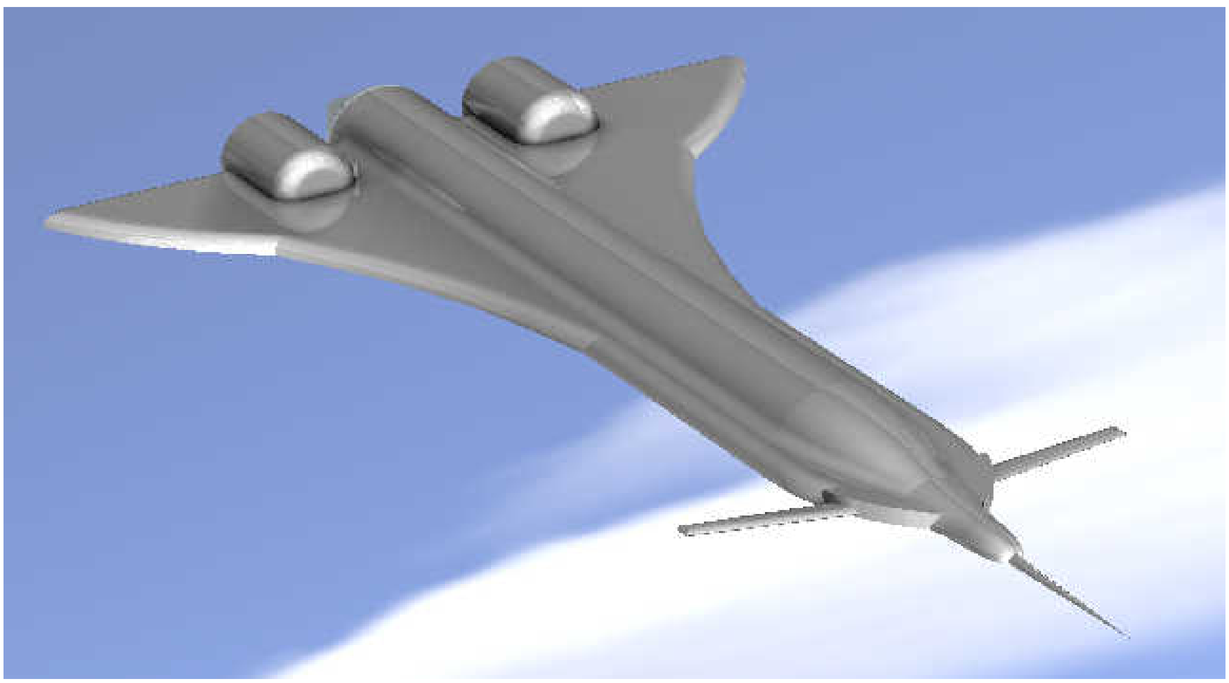
Fundamental Aeronautics Student Competition
High School Division (Advanced Curriculum): 2008-2009 Academic Year

THE Lazarus T1



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Abstract

The decade beginning in 2020 will see an introduction of much more advanced nanotechnology as well as more advancements in the chemistry of newer and more innovative materials. Thus, the years to come will use planes that change fundamentally on the wider perspective because of the many crucial minute intricacies added to the plane body to improve the plane's performance overall.

Looking through the various supersonic aircraft of the past, different aspects of the most effective and changing designs of the past are implemented in our future supersonic design as a means of maximizing expected performance. The Concorde, with its appealing sleekness and its technological innovations to bring supersonic transport to the 1970's, inspired much of the Lazarus T1's design. However, most of the newer innovations came from military and NASA experiments that have made current supersonic transport a feasible reality ever since. Operation Quiet Spike with the Jouster, SR-71 Blackbird for its innovative chine shape, and Boeing's X-48 blended wing body were all inspirational designs of the past that influenced this design.

The overall shape of the Lazarus T1 was developed as we attempted to modify it for suitable supersonic flight. Unlike conventional aircraft, with poorly integrated parts, the Lazarus T1 employs the ultra-sleek, highly-efficient shape of the Blended Wing Body Design, first proposed by Boeing and NASA. However, to make this design suitable for supersonic flight, chines were integrated to reduce the supersonic boom and make the blended wing body a better experience for the passengers (such as in improving availability of windows). The body is more efficient still through the removal of the empennage and the use of a canard, which compensates for the changing center of lift of the Lazarus T1 at supersonic speeds.

The Lazarus T1 also contains micro-innovations that boost the efficiency of the plane down to the smallest level. Mesoflaps quell the development of airflow boundary separation at speeds above Mach 1. This also applies within the engines, where flow separation occurs often. Specially designed hydraulic lifters carefully elevate the wing's camber to make climb, descent, and cruise conditions efficient. Muffling material on the nacelle of aircraft engines absorbs sound and reduces takeoff noises.

Lowering the sonic boom after passing the sound manifold was also advanced through experiments performed in the previous decade. The Jouster systematically sends three shock pulses from a protruding antenna at the nose to interfere with the resulting shock wave of the plane. Active noise canceling—now available to focus sound in parallel lines—will be used to cancel noise even further.

Further proposals are also suggested to improve supersonic flight which are not yet viable at this time. By 2020 we expect that they without doubt will. At that time we envision supersonic flight as being ubiquitous. But first the advancement in supersonic flight has to regain momentum.

Basic Structural Design: Wings and Fuselage

With the onset of the twenty first century, an influx of must smaller and lightweight technologies has come into the market. Our fundamental airplane design focuses on utilizing these much smaller and more lightweight technologies to effectively modify the larger airplane wing design for maximized subsonic climbing and descent as well as supersonic cruise efficiency.

Blended Wing Body

Seen from the larger scale, our airplane employs the blended wing body design, which was initially intended for subsonic speeds. Essentially created for maximum lift during cruise conditions, the blended wing body (BWB) conserves an enormous amount of fuel normally wasted to the unscrupulous designs of current airliners today. The blended wing body, which effectively "morphs" fuselage and wing, allows for the generation of lift along the entire plane's surface area. The BWB will suit the future of airline design.

With blended delta wings, the BWB uses the lifting forces needed at supersonic flight without the same friction impinging on interfering surfaces.

However, the currently accepted architecture of the BWB lacks the sophistication in technology and design to suit the much more demanding innovations of supersonic flight. Along with the super-efficient, maximizing lift capabilities of the BWB, the Lazarus T1 employs minute but substantial technology that allows for a dynamically changing camber, allowing for suitable flight in both subsonic and supersonic conditions.

Hydraulic Lifters

This technology—the ultrasmall, superlight hydraulic curvature setter—lets the plane alter its camber line in dramatic ways:

1. Upon takeoff, subsonic flights lower than 0.7 mach and landings at the specified speeds, the wing thickens with the hydraulic lifters. The camber bulges upward near the leading edge, effectively creating less drag with more lift at lower speeds, which suits subsonic flight and critical moments at takeoff and landing. This condition parallels the uses of current aircraft flaps without the need of bulky retractor systems and imperfect flap surfaces.
2. Approaching the sound barrier and at supercruise, the aircraft wings will thin out to a camber that almost completely eliminates parasitic drag (or form drag) caused by normal cambers of subsonic flights. This flattening maximizes supersonic cruise efficiency.

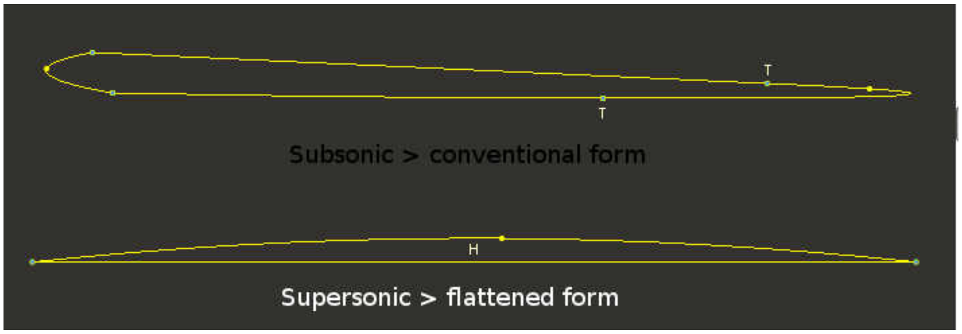


Illustration of wing thinning with hydraulic lifters.

Hence, the BWB will be able to efficiently draw lift at both subsonic and supersonic flight speeds, which eliminates one crucial issue prevalent with the passive shape of the Concorde. The Lazarus T1's dynamic structure, made possible by the much more compact technology of the future, will quell this previous design issue.

The blended wing body is also made possible by the expected advance of computer technology of the future. Increasingly complex and powerful computer technology with high processing power will be able to gather the data from sensors at key locations on the wing and output commands to the hydraulic lifters. The computer functions as the imaginary "vertical stabilizer" of the past, which will (with the addition of chines) make the entire empennage redundant in the year 2020 as the computer will make simple manipulations to assure that the Lazarus T1's directional stability maintains a constant heading.

Chines

Purposely modified changes to the fundamental BWB that compensate the conceptual shape for the effective mitigation of the sonic boom will further increase the high performance capabilities of the Lazarus T1.

Although the BWB will still blend together the wing and fuselage, chines, such as those used on the SR-71 Blackbird, will reduce the effects of the sonic boom through the powerful vortices that are generated by the aircraft. They also synchronize themselves with the effects of the blended wings such that maximum lift continues to be generated along with the benefits of the blended wing.

Additionally, the chines create a very, very gradual bulge on the upper wing, which allows for the installment of windows that cannot be implemented with all blended wing designs. This provides for customer satisfaction through a much more friendly flying experience.

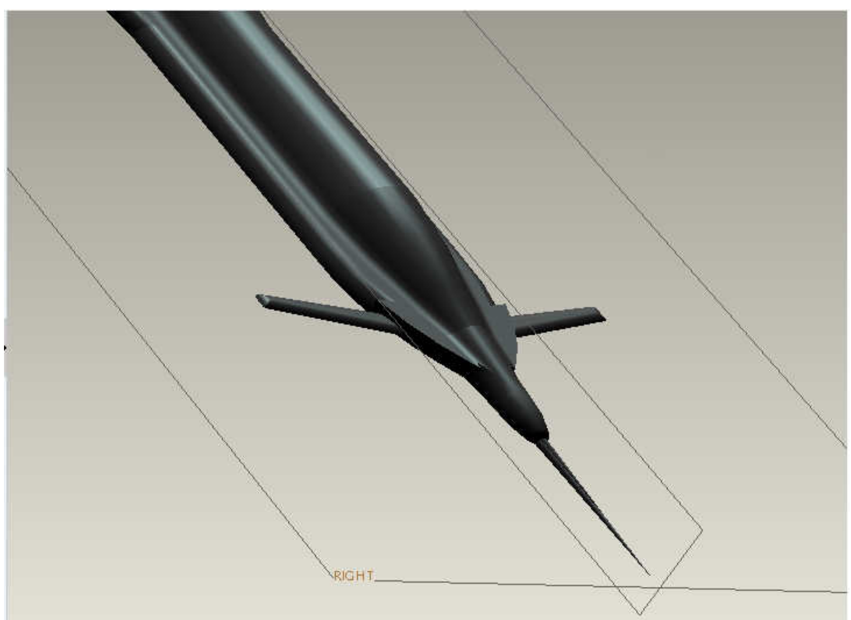
Structural Specifics

Canard: Maneuverability

A canard, essentially horizontal stabilizers placed at the front of the fuselage, will be key to the maneuverability of this fundamental blended, delta wing design. A major source of problem with supersonic flight comes from the high aerodynamic forces that cause the center of lift to move backward. This change is crucial to maneuverability as the center of lift must be a specific distance relative to the center of mass for a plane to fly effectively. On the Concorde, engineers optimize the shape of the wing to minimize center of lift movement.

On the blended wing design, the swept delta wings along with the center of lift behind the center of mass will allow for the canard to be used as a means of maintaining longitudinal stability along its lateral axis. Like balancing torques in high school physics class, the canard raises the plane up as does the center of lift on opposite sides of the center of mass. The canard will easily be adjusted to pitch the plane upward or downward even with a moving center of lift. Unlike the concord, Lazarus T1 circumvents the problem of Concorde associated with using ailerons as pitching devices (horizontal stabilizers). This releases stress from the delta wings, which is and gives much greater maneuvering capability to the Lazarus T1.

Chines may be reputed to make canards negligible, but the key to adding the canard to the Lazarus T1 stems from the need for further maneuverability to planes already scrapped of moving parts.



Close-up view of the canards and jouster.

Leading Edges: Countering Huge Air Forces

The leading edges of the planes must withstand huge amounts of forces, and with the changing camber of the aircraft, it must be flexible to form the perfect curve seen on normal jet wing designs.

Therefore, a special polymer will be engineered to satisfy these requirements. Called nanocarbon modifiers, the material sustains extreme flexibility as it functions as the camber that constantly stretches and retracts when the hydraulic lifters manipulate the change of the wing. At supersonic flights, the leading edge sustains extreme temperatures, which is possible because of the high conduction of heat of the material.

Mesoflaps: Controlling Shock/Boundary Layer Interaction

Approaching supersonic speeds, the boundary layer interaction between the plane surface and the airflow begin exerting great forces on the airframe. This results in increased drag and flow separation that inhibits the full aerodynamic efficiency of conventional supersonic aircrafts.

Thus, Mesoflaps, pioneered by University of Illinois professors, will get rid of the costly, complex, and heavy bleed systems of current air force aircrafts by using these "smart" mesoflaps.

The Smart Mesoflap Technology automatically begins its use when the extremely low pressure at supersonic speeds of the boundary layers diverts these small flaps to "cavity" areas, places where airflow separation occurs. Placed at crucial points along the nose, fuselage, and wing, the mesoflap will create an actively changing system of tiny flaps that self-adjust upon need. Use of aeroelastics (such as NiTinol) will eventually adjust itself to optimize its effects on reducing boundary layer intensification.

This system is expected to be cheap, reliable, small, and weightless. Besides, the future of aviation entails an era where smaller technology benefits the aircraft as a whole. This is one of them.

Engines: Suitable for Supersonic Flight

The Concorde proved that reliable and powerful power plants (Rolls-Royce/Snecma Olympus 593) could sustain long hours of supersonic flight. Even though modern engines easily sustain their performance above the speed of sound, new research and technology has revealed the great potential in air diversion to effectively maximize the thrust generated by the supersonic engines. Thus, these engines will not sacrifice fuel consumption for lift that is already available during operation.

Turbofans for Optimum Performance

The Concorde used turbojet engines to have the maximum supersonic capabilities possible at the time.

Fifty years have passed, and the prospects of switching to the more efficient, quieter turbofan usage has opened a new realm in engine technology. Because of the slightly slower cruise speed (.2-.4 mach slower than the Concorde), a turbofan suits the revolutionized version of a future supersonic jet, our Lazarus T1, perfectly.

The turbofan functions like the turbojet engine except with a slightly larger diameter intake. Airflow is thus increased but output decreased in comparison to the turbojet used by the Concorde.

Supersonic Engines

Several modifications must be made in order for engines flying at supersonic speeds to maintain their performance capabilities.

1. Assure laminar flow attains to the engine surfaces—prevent boundary-layer flow separation.
2. Lower airspeed below Mach 0.5 so engines remain operational.

The perfect solution is a system of flaps that diverts air to the flow separation areas to keep the boundary layer attached to the engine frames. This allows the airflow to continue smoothly across the entire length of the engine. The technology of Smart Mesoflap Systems, as described above, will function as a solution to engine at supersonic speeds as well.

The smart flaps will rely on nickel and titanium alloy that, with correct temperature and stress, morph into the desired shape after several trials. This can easily be accommodated for the new supersonic engines that need special tuning to adjust for perfect airflow.

The benefits of this simple but precise technology are astounding, especially for the engine that must overcome the vacuum effect of supersonic flight. Maximized thrust, quieter engines (from the smoother flow of air), and smarter fuel conservation for a technology very feasible in the future considering the nano-sized technologies we easily deal with today.

However, there are more solutions as well. To compensate for both issues, a "recycle" system also works, though a separate and intricate pumping system must be implemented. Instead of allowing certain places to adhere extra flow separation qualities, a "bleed system" will be used, but instead of the conventional system used by the Concorde in which the air is completely wasted, the design will pump air up and down the engine to places to "cavities" where air is deprived. This self-adjusting system will be directed by a computer. Though extremely advanced, the Lazarus T1's intricate new technological innovation will be possible in a future of nanotechnology.

Sensors for Pilot Observation: Analysis of aircraft performance will no longer be restricted to the testing room. The year of 2020 will be at the apex of the nanotechnology revolution, opening a new realm of sensor technology that will directly bring airflow analysis to the front seat of the pilots. This will give clear indication of engine injections, like birds, debris, or other harmful materials that are potential hazards to the operation of the engines of the Lazarus T1.

Material and Benefits

Regarding structure, the primary objective is to maximize durability at the high stresses and temperatures of supersonic conditions while minimizing weight and expense. Whereas aluminum is the conventional material used for such purposes, carbon fiber and Kevlar composites possess a greater weight to strength ratio and will therefore be used to maximize the efficiency of the Lazarus T1, as well as ensuring rigidity so that aeroelastic issues such as divergence or flutter.

Since the Lazarus T1 is designed to fly at Mach 1.6 to 1.8, extreme skin temperatures should not be problematic; however, titanium and steel may be substituted for polymers to reinforce the Lazarus T1's thermal resistance. The Lazarus T1 will also be covered with a paint of high reflectivity in order to avoid overheating. In order to reduce noise, the engine nacelle and areas around the exhaust will be lined with mufflers.

In addition, nanostitching being developed at MIT is projected to strengthen airplane skins by several factors, particularly in weak areas.

Airplane Component	Material	Reasoning
Wings and fuselage	Composites (carbon fiber, kevlar, aluminum)	Stronger, light, more durable than ever.
Nose	Nanostitching application	Due to heating.
Engines	Steel	Heating and mechanical forces as well.
Mesoflaps	NiTinol	"Smart" material that bends into the right shape.

Environment and Setting

Use of ultra-clear, fast, and reliable cameras to send images of the bottom of aircraft to pilots-for taxi, takeoff, visual awareness will improve safety in airport environments where sharp turns and difficult maneuvers over aging concrete are required. This is a simple addition to the design since 2020 will definitely bring an improvement in nanotechnology.

The plane will also see better customer satisfaction compared to planned innovations like the Blended Wing Body design or the Concorde design. Not only will the entire cabin have windows along the length of the fuselage (which the blended wing does not offer), the computer-controlled stability of the plane will also make the flight much smoother and less turbulent.

Goal in Performance

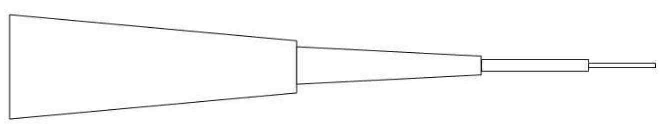
Goals are important precursors to design and development. By the year 2020, we expect to have these numbers and performance standards in place:

Reducing Supersonic Boom

Chines: As stated above, chines will decrease the effect of the sonic boom through the carefully shaped front section of the plane.

The Jouster: An innovative and very long antenna attached to the nosecone, the jouster will employ the technology to systematically synthesis personal sonic waves. Three sonic waves will effectively interfere with the sonic boom of the large aircraft and "cancel out" as opposing waves interfere through the principle of superposition. As demonstrated by the waves depicted, most of the sonic boom will be reduced using this innovative technology.

Through computer technology, the Jouster will adjust itself based on temperature and pressure, factors that determine the speed of sound and the sonic boom cone shape. The computer within will deploy the Jouster right before entering a sonic boom and, afterward, retract again, as to avoid potential structural weaknesses in tensile strength. This dynamically changing length further improves the dynamic capabilities of the Lazarus T1.



An extended jouster.

Active Noise Cancellation

As sound is a wave, at some point in the future it may be possible to use destructive interference to lesson or nullify the sonic boom. Demonstrations by inventors such as Woody Norris illustrate the possibility of manipulating and organizing sound waves. As Sonic booms possess associated Mach cones of calculable angles, noise-cancellation devices, though at this point not viable for eliminating sonic booms, will surely by 2020 become a possible consideration.

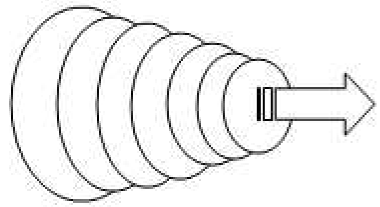


Figure illustrating the Mach cone resulting from sonic booms.

Expected Performance Goals

The sonic boom created by the Concorde generated 1.94 psf (pounds per square foot). The optimizing shape of the plane will reduce these numbers to around 1.50 psf as the engineers of the time did not have the computer technology of today to fully optimize its shape. The noise-cancelling technologies of the Jouster and the cylindrical active noise cancelling system will synchronically bring down the sonic boom significantly, down to 0.4 psf as the aircraft actively cancels out the concentrations of pressurized sound.

Before (Concorde): 1.94 psf
Current (Space Shuttle): 1.25 psf
Future (Lazarus T1): < 1 psf

Takeoff/Landing: Airport Noise

Jet engines create most of the noise during take-offs at airports because of the sudden "slicing" effect of engines in its sudden impulse in thrusting the aircraft upwards. Unlike the Concorde's noisy and old turbojets that relied on propulsed air and afterburners, the Lazarus 11's plane will use the much quieter but still powerful turbofans of the future. Like the GE90-115B currently on Boeing 777 aircraft, which has made flying much more quiet, the Lazarus will employ the same technological shift while still providing the right performance for current airport standards.

The engine nacelle will also be lined with special mufflers to absorb noise, as discussed above.

Fuel & Freight

Passengers and Other Payload

The Lazarus T1 will be able to carry approximately 70 passengers. The seating will be arranged in two groupings of two columns with an aisle in-between, necessitating 18 rows.

The Lazarus's abnormally shaped blended wing body makes the plane an unconventional problem when considering the conventionally shaped freight boxes it must carry. Even though baggage will be fine for all passengers to bring, extra freight may not be feasible because of the need to compensate for fuel tanks. For its very sleek design, the plane will also encounter trouble when attempts to retrofit it into cargo planes are made.

Fuel

Most significantly, fuel will be stored in the wings. As in the Concorde, computers will be used to divert fuel about the plane in order to maintain lateral and longitudinal stability. The miles for a gallon of fuel per passenger will be significantly increased compared to the Concorde when one assess the data because the Lazarus improves itself on aerodynamic efficiency and engine performance in the following ways:

1. "Smart" flaps OR Recycling Bleed Engine System to quell the supersonic boundary separation within airplane engines.
2. Aeroelastic materials to reduce friction.
3. Blended wing shape optimized for supersonic flight.
4. Removal of the empennage; replacement with a computer system.
5. Efficient turbofan technology.
6. Takeoff/Landing Efficiency: changing camber relies less on engines propulsion.

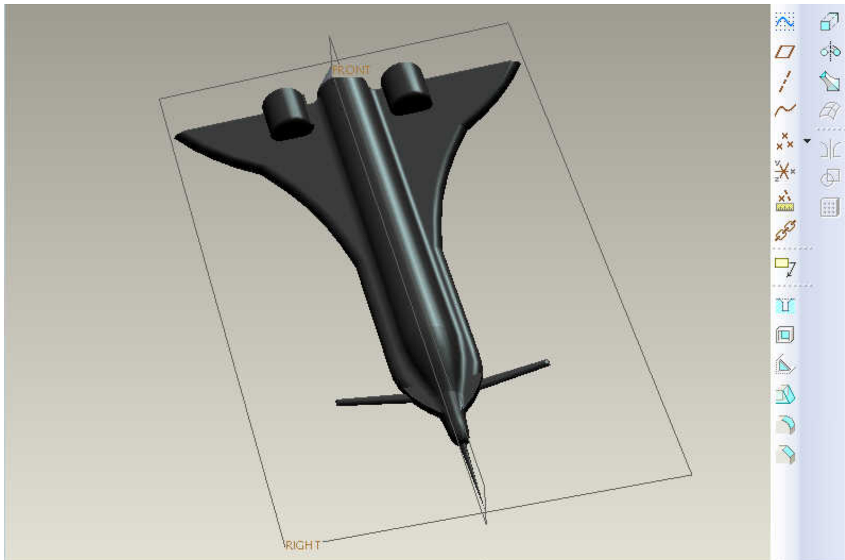
Cruise Speed

As NASA has set a goal for 1.6-1.8 mach, this will be the set goal of the Lazarus 11. This slightly lowered speed compared to the mach 2 Concorde allows the plane to use turbofans, as these become more efficient at slower speeds compared to turbojet engines. This seems the optimum performance when everything is factored in.

Range

Considering the extra space for fuel tanks because of the blended wing design (in which the undercarriage has more room), the Lazarus T1 will have a choice of ranges in which to operate; of course short distance flights for supersonic aircrafts are unreasonable, but long-distance flights are not. The Lazarus will be built to withstand ranges surpassing the oceans and will definitely reach the envisioned 4000 nautical mile distance NASA forecasts for 2020.

Preliminary Views of the Lazarus T1



Development of Lazarus T1 in using CAD Pro ENGINEER software.

A side view of the Lazarus T1.

And Beyond

Just recently the teroflop barrier has been broken, ushering in numerous computing possibilities. As a more exhaustive method of optimizing airframe efficiency, genetic algorithms taking advantage of increased computer processing power might be used. Unfortunately we were not able to obtain flow analysis components compatible with the school edition of Pro ENGINEER; however, there does exist components such as EFD Pro which allow for tests of aerodynamic efficiency in the digital environment.

A genetic algorithm method of optimizing airframe shape would set up initial preconditions (for example minimum aircraft height and width), and then the computer would be programmed to tweak the airframe shape gradually. With each tweak a flow analysis check would be made. In this way the most efficient frame can be found with a comprehensive "brute force" method.

The algorithm would have the basic structure below.

```
Preconditions:

      Minimum airframe height: __
      Minimum airframe width: __
      ...
      Minimum number of passengers: __
      Maximum front cross-sectional area: __
      ...

Processing and selection algorithm:

      1. Tweak specific airframe shape by predetermined increment.
      2. Run simulated experiment testing aerodynamic efficiency, etc.
      3. Record results.
      4. Until possibilities exhausted, return to (1).
      ...
      5. Compare results to determine optimal airframe.
```

In this manner the cost of field tests will be significantly reduced, and the frame efficiency can be more accurately and quickly determined.

Conclusion

Naturally the Lazarus T1 by no means encompasses the full range of possibilities and improvements that can be made in supersonic flight. One method of improvement viable even now is the use of genetic algorithms to more closely approximate the ideal airframe. But with the the next decade numerous other technologies will undoubtedly arise improving the efficiency and sustainability of supersonic flight. For now, however, the initial taxon must revive it.

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