Affordability Advantages in Integrating the Aircraft and Space Launch Operations – Part 2

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ABSTRACT

This is a follow-on paper of our 2012 work with the same title[i]. Both papers have the same goal of providing a high-level concept that shows a Hybrid Suborbital Aircraft (HSA) can be used for passenger Point-To-Point (PTP) and Earth-To-Orbit (ETO) operations to achieve remarkable costs reductions. While the original paper introduced us to the concept and the cost advantages, we hope this paper will refine and optimize the concept. We will investigate what loads would be on such aircraft and is it possible to achieve our goal of transporting 100+ passengers more than 4,000 miles or delivering a 100,000 lb gross weight upper stage and payload to the Karman line. Such an upper stage delivered to the Karman line should be capable of transporting 20,000 lb to low earth orbit. By developing and operating two versions (a passenger PTP version and a ETO version) of the same aircraft we hope to show remarkable development and re-occurring cost savings can be achieved that couldn't materialized if operated as a single function aircraft. In future papers we will continue our investigation of the SABRE, LACE or modified turbojet engines that utilize liquid methane to cool inlet air so that it can be compressed and burned in our liquid rocket engines. Also in future papers, we will also investigate the design of a re-usable manned and unmanned upper stage that transport payload from the HSA to Low Earth Orbit as well as the Thermal Protection System and building frame and materials of the HSA.

In this paper we hope to determine:

- **What is the size of the Hybrid Suborbital Aircraft (HSA) and how does it compare to the original Concorde?**
- **What are the ETO-HSA design Considerations?**
- **What are the upper stage dimensions and which engines and propellants will be selected?**
- **What are the sequence of operations to launch an upper stage off of a HSA?**
- **How does delivering Payloads to LEO relate to airline passenger service?**
- **How does the cost of the Boeing 787 or Concorde relate to lowering the cost to orbit?**
- **How many PTP-HSA aircraft will be needed, how will the fleet compete?**
- **How does the PTP-HSA compare to the Concorde fleet business model?**
- **How is the PTP-HSA different than the Concorde?**
- **What is the PTP flight range, flight path, wing loads, and inlet conditions of the different versions of a 410,000 lb gross weight PTP-HSA?**
- **What is the maximum staging speed and altitude a 410,000 lb gross weight ETO-HSA can transport an upper stage?**
- **How much heating will build up on the aircraft as it reenters the atmosphere and what counter-measures should be taken to mitigate this heating?**

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I. NOMENCLATURE

PTP	= Point-To-Point
HSA	= Hybrid Suborbital Aircraft
ETO	= Earth-To-Orbit
LEO	= Low Earth Orbit
LOX	= Liquid Oxygen
LH_2	= Liquid Hydrogen
CG	= Center of Gravity
Delta V	= delta velocity
GLOW	= Gross Liftoff Weight
MTOW	= Mean Takeoff Weight
RP1	= Rocket Propellant Number One
SRB	= Solid Rocket Booster
US	= United States
SUSTAIN	= Small Unit Space Transport and Insertion
#	= pounds or number
K	= thousand
M	= million
B	= billion
$	= dollars
Ave	= average
ACMI	= Aircraft, Crew, Maintenance, and Insurance
QD	= Quick Disconnect
~	= approximately
hr	= hour
lb	= pound
LNG	= Liquid Natural Gas
a.k.a	= also known as
PCM	= Passenger Compartment Module
&	= and
m/s	= meters per second
Atm	= atmosphere
psi	= pounds per square foot
K	= Kelvin
kg/m^3	= kilograms per cubic meter
km	= kilometer
sec	= second
DDT&E	= Design, Development, Testing, and Engineering

II. BACKGROUND

In the previous paper of the same title, we introduced the concept of using a supersonic aircraft to transport an upper stage to a very high altitude, namely the Karman Line. We also provided a modification of the fictitious supersonic aircraft whereby it contained liquid rocket engines that would ignite once the aircraft reached a designed cruising altitude and speed using conventional air breathing engines; in this case, we chose 60,000 ft and Mach 2. Bear in mind that <u>we are using the supersonic aircraft to perform much of the same launch vehicle functions as the first stage of a 20,000 lb payload class of launch vehicle</u>, such as a Delta IV medium, an Atlas V 401, or a Falcon 9 v1.0. To get a measure of the enormity to the re-occurring cost savings we are proposing, you should compare the costs of building, processing, and operating just the first stage and ground support equipment of those vehicles to the costs of operating a commercial aircraft.

As we previously stated in that paper, most passenger aircraft (including supersonic aircraft) have propellant carrying capacity to travel for many hours after reaching cruising altitude since these same aircraft can reach cruising altitude and speed in less than 30 minutes. We wish to utilize this propellant capacity to operate the liquid rocket engines while they propel the supersonic aircraft from cruising altitude to the Karman Line and beyond.

In that same previous paper, we provided the lower and upper limits on the costs of operating a commercial (747 size) aircraft via their ACMI and private charter rates as being between $4,600 and $60,000 per hour respectively. We used this information to determine the lower and upper operating costs of using some sort of **highly competitive**, commercial, supersonic aircraft to launch our upper stage to the Karman Line as between $102,000 and $305,000.

How significant are the re-occurring cost savings if the first stage costs only $305,000 for a 20,000 lb payload class launch vehicle? We know that the cost (purchase price) of an expendable Centaur class upper stage is approximately $28 million. When this cost is compared to the marginal cost of operating the HSA, we see the cost of the HSA falls within the margin of error and goes away. If we assume the second stage to our system utilizes the same expendable Centaur class upper stage as a Delta IV medium, we see that the cost of the Delta IV medium Common Booster Core goes away. Since the cost (purchase price) of a Delta IV medium is approximately $140 to $170 million, then the savings of using the HSA could be $110 million or more during each mission.

What we finally concluded in that paper was that if our findings were within an order of magnitude of being correct, such a launch system would be a **revolutionary leap** in reducing the cost of going into orbit!

III. INTRODUCTION

The key phrase from the background section is that a supersonic aircraft that can transport upper stages to the Karman Line must also be HIGHLY COMPETITIVE in the commercial passenger market. The commercial passenger airline industry absolutely dwarfs the Earth-to-Orbit (ETO) transportation market ($5,000B vs $2B) via 642 million passengers on 8.9 million airline flights each year [ii] vs less than 543[iii] to EVER go into space with a maximum of only 26 commercial space flights each year.

Consider the cost to launch a commercial rocket that would take 7 passengers to Low Earth Orbit at a total cost of $140 million[iv] while consuming 46,300 gallons of LOX and 29,600 gallons of kerosene[v]. The cost of operating a commercial aircraft that transports 271 passengers over 8,578 miles (Qantas Flight 7, the world's longest non-stop flight[vi]) while consuming 63,705 gallons[vii] of kerosene during the 15.5 hour flight is relatively low in comparison. We know the costs are low to operate the airplane because the estimated ticket revenue for this 8,578 mile flight is less than $600,000 whereas most of the tickets costs $1,716[viii] round-trip while spending approximately $382,200 just on fuel at $3.00 per gallon. From this economic exercise it should be relatively simple to advocate that the means of reducing the costs of going into space starts with utilizing a commercial aircraft system.

In the previous paper, we offered a high-level design of an aircraft that had the characteristics of the Concorde except that after it reached cruising speed and altitude, a rocket engine was utilized to push the Concorde to very high altitude where an upper stage could be launched. We will refer to such an aircraft in this paper as a Hybrid Suborbital Aircraft (HSA), or a Space Truck, or the Space El Camino.

IV. SIZING THE HSA

What is the size of the Earth-To-Orbit (ETO) Hybrid Suborbital Aircraft (HSA) and how does it compare to the original Concorde?

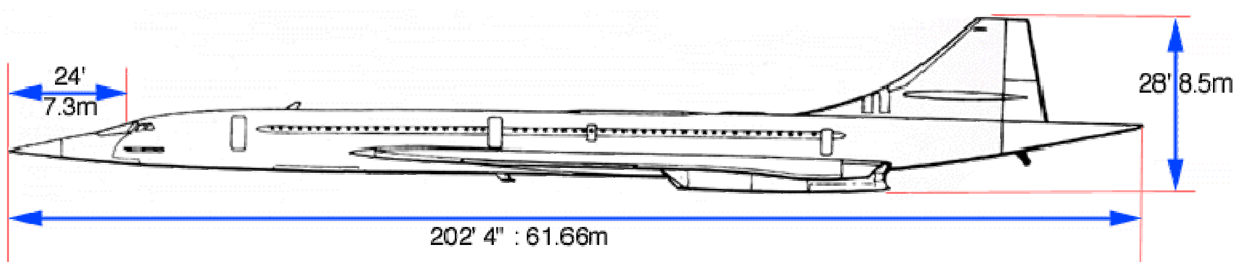
We wish to answer that question by working backwards from payload capacity. In an accompanying paper, we expound the benefits of an aerospace funding program called Space Billets that provides a guaranteed flight rate at a guaranteed rate per pound. As greatly illustrated in that paper, a normal Space Billet is an open ended fixed contract that is worth $20M for transporting 10 tons or 3 astronauts to Low Earth Orbit (LEO) at a guaranteed flight rate of 250 missions per year ($5 billion per year). Using Space Billets as a ground rule, we need to design a launch system that would deliver 20,000 lbs to LEO.

From our original paper we assumed the HSA would discharge the upper stage at an equivalent altitude of 100 km (62.5 miles) and zero velocity, which is often referred to as the Karman Line. If we assume the 100,000 lb upper stage is some version of a pressure-stabilized upper stage, similar to the Centaur that utilizes RL-10 engines, we can estimate the amount of payload that can be delivered to LEO via the rocket equation as: 18,872 lb total and 9,982 lb usable. While the 9,982 lb of usable payload is almost exactly half of the 10 tons amount desired for Space Billets, we started with zero velocity at the Karman Line and with some modifications and further development of the aircraft, we can deliver the upper stage to higher altitudes or with some initial forward velocity.

Had the aircraft staged the 100,000 lb upper stage at 7.86 Mach and 162,000 meter altitude, 28,700 lb of total mass (of which 16,100 lb is payload) can be transported to a 125 mile circular orbit. The 16,100 lb of usable payload is close to fulfilling the requirements of a 10 ton Space Billet mission, but the Mach 7.86 speed of the aircraft and upper stage ejection may sound un-realistic, so we need to determine what is a realistic speed that can be obtained by our aircraft before we can determine if the gross mass of the upper stage needs to increase or decrease to meet our 10 ton of usable payload requirement.

In the paragraph above, we stated equivalent velocity because the upper stage could be discharged much earlier and merely travelled ballistically until it reached the Karman Line without any further acceleration. Simple motion equations will show that an object travelling vertically at **Mach 3.45** will ballistically reach the Karman line from a starting altitude of 30 km (~100,000 ft) in 120 seconds. What this means is that if the SR-71 "Blackbird" crews so desired, they could have pointed their aircraft straight up and nearly reach the Karman Line and get their astronaut wings. And if the 50 year old technology in an SR-71 can reach the Karman Line without the use of rocket engines, then it should be possible to design (with today's advances in materials and computer analysis) and develop an aircraft today to reach the Karman Line while transporting 100,000 lb of payload/upper stage. And finally, if the SR-71 aircraft traveled at 45 deg to the horizontal instead of straight up it would reach an altitude of 66.8 km at a horizontal speed of Mach 2.45.

Figure 1: Side view of reference aircraft; A Concorde



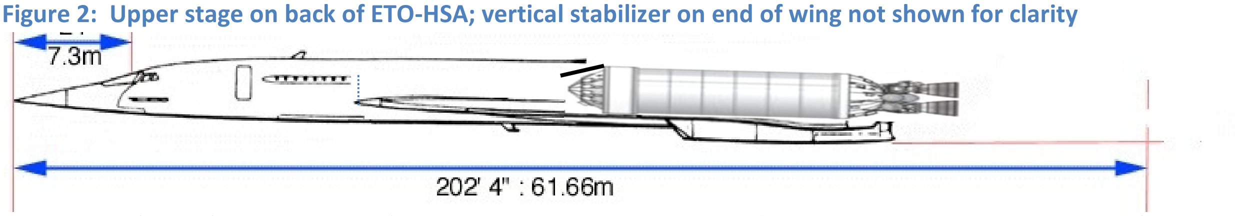
V. ETO-HSA Design Considerations

We intend to launch an Earth-To-Orbit (ETO) upper stage off of the HSA while it is being propelled by liquid rocket engines past the Karman Line after it has been propelled to supersonic conditions via air breathing engines. Some of the problems that we wish to address with this concept are:

- Explosive vapors from upper stage
- Staging of Upper Stage
- Fuel to Base after Mission
- Pre-Conditioning of Upper Stage Engines
- Loading & care of astronauts and payloads
- Transport of Command Center
- Location of Vertical Stabilizer(s)

In order to eliminate any potential accumulation of explosive hydrogen gases, we propose that the upper stage be placed outside of the aircraft while also outside of the airstream. We wish to accomplish this by removing the walls and ceiling of the aircraft around the upper stage. That is to say, the back part of the aircraft would have a flat floor, but nothing above the floor. The upper stage would be mounted onto the floor of the aircraft and only its wings (if it has any for a reusable return to earth) would stick out into the airstream.

Figure 2: Upper stage on back of ETO-HSA; vertical stabilizer on end of wing not shown for clarity



In front of the upper stage is the payload or manned capsule (but the capsule could also be part of the upper stage in a fully reusable manned upper stage). The sides of the aircraft only envelope the payload or capsule. An air tight, high pressure seal is formed between the aircraft and the very top of the upper stage so as to allow last minute hands-on touch of capsule, payload, or space travelers.

In front of the payload or capsule is the Command Center which houses up to 16 operators and their stations in a self-enclosed environment with the HSA pilots. The command center is the normal size fuselage which is approximately the same size as the Concorde or 9 ft 5 inch external. While approaching the Karman line, operators must retreat into the Command Center before the air tight seal is broken with the upper stage. After the upper stage has been staged from the HSA the part of the aircraft that enveloped the payload / capsule would come together to form an aerodynamic fairing.

Since the latter part of the ETO-HSA fuselage is a flat floor, the vertical stabilizer would need to be located at the two outer ends of the delta wing. Also on the outer end of the delta wing would be any thrusters that would control the aircraft after it left the atmosphere. There may be additional thrusters in the nose of the aircraft. The use of hydrogen and oxygen for the rocket engines on the aircraft and upper stage will provide gaseous hydrogen and oxygen for thrusters and APUs.

Fuel to Return to Base after Mission

Since the wing of a supersonic aircraft is very thin as you approach the end, it would be very difficult to insulate that portion of the wing. On the Concorde, this area of the wing was represented by fuel tanks 5a and 7a and they only held 2,225 kg of fuel each[ix]. Since our aircraft would need very little fuel on its return route back to the airport, but still needs fuel to be held in these tanks as the HSA re-enters the atmosphere for thermal control, these two tanks should continue to carry Jet-A fuel. The four supersonic engines burn a total of 1,100 kg/hour while idling, so the 4,450 kg of fuel in these two tanks should be sufficient for most of the return flights back.[x]

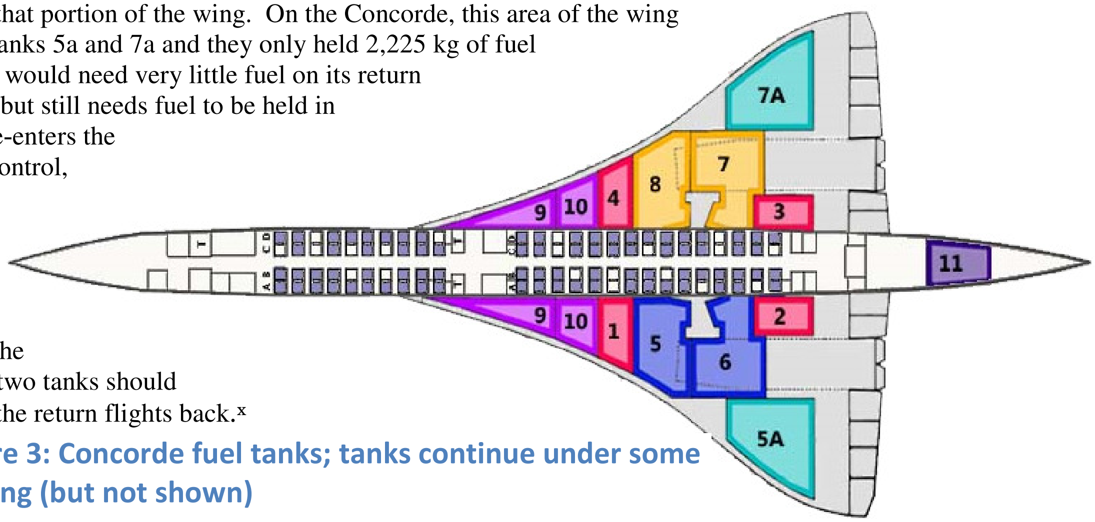


Figure 3: Concorde fuel tanks; tanks continue under some seating (but not shown)

Turbopump Conditioning

One of the most difficult tasks in launching rockets is to pre-condition the liquid rocket engines so there isn't any chance that vapor will travel through the turbopump or other critical plumbing. This task is easily accomplished on the launch pad by sending a trickle of cryogenic fluid through the engine up until time of use. It is not possible without consuming a large portion of the propellant capacity to continuously send a trickle of cryogenic propellant through all liquid rocket engines during the 30 minutes it takes for the traditional air breathing engine to propel the aircraft to the cruising altitude and speed. Our chosen method to overcome this problem is to locate the turbopump inside the propellant tank so it only sees the cryogenic temperatures without actually consuming liquid propellant.

Upper Stage Dimensions

We are proposing that the upper stage mass is 80,000 lb and would resemble a centaur upper stage in the expendable form. Because the ETO-HSA does not achieve the optimum staging speed of Mach 10, but only achieves Mach 7.8, our second stage will need to provide more energy and more thrust. More thrust is obtained by utilizing 5 equivalent RL10-B2 engines and more energy is obtained by enlarging the upper stage to hold more propellant.

Our notional upper stage is similar to that of a Centaur V2 in that it is 10 feet in diameter and would stick out a bit in the airstream if the aircraft fuselage was the same as Concordes' at 9ft 5in. Our proposed upper stage is larger than the Centaur V2, which weighed 50,810 lb gross and 4,960 lb dry. The Centaur V2 is 10 feet in diameter by 41.6 ft long[xi]. In order to hold nearly 28,000 lb of more propellant (21,000 lb LOX & 7,000 lb LH2), the V2 would need to grow by 24 feet in length for a total of 65.6 ft; we estimate the dry weight of the enlarged V2 with five equivalent RL10 engines to be 12,300 lb. The Concorde fuselage from the flight deck door to rear bulkhead is only 129 feet long and the first 12 rows of seats would be taken up by a command center that would monitor and control the upper stage and payload. This would leave over 31.9 feet of length for the payload or capsule.

Figure 4: Calculating the length of fuselage available for payload using Concorde as model

Total length of Concorde	202.333	feet
Length of fuselage from flight deck door to rear bulkhead	129.000	feet
Length of fuselage dedicated to entry way, lavatory, Command Center, & bulkhead	39.000	feet
Length of fuselage for upper stage and payload	90.000	feet
Length of conventional Centaur V2	41.600	feet
Added length of Centaur V2 to hold 28k lb of more propellant	24.000	feet
Total length of lengthed Centaur V2	65.600	feet
Length of RL10A-4 engine	7.500	feet
If RL10 engine overhangs, Length of Centaur on Concorde fuselage floor	58.100	feet
Length of Concorde fuselage remaining for payload or capsule	31.900	feet

From the table above, we have more than enough room at 10 ft diameter by 31.9 ft of length for a 20,000 lb payload. If needed, some of the length of the command center can be reduced to provide even more length for the payload. Just as a reference on the amount of payload capacity and height needed for a manned capsule, the seven seater SpaceX Dragon capsule is 20 feet tall by 12.1 feet in diameter, but has a dry mass of just 9,300 lb[xii].

Engine Selection for Upper Stage

In the example above, we based our upper stage performance and dimensional calculations upon five equivalent RL10 engines. The problem with the standard RL10 engine is that it causes horrible aerodynamic drag because of its large bell shape nozzle. In order to reduce the aerodynamic drag from the upper stage, we must install an expendable fairing or utilize an aerospike engine. A LOX-hydrogen, expander cycle aerospike engine would be the ideal engine for the upper stage for the following reasons.

- Hydrogen is the most efficient fuel; providing 60,000 btu/lb versus only 20,000 btu/lb for most hydrocarbons.
- With a staging mass of 100,000 lb, our LH2-LOX upper stage can transport 16,400 lb to a 138 mile high orbit, where as a RP1-LOX upper stage of the same mass can only transport 9,876 lb of useful payload to a 98 mile high orbit.
- Expander cycle engines have been demonstrated to be refurbished and reflown within several hours of use on the Delta Clipper project[xiii].
- Again, the elimination of a bell nozzle on the rocket engine is required for a supersonic aircraft; thus the absolute necessity for the aerospike engine for both HSA and upper stage.

The problem with the aerospike engine is that there is very little test data and no flight data using the aerospike engine configuration. Rocketdyne test a toroidal aerospike engine in 1967 that was pressure fed, utilized LOX-LH2, and produced nearly 250,000 lb of thrust[xiv]. In 1998, Lockheed Skunkworks was testing the RS-2200 Linear Aerospike Engine as part of their Venture star project[xv]. The RS-2200 engine produced nearly 500,000 lb of thrust using LOX-LH2 and used a gas generator cycle.

Launch Sequence of Operations for ETO-HSA

- Days, weeks, or months before launch; a Quick-Disconnect adapter is attached to the payload or crew capsule
- Launch crew travels to HSA upper stage recovery and refurbishment and installs HSA upper stage onto back of HSA
- Launch crew travels to location of payload or capsule processing and picks up same with the QD adapter and quickly attaches Payload and QD to upper end of the HSA upper stage.
- ETO-HSA travels to launch site (airport) and all tanks are filled with propellant
- **LAUNCH!** Afterburners on supersonic engines are only utilizes for the first 2 minutes of flight and as the aircraft goes through transonic
- HSA air breathing engines solely provide thrust until the HSA reaches Mach 2 at an altitude of at least 60,000 ft.
- Just before HSA rocket engines ignite, Command Center personnel retreat to Command Center through bulkhead, and seal off back of plane.

- HSA **and** Upper Stage rocket engines are ignited and air intakes into the air breathing engines are closed. Upper stage rocket engines are fed propellant from HSA via umbilical. By igniting the Upper Stage rocket engines at this point, we verify the condition of the engine way before it is really needed after Upper Stage Separation.
- As the HSA approaches the Karman Line, the seal with the upper stage is retracted in preparation of upper stage jettison.
- Upper Stage engines are throttle back to idle while HSA engines remain at full power for final 3 seconds before Upper Stage Separation.
- **UPPER STAGE SEPARATION!**
- HSA speeds away by firing at full throttle for another 3 seconds; then are shut down. At the same moment, the Upper Stage engines are brought back up to full power
- Upper Stage engines fire for approximately 361 seconds total (or 278 seconds since upper stage separation) until orbital velocity is obtained.
- Upper Stage jettisons Payload, but retains QD adapter.
- **Payload is delivered to LEO!**
- Upper Stage ignites and fires aerospike engines again with GO2/GH2 thrusters to deorbit; tail first.
- Since it has no wings, the Upper Stage uses thrusters to keep its heavy aft end flying tail first as it enters the atmosphere
- Similar to the Apollo Capsules, once the Upper Stage has gone through the atmosphere and has reached terminal velocity, it deploys parachutes to slow down to under 19 mph.
- At 500 ft, parachutes are jettisoned and aerospike engines are re-ignited for the third time.
- The Upper Stage utilizes remaining propellant in aerospike engines and/or thrusters to land upright, on legs as demonstrated by the Delta Clipper project.
- 1,606 lb of propellant will allow the Upper Stage aerospike engines to fire for 10 seconds and provide a change in velocity of 600 m/s (Mach 2) to the empty Upper Stage (that doesn't have a payload) and land upright on legs.

VI. Develop profitable supersonic airliner in order to modify into space launcher

How does delivering Payloads to LEO relate to airline passenger service?

Some may say, "*So What, I have seen other aerospace engineers promote ludicrous savings with their launch vehicles including those who first promoted the Space Shuttle. How is this system different than anything else that has been promoted?*" What is different in this paper is the proposed vehicle starts out as a highly competitive aircraft fleet of at least 75 aircraft that are each making several Point-To-Point flights each day. No government money (and because of it no government interference with the design) will be needed by the launch vehicle venture. By manufacturing 75 aircraft, we have spread out the development cost until each $1 billion in development cost only adds $13 million to the cost of each aircraft. Boeing spent approximately $12 billion with private enterprise money in developing the 777 and NASA spent $15 billion to develop the Space Shuttle, so we could safety assume that $12 to $15 billion is the upper limit on the amount of funding needed to develop our Hybrid Supersonic Aircraft[xvi]. The $12 billion of development cost could be amortized across each of the 75 aircraft by adding only $160 million to their purchase price. By way of comparison, Boeing will produce over 5,000 of its 787 aircraft in the next 7 years that will cost over $32 billion to develop and has an average sell price of $211 million. If the development cost was amortized across those 5,000 aircraft, it would add no more than $6.4 million to their price or 3%. Also by way of comparison, NASA spent $15 billion to develop the Space Shuttle, but only had a total of 145 flights. If that development cost was amortized over those 145 flights, **each flight** would have $157 million just in development cost added to their marginal costs, including 3% interest over the program's 30 year life.

How Does the Cost of the Boeing 787 or Concorde relate to Lowering the Cost to Orbit?

ALL 10 ton class launch vehicles require $100's million to several $ billion to develop. Many launch vehicles have started out as ballistic missiles (developed by military money) and converted over to Earth-To-Orbit launch service at relatively lower cost. In order to GREATLY reduce the cost of our launch vehicle (and with it the cost of getting into orbit), we wish to modify a highly successful, highly competitive supersonic aircraft so it can launch an upper stage from it after it has reached a very high altitude at a very high velocity. By utilizing a highly successful aircraft, we will spread the $ billions of development cost to 75 or as many as several thousand aircraft.

Thus, a reusable, highly efficient launch vehicle can be developed from a modified aircraft for a few $100 million instead of many $ billion. Had British and French governments not absorb the development costs, the Concorde would have been too expensive to fly.

How many Point-To-Point (PTP) HSA will be needed?

In 2006, there were 28 million scheduled flight departures that carried over 2 billion passengers. The total global airline industry revenue for 2006 was $500 billion for 31,000 flights per day. If 0.5% of those passengers fly first class, that would amount to over 10 million passengers that would pay $20,000 to fly at supersonic speeds from Point-To-Point in our Hybrid Supersonic Aircraft (HSA) and receive their astronaut's wings. If our HSA can transport 100 passengers at a time, we **would need 300 flights per day**, every day to transport these 10 million first class passengers. The 10 million passengers would generate $200 billion in revenue for this supersonic airline. On the other hand, if we can get the price of the ticket closer to a normal coach ticket price of $1,716 round-trip, the number of flights would increase many times the expected 300 flights per day which would require much more than 75 aircraft which would further spread the development cost. In the chart below we show how our PTP-HSA is more profitable than existing commercial airline flights at a round-trip ticket price of $1,716.

	Flight distance (nau. miles)	# of passengers	Ticket - round trip	Revenue per round trip	Fuel - US gallons (one way)	Fuel cost (round-trip)	revenue / 2-flight after fuel	Hours per flight	Flights per 16 hour work-day	Revenue per 16 hour day	Passenger miles per 16 hour day
Qantas Flight 7	8578	271	$ 1,716	$ 465,036	63,705	$382,230	$ 82,806	15.5	1.0	$ 41,403	2,324,638
PTP-HSA V2	4,000	100	$ 1,716	$ 171,600	20,065	$120,390	$ 51,210	2.7	6.0	$ 153,630	2,400,000

As stated earlier, Qantas Flight 7 (the world's longest non-stop flight) lasted 15.5 hour of flight time, which would require two complete flight crews to transport 271 passengers from Sydney to Dallas. In the chart above, we compare the amount of profit of operating the world's longest non-stop flight versus the Point-To-Point mission on the HSA. Even when we charge the same amount per round-trip ticket, the PTP-HSA will generate far more profit for the carrier because they can fly more often for 16 hour work-day while carrying only 37% of the passengers.

When we compare these financial numbers to the PTP-HSA, we see the PTP-HSA should be able to transport 100 passengers for 4,000 miles in 2.666 hours (data is also presented in Figure 16 on page 15; 42 minutes at high Mach; 17 to 30 minutes to get to cruise speed and altitude; 33 minutes to approach and land; 15 minutes to taxi to and from gate each, and 40 minutes to unload and reload passengers into the aircraft and refuel). As a result, airline crews should be able to conduct six flights per 16 hour two-shift work day. If mid-air refueling could be accomplished in 30 minutes, the same aircraft could travel 8,000 miles in less than 4 hours total time from gate-to-gate!

How does the PTP-HSA compare to the Concorde fleet business model?

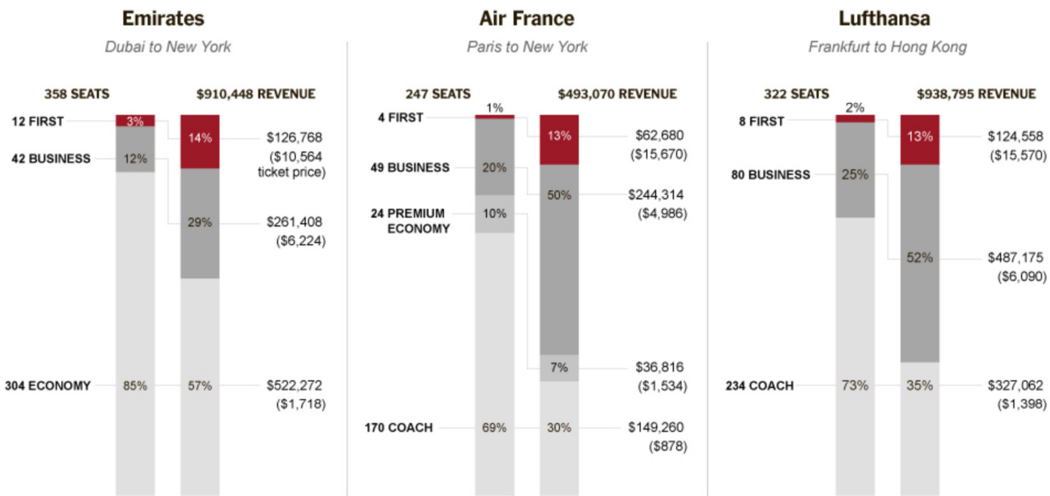
A total of 20 Concordes were built, including two prototypes and two pre-production planes. British Airlines (BA) operated 7 Concordes while Air France operated only 5. BA operated multiple flights per week between London, NYC, Washington, Dallas, Singapore, and Bahrain. They flew these aircraft a dozen times a week during an age when flying was not as popular as it is today. In addition, 580 of people have pre-paid Virginia Galactic $200,000 for a chance to fly straight up 110 km (10 km above the Karman Line) and return to the same airport[xvii]. Our aircraft can accomplish that feat with nearly every flight while taking passengers to their final designation.

Concorde had a maximum flight range of 4,500 miles that it could fly at 1,350 mph (2,172 km/hr) in approximately 3.337 hours while transporting 100 passengers with 95,680 kg of fuel[xviii]. Concorde passengers could be expected to pay more than $10,000 for a round-trip ticket from London to NYC in 2003 or $12,760 in 2014 money for total revenue of $500,000 for a one-way flight.

In comparison, between 1% to 3% of the passengers who fly Emirates, Air France, or Lufthansa on international flights fly first class and pay between $10,000 to $16,000 while 69% to 85% of the passengers on the very same flight are only paying $878 to $1,718 to fly in coach[xix]. All of the passengers on the same plane will arrive at the airport at the same time, just the first class passengers have a little more room and privacy among a few other things.

In the figure below, the first class passenger tickets would generate 13% of the total revenue for the flight even though they make up less than 3% of the passengers; so the first class passengers are already providing a minimum of $65 billion of the total industry revenue. Also in the figure below, you see that the maximum amount of revenue that can be generated per round-trip flight is just under $1,000,000.

Figure 5: Typical seats & revenue distribution for selected flights[xx]



How is the PTP-HSA different than the Concorde?

Some have argued that Concorde was an economical failure since BA and Air France never paid for the development cost of the aircraft and purchased more than half of their fleet for a token amount. Even with this great subsidy from their governments, BA and Air France did not expand their fleets or flight rates. How will the HSA be economically successful where Concorde was not? Concorde was extremely limited where it could fly since it flew supersonic. The sonic boom it created restricted its flight path to over open ocean when it was supersonic or it had to fly sub-sonic while traveling over land. The HSA will be different because it will fly so high that it will not produce a sonic boom and would have a nearly unlimited flight path since no other aircraft flies that high. The HSA can charge a greater premium than Concorde since it flies faster and by flying faster it would reduce the flight time. Business travelers could fly from NY to Hong Kong; have a meeting; fly to Frankfurt, Germany; have another meeting; and fly back to NY in the same business day. Therefore, the HSA should be successful because:

- There are more 1st class and business class passengers today
- The HSA can fly overland since it flies too high to produce a sonic boom.
- The HSA flies faster than the Concorde and should be able to charge a premium
- The HSA fleet should be much larger than the Concorde and so will be more than a novelty flight for a lucky few, but rather **THE** choice of aircraft for the top 10% of fliers (if not more if the price can be as low as predicted).
- The entire Concorde fleet flew less than two dozen flights per week and after the 2001 accident, BA had a Concorde in reserve for every active flight. Whereas, the HSA fleet could have as many as 300 to 3,000 flights per day. The greater number of flights will spread the development, unit, and maintenance costs of each flight so that they are closer to normal aircraft costs and greater profits can be made even from lower ticket prices.

The 4 Versions of the HSA vs the Concorde

We have created the chart below to easily see the difference between the 4 versions of the HSA and how they compare to the Concorde. Note Version 3 failed to achieve range targets and is only briefly mentioned. Complete weights, flight range, and flight time is provided on page 15.

HSA PTP = Point To Point **Passenger** aircraft
HSA ETO = Earth-To-Orbit air-launch aircraft (which is a modified version of HSA PTP)

Figure 6: Comparing the 4 Versions of the HSA to the reference Concorde.

	Concorde	**HSA PTP (non-regen)**	**HSA PTP (LOX Regen)**	**HSA PTP (LOX Regen Lower Inlet Temp)**	**HSA ETO (non-regen)**
Version	Reference	Version 1	Version 2	Version 3	Version 4
Maximum Operating Cruise Speed on Air Breathing engines	Mach 2.04 = 1,350 mph				
Maximum Rocket Speed	n/a	Mach 8.6	Mach 13.2	Mach 5.9	Mach 7.86
number of passengers	100	100	100	100	16
Purpose of aircraft	passenger service	Concorde sucessor	Ver1 with greater range	Lower inlet air temp on Ver2	Freight transport & Launch delivery
How is Liquid Oxygen (LOX) generated	n/a	carried from ground	generated during subsonic flight	gen during supersonic flight	carried from ground
Technology Readiness Level (propulsion system)	9	4	2	2	4
TRL (Airframe)	9	2	2	2	2

Why the Wavy Lines?

In the following figures you will see wavy lines for the Point-To-Point version and wonder what is causing this pattern. On the PTP aircraft, we operate the rocket engine for a few seconds to push the aircraft to a very high altitude where it is allowed to glide as far as possible. As the plane glides downward, it picks up speed. When the plane obtains sufficient lift by the combination of speed and air density, lift becomes greater than the weight of the aircraft and the plane goes back up. Please note that the dips are taking place in ~4 minute intervals and a passenger would barely notice the momentary increase in downward acceleration. Due to limits of our program, the angle of attack is held constant for long stretches of flight and a human pilot may make subtle changes.

VII. ANALYSIS OF 4 VERSIONS OF THE HSA

V1 - Flight Range of 410,000 lb gross weight Non-Regen PTP-HSA (Airliner)

The figures below show three passenger versions of the HSA (referred to as the PTP-HSA) with the same gross weight as the Concorde. In the first figure, we show the HSA carrying all of the RP1 and LOX with it when it takes off from the airport; we refer to this version as the Non-LOX Regen PTP-HSA RP1-LOX. The Non-regen version HSA achieves a maximum altitude of 38.7km (at 228 seconds) and a maximum velocity of Mach 8.6 at the moment it runs out of fuel at 184 seconds, but continues to fly for a total of 1,833 seconds at which time the aircraft goes subsonic at 1,988 miles and the modeling program halts. A 3rd version reduces the inlet temperature to the engines.

Figure 7: Point-To-Point non-regen HSA with 160,000 lb of LOX-RP1 – 2,525 km = 1,570 miles in 30.55 minutes

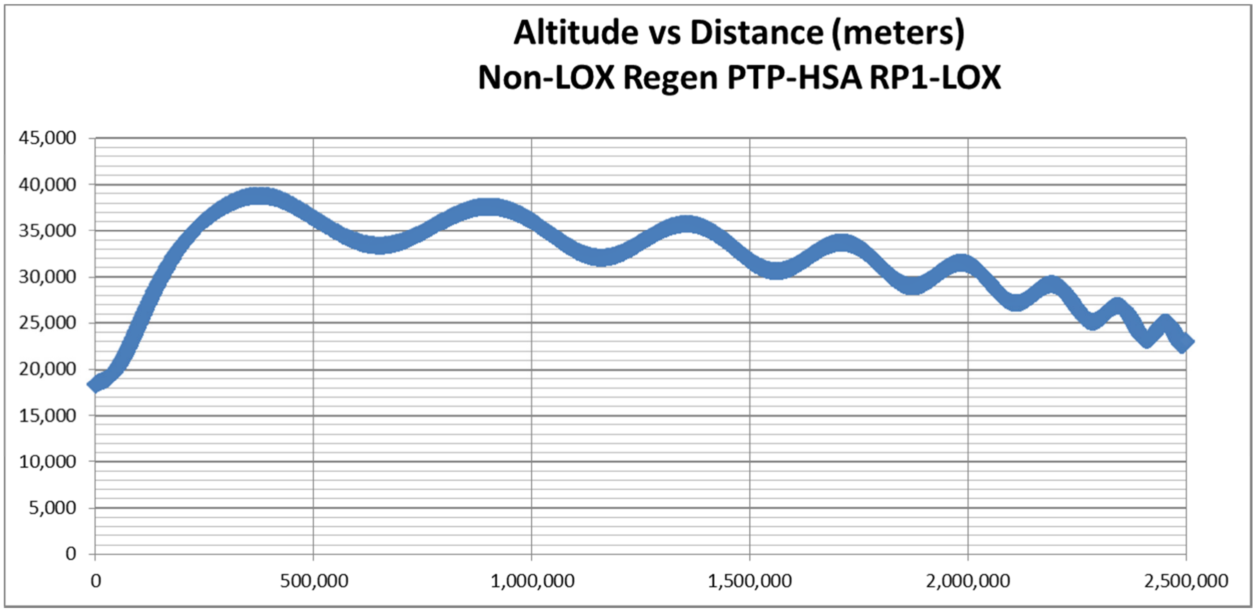
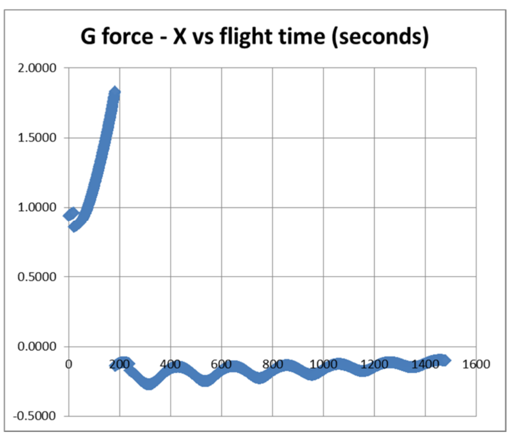
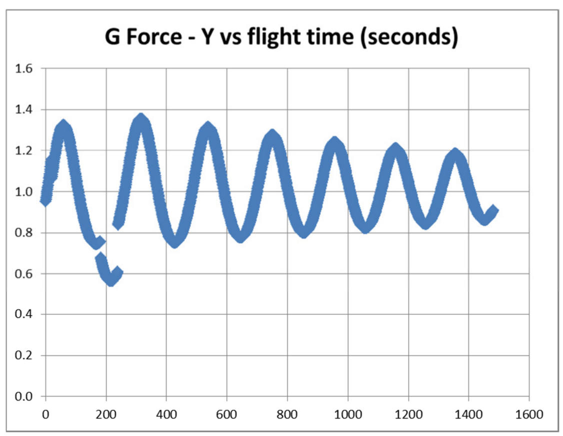


Figure 8: Acceleration in the X & Y directions for Non-Regen LOX-RP1 PTP HSA





V2 - Flight Range of 410,000 lb gross weight LOX-Regen PTP HSA (Airliner)

In the next section, we remove LOX from the vehicle and generate high pressure air at high Mach numbers which is sent through a modified jet engine or SABRE (Synergistic Air-Breathing Rocket Engine) system whenever the aircraft is at an altitude of less than 40 km (131,000 ft) and a speed of less than Mach 5.5. The design and characteristics of HSA engine is so important and complex that it can not be included in this single paper, but will be part of a future paper on this series.

The SABRE combines a turbo-compressor with a liquid-Methane precooler positioned just behind the inlet cone. At high speeds this precooler cools the hot, ram-compressed air leading to an unusually high pressure ratio within the engine. After cooling the pre-cooler, the hot gaseous methane is fed to the turbine of the turbopump then into the liquid rocket engine combustion chamber. The compressed air is subsequently fed into the rocket combustion chamber where it is ignited with the gaseous methane. The high pressure ratio allows the engine to continue to provide high thrust at very high speeds and altitudes. There aren't any air breathing engine turbines since the air breathing engine compressors are always powered by the methane turbopumps and 100% of the air will be routed through the liquid rocket aerospike engines. The turbopumps are powered by hot methane gas that has been heated by cooling the pre-cooler and the aerospike engine.

In this version of the HSA, we were not storing LOX on the aircraft and as a result the air-methane aerospike engine can only operate when the aircraft is generating compressed air. The LOX regen version of the HSA has a range of at least 4,000 miles, which it would travel in approximately 105 minutes of high speed and low speed flight. The air-methane engine ran for only 378 seconds after reaching "normal" cruising speed and altitude of Mach 2 and 60,000 ft. The LOX regen version PTP-HSA achieves a maximum velocity of Mach 13.2 just after it runs out of fuel at 378 seconds, but it doesn't reach its maximum altitude of 38km until 677 seconds into the high speed flight. We assumed a weight penalty of 50,000 lb of equipment weight on the aircraft for the additional precooler system.

Figure 9: Point-to-Point HSA with 135,000 lb liquid methane fuel plus LOX regen under 40 km yields range of 5,500 km = 3,420 miles in 42 minutes of high speed flight! Since this is half the distance of Qantas Flight 7, it would still take only 5.32 hours of total flight time with a refuel in Honolulu instead of 15.5 hours for Qantas Flight 7.

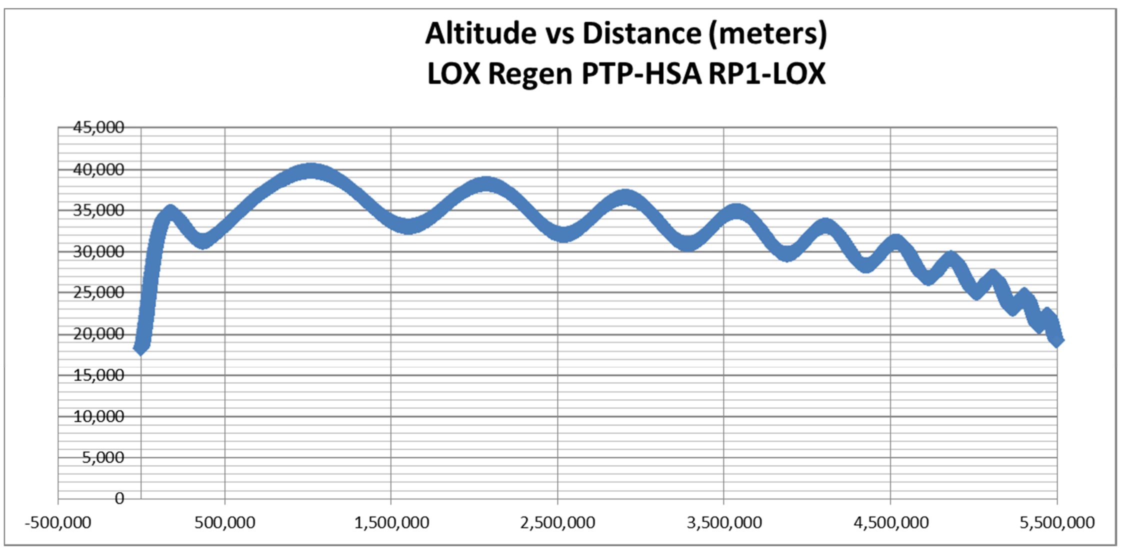
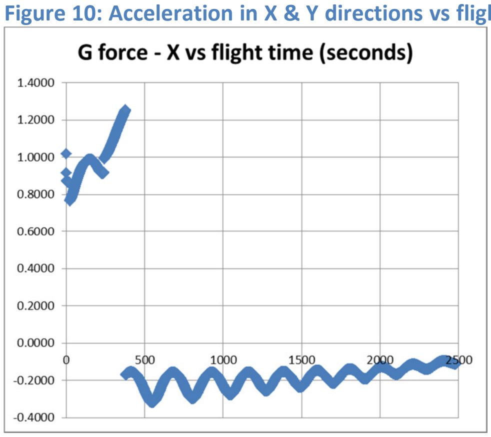


Figure 10: Acceleration in X & Y directions vs flight time - out of fuel after 378 seconds but continued to fly for 2,500 seconds



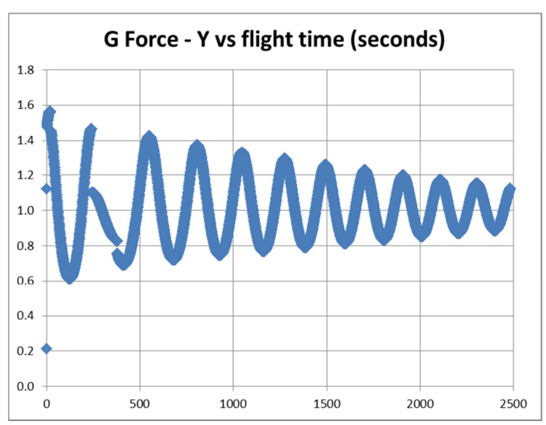
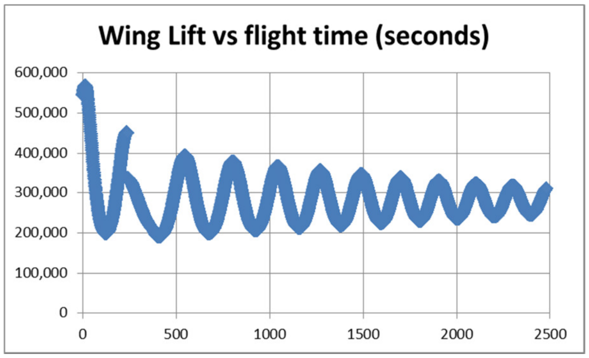


Figure 11: Wing Lift (lbs) and Lift to Drag ratio (max) vs Flight Time for P2P LOX Regen HSA



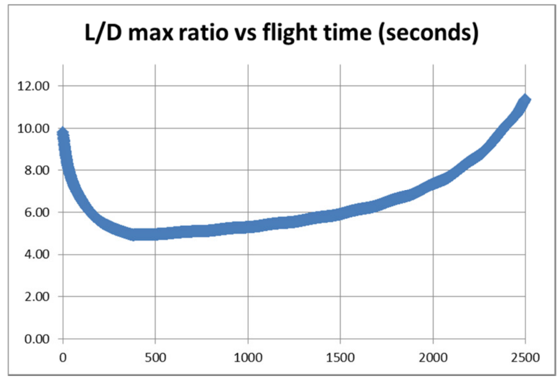
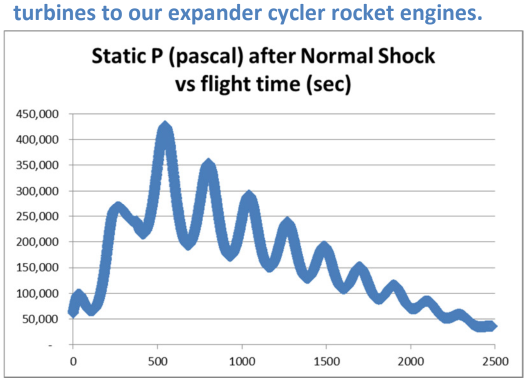
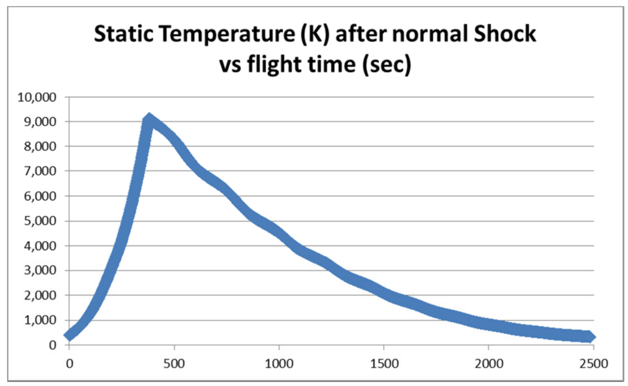


Figure 12: Static Pressure & Temperature at Aircraft Inlet after Normal Shock before Pre-Cooler. Maximum static pressure of 425 kP is reached after the engine has run out of fuel, but 268 kP is reached while the engines are operating. Maximum static temperature of 9,134 deg K is reached at the moment the engine runs out of fuel and maximum speed of Mach 13.2 is reached. By always utilizing a small portion of ambient air, we will obviously have enough heat energy to operate the turbines to our expander cycler rocket engines.

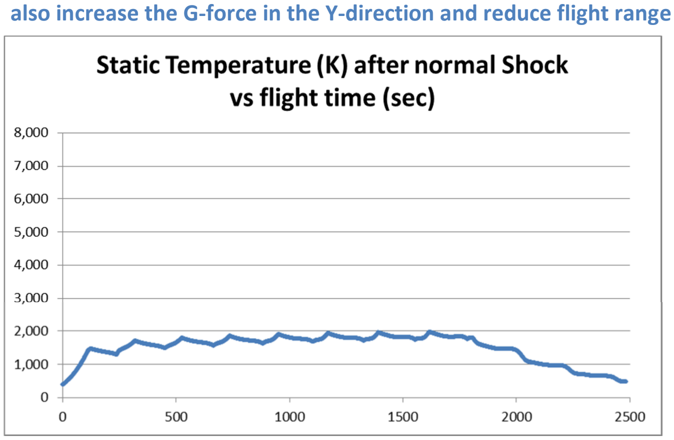


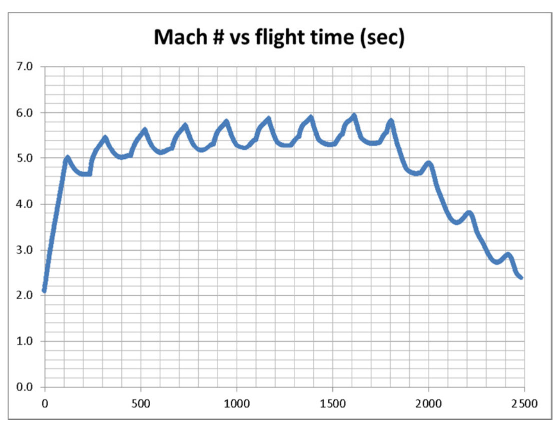


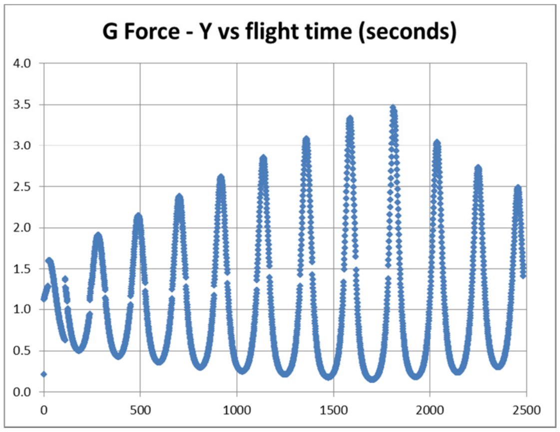
V3 -Reducing Static Temperature after Normal Shock

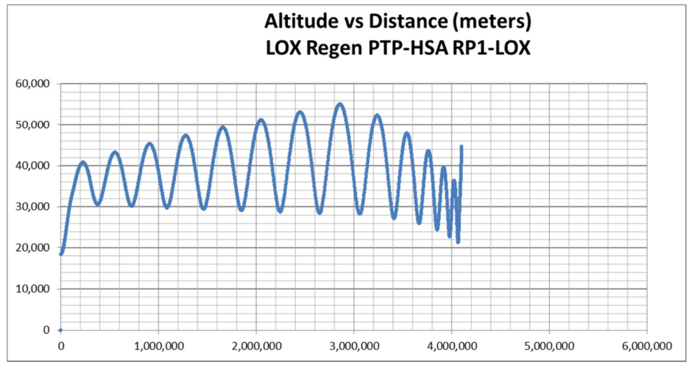
Many days can be spent adjusting the flight parameters. In the graphs below, we tried one solution which was to operate the same aircraft as above, but we changed the altitude at which the air breathing engines stop operating from 50 km to 35 km; and we changed the angle of attack from 2.7 deg to 8 deg when the static temp after shock reached 1,400 deg K. While this method reduced the static temperature, it also greatly reduced flight range. Another method (which would avoid the multiple engine starts) is to generate and store as much LOX as possible during the 30 minute flight from the runway until cruising speed and altitude are reached. More LOX can be generated because the aircraft is subsonic. This method will be greatly explored in our next paper in this series next yr.

Figure 13: Changing the flight parameters will lower the Static Temperature after Normal Shock in the engine inlet, but it will also increase the G-force in the Y-direction and reduce flight range









V4 - Flight Path of 410,000 lb gross weight Non-Regen ETO-HSA (launch vehicle)

In the figure below, we show the flight path of a Non-Regenerative 410,000 lb gross weight aircraft that delivers a 100,000 lb upper stage (and payload) to 7.86 Mach and 162 km altitude. The upper stage would transport 28,700 lb of total mass (of which 16,100 lb is payload) to a 200 km (125 mile) circular orbit. The HSA uses normal air breathing engines to Mach 2, then RP1-LOX to 7.86 Mach; the upper stage uses LH2-LOX engines. After delivering the upper stage to the Upper Stage Separation point, the ETO-HSA could glide back to its initial runway, but it also has over 4,450 kg of fuel in the outer most tanks (5a and 7a) as discussed in Chapt 5 on page 5 or it could have 13 minutes of powered flight for landing. We assumed our aircraft was only capable of 80% of the maximum Lift to Drag ratio according to Kuchemann. The upper stage requires five equivalent RL10B-2 engines.

Figure 14: HSA (**BLUE**) and Upper Stage (**RED**) flight altitude vs distance (meters)

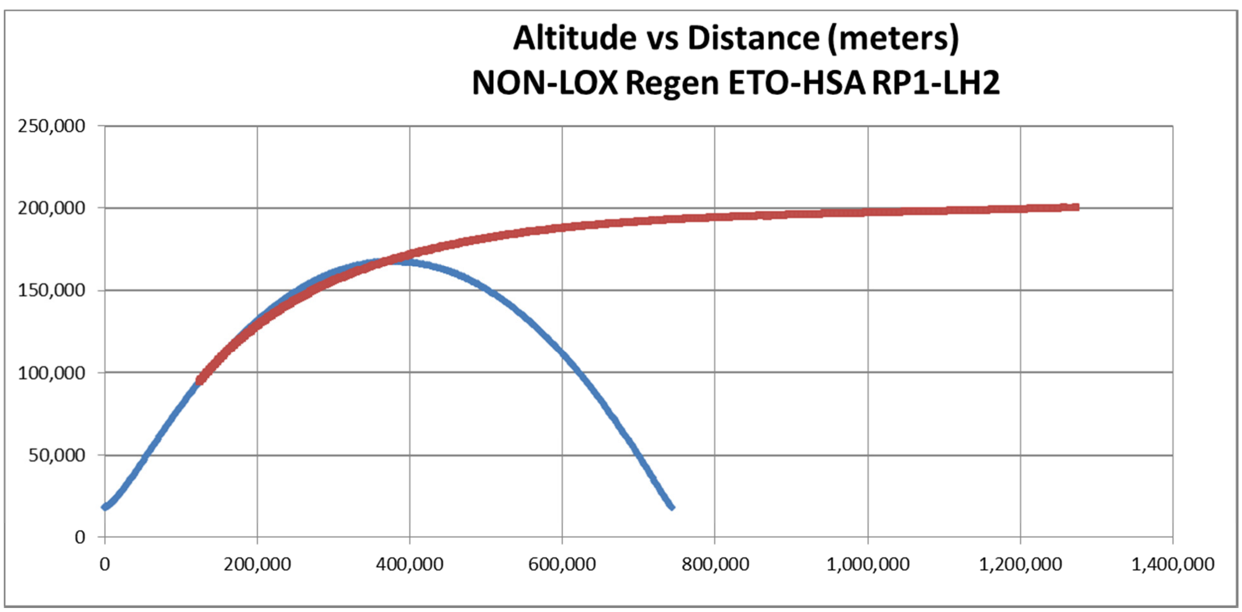


Figure 15: Weights & Propellants vs Concorde (version 3 has been eliminated)

Weights and Propellants (lbs)	Concorde	HSA P2P (non-regen)	HSA P2P (LOX Regen)	HSA ETO
Max Taxing Weight	412,000	412,000	412,000	412,000
Max. Take Off Weight	408,000	408,000	408,000	408,000
Max Wt W/o Fuel (Zero Fuel Wt)	203,000	203,000	253,000	149,750
Operating Weight Empty	173,500	173,500	223,500	156,100
Max Landing Weight	245,000	245,000	263,000	245,000
Max. Payload of HSA	29,500	29,500	29,500	100,000
Max. Useful Payload of 2nd Stage	n/a	n/a	n/a	16,100
Max Baggage Weight	6,100	6,100	6,100	n/a
Max Weight of Fuel of HSA	207,834	210,940	134,440	160,000
Fuel / Oxidizer to Mach 2.04	Jet-A / Air	Jet-A/air	LNG/Air	Jet-A/air
Fuel / Oxidizer above Mach 2.04	n/a	RP-1/LOX	LNG/LOX	RP1/LOX:HSA LH2/LOX:2nd stage
Max Fuel volume of HSA	119,280 liters = 26,240 imperial gallons = 31,510 US gallons			

Figure 16: Airspeed & Flight time vs Concorde (version 3 has been eliminated)

Airspeed and Altitude Limits	Concorde	HSA P2P (non-regen)	HSA P2P (LOX Regen)	HSA ETO
Maximum Operating Cruise Speed on Air Breathing engines	Mach 2.04 = 1,350 mph			
Maximum Rocket Speed	n/a	Mach 8.6	Mach 13.2	Mach 7.86
Rocket Burn Time	n/a	184 seconds	378 seconds	47 seconds
Maximum X- Direction Thrust	1.5 g	1.83 g	1.25 g	3.56 g
Maximum Y-Direction Thrust	?	1.76 g	1.6 g	4.66 g
Maximum Permissible Range	4,500 Miles	2,188 miles	3,800 miles	1,570+ miles
Total Flight Time (gate-to-gate)	3.60 hr	1.81 hr	2.00 hr	1.81 hr
Total Cruise Time	2.29 hr	0.51 hr	0.69 hr	0.51 hr
Time (Take-off to Cruise)	0.50 hr			
Time (Approach until landing)	0.55 hr			
Time (Taxi from Gate + Taxi to Gate)	0.25 hr			
Time (Off-load & Re-load passengers & payload + refuel)	0.5 hr			8 hours
Average Take-off speed	250MPH			
Average Landing speed	185MPH			
Maximum landing gear speed	270Kts (Mach 0.7)			
Maximum operating altitude on air breathing engines	60,000Ft			
Maximum altitude w/rockets	n/a	127,200 ft	133,750 ft	550,000 ft
Maximum positive incidence (angle of attack)	16.5 Degrees			
Maximum negative incidence (angle of attack)	-5.5 Degrees (Above Mach 1.0)			

VIII. EQUATIONS & ASSUMPTIONS

We used the following equations and assumptions to produce these charts:

Angle of attack	= 3.6° start / 2.6° cruise
(t/c) - wing thickness/chord	= 3.5%
Chord length	= 30.48 meters = 100 ft
Cross-section area	= 6.45 m^2
Delta wing area	= 450.57 m^2
Gross take-off weight	= 410,000 lb
Maximum fuel/propellant wt	= 160,000 lb = 119,280 liters = 31,510 US gallons

Aerodynamic Drag

Total Drag = Cd.pressure + Cd.lift + Cd.skin
Total Drag = Pressure drag + Lift Induced drag + Skin drag

Maximum Lift to Drag Ratio for supersonic flight:
As developed by Dietrich Küchemann [xxi] and verified in wind tunnels.

$$L/D_{max} = \frac{4(M+3)}{M}$$

Basic equation for aerodynamic drag:
Area (A) has different meanings for the different drags.

$$F_D = \tfrac{1}{2}\rho v^2 C_D A$$

Pressure or wave **drag coefficient** =

$$C_D = \frac{5.33(t/c)^2}{\sqrt{M^2-1}}$$

Where M = Mach #
A.p = cross-section area of aircraft
The LOX-Regen aircraft only saw a maximum Pressure Drag of 220 lbs 19 seconds into flight.

Lift Induced drag coefficient =

$$C_D = \frac{4\alpha^2}{\sqrt{M^2-1}}$$

Where alpha = angle of attack in radians
A.l = delta wing area
The LOX-Regen aircraft has a maximum of 36,045 lb of Lift Induced Drag 17 seconds into flight at an altitude of 19,090 meters.

Skin Friction drag coefficient =

$$C_f = \frac{0.0583}{Re^{0.2}},$$

A.s = total surface area of aircraft
The LOX-Regen aircraft has a maximum of 33,044 lb of Skin drag near its maximum speed of 17.1 Mach at 37,139 meters altitude at 548 seconds into flight.

Reynolds number =

$$\mathrm{Re} = \frac{\rho v l}{\mu} = \frac{v l}{\nu}$$

Where:

v = Velocity of the fluid
l = The characteritics length, the chord width of an airfoil
ρ = The density of the fluid
μ = The dynamic viscosity of the fluid
ν = The kinematic viscosity of the fluid

Kinematic viscosity = (0.00009 T^2 + 0.0859 T + 13.583) x 10^{-6} m^2/s where T = temperature in Celsius

Aerodynamic LIFT

Coefficient of Lift =

$$C_L = \frac{4\alpha}{\sqrt{M^2-1}}$$

Where alpha = angle of attack in radians
The LOX-Regen aircraft has a maximum of 573,713 lb of Lift 17 seconds into flight at an altitude of 19,090 meters (angle of attack of 3.6°), which causes the maximum lift induced drag.

Notice that angle of attack is singular for aerodynamic lift whereas it is squared for lift induced drag. For an angle of attack of 2.6°, the Coefficient of Lift will be 22 times larger than the Coefficient of Lift Induced Drag at the same Mach number.

Figure 17: The table shows the parameters we utilized to determine performance of engine for both the Non-Regen version (engine 7a) and the Regen version (engine 7b)

Parameter	**Units**	Non-regen	LOX-Regen
Engine number		7a	7b
Engine		NK-43	NK-43
engine weight	lb	3,077	3,077
Sea Level Isp	sec	246	795
Sea level Thrust	lb	280,795	280,795
Vacuum Isp	sec	346	1,118
Vacuum Thrust	lb	394,940	394,940
Mixture ratio	LOX:Fuel	2.8	2.8
Fuel		RP1	RP1

IX. Thermal Management

The PTP LOX-Regen aircraft sees an average of -33 deg C in its 2,800 second long travel. The aircraft had maximum potential plus kinetic energy of 1,200,000 MJ at the moment it ran of fuel at 379 seconds into flight while traveling Mach 13.2 at an altitude of 39.1 km. After 2,121 seconds of gliding, the energy of the aircraft was only 38,168 MJ at an altitude of 19,165 meters and a speed of Mach 1.6. Since the aircraft spends most of its time flying above 25 km, it will need to shed this 1,161,900 MJ of energy as radiation in 547.7 MJ/sec = 547.7 MW.

If we assume the delta wing radiates all of the waste heat as thermal radiation (none is transferred to the air, we can use the following equation for black body radiation:

Where $P = \sigma \cdot A \cdot T^4$

P = Power = 547.7 MW

σ = (Stefan–Boltzmann constant) 5.67×10^{-8} W•m^{-2}•K^{-4}

A = Area of delta wing = 450.57m^2

Solving for T yields: 2,151 deg K = 1,878 deg C = 3,412 deg F

Obviously we can get lower temperatures by assuming some energy is transferred to the passing air by convective heat transfer or by assuming both sides of the delta wing radiate heat resulting in an aircraft surface temperature of T = 1,834 K = 2,842 F. Of course, the leading edge of the wing will have the most heating and we become the hottest. These calculations were to show the worst case for the average sections of the wing & fuselage acreage.

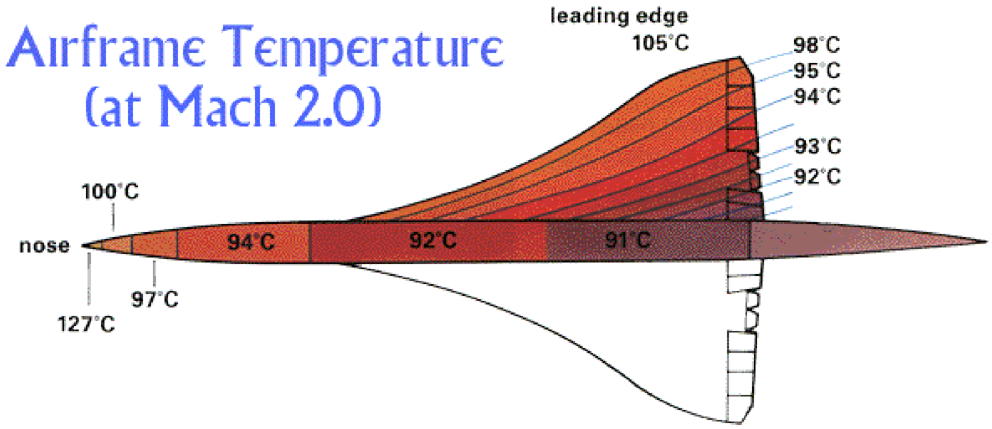
If we assume 90% of the heat energy goes to the leading edge of the wings and the remaining 42.13 MW would be absorbed by the bottom of the delta wing. The wing acreage would have a temperature of 1,210 K = 1,718 deg F while the leading edge of the wings (assumed to be 33.88 m long x 106.7 cm thick = 72.28 m^2) would see temperatures as high as 3,310 K = 5,500 F.

How much heating will build up on the ETO HSA as it flies greater than Mach 2 and what counter-measures should be taken?

The Concorde flew at Mach 2 at 60,000 ft altitude and its nose heated to 127 Celsius (260 deg F) as shown in the figure below[xxii]. Please notice that most of the skin temperature is below 99 deg C. In comparison, the SR-71 "Blackbird" aircraft flew at Mach 3 at 80,000 ft altitude and its nose heated to 426 deg C (800 deg F)[xxiii], [xxiv]. The X-15 rocket-airplane flew much faster at Mach 6 and its skin temperature reached 1,200 deg F[xxv]. The HSA will fly at Mach 2 at 60,000 ft altitude like the Concorde but then in the next **169 seconds** gain speed as it gains altitude until the wings produce almost no lift as the HSA approaches the Karman Line. There is such little air above 125,000 ft altitude, many launch vehicles jettison the payload fairings at this altitude, such as the Ariane 5 (110 km)[xxvi], rather than take the heavy payload fairings all the way to orbital velocity. Since satellites and their solar panels are not aerodynamically shaped, they would be quickly torn to pieces if there were any aerodynamic effects at this altitude.

After the HSA has delivered the upper stage to a very high altitude at hypersonic speed, it has gain much potential and kinetic energy. As the HSA falls back to the troposphere, it will trade this potential energy for greater velocity until aerodynamic heating reduces its velocity.

Figure 18: Temperature profile of the Concorde at Mach 2.0



X. SUMMARY

In this second of a series of papers on the subject, we have presented more details on the affordability advantages of integrating an aircraft with launch operations. The goal of this paper is to show the economic advantages of using an aircraft to air launch an upper stage (and payload) at a very high altitude and at hypersonic speeds. Since no such aircraft currently exists, we have presented economic justification for developing and operating a fleet of such aircraft

We have shown two configurations of the Hybrid Rocket/Air breathing Suborbital Aircraft which we referred to as the HSA. We have based our concept using the basic characteristics (weights, size, speeds, capacities, etc.) of the Concorde for the simple fact the Concorde flew with passengers for more than 27 years. An actual aircraft designed with suborbital flight with air-breathing rocket engines may look very different.

In the primary configuration, we have provided some economic feasibility numbers to show how such an aircraft could establish a business case and obtain a niche market by providing high speed airline service from Point-To-Point. A large fleet would spread the development cost to the point that the unit cost of our proposed supersonic aircraft is closer to comparable conventional aircraft. Although the aircraft will carry fewer passengers per flight, they should be able to conduct more flights per day because the travel times are much shorter; resulting in an aircraft that can transport just as many passengers and can transport those passengers to their destination faster, who can be charged a premium for the reduced flight time. A large, profitable fleet of supersonic aircraft is important to this paper because it is our premise that it will be enormously cheaper to procure an operational supersonic aircraft (with high altitude capability) to which we would modify so that it can launch upper stage payloads into Low Earth Orbit rather than to DDT&E and Produce a single purpose aircraft or rocket launch vehicle.

We conducted analysis of different versions of aircraft showing:

- Flight range,
- wing loading,
- temperature, and
- lift-to-drag ratio among other parameters to determine some figure of method on how well the HSA could function.

Results were encouraging enough that more research should be devoted to determine the optimum flight parameters for greatest range.

Because the air breathing / rocket engines are so complex and so critical to the justification for this aircraft, we have decided to make them a topic by themselves in a future paper. We also discovered that the cost of delivering a 100,000 lb upper stage (and payload) to high altitude point via the HSA was so small, that it would only make sense to utilize a reusable upper stage. We have decided to also make the design of a reusable upper stage as a topic of a future paper. And finally, a future paper may be needed to discuss the HSA Thermal Protection System as well as the materials for constructing and techniques for constructing the HSA.

Some of you will say "*So what, you can launch payloads into space hundreds of times per year, but we only need 26 payloads per year today*". An accompanying paper presented at the same time was entitled, "***Space Billets, How to Fund Manned Lunar Missions with Current NASA Budget***[xxvii]". That paper delineates a plan for NASA to make routine trips to the moon, go to Mars, and establish a space hotel for the same funding as today's budget if such a launch vehicle as presented herein could be built that can make 100's of missions per year at a flat, guaranteed rate.

END

Please see: http://www.theusaparty.com/policy.html
Http://theUSAparty.com
Providing peaceful solutions to divisive topics including Space Commercialization, Global Warming, Healthcare, Education, Immigration, Taxes, & Budget.

http://Spacepropulsion.org
The Space Propulsion Synergy Team is Government, Industry, and Academia coming together to provide guidance to vehicle design via knowledge gained from lessons learned.

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[i] Douglas Thorpe, Russ Rhodes, John Robinson, "*Affordability Advantages in Integrating the Aircraft and Space Launch Operations", 48th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Atlanta, Georgia, 30 July-1August, 2012, AIAA 2012-4155*
[ii] http://www.transtats.bts.gov/
[iii] http://en.wikipedia.org/wiki/List_of_space_travelers_by_name
[iv] http://www.spacenews.com/article/civil-space/33436bigelow%E2%80%99s-fares-show-spacex-trumps-boeing-on-price
[v] http://en.wikipedia.org/wiki/Falcon_9
[vi] http://en.wikipedia.org/wiki/Qantas_Flight_7
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