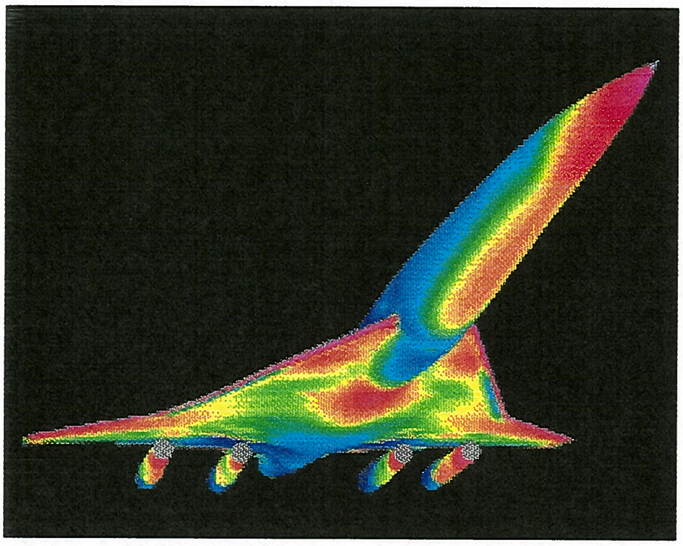
Manufacturing processes coursework

94%.

Javier Cuadriello Rodríguez
Imperial College
London 1998

"The Son of Concorde" & the "Heat Barrier"



Javier Cuadriello Rodríguez
Aeronautics 2nd Year
Imperial College.
London 1998

INDEX

1.Introduction

During the 1950's the aviation industries of Russia, the USA, Britain and France built military aircraft that were capable of flying faster than speed of sound. With this experience all four countries began feasibility studies of supersonic aircraft for civil use. This was motivated by a belief in the virtue of speed. It was argued that by increasing the cruising speed of an airliner it would be possible to increase the number of trips made in a given period of time and hence increase the productivity of that airliner. Also, it was believed that an increase in speed would have a big appeal to travelers by reducing journey times. There was a strong conviction that supersonic transport would be very attractive for both airlines and traveling public.
Concorde was formally conceived on 29 November 1962 when the Anglo-French Concorde Agreement was signed by representatives of the British and the French Governments.
Concorde was built by two companies, the British Aircraft corporation (BAC), and Sud Aviation (later to become part of Aerospatiale).
It took six years to create Concorde, the first prototype flew on 2 March 1969.
While the aircraft still has a useful life ahead of it, plans are already being made for the next generation in the coming millennium. The new aircraft will not be faster, but it will be more economic to operate, as it will be able to carry 250 passengers. It is believed that the primary market will be on trans-Pacific routes between the US and Asia. The US has already committed to spending USD 200 million developing the "Son of Concorde", the Japanese USD 56 million and the Europeans USD 15 million, according to Revue Aerospatiale. While in theory, the Europeans have a head start, the race to produce the next generation will be fast, furious and expensive.

<u>Economic factors</u>

In the case of Concorde £10^9 public money was spent in the development. There are different opinions about the success of the Concorde program. It was a technological success however very few aircraft were built and the only airline that got the plane were the British and French public airlines. Back in the seventies the were commercials in aircraft magazines claiming that "one day there will be to kinds of airlines, the ones with Concorde and the ones without it". However tickets for Concorde are too expensive for the average traveler, sonic booms produced by the aircraft limit in a great manner the routes it can take and it doesn't have Trans-Pacific capabilities with limits its market in the Pacific Ring. All this limitations are reflected in the requirements for the successor of Concorde. We can't get rid of the sonic boom but the new aircraft will have to be bigger, cheaper and carry more passengers further away.

two.

In order to obtain these improvements we must use new materials and manufacturing processes. Since the time of Concorde and the first Space Shuttle many new techniques have developed and/or have been started to be widely used.

2.The heat problem: "The Heat barrier"

The main limitation for high-speed travel is not engine thrust but the heat the aircraft skin and structure has to stand. Some have called this the "heat barrier" using the analogy with the "sound barrier".
The temperature increases with speed due to kinetic heating following the following relation:

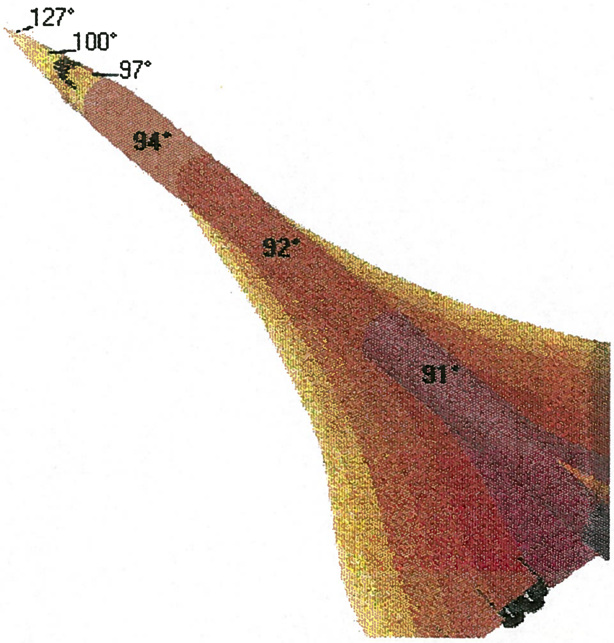
$\Delta T = \frac{v^2}{2C_p}$ Where v is the air speed and Cp is the specific heat capacity.

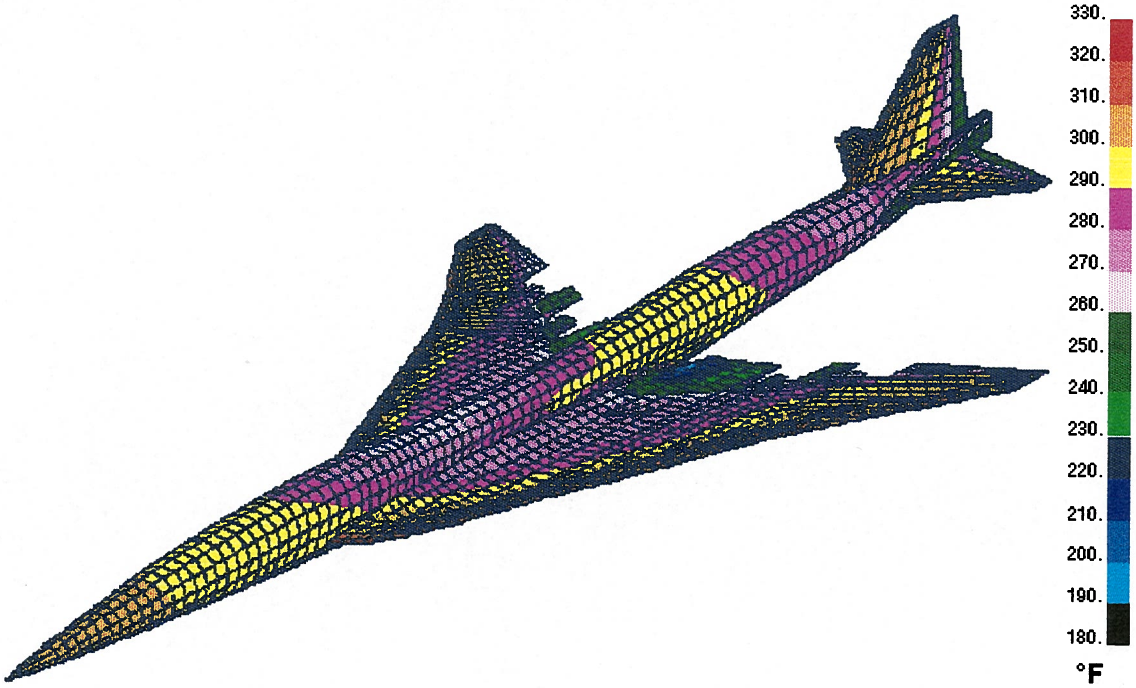
i.e. the temperature rise depends on the square of the airspeed.
Therefore supersonic aircraft get really hot at cruise speeds and have to withstand these temperatures for long periods of time.
In a normal 'hot structure' aircraft the heat of the skin will be transferred to the structure of the aircraft. This is not the case of the Space Shuttle which has a unloaded skin made of ceramic tiles that keep the supporting structure relatively cold (about 175°C) compared with skin heat during re-entry. Therefore the orbiter structure could be made mostly out of aluminum except the aft section that is made of Titanium and boron-epoxy composite material. However this is not practical for a civil aircraft that has to be economical, simple and as easy to maintain as possible, the tiles in the Space Shuttle are very expensive, complex, maintenance costs are really high and they add a dead weight to the vehicle. It won't be viable to cover a civil airliner with ceramic tiles. Even in the newer shuttles Nomex felt materials have replaced some of these tiles in the less hot areas. In Challenger some of the LRSI (low temperature reusable surface insulation) have been replaced by this advanced fabric insulation. In Atlantis and Endeavor all the LRSI have been replaced.

an

The speed of Concorde was limited to Mach 2 at higher speed the structure became too hot for the aluminium. As can be seem in the image below some parts of Concorde get up to 130°C. If it was traveling faster the temperature would increase even more and the aluminium structure would over age very fast decreasing the service life and therefore making the aircraft economically inviable.

Therefore it is important to find materials that can maintain its properties at high temperatures and for long service lifes.

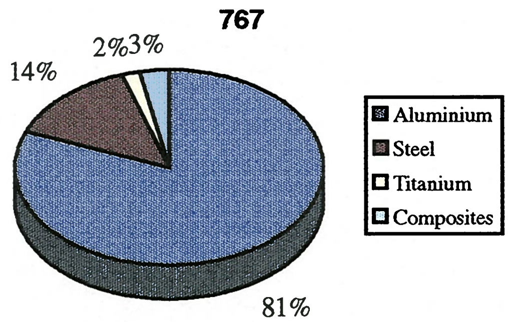


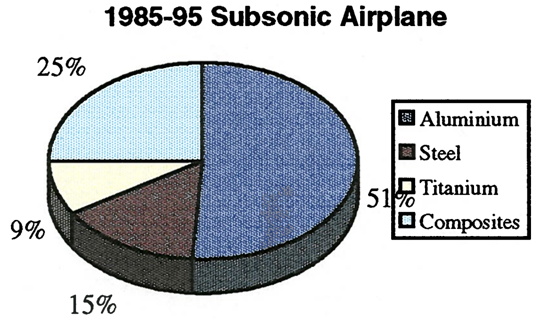


Predicted Heat distribution over the McDonnell-Douglas concept.
(Note: 330 °F = 165 °C , 300 °F = 148 °C)

3. How Concorde and the Space Shuttle were built

The Space Shuttle Orbiter and the Concorde structure are primarily made out of Aluminum, however even in the "old" Concorde we can find new composite materials such as glass reinforced plastic (GRP) and carbon fiber reinforced plastic (CFRP). The nose and the dorsal fin panels of Concorde are made from GRP, however these are not part of the load-bearing structure.
The reason for restricted use of these new materials in Concorde and in other aircraft was the lack of experience with these materials that there was at the time Concorde was designed. Designers had always been using "nice" isotropic metals and in order to use composites the have to move to very anisotropic designs. Also there was a lack of experience in assembling large structures using these materials and how to inspect them to keep the high certification standards. There was neither the necessary tooling nor manufacturing processes to deal with some of the new materials such as Titanium and Composites.
For the same reasons even today the use of these materials is restricted in the aircraft world. Even in cheaper less risky programs such as subsonic airliners the amount of new materials used hasn't grown as fast as predicted. However the percentage of new materials such as composites and Titanium has increased over the past years as can be seen in the graphs below.

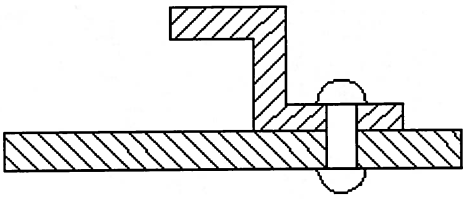




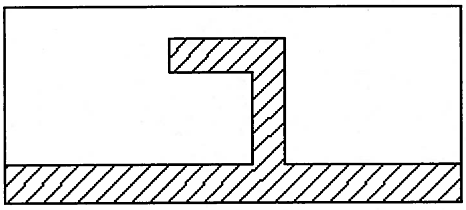
Aerospace industry is usually considered one of the most advanced. However it is also one of the most conservative ones, especially in the civil market. This is due to the extremely high cost of research, prototyping and testing required. Also the safety standards are extremely high and the aircraft must have very long service lifes. For these reasons new technologies and materials must be considered very carefully.
Usually the choice of material is not too critical, for example imagine we want to built a certain piece of a wing, you have the option of using a new composite material that is lighter and stronger, in the other hand you have aluminium. Choosing the new material would give a better performance however if aluminium can do the job and still be economically viable it would probably be chosen as it is a very well proven material that you know how to design, inspect, machine, you have the tools to do it and you know how is going to behave in the long term.
In the case of Concorde and the Space Shuttle the temperature that the structures had to withstand was of about 120°C for Concorde and 170°C for the Shuttle. There was an aluminium alloy available since World War II that could do the job. This allowed

to reduce the development costs of these two machines using existing and proven materials and manufacturing processes.
The material of choice for Concorde was Hiduminium RR58. Concorde is a traditional design in the sense that it is, as every other civilian aircraft, a long cylinder that contains the payload, crew, furnishings, fuel and equipment. This is basically a big pressure vessel whose pressure during flight is about 74kPa higher than the outside. The fuselage is also subjected to the forces applied by the wings, fin and undercarriage. All these forces tend to bend the fuselage as cantilever.

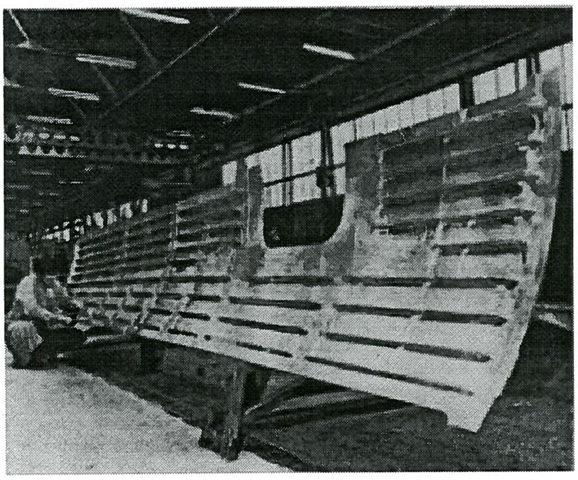
Two types of construction are used in the fuselage of Concorde and in most other contemporary aircraft. A minority of the skin is made from thin sheet to which extruded longitudinal stiffeners are attached by rivets (image a). On the other hand, in the majority of the fuselage the skin and the stiffeners are machined as one from thick plate by numerically controlled machine tools (image b).

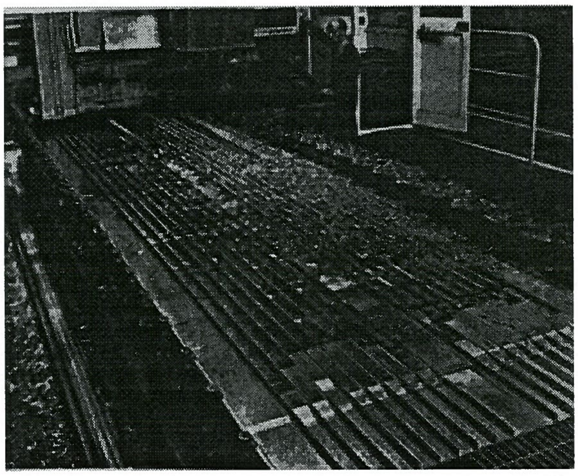


(a)



(b)





Up to 75% of the plate's volume may be machined away as small chips and while the new plate cost about £0.5Kg^{-1} (in 1970's money) , the machined chips fetch only about £0.1 Kg^{-1} (in 1970's money) on the scrap market. With cheap supplies of energy and material the cost of integrally machined skin panel was competitive with that of a panel assembled from thin sheet. But the integral panel is technically superior. Stress concentrations such as rivet holes are done away with, and rubbing between skin and stiffener is eliminated. Also the thickness of the machined skin can be varied to suit local loading needs, whereas that of the assembled panel is everywhere the same.

The movable control surfaces of Concorde (the rudder and the elevons) are made of aluminium honeycomb.

4. Other Supersonic Aircraft

Military aircraft have been flying at speeds up to Mach 2 since the 1950's. Most of these planes require the use of afterburner to fly supersonic and therefore spend most of their time at subsonic speeds. Therefore they don't spend as much time as Concorde under the extreme heat of supersonic flight. Remember that Concorde can fly supersonic without the continuos use of afterburner with allows it to save a lot of fuel and therefore it is able to cross the ocean without refueling.
In the military world there have been aircraft that were design to fly at speeds of Mach 3.0+. Military aircraft are not as concerned about safety as civilian aircraft and therefore it can be experimented with new materials and fabrication techniques, also some of these aircraft were built in the Cold War period when there was a lot of money available in other to get ultimate performance.
These aircraft provide a very valuable experience in the choice of materials and manufacturing processes used in their fabrication.

In appendix A it can be seen which materials were used in the construction of the XB-70, this is very large aircraft and therefore it is similar in size to a passenger aircraft. The next aircraft is the SR-71; the most interesting fact about this plane is the extensive use of Titanium used in its construction. The Mig-23 and Mig-30 show that some times steel can do the job when Titanium is not an option due to cost. Finally the X-15 provides the best experience we have with hypersonic planes, it is very different from a passenger aircraft but apart from the Space Shuttle is the only aircraft that has flown faster them Mach 7. It didn't have ceramic tiles as the Shuttle and therefore it is interesting to see how it managed to withstand extremely high temperatures up to 650°C.

5.THE SON AND GRAND SON OF CONCORDE

5.1 New civil projects

There are two different approaches for new high-speed transport. The first one is the true son of Concorde; it will be Concorde style aircraft but bigger, cheaper and more advanced in the materials and electronics fields. The other approach is a hypersonic plane that flies in the very high layers of the atmosphere at very high Mach numbers. In the next section the next supersonic transport will be discussed first followed by a brief discussion about the hypersonic vehicles.

5.2 The Son of Concorde

The Specifications for a new supersonic civil aircraft have already been set by the United States (N.A.S.A. and BOEING) and in Europe (by the partners in the Airbus consortium). The goals set for the new aircraft can been found in the lines below.

Specifications:

N.A.S.A.
Among N.A.S.A.'s technology goals for removing the environmental and economic barriers are:

(1) Quiet supersonic engines able to meet subsonic aircraft noise standards.
(2) Clean supersonic engines with emissions 75 percent lower than today's aircraft.
(3) Low-cost materials and structural concepts for affordability.
The result will revolutionize overseas air travel[1].

Aerospatiale and British Aerospace, who built Concorde, and Daimler-Benz Aerospace have already pooled their preliminary-projects in the European Supersonic Research Programme (ESRP).

European Specifications for the future supersonic transport (Airbus partners)

Their objective: to deliver a new generation supersonic by the year 2010 which will carry up to 300 passengers over 10,000 km at a cruising speed of Mach 2.2, with half the fuel consumption per passenger of Concorde.

Technical specifications[2]	
Range	>5,500 nm
Thrust	50,000 lb.
Mach cruising speed	2.05
Take-off weight	340 t / 760,000 lb.
Passengers	250 to 300 (in 3 classes)
Fuel consumption	0.05 kg/pax/km

[1] From NASA web site http://www.nasa.gov
[2] From Aerospatiale web site

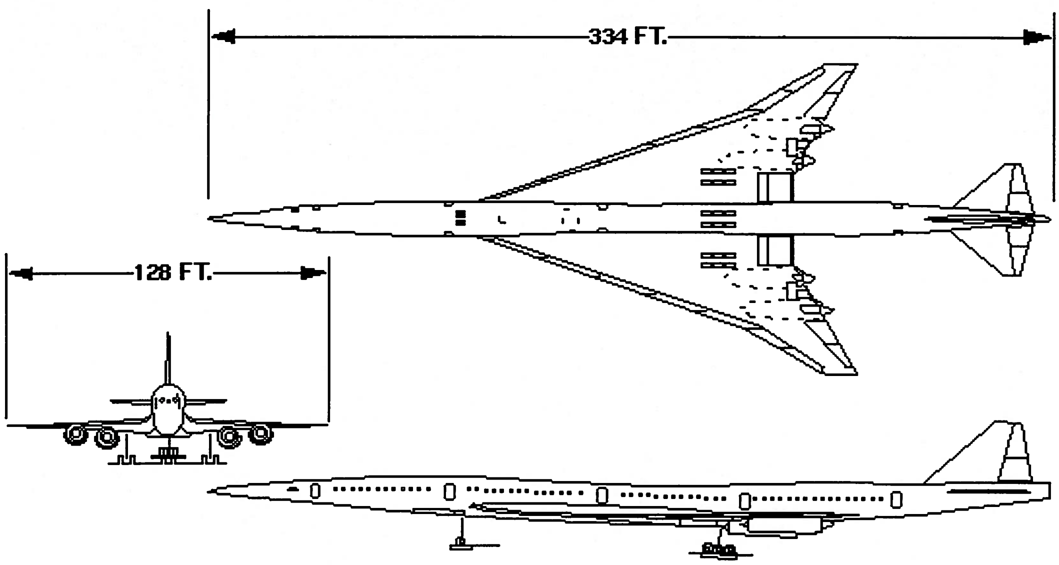
USA Specifications (Boeing-McDonnell Douglas) BOEING

Technical specifications[1]	
Range	5,000 N mi.
Takeoff Gross Weight	750,000 lb.
Empty weight	300,000 lb.
Cargo Volume	2000 cu. Ft.
Cruise Speed	Mach 2.4 (1,600 mph)
Altitude	60,000 ft.
Passengers	300 (3 classes)

These can be compared with the requirements for Concorde below.

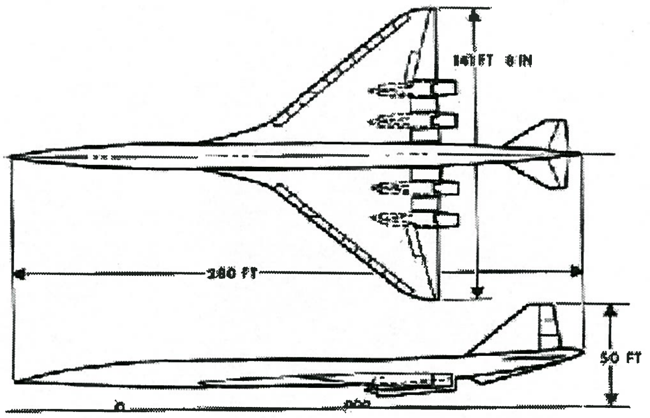
Concorde specifications	
Range	3,880 mi. with maximum payload and reserves
Thrust	4*38,030 lb. With afterburning
Cruising Speed	Mach 2.04
Ceiling	60,000 ft
Passengers	100
Weight	Empty 173,500 lb. Loaded 408,00 lb.

There are several proposed shapes for the new supersonic transport. The all look basically the same. Some of these proposed designs can be seen bellow these lines. Which ever of them is built (if any) will provably be manufactured using the same processes. Therefore we will concentrate in which materials will make the plane and the most advanced processes to manufacture these materials.

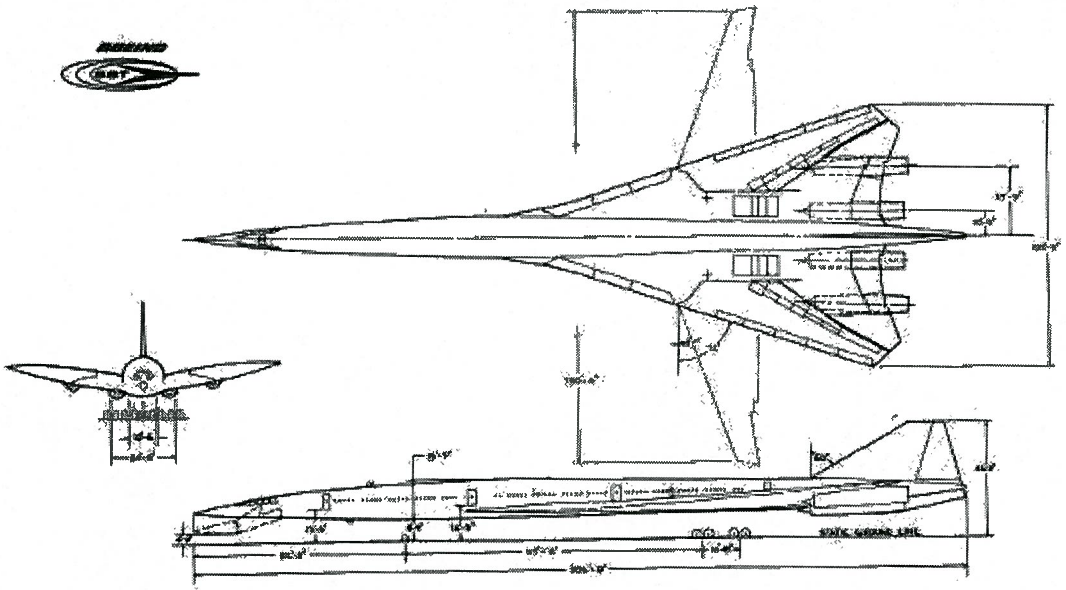


McDonnel-Douglas Proposal (before merge).

[1] From Boeing web site http://www.boeing.com

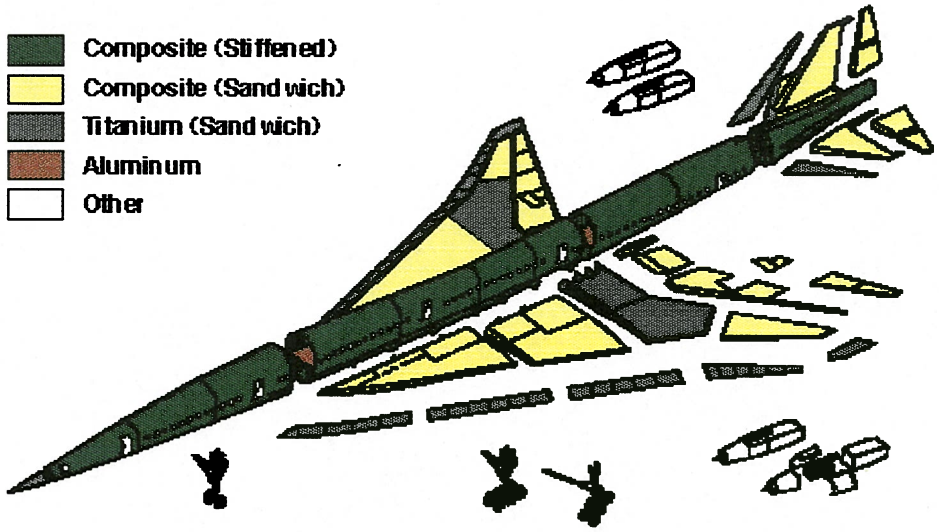


Boeing proposal



Boeing proposal (dismissed)

Materials and Manufacturing processes:



HSCT manufacturing Breakdown

The materials that will make the new supersonic transport possible are Titanium, advanced aluminium alloys and composite materials.

In order to build this more advanced aircraft with increased performance we are forced to use more advanced materials and new production techniques both to deal to the new materials and to improve the way old materials that were used. Since the time of Concorde many techniques have been developed and other, like numerical control machining have begun extremely common. This is very important as when some technique becomes common practice it also becomes much cheaper and therefore it can be used more. In the following pages I discuss some of the new of this new techniques and materials.

Superplasticity forming and diffusion bonding

Titanium has been for a long time a very attractive material for its heat and corrosion properties. However its use has been greatly limited by its cost and by the lack of experience in its manufacture. The relation with this material for a long time can be resumed in what the aircraft manufacturer said about Titanium during the construction of the engines for the Canadian interceptor *Avro CF-105 Arrow* in 1954, *'it broke tools and spirits'*. But since that time some new way to deal with Titanium could finally make it a more viable option. Probably the most important of the 'new' techniques are Superplasticity and diffusion bonding described below.

Superplasticity

Principles

The stress necessary to deform a metal is given by $\sigma = c \cdot \Sigma^n \cdot \Sigma^m$

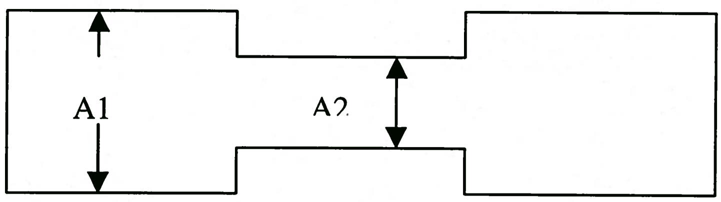
For most metals at room temperature m is very low (0.1 approx.). As temperature increases n decreases.

But for some metals m increases and can approach unity
i.e.

For m=1, $\sigma = c'' \cdot \dot{\Sigma}$

$\dot{\Sigma} = \frac{1}{c} \cdot \frac{dl}{dt} = -\frac{1}{A} \cdot \frac{dA}{dt}$ where l = length and A = cross section of load bearing material.

Rewriting $\sigma = \frac{P}{A} = \frac{-c''}{A} \cdot \frac{dA}{dt} \Rightarrow -\frac{dA}{dt} = \frac{P}{c''}$



Then if m=1 $-\frac{dA1}{dt} = -\frac{A2}{dt} \Rightarrow$ no necking instability.
Therefore if m=1 infinite tensile strain is possible.

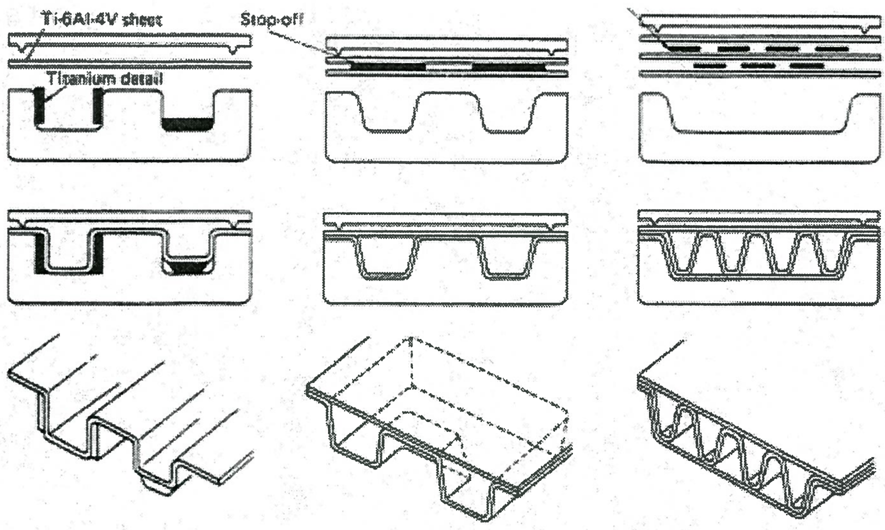
Uses

This is possible for example in very fine grain Ti-6Al-4V. Interstitial content has an m value of 0.6 approx. at 930oC. This allows a tensile elongation of over $103^{\%}$.
The load required to deform the metal is only a few MPa, this allow to use gas to apply this pressure. In this way we can inflate a structure to its shape, for example fuel tanks or different sandwich structures (see images below).

Diffusion bonding

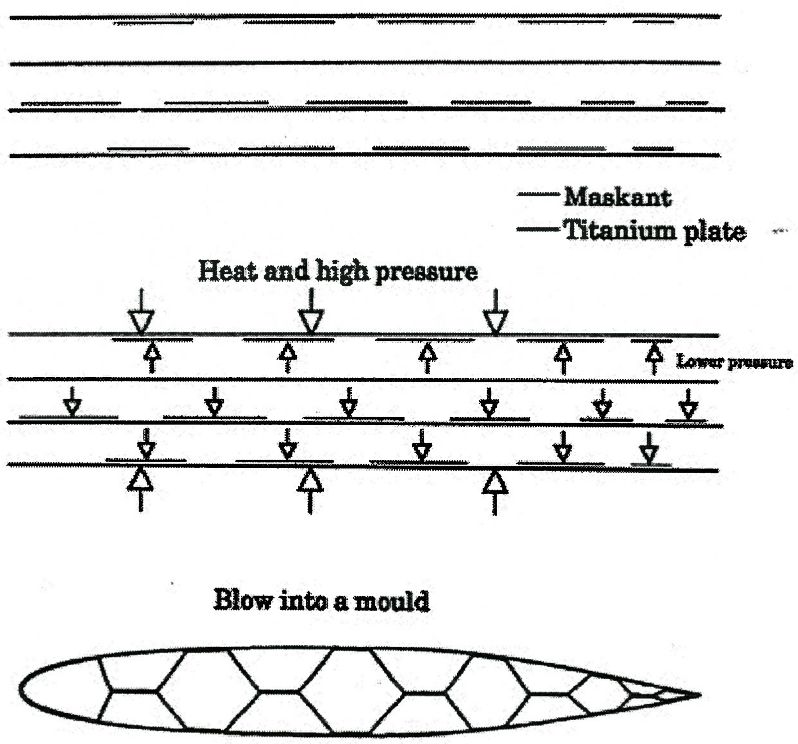
Above 600°C Titanium dissolves the oxide film on its surface and bare metal is exposed. Bare metal surface pressed into contact will bond as atoms diffuse across interface. In about two hours the bond line disappears and the bond has strength close to that of the parent metal.

These two processes are usually used together; this allows complex 3-D shapes to be created from sandwiches.



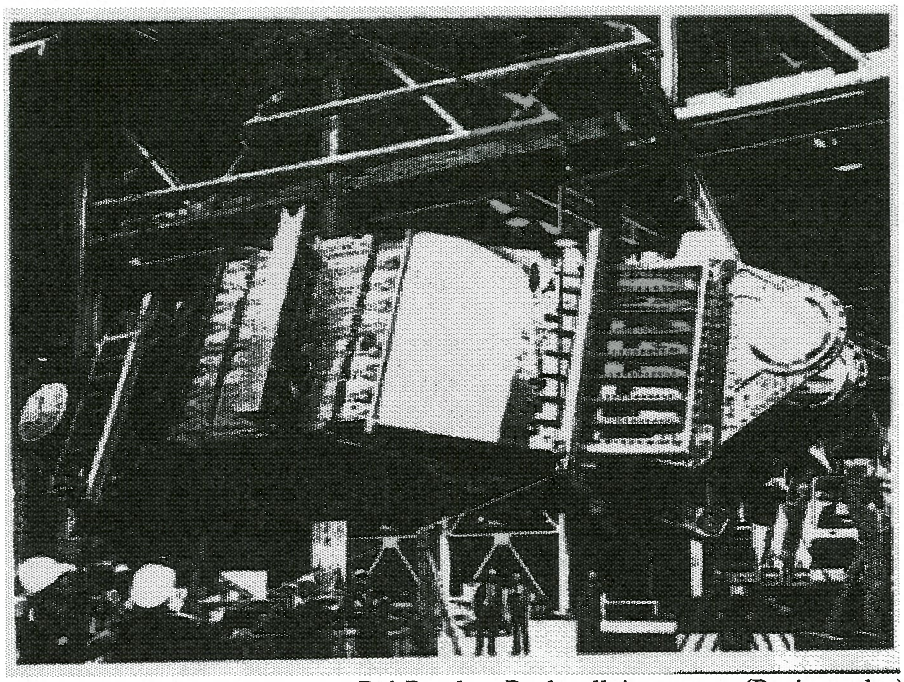
(a) reinforced sheet; one sheet (b) integrally stiffened structure; two sheets (c) sandwich; multiple sheets

Using these techniques could allow for example to make a wing in one piece. However a structure's design must alloy for easy repair and replacement, and this requirement limits the size of one-piece structures. Designers must weight the odds and costs of replacement against the lower production costs that result from elimination of fasteners and parts. Small pieces like the Eurofigher canard are made using this method.

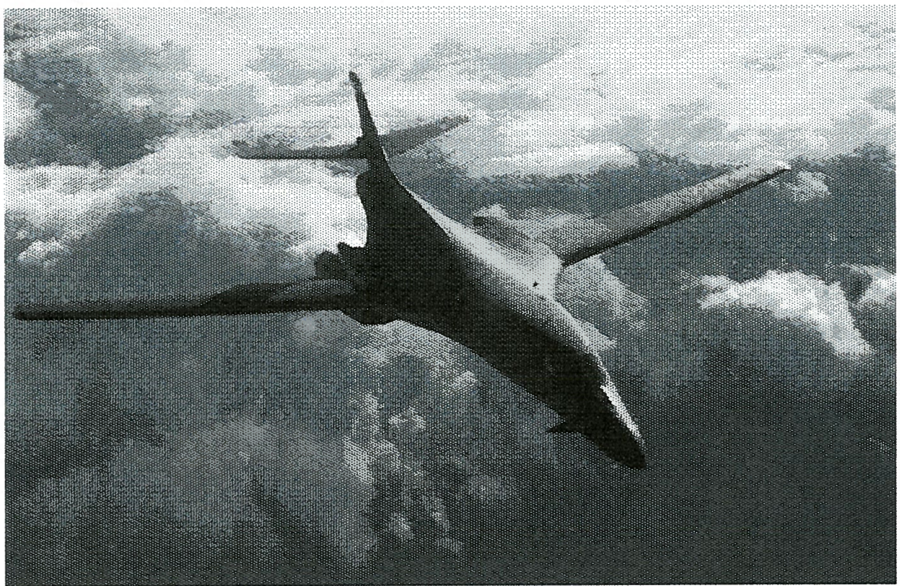


Superplastic forming and diffusion bonding were used extensively in the B-1 bomber structure. The central part of the aircraft was made out of Titanium using these

techniques (see image below). It's use in a future supersonic transport aircraft if obvious.
These processes are extremely important and extremely useful, they allow us to deal with materials and shapes that were very difficult or impossible to manufacture before. Therefore they not only allow us to use a new material such as Titanium but also allow to do this with it that can't be made with older materials such a for example steel.
Titanium is much more expensive than steels, however if used properly the resulting structure can result being cheaper.



B-1 Bomber. Rockwell Aerospace. (Boeing today)



B-1 Bomber. Boeing Co.

NCNC machining

This technique allows to fabricate pieces to a very high accuracy and to reproduce them again and again. It also allows us to send the computer drawing of the piece directly saving a lot of time. This technique has been in use for a relatively long time being already used in Concorde. Today it is so common that even second year aeronautics students use it in building their applications projects.

Welding

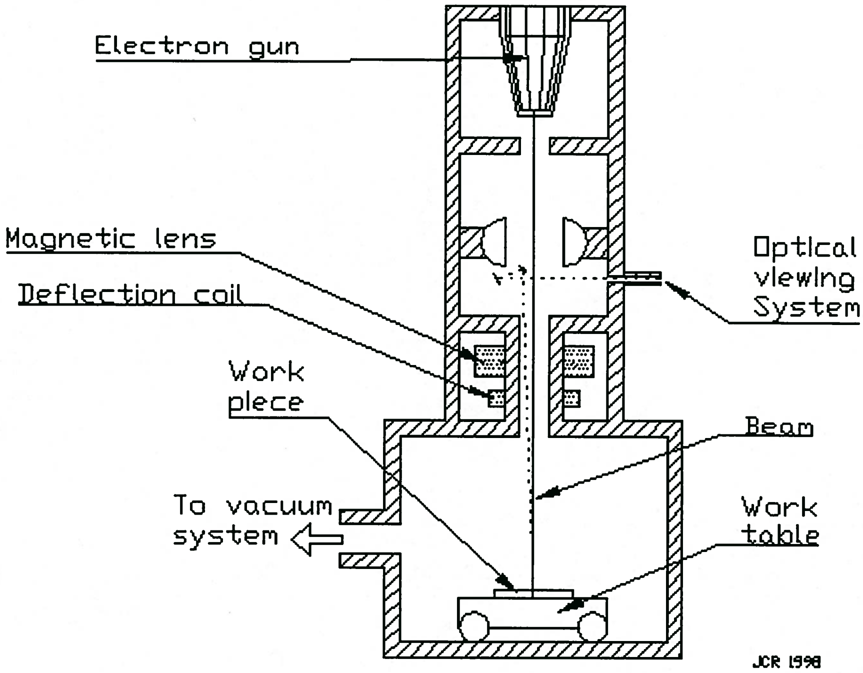
Weldings are always a critical part of the structures as they can initiate cracks and change the properties of the materials due to the heat applied during welding. Therefore producing better welding is an important issue. A description of two different techniques can be found below. The first one is relative old and the second one is relatively new. There are of course many other ways of welding that are not mentioned here as this subject could easily take a whole essay by itself, however these two show quite well the improvements that have been made in this field.

<u>Tungsten inert gas (T.I.G.) welding</u>

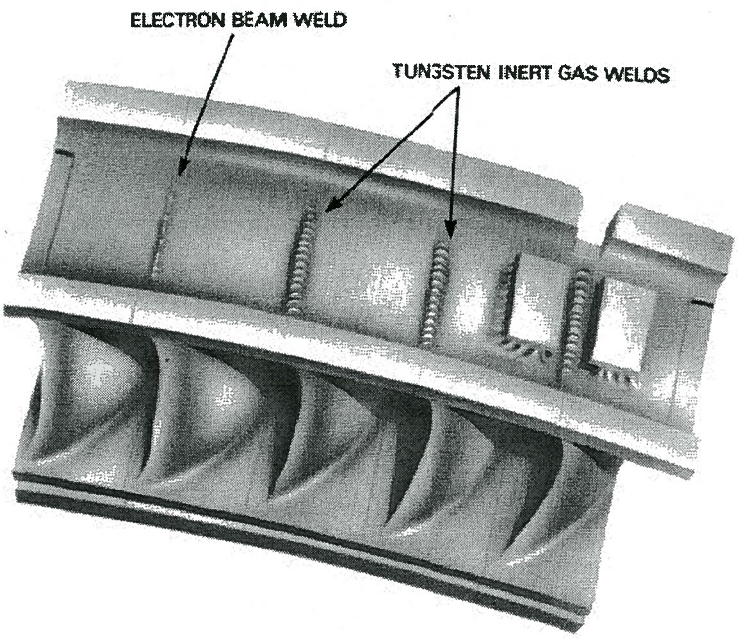
The most common form of tungsten inert gas welding in use is the direct current straight polarity i.e. electrode negative pole. This is widely used and the most economical method of producing high quality welds for a range of high strength /high temperature materials. For this class of work, high purity argon shielding gas is fed to both sides of the weld and the welding torch nozzle is fitted with a gas lens to ensure maximum efficiency for shielding gas coverage. A consumable four per cent thoriated tungsten electrode, together with a suitable non-contact method of arc starting is used and the weld current is reduced in a controlled manner at the end of each weld to prevent the formation of finishing cracks.

<u>Electron beam welding (E.B.W.)</u>

This system, which can use either low or high voltage, uses a high power density beam of electrons to join a wide range of different materials and of varying thickness. Automation has been enhanced by the application of numerical control to the work handling and manipulation. Seam tracking to ensure that the joint is accurately followed and close loop under bead control to guarantee the full depth of material thickness is welded. Focus of the beam is controlled by digital voltmeters.



The difference between these two kinds of welding can be easily seen in the image below. Obviously the electron beam welding produces a much better weld.



Polymers

Thermoset materials such as epoxies generally cost less and perform better than other polymer systems, working well at temperatures up to 100°C and higher for short intervals. Bismaleimide materials retain their properties up to about 200°C. Early problems with brittleness have been largely overcome through blending with thermoplastics.
Thermoplastics are far less brittle than thermosets and are thus more resistant to damage. A highly efficient method of joining thermoplastic parts is by dual resin bonding. Here surfaces are fused under heat and pressure to create a joint that is vastly superior to an adhesively bonded joint.
Thermoplastics offer many advantages in the 100-180°C range. There is however an inherent material cost. Dual resin bonding involves coating surfaces with a chemically compatible resin whose melting temperature is slightly lower than that of the surfaces being bonded.

COMPOSITE MATERIALS

In the past decades there have been considerable advances in the composite technology. However the full potential in the design, manufacturing and specially the application of composites has not been realized. The use of composites in loaded structures has been limited, mainly to the lack of experience and confidence. Even today we must remember that there are only a few decades of experience with composites (excluding wood) in comparison with thousands of years of experience with metals. We must remember that composite structures are not just an extension of their metal counterparts and shouldn't be used as just a material replacement that merely save structural weight, what has been called the "black aluminium approach". Due to the enormous benefits that composites have to offer they will surely be present in a great extent in a future supersonic transport.
There are many kinds of composites and many manufacturing processes for them. Some of this kinds and methods are described below.

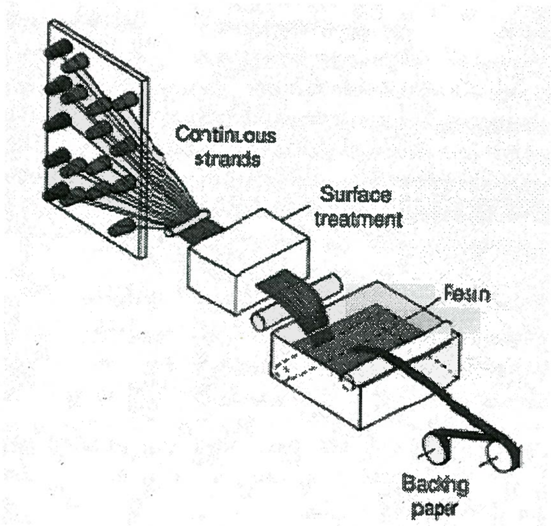
Polymer composites

Unreinforced polymers are considerably less stiff (modulus) and strong (yield and fracture strength) then other engineering materials (metals, ceramics). On the other hand, the glass, carbon and Kevlar fibers commonly used in composites have very good stiffness and strength properties. These materials are strong and light and also possess some toughness. There is quite a big experience dealing with these materials, for example approximately 30% of the 767 consists of such composites.

Several methods have been developed to fabricate fiber-reinforced polymer matrix composites. Some of then are describes below.

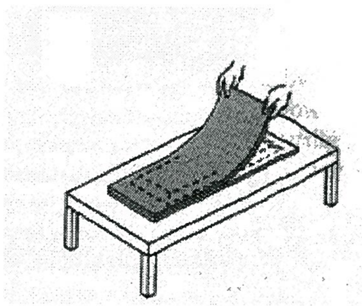
Sheet production using continuos fibers

The first step is to produce so-called prepreg tapes or sheets of the composite that will be subsequently consolidated into a laminated structure. To accomplish this, continuos fiber unwound from bobbins forms strands that are first coated with agents to promote good bonding to the matrix polymer (resin). These strands are then continuously immersed in resin baths that will become the matrix that surrounds the fibers.



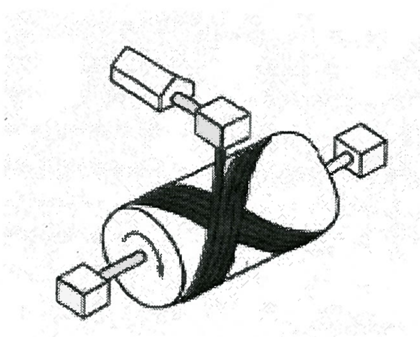
Assembly into laminated structure

Sheets can be compression molded or hand laid in molds to make laminates.



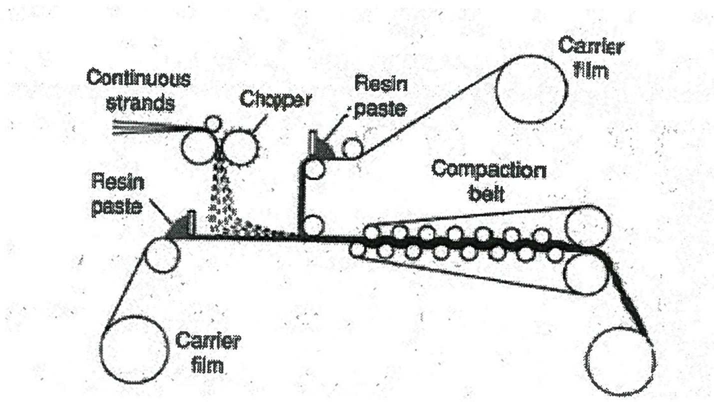
Filament winding

Tape prepregs can also be wound over large shapes and cured to make large lightweight containers or bars. The angle of the filaments can be change in order to maximize the strength in the desired direction.



Sheet production using cut fibers

A sheet can be produced by cofeeding and compacting chopped fiber and resin. Shaped composite parts are commonly injection molded by continuously adding chopped fiber of about 1cm long along with the polymer feedstock. Controlling the fiber orientation is an important concern in this process.

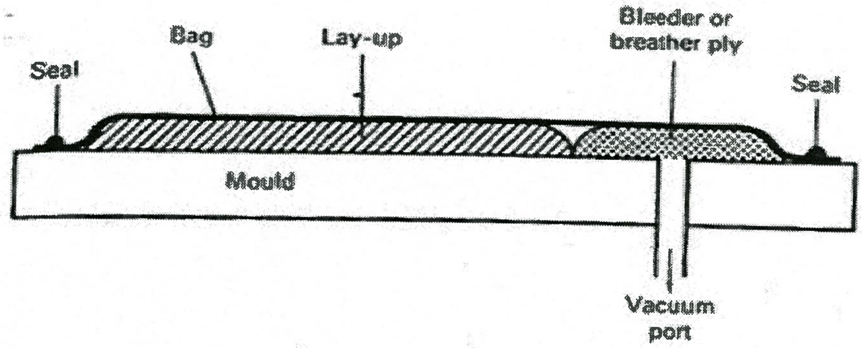


Spray up

Chopped rovings and resin are sprayed simultaneously into a prepared mound and rolled before the resin cures.

Vacuum bag, pressure bag, autoclave

Layers of fibers, usually unidirectional sheets, are pre-impregnated with resin and partially cured to form a prepreg. The pre-preg sheets are stacked on the mould surfaces in predetermined orientations, covered with a flexible bag, and consolidated using a vacuum or pressure bag in an autoclave at the required curing temperature.



Centrifugal casting

Mixtures of the fibres and resin are introduced into a rotating mould and allowed to cure in situ.

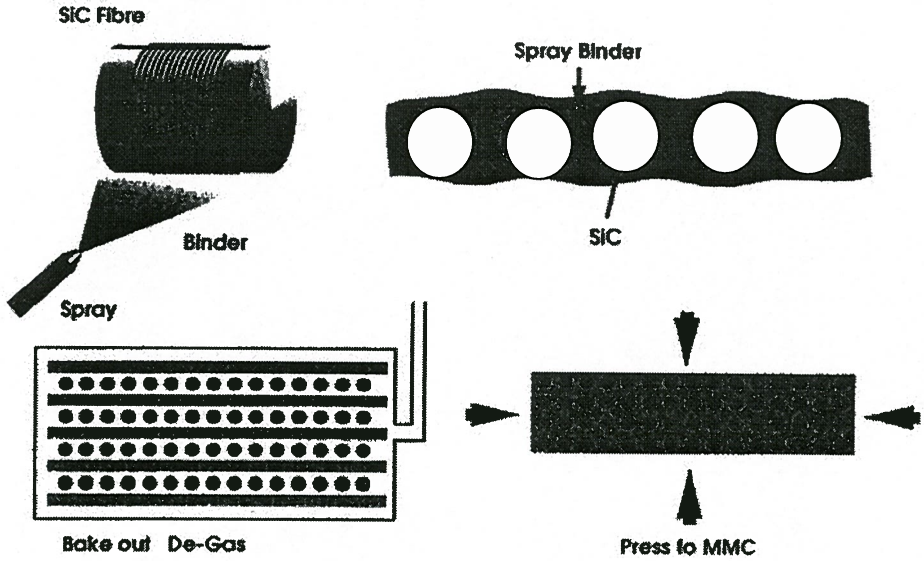
All these methods of dealing with composites and many others not described here allow us to really use composites effectively and to take advantage of its very interesting properties.

Metal matrix composites

Metal matrix composites allow us to combine some of the interesting properties of metals (toughness) with the interesting properties of ceramics (strength). Manufacturing these composites in hard and expensive and that's why the are still not very much used. However new manufacturing processes will make then easier to make and therefore cheaper. The will almost sure be used in the future supersonic transport.

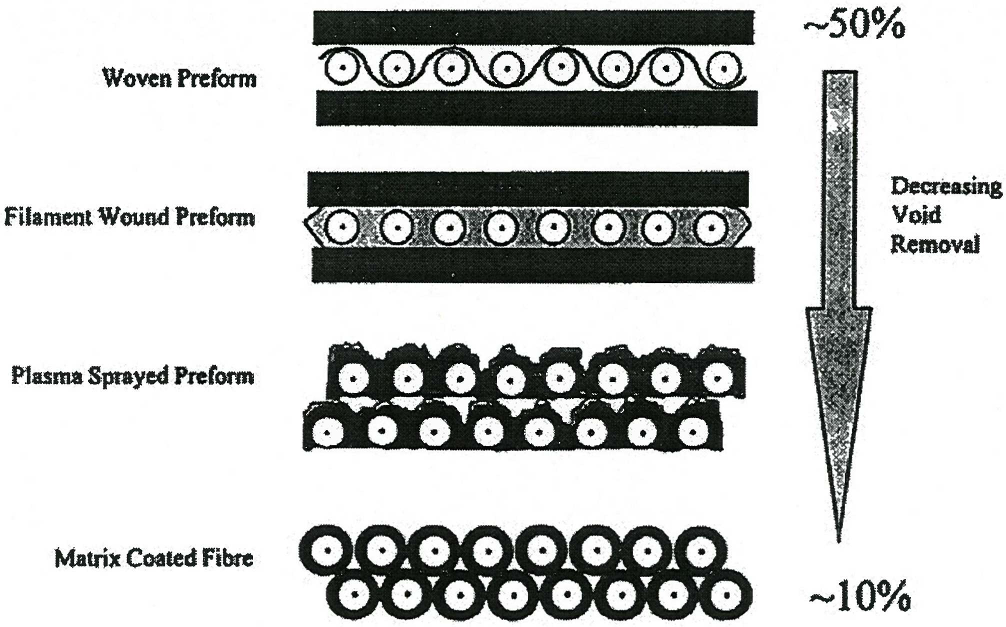
PLASMA SPRAY COATING FIBERS

PLASMA SPRAY COATING FIBERS

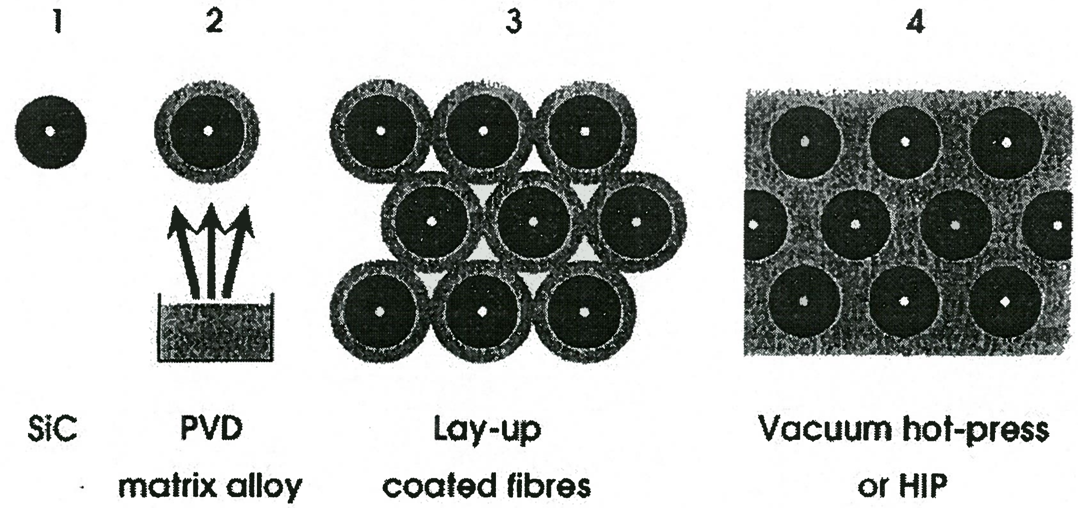


e 1. **Schematic illustration of the foil/fibre filament winding method for titanium MMC fabrication.**

FIBERS FOIL



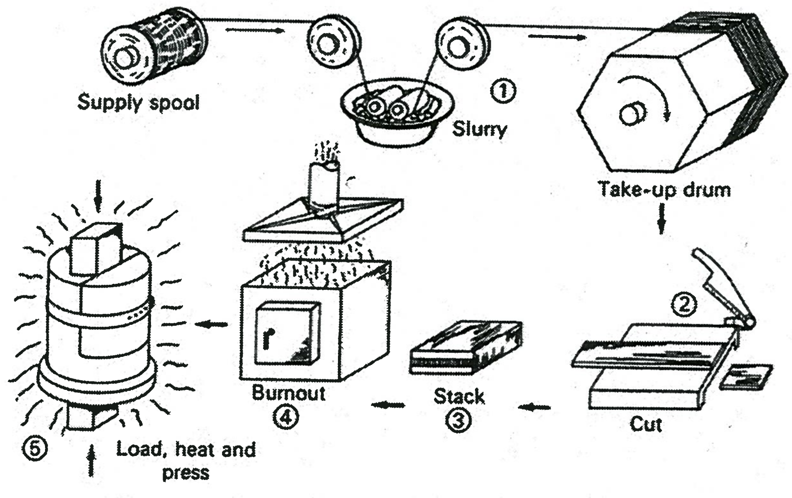
PHYSICAL VAPOUR DEPOSITION



Schematic of the DRA matrix coated fibre process for the fabrication of fibre reinforced MMCs.

Ceramic matrix composites

Continuous fiber reinforcement is the most widely used method to develop glass matrices. It is know used for glass-ceramic and other matrices.



Processing using a slurry and hot pressing for continuous fibre reinforced glass or glass-ceramic. (Source: Prewo, 1989.)

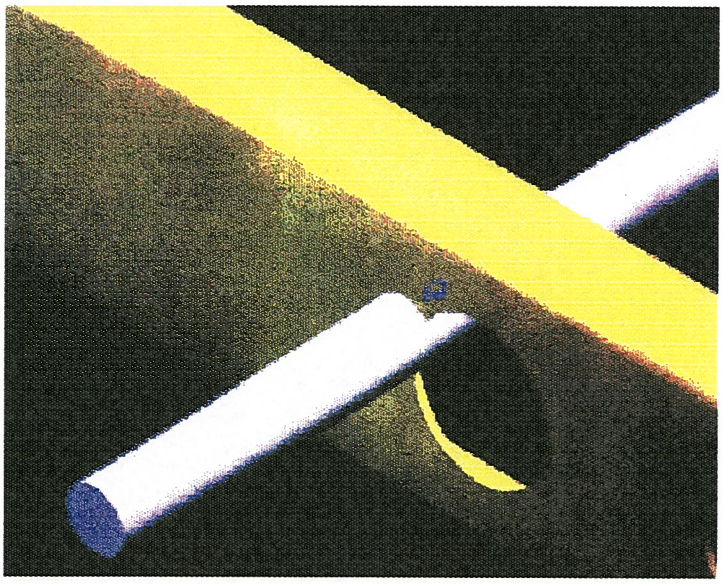
Carbon-carbon

Applications for dense carbon-carbon composites include racing cars and aircraft and high temperature gas turbine components such as exhaust nozzle flaps and seals.

To produce C-C composites first a slurry is made out of fibers and resins, this is poured into a mould, then the water is extracted. The fibers form in the desired shapes. The resin in then carbonized and the gas is extracted. In order to obtain a higher density composite the material must repeat this process several times.

Virtual pre-assembly/CAD

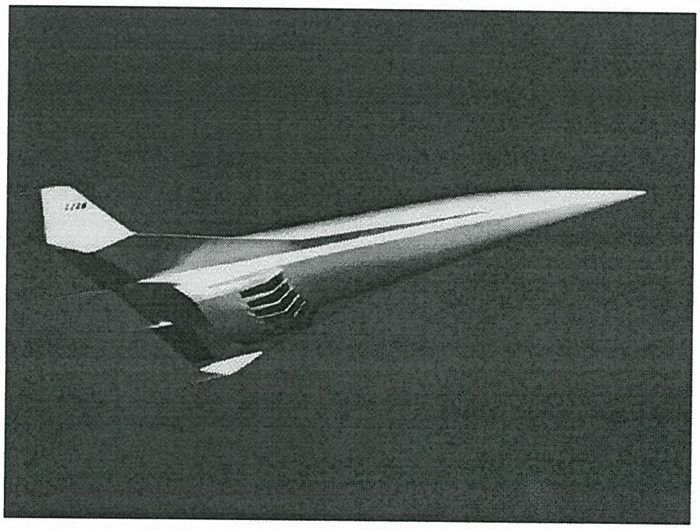
Prototypes are always very expensive to build; therefore we must try to get it right as soon as possible. Modern computer programs allow the plane to be built in a virtual world before any prototype is built. This allows us to detect mistakes before production saving a huge amount of money and time (see image below). It also allows to rehearse the best and most efficient way of assembly. Now a component can be designed, tested and assembled in the computer, then send it directly t a numerically control machine to produce the final product. We can even put virtual people in it to seen if it fit the human dimensions.
Also computers allow people to work on the same project from different parts of the world which very important in a something like the future supersonic transport that will be almost for sure an international project.
By the time the 'new Concorde' is built all this methods would be even more advanced and common that they are today and they will surely help to make the project cheaper and the final product better.

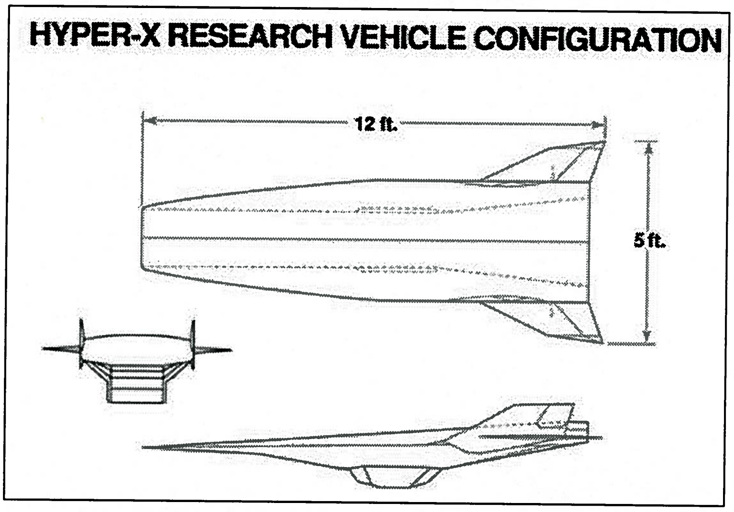


Non destructive testing

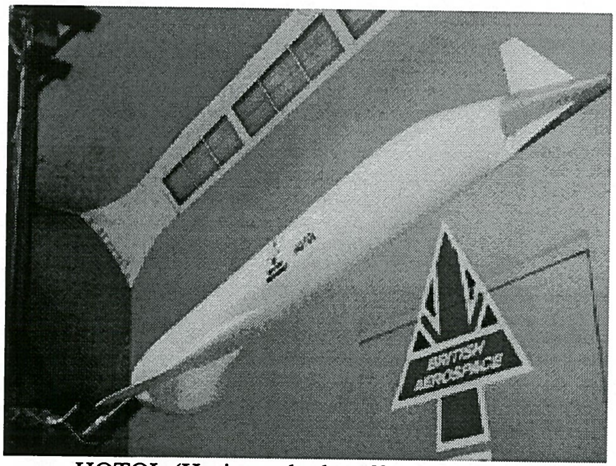
New technologies to non-destructive testing and inspection have been developed since the times of Concorde, these allow not only to inspect quality of the product in the factory but also to inspect the component in their service lifes. This has very important implications for composites, as it is important to find delimitation and internal damages. These techniques can save a lot of money in the development, production and operation of a future supersonic transport. Some of them that I won't describe in detail are the following: Radiographic Inspection, acoustic emission Inspection, thermographic inspection, eddy-current inspection.

5.3 Hypersonic civil transport aircraft



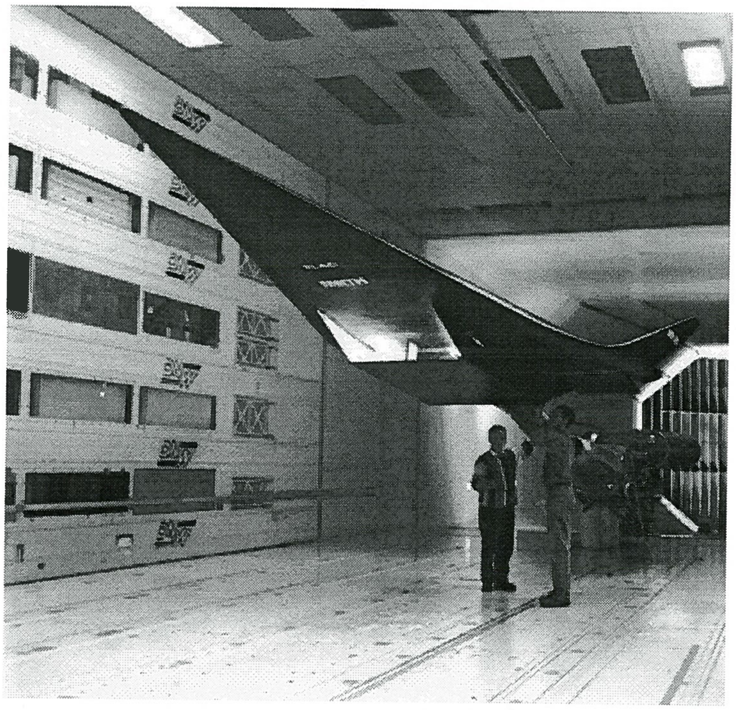


. The more serious project about this was the American x-30 that was cancelled due to it amazing cost. However smaller scale research continues to be done in this field with wind tunnel testing and with vehicles such as the Hyper-X. Other machines such as the British HOTOL or the German Sanger intended to be a Space Shuttle replacement more than a civil transport.
These hypersonic vehicles should fly at speed up to Mach 7 and the heat problem becomes extremely important.



HOTOL (Horizontal take off and Landing)

Although the X-30 was cancelled NASA has initiated the Hyper-X program to validate hypersonic air-breathing vehicle and engine design methods in flight. Hyper-X will demonstrate hydrogen-fueled, airframe-integrated, dual-mode ramjet and scramjet propulsion, with flight tests at 5, 7, and 10 times the speed of sound. This technology will have application in both aviation and space access systems. However the manufacturing processes for the Hyper X are not of interest here as it is only a very small unmanned aircraft.
In the same way we had to wait for more than twenty years for technology to be advanced enough to produce a better plane than Concorde may be we will have to wait another 20 or more years for its "grandson".
However by the time the X-30 project was cancelled some very important parts of the design were already decided, for example it was already decided how the fuel tank was going to be made. This is a very conflictive part as it had to take some of the most severe temperature gradients than anything had had before, for the cryogenic temperatures of the fuel to the extremely high temperature of the outside.



6. Conclusion

Materials technology and manufacturing processes can make the difference in what can and cannot be made, both because it really couldn't be made or because it was so expensive that nobody wanted to pay for it. The son of Concorde will be made sooner or later, we just have to wait until some new technologies are cheap enough and have been very well proven or until there is a very strong political motivation, or provably both. Since the time of Concorde technology has advanced enough to make us think in a bigger, cheaper, longer rage supersonic civil transport, however maybe this is not the right time yet and it would be better to wait until a supersonic aircraft could be designed, built and operated at the same cost of any other subsonic civil transport. I think it is obvious that this time hasn't come yet. In the other hand the must always be somebody that gives a leap ahead to revolutionize an industry as it happen with Comet and the 707, however for some reason it didn't happen with Concorde.

7. References

Aerospace America, September 1992

Aerospatiale Web site

Air & Space. Smithsonian Institution. May 1998, Washington D.C. USA

Airbus Web site

B.T. Åström. manufacturing of Polymer Composites. Chapman & Hall. Suffolk 1997.

Boeing Web site

British Aerospace Web site.

D.A.S.A. Web site

Dryden Flight Research Center Web site.

Ericsson Connexion No.2 June 1997

F.L. Matthews and R.D. Rawlings. Composite materials: engineering and Science. Chapman Hall, 1994 Oxford.

Imperial College Master in Composite Materials notes. Imperial College, London 1998.

Manufacturing processes course notes, Imperial College, London 1998

Michael C.Y. Niu. Composite airframe structures. Hong Kong Conmilit press ltd.Hong Kong 1996.

N.A.S.A. Langley research center web site.

N.A.S.A. Web site

New York 1988.

O.N.E.R.A. Web site

Properties of Materials course Notes, Imperial College, London

The Jet Engine, Rolls Royce, Birminghan UK, 1996

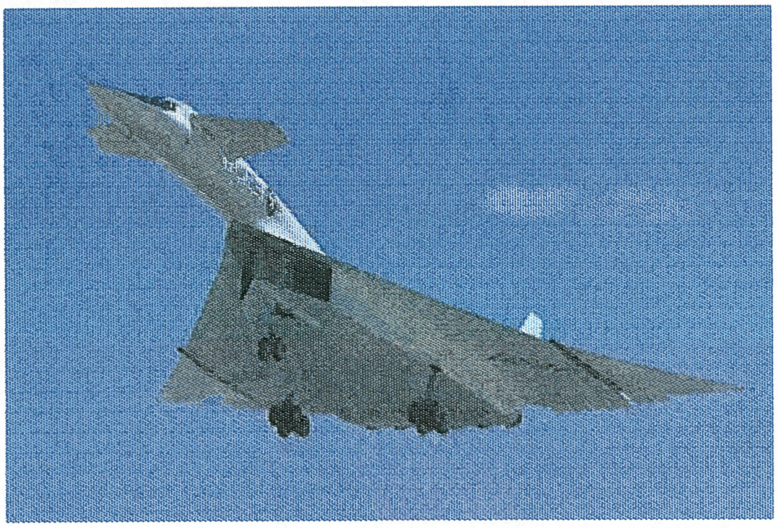
The Skin of Concorde, Open University press.

The Space Shuttle operator's manual, K.M Joels, G.P. Kennedy, Ballantine books,

APPENDIX A -*OTHER INTERESTING SUPERSONIC AIRCRAFT*

Other Supersonic Aircraft

XB-70 "Valkyrie"



Specifications:

Manufacturer: North American
Designation: XB-70
Nickname: Valkyrie
Type: Experimental

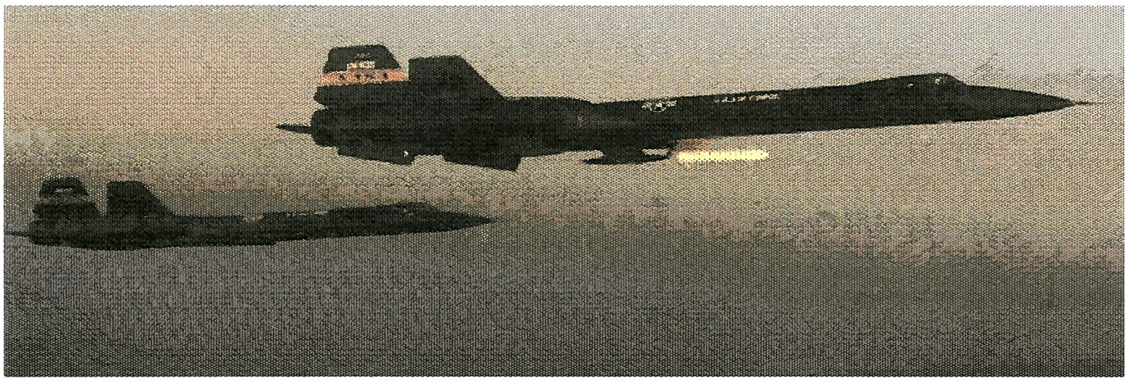
Length: 185' 10" (56.64 m)
Height: 30' 9" (9.37 m)
Wingspan: 105' (32.00 m)
Gross Weight: 534700 lbs. (242494 kg)

Powerplant: General Electric YJ-93
No. of Engines: 6 Thrust: 30000 pounds each
Range: 4288 miles (6904.00 km)
Cruise Speed: 2000.00 mph (Mach 3.0) @ 72,000 ft
Max Speed: 2056.00 Mph (Mach 3.1) @ 73,000 ft
Ceiling: 77350.0 ft (23575.0 m)

The XB-70 was originally conceived as an advanced bomber for the United States Air Force, production of the XB-70 was limited to two aircraft when it was decided to limit the aircraft's mission to flight research.
The XB-70 was the world's largest experimental aircraft. Capable of flight at speeds of three times the speed of sound (2,000 mph) at altitudes of 70,000 ft, the XB-70 was used to collect in-flight information for use in the design of future supersonic aircraft, military and civilian.

The forward fuselage was constructed of riveted titanium frames and skin. The remainder of the airplane was constructed almost entirely of stainless steel. The skin was a brazed stainless-steel honeycomb material.

SR-71, A-12, YF-12 "Blackbird"



Specifications SR-71A	
Powerplant	Two Prat & Whitney J58 turbo-ramjets , each with 32,500 lb static thrust with afterburners
Max Speed	Maximum estimated **Mach 3.5, normal operating speed Mach 3**
Range	2,500 mi without refuelling
Operational Ceiling	85,00 ft, maximun ceiling estimated 101,500 ft
Weight	Empty 60,000 lb Loaded 170,00 lb
Span	55 ft. 7 in.
Length	107 ft. 5 in.
Height	18 ft. 6 in.
Wing Area	1,800 sq. ft.

Blackbirds are constructed with a titanium alloy that makes up about 93% of the plane's empty weight.
The special black finish also wards off heat caused by high speeds and actually radiates significantly more friction-generated heat than it absorbs at cruising speeds of Mach 3.
In the development of this plane the Lockheed Skunk works had not only to design and build the plane it self but first design and build the tools that would allow the to work the Titanium. This adds a huge amount of money to the proyect.

Mikoyan Gourevitch Mig-25 "Foxbat" & Mikoyan Gourevitch Mig-31 "Foxhound"

Mig- 25

Mig-31

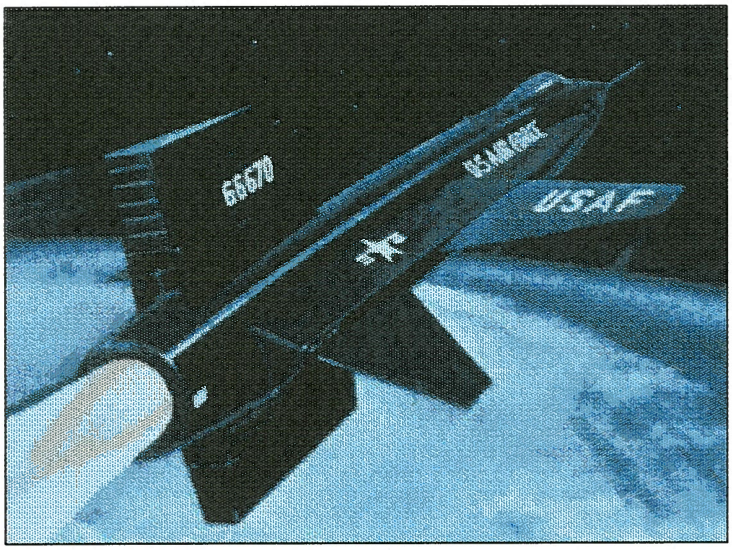
Type: **MiG-25**	Type: **MiG-31**
Function: fighter, interceptor	Function: fighter, interceptor
Year: 1978	
Engines: 2 * 12250kg Tumansky R-31	
Wingspan: 13,95 m	Wingspan: 13,46 m
Length: 23,82 m	Length: 22,69 m
Height: 6,10 m	Height : 6,15 m
Empty Weight: 20000 kg	Empty Weight : 21 852 kg
Masse maxi au décollage : 37 524 kg	Masse maxi au décollage : 46 200 kg
Maximum speed : **Mach 2,82**	Maximum speed at 17 500 m: **Mach 2,83**
Ceiling : 24 400 m	Ceiling : 20 600 m
Maximum action range : 1 450 km	Maximum action range: 1 400 km

This was the USSR's answer to the design in the US of fast, high- flying aircraft as the XB-70, F-108 and SR-71. The MiG-25 lacked technological refinement, but its performance caused much concern in the west. It was also used as a reconnaissance aircraft, which in the Middle East proved invulnerable to the Israeli F-4 Phantom IIs. Over 1200 have been built, of which about 75% were interceptors.

The Mig 25 is a large plane. It can flight at speeds of about mach 3. It can get to temperatures of up to 300°C. The Mig 25 is primarily built out of steel. Titanium was considered but it was too expensive for extensive use, therefore it was only use in the hottest parts as the leading edge of the wings.

The Mig 31 is a later development of the Mig 25.
In the Mig-31 Mikoyan's engineers reduced the mix of nickel-steel form 80% to 49% using Titanium, Aluminum and composite materials instead.

<u>X-15</u>



Wingspan:	6.7 m (22 ft)
Length:	15.5 m (51 ft)
Height:	4 m (13 ft)
Weight, gross:	17,237 kg (38,000 lb.)
Engine:	Thiokol (Reaction Motors) XLR-99-RM-2 rocket engine rated at 250,000 Newton (57,000 lb.) thrust at sea level
Manufacturer:	North American Aviation, Los Angeles, Calif., 1959

The North American X-15, a rocket-powered research aircraft, bridged the gap between manned flight in the atmosphere and space flight. After its initial test flights in 1959, the X-15 became the first winged aircraft to attain hypersonic velocities of Mach 4, 5, and 6 (four to six times the speed of sound) and to operate at altitudes well above 30,500 meters (100,000 feet).

The substructure of the X-15 is titanium with a covering of Inconel X, a nickel alloy capable of withstanding temperatures of 650°C (1,200°F). The black color of the aircraft helped to dissipate heat, and the gaps along the fuselage closed as the external temperature increased.