Spaceport Puerto Rico has visited Malaysia and vice versa, the planners of Spaceport Malaysia have visited Puerto Rico. Puerto Rico is a state under the USA (United States of America). At this time there was already an idea of Twin Equatorial Spaceports (TEST) between these antipodal equatorial spaceports.

CERTIFICATE OF COLLABORATION

This certificate expresses the strategic collaboration between Spaceport Malaysia and Spaceport Puerto Rico for the symbiotic establishment, development and operation of the two equatorial spaceports known as TEST (Twin Equatorial Spaceports)

signed on 15 April 2014

in San Juan, Puerto Rico, the United States of America.

SPACEPORT MALAYSIA

SPACEPORT PUERTO RICO

Norul Ridzuan Zakaria
Founder & President

Sylvia Ramos
Chairman & CEO

Figure 4. The Certificate of Collaboration signed between Spaceport Malaysia and Spaceport Puerto Rico dated 15 April 2014.

Spaceport Curacao was listed by FAA (Federal Aviation Administration) as one of the commercial spaceports planned for development outside the USA. Curacao is an autonomous country within the Kingdom of The Netherlands.

#	Country	Spaceport, Latitude
1	Canada	Canso Spaceport, Nova Scotia, 45^{O}N
2	Curacao	Caribbean Spaceport, 12^{O}N
3	Italy	Grottaglie Spaceport, 40^{O}N
4	Malaysia	Spaceport Malaysia, 3-5^{O}N
5	Netherlands	Schiphol Spaceport, 52^{O}N
6	Portugal	Azores Spaceport, 38^{O}N
7	UAE	Spaceport Abu Dhabi, 24^{O}N
8	United Kingdom	Glasgow Spaceport, 56^{O}N Cornwall Spaceport, 50^{O}N Sutherland Spaceport, 58^{O}N

Figure 5. Proposed Commercial Spaceports outside USA according to FAA (2020).

Guiana Space Center in Kourou, French Guiana is operated by European Space Center (ESA). This is where major large and heavy launch vehicles such as that of Arianespace series of launch vehicles are launched. At one time Soyuz launch vehicles were planned for launching from the spaceport too.

Smaller lighter launch vehicles such as that of Vega series of launch vehicles are also launched from Guiana Space Center. In February 2015, a Vega launch vehicle with its payload, IXV (Intermediate Experimental Vehicle) was launched from this spaceport. IXV was ESA suborbital reentry vehicle meant to provide significant data for future development of point-to-point suborbital spaceplane.

The IXV mission was a successful one. It contributed significantly to the development of idea and concept of antipodal equatorial spaceports and antipodal equatorial spaceplane, the content of this paper.

The countries within the red circle drawn by the authors on the map of South East Asia are Malaysia, Singapore, Indonesia, Cambodia, Philippines, southern Vietnam and a little bit of northern Australia. There was a plan to develop a spaceport in Singapore, but certainly there is a serious plan to develop a commercial spaceport in Malaysia.

There was a plan to develop a commercial spaceport in Singapore in the very early years of 2000s. The plan however faded after realizing that factors such as STC (space transition corridors) almost make impossible operations of spaceport on a crowded small island city with busy air and marine traffic. However a spaceport restricted for suborbital flights is possible in Singapore as demonstrated by a plan to develop similar spaceport in Abu Dhabi, UAE, another small crowded country with busy air and marine traffic.

Unlike Singapore, Malaysia has ample land for selected operations of spaceport. More importantly there have been efforts to develop a commercial spaceport in Malaysia since the very early years of 2000s. More significant is the latitude of Malaysia which is close to the latitudes of Guiana Space Center, Spaceport Puerto Rico and Spaceport Curacao. For example there is currently an ongoing plan to establish a ground segment of spaceport operation in the state of Perak with latitude around 5^{O} North which is similar to the latitude of Guiana Space Center

There is a plan to establish a launch complex in Indonesia with an idea for launching launch vehicles from Papua in the far east of Indonesia. Although there have been few announcements by the Indonesian government, there is still no official takers of the plan either from the government sector or private industry.

Therefore the most likely candidates of antipodal equatorial spaceports are Spaceport Malaysia and another spaceport in the Southern Caribbean, which could be Guiana Space Center, Spaceport Puerto Rico or Spaceport Curacao. Spaceport Malaysia however is yet to decide its final location in Malaysia.

"H-LINK": THE MOST EFFICIENT TRANSPORTATION ROUTE

The main authors at USAS (Universiti Sultan Azlan Shah) hypothesized that if there are 2 routes of transportation that configured from north to south across the latitudes (latitudinal), the most efficient connection between the 2 routes is a route configured from west to east across the longitudes (longitudinal) connecting the latitudinal routes at the transit points of the latitudinal routes. Graphically, the latitudinal routes are "vertical", while the longitudinal routes are "horizontal". The authors called this hypothesis, "H-Link" because those routes when they are connected looks like the alphabet "H". In the real scenarios, vertical routes may not really be vertical, but at angles approaching vertical. So does the horizontal route that it may not really be horizontal, but approaching horizontal.

The continent of America consisting of North America and South America can be considered as being configured from north to south or vertically. Conventional flights from North America (USA and Canada) are configured to fly "vertically" southward when they wish to reach destinations in South America and vice versa. There can be a transit point for the flights from both direction between North America and South America. Flights from major cities in North America and South America can reach the transit point in Southern Caribbean within 5 to 7 hours.

The continent Asia and Oceania can also be considered as configured from North to South although as for Asia it also lie from west (Middle East) to east (Far East). The flights from the Middle East including the Arab Peninsular and Far East including Japan and China fly "vertically" southward if they wish to reach destinations in the Oceania particularly Australia. They however can stop at a transit point in South East Asia after flying within 5 to 7 hours too.

Therefore Southern Caribbean can be a hub for flights from North America and South America, while South East Asia can be a hub for flights between Middle East or Far East and Oceania. These hubs or transit points are the most potential antipodal spaceports because the suborbital hypersonic flight between the spaceports will be the "horizontal" flight connecting the 2 "vertical flights" as in the H-link hypothesis. The geolocation of the antipodal spaceports at both in Southern Caribbean and South East Asia is perfect for the H-link to be effective. The meaning of effective is not only the "shortest" or "fastest", but also the "safest".

The H-Link is actually very important because the "vertical" flights will be the feeders to the "horizontal" antipodal equatorial flights. Those conventional airplanes will be feeding passengers and payloads to the spaceplane. This will be very important so that the antipodal spaceflight will be cost effective.

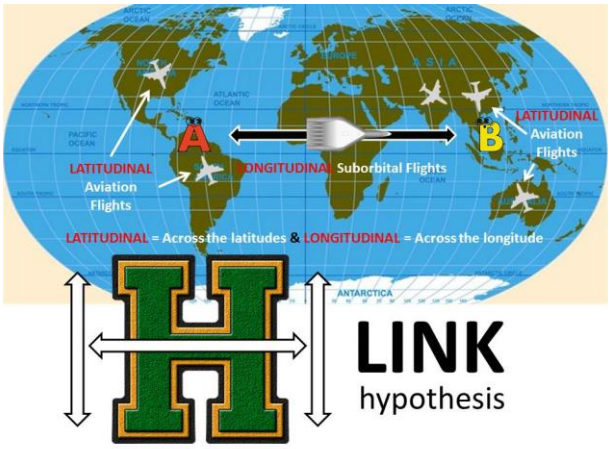

Figure 6. H-link is a hypothesis by the main authors stating that 2 latitudinal or vertical routes can be very efficiently connected by a longitudinal or horizontal route. In this case the latitudinal routes are conventional flights from the north to south and vice versa and the longitudinal route is the spaceflight connecting the transit points of the latitudinal flights.

SAFETY FEATURES ALONG THE ROUTE

In planning the antipodal equatorial spaceports, safety features along the route should also be given attention. Emergency landing sites and tracking facilities for the spaceplane should be established along the route.

In an exercise conducted in 2014, where Spaceport Puerto Rico and Spaceport Malaysia were simulated as the antipodal equatorial spaceports, emergency landing sites were set up between the spaceports, particularly in the oceans. For an eastbound flight from Spaceport Puerto Rico to Spaceport Malaysia, 2 sites for emergency landing were identified; Praia, Cape Verde in Atlantic Ocean, and Male, Maldives in Indian Ocean. Both islands are capable of supporting an emergency landing of the spaceplane on land to avoid landing on water in the oceans.

THE ANTIPODAL EQUATORIAL SPACEPLANE

The distance over the great circle on the Earth's surface between Southern Caribbean and South East Asia is 20,000km. Therefore the antipodal equatorial spaceplane to fly between the antipodal equatorial spaceports in Southern Caribbean and South East Asia must be able to fly for a distance of at least 20,000km. This is the most important technical requirement which influence the specification of the spaceplane.

Another very important requirement influencing the specification of the spaceplane is the flight time to enable the objective of the "spaceline services" between the spaceports, which is to enable passengers fly between the spaceports and be back home within the same day or 24 hours inclusive of time taken for all spaceports handlings and his or her activities at the spaceports.

The authors have visualized a scenario, where a passenger spent 2 hours after his/her arrival at the home spaceport before boarding the spaceplane to fly to the other spaceport for 4 hours. Upon arrival at the other spaceport, he/she check-in at a lounge, rested and had a meal for 2 hours. Then he/she had a meeting for 3 hours at the meeting room near the lounge. 1 hour later he/she boarded the spaceplane and flew back to his home spaceport for 4 hours. Finally he/she spent another 2 hours for a light meal and clearance at the home spaceport. Therefore the passenger has completed his tasks of twice travelling onboard the spaceplane, resting, having meals, meeting and settling clearances at both spaceports within 18 hours, with another 6 hours available for other travelling (total 24 hours).

This visualized scenario calls for a spaceplane that is able to fly for at least 20,000km in 4 hours or less, meaning the spaceplane has to be able to travel at the speed of 5000km/h or Mach 4.0. There was a manned hypersonic aircraft operational in the 60s called X-15 which was able to fly at the speed above Mach 6.0. There was also a manned supersonic aircraft started operating in the 60s and remained in operation until 1999 called A-12 and later SR-71 Blackbird that was able to fly at over Mach 3.0. The manned operation of both aircrafts has shown that human passengers can be safely flown between Mach 3.0 and Mach 6.0 with suitable "safety" cabin. In this case, the spaceplane will be more towards the Blackbird rather than the more extreme X-15 in term of speed.

Figure 7. A photo of A-12 captured by the leading author from the observation deck at the front of California Science Center in 2009.

The Authors have written a paper describing a new conceptual design of aircraft called Y-fuselage which according to the authors is applicable for long distance across the ocean point-to-point suborbital spaceplane. The concept is called Y-fuselage because it looks like an alphabet "Y" with a single fuselage at the front and twin fuselages at the rear. One of the most important advantages of the Y-fuselage configuration is that it can be designed to be high seaworthiness which will be very significant for safety when flying across seas and oceans. This Y-fuselage design is proposed as the configuration for the antipodal equatorial spaceplane.

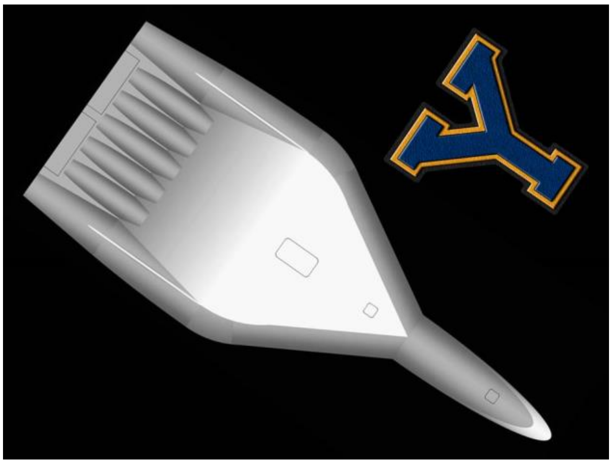

Figure 8. The Antipodal Equatorial Spaceplane in Y-Fuselage Configuration.

The wingless structure is actually a floating body more suitable for suborbital flight above the Karman line of 100km from sea level. The spaceplane however is meant not to be wingless, but it will be equipped with extendable/retractable wings. The wings are to be functional and useful when flying in thick atmosphere at low level and during landing.

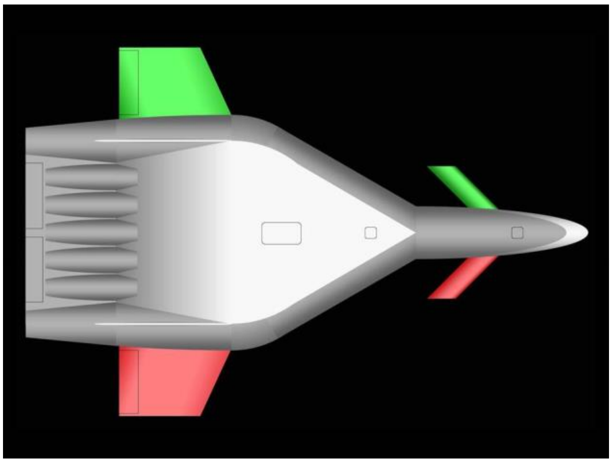

Figure 9. The spaceplane will be equipped extendable/retractable wings.

X-15 was powered by rocket propulsion, while the Blackbird was powered by a combination of turbojets and ramjets. As for the spaceplane, the authors proposed it to be powered by both rockets and turbofans. The rockets are to be used for launch and suborbital flight while the turbofans are to be employed for horizontal landing on runways as during landing, the rocket fuel will been depleted. This is for safety and economy.

The authors proposed the spaceplane to be power-air-launched from "universal carriers" for safety and economy. Universal carriers are popular conventional fixed-wing large passenger jets such as Airbus A330, A340, A350 and A380 or Boeing 747, 757, 767, 777 and 787 or Ilyushin Il-96.

Since the universal carriers will serve as the first stage of this air-launch transportation system, the design and development of the spaceplane should be executed with the collaboration from the manufacturers of the universal carriers, be it Airbus, Boeing of Ilyushin. This will only increase the safety and economics of the system.

The usage of these passenger jets will enable the usage of existing airports and airport facilities for safety and economy and a possibility of some airports to be upgraded into spaceports offering both conventional aviation and spaceflight. The spaceplane is to be power-air-launched from above the rooftop of those universal carriers, unlike X-15 or Virgin Galactic SpaceShipTwo that were launched from below the wing of their carrier airplane. Launching from the rooftop will allow larger spaceplane operation. The authors proposed the spaceplane to be launched from ULAR (Universal Launch from Air Rail) a rail system fixed on the rooftop of the universal carriers. ULAR is universal in such a way that it can be fixed on the rooftop of all the universal carrier airplanes.

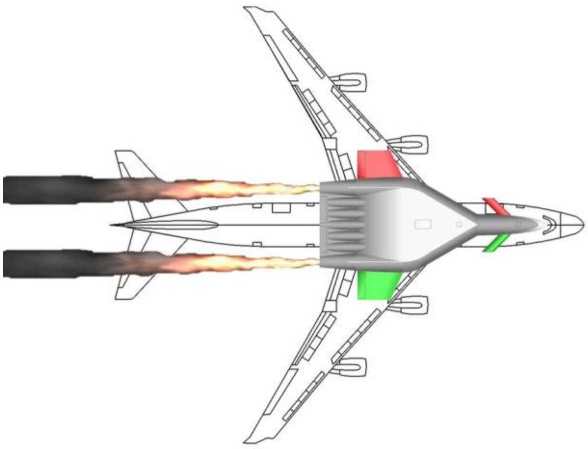

Figure 10. The spaceplane is to be air-power-launched from universal carrier, which is a popular conventional fixed wing large passenger jet for safety and economy.

The authors proposed the spaceplane to be able to accommodate 90 passengers also for safety and economy. The passengers will be placed inside a safety pressurized cabin in the shape of a triangle located at the center of the spaceplane. This is the strongest and the most stable structure within the spaceplane.

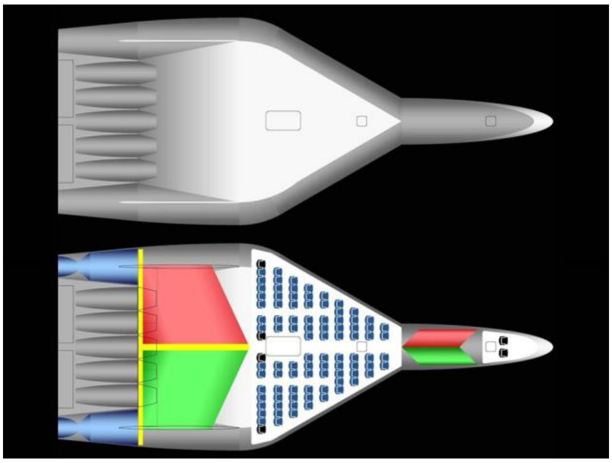

Figure 11. The cabin at the center of the spaceplane can accommodate 90 passengers and is the strongest and most stable structure within the spaceplane.

As the flight is to last for 4 hours, the passengers will be given access to foods and beverages (F&B). There was a study conducted in 2010 by the leading author and other researchers in Malaysia of an F&B system for space hotels in orbit. The system proposed the foods and beverages to share a spherical container to be delivered to the guests of the orbital hotels using a vacuum system. After the guests have consumed the meal, they will return each container into the vacuum system. Therefore the vacuum system is to be a 2-way delivery system. A similar system is proposed to be utilized onboard the spaceplane so that meals can be served without the need of crews or flight attendants. However, there will be holographic flight attendances (HFAs) entertaining the passengers onboard the spaceplane while in flight.

In one exercise, the leading author and other researchers in Malaysia have proposed the employment of holographic flight attendants (HFA) on board suborbital spaceplane. The HFA was among the few new technologies proposed to be employed onboard an upgraded version of Dream Chaser spaceplane for carrying passengers. Those technologies were presented to a technical team of Sierra Nevada Corporation which visited Malaysia in 2013.

As the spaceplane is to fly above seas and oceans during most of its flight, seaworthiness will be a major safety factor. The spaceplane must be able to survive emergency landing on the water and able to stay afloat better than other aircrafts in the seas and oceans. The Y-fuselage configuration which will enable the turbofans to be installed above the empennage at the rear end of the spaceplane will only enhance its seaworthiness, because such installation will avoid intrusion of seawater into the turbofans. If the turbofans still operate after the emergency landing, they can be used to provide limited and controlled thrust to move the spaceplane on the water.

For further safety, there is an exit door on the roof of the spaceplane, where the passengers can safely exit the cabin when the spaceplane is landed on the ground or on the water during emergency. For example, after the spaceplane has safely landed on the water due to an emergency, all the passengers will be able climb out of the cabin and exit through the roof door and they may wait for rescue while staying dry on the rooftop of the spaceplane, if being on the rooftop is better in term of safety than staying inside the cabin.

The authors have visualized another futuristic scenario to further explain the operation of the antipodal equatorial spaceplane. According to this scenario, a universal carrier carries the spaceplane on its rooftop to its normal flight altitude of 15,000m from the sea level after taking off from the 1st antipodal equatorial spaceport. During this time the spaceplane had its wings fully retracted to increase its aerodynamic and stability while being carried on the rooftop of the carrier.

After orienting the carrier at a positive angle towards the 2nd antipodal equatorial spaceport, the spaceplane ignites its twin rocket engine and power-air-launches itself from the rooftop of the carrier. This is to provide an initial orientation of the spaceplane toward space to enable the spaceplane to reach space the safest and most economic.

The rockets take the spaceplane into a “large arch” flight profile where a region at the zenith of the arch is above the Karman line of 100km from sea level. When the spaceplane reaches this region and this height, all its passengers and crews are certified as “astronauts”. During this whole phase, the wings of the spaceplane are still fully retracted.

After passing this region, the spaceplane starts to descend and perform reentry while still maintaining the large arch flight profile. Its rocket fuel has been depleted by this phase to ensure safety and economy. To maintain its height or reduce the effect of gravity in its large arch flight profile, the spaceplane may employ ABU-MAT (Auxiliary Booster Unit for Medium Altitude Trajectory), which is a relatively small rocket booster with multiple solid fuel canisters under the rear belly of the spaceplane specially designed for such purpose.

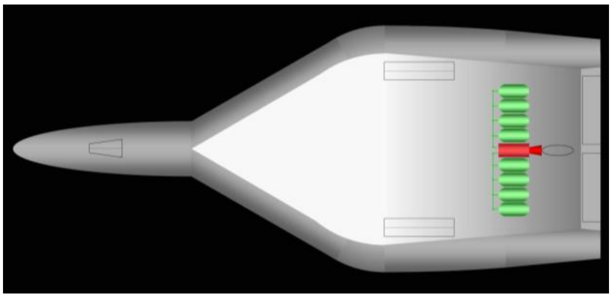

Figure 12. ABU-MAT (Auxiliary Booster Unit for Medium Altitude Trajectory) is a relatively small rocket booster with multiple solid fuel canisters under the rear belly of the spaceplane.

When reaching 15,000m from sea level, the spaceplane extends its wings and ignite its 5 turbofans. The number of the turbofans is proposed to be 5 to limit their diameter so that they don’t need to have such large diameter if they are lesser (2 or 3 units instead of 5), which will negatively affect the aerodynamics. With the wings and turbofans, the spaceplane safely lands horizontally on the runway of the 2nd antipodal equatorial spaceport.

Figure 13. An Illustration of a Y-fuselage antipodal spaceplane landing horizontally at an antipodal spaceport by the presenting author.

FUTURE PLANS

The authors plan to write to the authorities governing Guiana Space Center and government agencies overseeing the planning of Spaceport Puerto Rico and Spaceport Malaysia to be aware of the potentials available to them for the operation of antipodal equatorial spaceports and antipodal equatorial spaceplane and to take advantage of those potentials.

CONCLUSIONS

There is a great potential in the operation of antipodal equatorial spaceports and antipodal equatorial spaceplane. As for the spaceports, one shall be in the Southern Caribbean while the other one shall be in South East Asia as the Southern Caribbean is antipodal to South East Asia to take advantage of all the antipodal and equatorial factors. As for the antipodal equatorial spaceplane, it shall be designed and developed specifically to fly between the 2 spaceports the safest and most economic, with the objective to enable its passengers to be back home within the same day (24 hours) after completing his or her tasks at the other end. As the distance between these antipodal equatorial spaceports is approximately 20,000km or half the circumference of Earth, the spaceplane need to be able to fly at Mach 4.0 for safety and economy. It is very important for the safety that the spaceplane to have high rate of seaworthiness because most of its flight will be above the seas and oceans.

The development and operation of antipodal equatorial spaceports and spaceplane will contribute effectively to the development of economy not only at the spaceport regions, but also globally as there will be economic collaboration involving international airline services, major aircraft manufacturers, infrastructures development along the route between the spaceports consisting of emergency landing sites and tracking stations and orbital satellite services. The spaceports and spaceplane will not only provide rapid transportation between the spaceport regions, but actually between "the western hemisphere" and "the eastern hemisphere" and in doing so will contribute significantly to the sharing of economy and hence the political stability between the two hemispheres.

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