2009 NASA AERONAUTICS COMPETITION

The Arrow

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"Time is money." A simple phrase, which in three words, defines one of the greatest downfalls of the Airline industry today. Businessmen, tourists, and travelers board airplanes and wait anywhere between one and twenty-two hours to reach their destinations. Technology advancements have allowed planes to have higher efficiency levels, while at higher speeds, but the barrier for commercial supersonic planes remains just as it did ten years ago. The introduction of modern technology in combination with new methods and designs will change the travel industry dramatically. Team Holton 1 introduces the sonic cruiser of tomorrow as the "The Arrow (Fig. 1.)." The Arrow has several key parts and implementations that resolve many of the most abundant inhibitors of supersonic flight, including noise and weight reduction, aerodynamics, fuel efficiency, and payload.

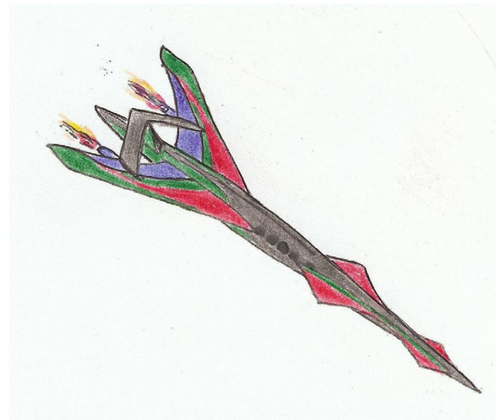


Fig. 1. The first Arrow draft.

The Idea

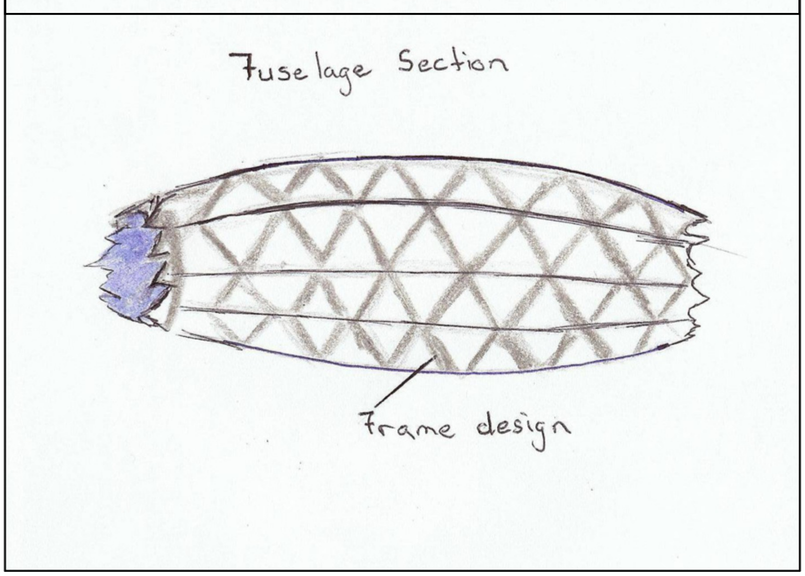
Most commercial aircrafts have rounded fuselages, with rather blunt front ends. When the air makes impact with such a surface at high speeds it creates drag, thus slowing the maximum speed of the craft.

Fig. 2. Low Resistance "Arrow"dynamics.

Inspiration for the shape and design of the Arrowhead was from two very unlikely sources: The modern #2 graphite pencil, and the much elder arrowheads. Both items have very obvious characteristics that can benefit the creation of a plane. For example, the drag created from pressure in the air can be compared to the resistance from a cloth when a pencil is being forced through. When an unsharpened pencil is forced through a shirt, the shirt will stretch and increase its resistance until it finally reaches its threshold and the pencil pops through with one sudden burst of energy. On the other hand, when a sharpened pencil is forced through a cloth it glides through it much easier, catching resistance in sections rather than all at once. Because of this fact, the longer and more coned a plane is the less likely a sonic boom will occur as loudly or with as much energy at once. The challenge of creating an arrowhead was very similar to the challenge of a supersonic airplane; what object can fly great distances at high speeds without wavering from its target due to resistance, and still hit its target with tremendous impact strength, all the while keeping its form?...an arrow, as shown in Fig. 2.

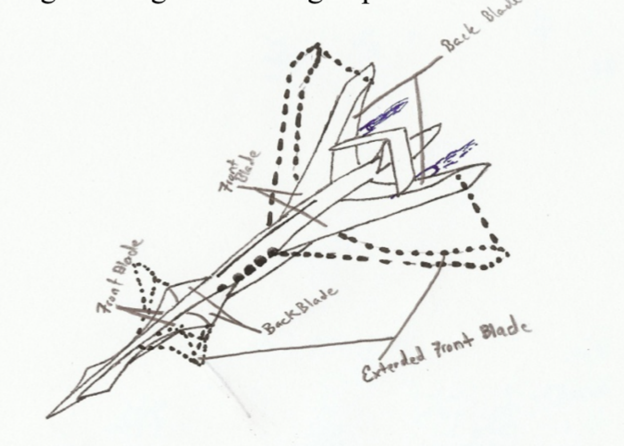
Framework and Dimensions

Fig. 3. Frame Shape of Fuselage



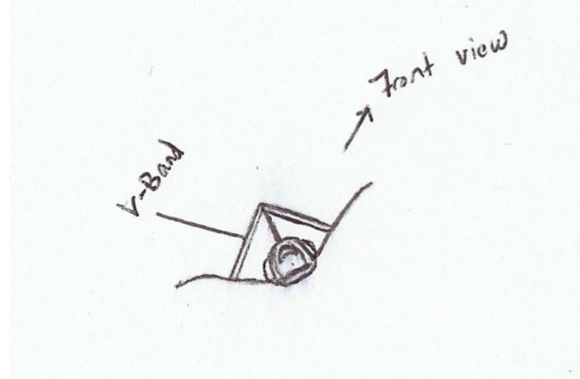
Two major inhibitors efficiency during high speed flight would be weight and shape. The Arrow is composed of interlocking hollow tubes of Aluminum lithium. Aluminum lithium is 10% lighter than aluminum alone, and just as strong. Because of this weight benefit, The Arrow has an advantage over the more commonly steel and aluminum framed aircraft. Just as many planes before The Arrow have done, the frame of the fuselage will be created through interlocking triangles together in the shape desired just as seen in Fig. 3 above. Due to the strength and lightweight of the aluminum lithium and the effectiveness of the triangle shape The Arrow will be as strong as a conventional plane while upholding a featherweight title.

Fig. 4. Diagram of wing expansion.



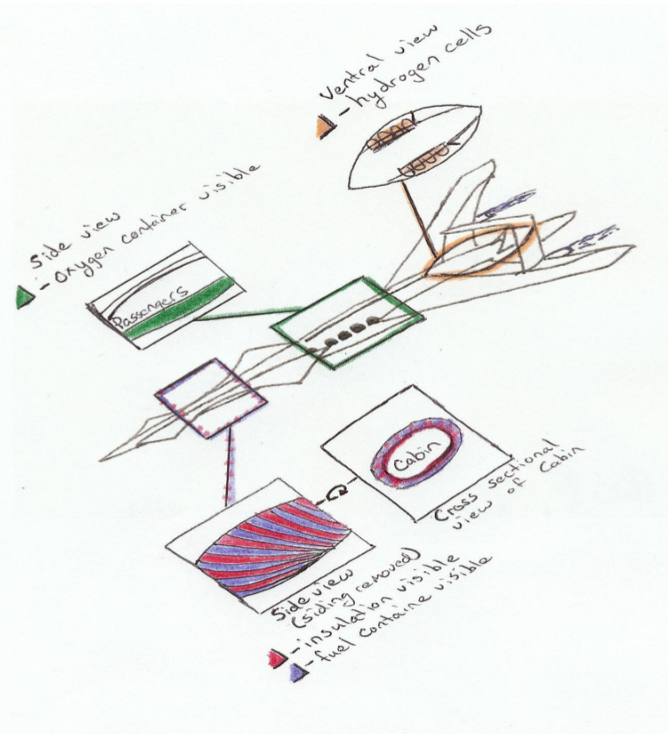
The dimensions of a plane are extremely important factors that contribute to cargo space, friction reduction, speed, as well as many other things. The Arrow has optimal dimensional conditions. The fuselage of the plane is 150 feet long, and has a width of only nine millimeters at its front point expanding slowly to a width of twenty feet at its widest point. This allows for minimal resistance from the beginning of flight, into supersonic flight as well. The height of the plane is fifteen feet at its largest point, which is also where its center of gravity is. The center of gravity on The Arrow is at the point of which the plane's rear wings begin. As shown in Fig. 4, both the front and rear wings are expandable much like the Navy's F-18

Fig. 5. An anterior view of The Arrow previewing the inverted "V" band.



Hornet. Because of this the front wings are forty feet wide when contracted and fifty feet when expanded. The rear wings have a 120 foot wingspan when expanded and a seventy foot wingspan when closed. This expansion of the wings in possible through the wings being separated into two parts a front and back wing blade for each. The front blade of each wing is hollowed out allowing for more sections that extend out using air pressure and hydraulics pushing the front wings forward and allowing the plan to take off the runway in a much shorter distance, as well as slow much quicker for landing. This also allows the plane to retract the wings while in flight to obtain much higher speeds and fuel efficiency. While viewing Fig. 5 it is visible that as most planes do, The Arrow will have a dorsal blade, but it will also have an inverted "V" connecting it to the back blades of each of the rear wings. This "V" is an attachment that greatly reduces noise pollution emitted from the plane. It does this through both sound modeling, as well as air current redirection (Morgenstern).

Fig. 6. Diagram of the Bilayered insulation, as well as Liquid O2 storage and Hydrogen storage.



Air, Fuel, Insulation

Due to the aircrafts limited amount of space available, the decision to give the vital substances double purposes has been imposed. In Fig. 6 the components of the plains fuel, oxygen, and hydrogen storage is diagramed. Around the cabin of the fuselage is a double layered "membranous-like" insulation container. The inner layer of the two contains a very potent yet light and flexible foam like substance to be used as a traditional insulator. Outside of that is a thin carbon fiber separator that keeps the bilayers separate. The second layer contains roughly fifty flat bag-like containers that are meant to contain fuel. As the fuel is injected it puts a slight more pressure on the insulation. The pressure will force the foam to condense for the time being and gradually expand once again as the fuel is dispensed and utilized. Because of this trade back and forth, the amount of maximum available space is neither increased nor decreased within the walls of the ship.

The extreme heat from friction on the plane will cause many unaddressed issues addressed. The Arrow will have several featured directed towards this problem. The outer casing of the plane will have thin sheets of carbon fiber reinforced silicon carbide where the heat expansion is least likely and will have thick sheets covering the areas of increased friction probability. These sheets can withstand temperatures of up to 2000*C before the heat affects their properties (Milauskas). Another alteration of the jet will be that it will have no windows, just as the Model Hypersonic Plane shown in Fig. 7.. This will accomplish several things. One, light windows cannot withstand high heat without shattering or melting, thus through eliminating windows the threat of in-flight disaster is dismayed more. Secondly, the windows required for use in intense heat are much too heavy to be implemented in the use of this aircraft. The use of cameras and the replacement of

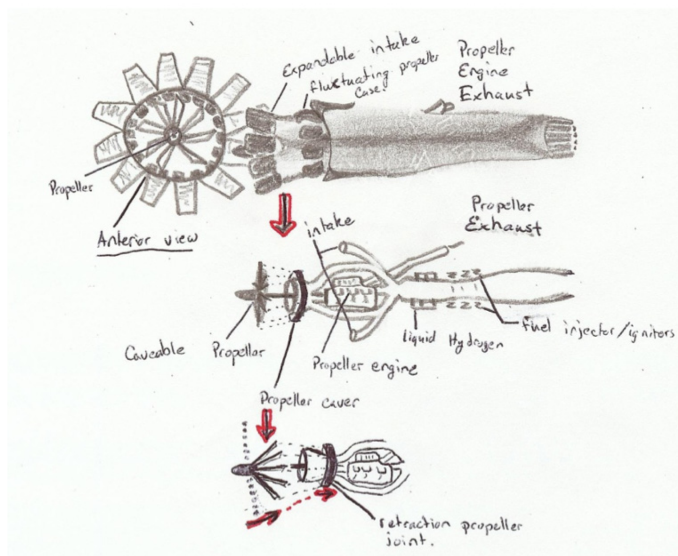
Fig. 7. A picture of a windowless hypersonic plane model.

the windows with small T.V.s showing the outside could be considerably cheaper when including the weight of the glass. Lastly, it is safer to not have windows on a plane, without windows it is possible to fly up another six or seven thousand feet in elevation (Day). By flying at a higher elevation the aircrafts fuel efficiency would increase dramatically due to the lower concentration of gases in the air. The safety reasoning behind the windowless plane is due to its ability to conserve the amount of oxygen in the cabin, preventing the chances of anoxia (Correspondent).

Engine

The engine design in mind for the Arrow is a combination of a propeller compression/propulsion system and the already well known Liquid Air Cycle Engine otherwise known as "LACE." The use of the propellers creates a much more efficient system at lower speeds, takeoff, and lower altitudes. By utilizing the propellers until their peak possible speed, then making the propellers turn inward to form a cone shape while rotating is beneficial to the LACE system. LACE works by compressing and then quickly liquefying the air. Compression is achieved through the ram-air effect in an intake similar to that found on a high-speed aircraft like Concorde, where intake ramps create shock waves that compress the air (Pietrobon). In the case of The Arrow, the

Fig. 8. LACE-Prop engine design.



propeller on the front can be shaped into a cone to create more pressure within the chamber where heat exchange occurs, thus aiding in the liquefaction of the air. The air would be forced into a more confined space than what is normal for a propeller allowing for the initiation of the ram-air compression and propulsion. As shown above, the LACE design then blows the compressed air over a heat exchange, in which the liquid hydrogen fuel is flowing. The hydrogen is a super-cooled substance and because of this it rapidly cools the air, causing the various constituents to quickly liquefy. By careful mechanical arrangement the liquid oxygen can be removed from the other parts of the air, notably water, nitrogen and carbon dioxide, at which point it can be fed into the engine as normal fuel(Reithmaier). The hydrogen is so much lighter than oxygen that the now-warm hydrogen is often dumped overboard instead of being re-used as fuel, while holding a net gain. Because of its conservative nature, hydrogen is a much more convenient and manageable energy source (Pietrobon). As seen in Fig. 8. The LACE-Prop engine will allow for high and low speeds whilst maintaining a high level of energy efficiency.

The world of technology is an ever-changing and evolving system of people, machines, and objects. Contemporary techniques and innovations can be combined within the mechanics of each thing utilized today; science only needs to take advantage of that fact. The airline industry can and will soon create a conventional super-sonic plane. The combination of stronger, lighter, and cheaper materials with more powerful and abundant energy resources have been the innovations for The Arrow. Along with the planes smoother and more aerodynamic shape, it will be stronger and lighter than the modern planes.

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