
60756
U.S. AIR FORCE

INTO THE INDIGO

The American military aeroplane
Design and development, 1944-1966

Submitted to the Faculty of History
of Art & Design and Complimentary Studies

for

B.Des. in Industrial Design

BRENDAN RANKIN
Department of Industrial Design
Faculty of Design
N.C.A.D.

To Mom, Dad and Paula.

ACKNOWLEDGEMENTS

There is no way of remembering everybody who contributed directly or indirectly to the compiling and writing of this thesis, but the following are to be especially thanked for their help;
David P. Plunkett and Liam MacMullan for their kindness and considerable generosity in providing information and reference material; library staff at the City of Manchester Central Library (who spent three weeks trying to find the Lloyd S. Jones book), N.C.A.D. Library and the Dublin Corporation Library; Peter Sealy for finding the two Lloyd Mallan books; Jack for letting me see the end of 'The Right Stuff'; Colin and B.J. for their endless patience and encouragement (and this new-found insight into bathrooms and Japanese design); Mairead, who inspected my introduction and conclusion and Fiona for her help and for asking 'What is your thesis on, anyway?'

A special thanks to my tutor Paul Caffrey for his perseverance and help, and to Mrs. Joan Nally for her endurance in typing all of this!

Thank you all,
Brendan.

CONTENTS

LIST OF ILLUSTRATIONS

24 Boeing XB-52 (Dorr,1989,753)

25 Boeing B-52H (Francillon,1988,27)

26 Boeing B-52A (Francillon,1988,8)

27 Boeing B-52D (Francillon,1988,13)

28 Boeing B-52G (Francillon,1988,115)

29 North American X-10 (Palmer,Bishop,Chant,1985,1687)

30 North American XB-70A (Mason,1985,4268)

31 North American XB-70A (Mason,1985,4266)

32 Lockheed YF-12A (Kermode,1987,357)

33 Lockheed SR-71A (Allen,1986,cover)

34 Clarence L. Johnson with U-2 (O'Leary,1986,116)

35 Bell X-1A (Mallon,1957,7)

36 North American X-15A (Taylor,Taylor,Mondey,1973)

INTRODUCTION.

The period 1944-1966 represents not just the coming of age of the aeroplane but also an era of tremendous social and technical change in the United States of America. Outside America, the world's other major economies, Japan, Britain and Germany had been devastated by the war, with a decline in industry and widespread austerity for the people. Britain was hit hardest of all in the wake of a huge wartime debt to America and the gradual breakup of her empire. Japan and Germany, on the other hand, were granted huge aid programmes by the United States, leading to strong economic recovery in both their cases. It is therefore clear how America became something of a godhead; American goods, American entertainment and the American style of living became coveted as symbols of victory and excitement (Lewis, 1989:p.9).

This thesis aims to explore the roots of post-war American aeroplane design, and in the context of America's strong political position after the war, examine how the aeroplane came to symbolise a quest for technological and ideological supremacy. The pioneering work of designers like Edward Wells of Boeing and Clarence Johnson of Lockheed is discussed in the thesis. Their sense of purpose and vision using the considerable finance available to them enabled them to redefine and reinvent the aeroplane at the dawn of the new jet age. The thesis also shows how outside influences such as the development of ballistic missiles provoked reassessment of the military aircraft's value, and how such reassessment was often wrongly interpreted.

The Air Force jet, with it's gleaming aluminium skin, was scientifically and visually an achievement and with it's heroic pilot and the words 'U.S. AIR FORCE' vividly emblazoned on it's flanks, it became an icon for all things American. Automobiles became decorated with aeroplane motifs: jet-engine intakes, wrap-around glass windscreens, metallic fenders, rocket-tipped lamps and of course huge

wings and fins. Even more austere household products such as the hair dryer took on the look of the jet engine, while control panels for cookers and washing machines were covered in a plethora of switches and dials resembling the flight deck of a fighter-plane. Everybody could take part in this new myth. (Heskett, 1980:p178).

Chapter 1 of this thesis deals with the sources of the growth in the aeroplane industry, and the need for expansion after World War II. During the war, America fought alongside the Soviet Union and Britain to help defeat Germany. It was not uncommon for the Allied powers to share technology and resources, and thus both the Soviets and Americans benefitted greatly from Britain's advanced jet engine research. With Germany's defeat, a huge body of aerodynamic research, much of it concerned with the problems of high speed flight, came into the possession of Allied scientists. With this combination of British jet engine and German aerodynamic theory, both America and the Soviet Union could use their considerable industrial resources to convert theory into reality. Soon after the war, they would end up in competition as mutual fear and insecurity towards the other power led to the Cold War and, after the explosion of the first Soviet atomic bomb in 1949, the Arms Race. Years of industrial and social abundance finally began in 1950 with 'the defence expenditure triggered off by the Korean War' (Lewis, 1989: p.15).

Chapter 2 deals with the fruits of this expenditure: the Stratojet, Hustler and the Century Series fighters, aircraft which were fast, high-flying and technologically advanced. They symbolised America's desire to have "the best", and carried the Air Force insignia proudly as vehicles for Eisenhower's affluent, confident America. Despite their undoubted importance to the future of aviation and their symbolic status, their military shortcomings have largely been overlooked. Air Force procurement policy often depended on visual appearance alone, and some

aeroplanes were given roles to which they were inherently unsuited.

Chapter 3 deals with the change in attitude that took place in the late 1950's with the revelation of the horrific effects of nuclear war, and loss of public acceptance of the levels of defence expenditure. One aeroplane, the Boeing B-52, came to symbolise this transitionary period, while it's survival thirty years hence illustrated it's inherent excellence of design. Aircraft took on drab green and black colour-schemes as public attention turned to the Space Programme as the new champion of the American Way.

In Chapter 4 , the last Air Force projects of the early 1960 s are discussed. Deciding it needed a modern, Space Air image, the U.S.A.F. invested in a series of programmes designed to stretch the limits of technology to their furthest. The aircraft produced, the XB-70, SR-71 and X-15 provided a wealth of information for both the aerospace industry and manufacturers of consumer products, yet their vast expense is difficult to justify.

In completing research, it became obvious that there was a lack of overall clarity about developments in American aeroplane design between World War II and Vietnam. Historical literature tends to disregard the design importance of the aeroplanes, concentrating instead on the huge costs of such projects to the taxpayer (e.g. - Lewis, 1989:Ch.4). Design literature (e.g. - Heskett, 1980:p.195 Bayley, 1986:p134), while acknowledging the technological achievement of the jet aeroplane, tends not to discuss it in a proper context, while aviation literature concentrates on the aeroplanes' development histories, their combat records, performance figures and weapons heads. Few texts attempt to deal with the American jet aeroplane in a proper policital, social and design context. In conclusion, this thesis analyses the importance of these aircraft politically and discusses their technological achievements in a design context.

Their exalted status as 'best, highest, fastest' is questioned, and reasons for their development illustrated with representative examples of each important type.

> Affluence was the song the sirens sang in the United States, from which war and it's economic expansion had finally banished the Depression. (Lewis, 1985:p.9).

Politically, the United States of America found itself in a very secure position after World War Two, with Hitler's Third Reich smashed and Japan beaten into submission beneath the apocalyptic power of the atomic bomb. Although the years immediately after the war were lean economically - the U.S. Government had instigated a series of massive aid plans for Europe and Japan - by 1950, a new era of abundance and affluence began. This was due to a number of factors : the large U.S. industrial corporations were cashing in on their wartime business, and a wave of innovative advertising campaigns wooed the upwardly mobile young American toward a brighter more optimistic future.

One event, however, would prompt astonished reactions throughout the Western world, and usher in the 'Golden Age' of the U.S. defense forces - the detonation of the first Russian atomic device in Siberia in 1949. The security enjoyed by the United States was suddenly eliminated - a second, distant, power challenged U.S. supremacy in the political world. The hasty dismantling of the defense forces after the war had to be reversed - and a new modern airforce was essential in providing a means of delivering nuclear weapons to strategic targets in Soviet Russia. The Cold War had begun, a frightening era of distrust between the superpowers that lasted for over thirty years.

However, Russia had already been seen as a potential enemy - President Truman and the U.S. Congress were known to distrust Stalin, especially after the dividing of Berlin and Germany after the war. The Department of Defense had created a new bomber wing, Strategic Air Command (SAC), within the Air Force which would fly aircraft capable of striking targets within the Soviet Union from bases on the U.S. mainland. This 'global bomber',

the Consolidated Vultee B-36 'Peacemaker', would be the largest, heaviest aircraft in the world, originally designed to attack targets in Nazi Germany and capable of carrying the latest, colossal, nuclear weapons. Despite the B-36's impressive credentials, it can be seen in retrospect to be a very retrograde step. The first Soviet jet-powered fighter, the MiG-9 "Fargo" had flown on 24 April 1946, and a huge lumbering bomber like the B-36 would be an easy target, especially in the "mass bombing" World War Two style missions planned for the B-36. A lengthy congressional hearing was organised to debate deployment of the B-36 - the bomber met with vehement opposition from the Navy, who felt that their aircraft carrier program offered a more potent nuclear strike force. Historian Alexander De Seversky noted the blindness of both factions[1] : an aircraft carrier made just as easy a target as a propeller driven bomber. It hardly mattered - President Truman approved both B-36 and aircraft carrier programs, and 385 production B-36's were ordered (See Dorr, 1989:p.698). Fig.1

The B-36 remained, however, a World War Two solution to a horribly different problem. Huge fleets of bombers had devastated German and Japanese cities during the war; a similar tactic would fail miserably faced with the threat of jet-powered fighter aircraft. In a curiously naive move, the Air Force ordered production of B-36J aircraft with jet-augmented propulsion. It must have been frustrating for America's aeroplane manufacturers who craved investment in new technology - most specifically in pure jet propulsion. Although heavily dependent on German aerodynamic research and British jet propulsion technology, the U.S. industry was optimistic about the development of a new generation of aircraft. Investment finally arrived with the granting of a defense contract for a new jet fighter to the Lockheed Corporation, whose design bureau was run by the celebrated Clarence L. 'Kelly' Johnson, responsible for the innovative P-38 Lightning Fig.2

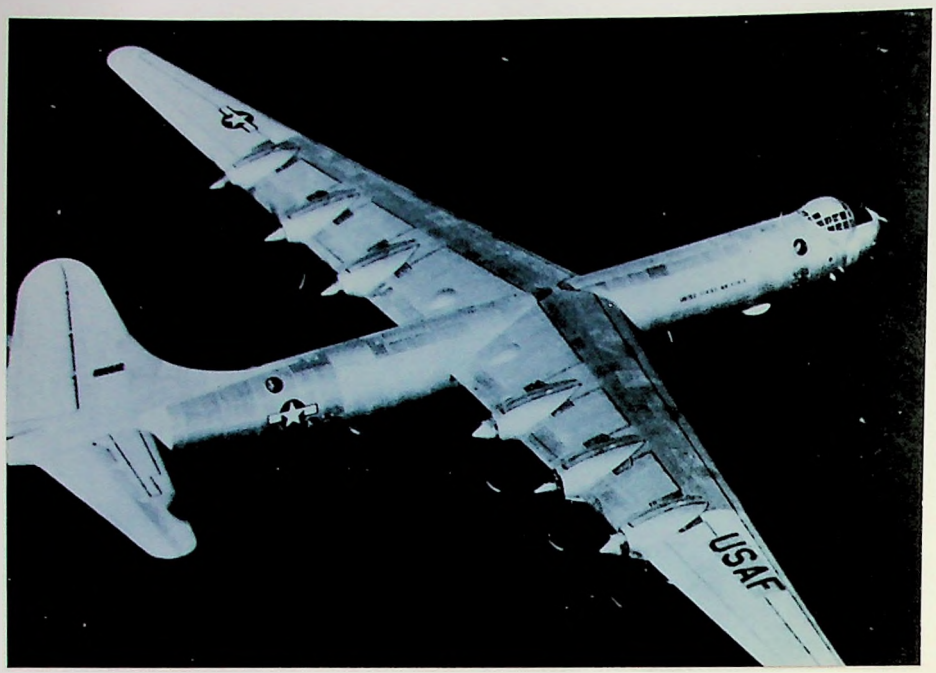


Fig. 1: Convair RB-36D 'Peacemaker. Note huge wing and long, cylindrical fuselage.

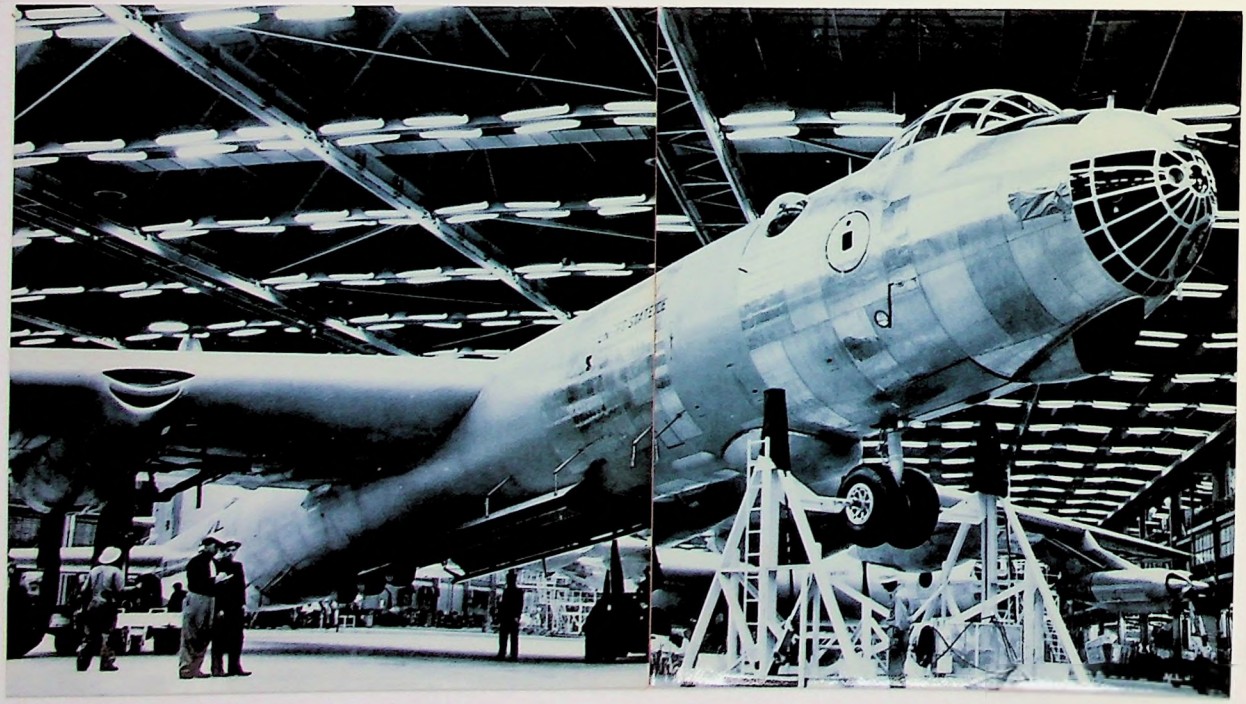


Fig.2: Andreas Feininger photograph of B-36J bombers in production. One of the aeroplane's twin-jet nacelles can be seen beneath the port wing.

during the thirties. The result was the P-80 Shooting Star, America's first operational jet powered aeroplane. Powered by a licence built British Nene engine, the Allison J33-A-35, the P-80 was seen as a confident new departure for the Air Force, and along with it's jet powered contemporaries[2], it represented a new, high technology image for the U.S. Air Force and Navy. Fig.3

It was hardly a "new departure" however. The Shooting Star was essentially an old-fashioned aircraft with straight, high aspect ratio wings[3] and a less than state-of-the-art engine. First real symbol of the "Bare Metal" jet era, the P-80 was an elegant, clean design, brash and confident and much admired by military and public alike. However, the first flight of the swept-wing MiG-15 in Russia in July 1947 came as a huge shock in the west - the 'Fagot' was vastly superior to the P-80 in every respect. Swept wings improved performance of fast aircraft very considerably : the first operational jet fighter, the German Me262[4] used sweptback and had sensational performance in it's day. Sweepback delays the effects of 'compressibility', the building up of air in front of an aerofoil moving at high speed, destroying lift. Previous efforts had concentrated on making the wing thinner, and thus weaker and more susceptible to fatigue. Swept wings could retain their strength and delay the buildup of air compression bubbles. So, although the MiG-15 and P-80 had ostensibly the same powerplant, the swept-wing Russian fighter was faster, higher flying and more manoeuverable. American fighters, lumbered with primitive aerodynamics, could never be a match for the MiG-15. (See Dorr, 1989:p.1343).

Borrowing from the same German research available to the Russian (and British) scientists, North American developed the first American swept-wing aircraft, the XF-86 Sabre, rolled out on 1 October 1947. The Sabre was a dramatic looking aeroplane - an open-nose air intake fed the jet engine, and it's Bare Metal fuselage was Fig.4

Fig.3: Lockheed P-80C Shooting Star.It's clean form and straight wings are clearly shown.

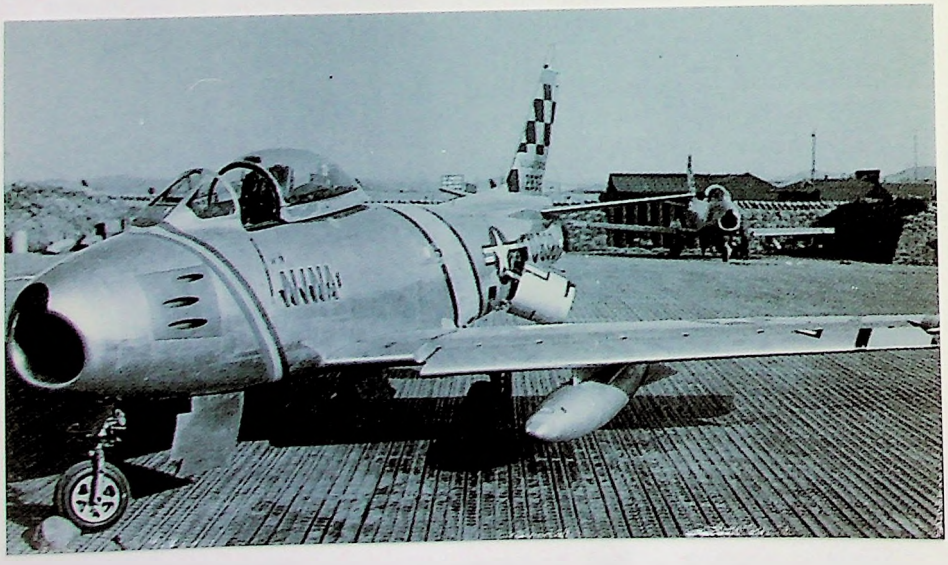


Fig.4: North American F-86 Sabre.

extremely clean and elegant. It was a vital aircraft for the USAF, and it came at a vital time. Public opinion of the Air Force was low, and the F-86 represented truly a new image of confidence and even 'style'. It was an influential aeroplane that made the 'jet' the symbol of American technology. A high-profile campaign in the Korean War of 1950-51 consolidated the F-86's reputation - it scored a high kill/loss ratio over Communist MiG-15's.[5] It should be remembered that these were times of conflict in the U.S. - the Korean War signalled the birth of anti-Communism and success in Korea was paramount to demonstrating the superiority of 'The American Way' over the Communist way. Thus was born the notion that the F-86 was superior to the MiG-15. It was not - both aircraft had very similar specifications and it seems that the Sabre's successes were due mostly to the skill and training of her pilots. (See Dorr, 1989:p.1346).

Nonetheless, the Sabre was a brilliant achievement, and paved the way of acceptance of the swept wing as standard for high speed flight. However, not all good ideas were greeted with such enthusiasm, and the success of the Sabre stood in stark contrast to the fate of another brilliant design of the 1940's : the Northrop Flying Wing, a futuristic and original concept which tackled some of the basic problems associated with flying - most importantly drag. Jack K. Northrop[6] was an innovative designer who had worked for Lockheed in the twenties, and was responsible for the wartime F-15/P-61 Black Widow, based on Kelly Johnson's P-38. Northrop recognised that the fuselage was responsible for much of the drag created by an aeroplane moving through the air, and sought to solve the problem by eliminating the fuselage altogether, creating a 'flying wing'. The first flying wing, the N-IM first flew in 1940 and impressive displays proved that the concept had a future. Then, while Convair was testing the relatively primitive YB-36, Northrop rolled out the colossal XB-35 flying wing with

Fig. 5

a span of 172 feet. A production run was ordered and despite problems with propellers and gearboxes, testing continued right through the late-war period. When emphasis shifted to the proven B-36 after the war, Northrop replaced the propeller engines with eight Allison J35-A-5 jet engines. Four vertical flow separators regained directional stability inherent without propellers.[7] However, the YB-49, as the jet-powered flying wing was designated, was said to be unstable and when both airframes were lost in accidents in 1948 and 1949, the Air Force withdrew support for the program. Fig. 6

The flying wings were a brave attempt to reinvent the aeroplane and tackle some of the difficulties of flying large aircraft. Graceful and elegant, they looked as if they belonged in a science-fiction movie, and may have been partly responsible for some of the UFO hysteria that gripped the U.S. in the late forties. When it appeared in the 1953 movie 'War of the Worlds'[8], it was still thought of as an 'airplane of the future'. Perhaps it was too far ahead of it's time - in 1988 Northrop revealed the B-2 Advanced Technology Bomber (ATB)[9], the U.S. strategic bomber for the 21st century and of 'Flying Wing' configuration, Jack Northrop didn't live to see the fruits of his efforts, dying in 1981.

In the meantime, Boeing had come up with a design that, in light of seemingly insurmountable problems, with the flying wing, marked a most significant breakthrough not just in the development of the bomber, but of the aeroplane itself. The B-47 Stratojet set the standard for aviation for the remainder of the 20th century, only 43 years after the birth of powered flight itself.

Figs.5&6: Northrop Flying Wings, including (top) the XB-35 and (bottom) the cleaner YB-49.

As we have seen, the immediate post war years in America were lean ones, and aircraft manufacturers were largely dependent on themselves for finance until the Arms 'boom' during and after the Korean War. Nonetheless, money was still available to finance development of new fighters and bombers, some of which proved successful and others, like the Flying Wing, less so. One Air Force requirement, drafted in 1944, called for an advanced 'medium bombardment airplane'. There were three principal contenders for the contract : North American Aviation, Glenn L. Martin and Convair, who produced designs designated XB-45, XB-48 and XB-46 respectively. As it happened, the North American design was chosen for interim service as the B-45A Tornado, America's first jet-propelled bomber. It's principal contender, the Convair XB-46 was:

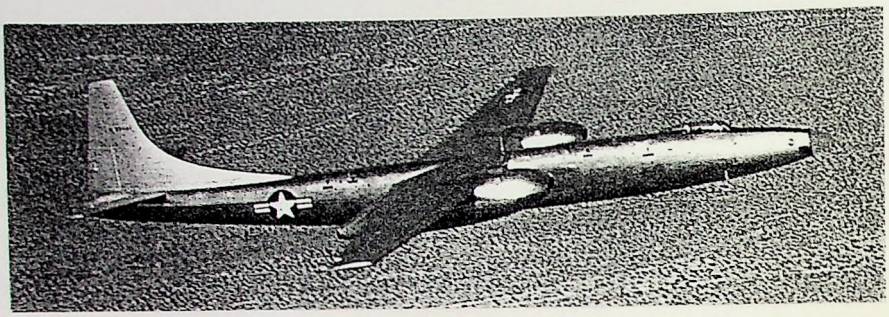
> a lovely aircraft, with sleek, extended lines in it's fuselage . (Anderton, 1976:p.9). Fig.7

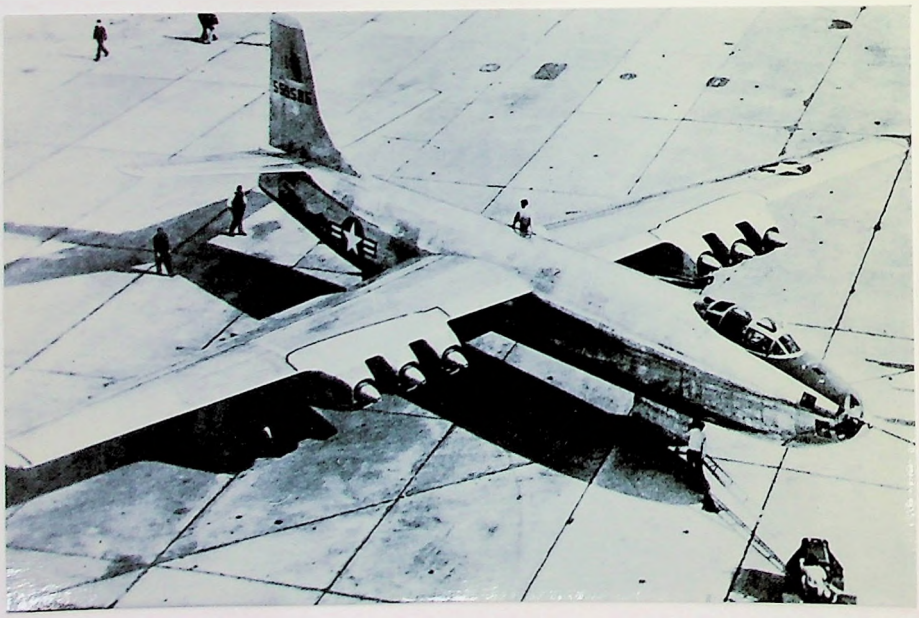
The aeroplane was extremely clean, with long thin wings and four turbojet engines mounted in streamlined pods. It had impressive performance (it covered the distance from Muroc Dry Lake, California to Wright Field[1] , Ohio at an average speed of 533 mph) but failed to the North American design on lack of development. The graceful Convair last flew in 1950 before being committed to the scrapyard.

A similar fate would befall the Martin XB-48, effectively excluded from the contest with mediocre performance and astonishingly high fuel consumption. The six engines (J35-A-5s) offered lots of power but special shrouds designed to keep the engines cool when running added enormously to the aircraft's drag. It was a case of creating a problem by solving another - it was ironic that the XB-48's wings were especially thin to offer least air resistance. The aircraft was not chosen for production - as Lloyd S. Jones surmised, the XB-48 Fig. 8

> did not show enough advancement of performance to merit a production order (Jones, 1980:p.165).

However, the XB-48 did incorporate a number of important





Figs.7&8: Convair XB-46 (top) and Martin XB-48. Neither received a production order.

features which would be adopted on later aircraft. It proved that at least six jets could be used on an aircraft. It was the first aircraft to adopt 'bicycle' undercarriage, where load bearing landing gear were located in tandem under the fuselage (the wings were too thin to accommodate full size wheels). Small outrigging wheels beneath the wings balanced the stationary aeroplane.

The three aforementioned aircraft, B-45A, XB-46 and XB-48 were all competent designs, yet all were rendered instantly obsolete on 12 September 1947. Boeing's new XB47 Stratojet represented arguably the greatest step forward in aviation since the Wright Brothers first flight 44 years earlier - as one observer was said to have commented :

> that thing has the look of the future
> (Dorr, 1989:p.703).

It came as a great surprise to see a swept-wing bomber so soon after the introduction of the F-86 Sabre - a large aircraft is inherently more difficult to develop than a small one. With a top speed of 650 mph and six new J47 turbojets, the B-47 was indeed a thing of the future. Fig.9

The design history of the Stratojet is interesting, the XB-47 starting out as a very conventional design based upon the B-29 Superfortress flown during the war. The design team, consisting of Edward C. Wells, George S. Schairer and Art Carlsen, recognised quite quickly that such an approach would not realise the potential offered by the exciting new jet engines - a new 'type' of aircraft was needed. It was George Schairer's interpretation of German ideas that proved crucial to the design of the XB-47 and subsequently the whole of modern aviation. Schairer's studies showed how wing sweepback could be adopted on a large aeroplane like the Stratojet, and Edward Wells insisted that a wing with 35^{o} sweepback be incorporated in the revised specification for the new aircraft. The new wing, which was extremely thin, offered phenomenal results in wind tunnel testing, but

seemed incapable of handling the loads imposed by six jet engines. Boeing solved the problem by considering the engines as dead weights which, when hung from the wing, could counteract it's bending moments. Careful placing of the engines could also increase the wings torsional stiffness. So, the engines were hung in two paired nacelles and two single nacelles beneath the wings; the heavier paired nacelles being located inboard where the wing was thicker and their effect most pronounced. (See Anderton, 1976:p.17).

This was a truly revolutionary breakthrough, one which has been copied on virtually every large jet aircraft since. As well as the aforementioned reasons for choosing the layout, it meant that engines, which tended to be unreliable in those days, could be serviced or replaced easily.[2] It also kept the leading edge of the wing clean and made for more efficient and economical flight. This became crucial in the mid-1950's when Boeing's jet-powered airliner, the 707, entered service with Pan American World Airways. The British Comet,[3] principal competitor to the 707 was laboured with engines buried within the wings, and could never challenge the 707 over the lucrative trans-atlantic route. It established a lead for Boeing in airliner design and production which it has never relinguished, while all other airliners have had to copy the engine/wing layout pioneered by Boeing on the B-47. Fig.10

> These were the basic design concepts that went into the XB-47 : thin, swept wings; nacelles used productively to relieve normal and gusting wing loads; extra installed thrust from rodats; installed drag from a parachute; tandem landing gear and fuel in the fuselage.
> (Anderton, 1976:p.17).

The B-47A entered service on 25 June 1950 and throughout it's service life was improved and modified until the introduction of the definitive B-47E with inflight refuelling capability and more up-to-date J47-GE-25 engines. It was a truly beautiful aeroplane,

Fig.9: Boeing B-47A Stratojet. It's clean lines and swept wings were seen as futuristic at the time.

Fig.10: Boeing 707 airliner. First flying in 1954, the 707 went on to revolutionise commercial air transportation.

it's lithe, clean fuselage and thin swept wings conveying a vivid sense of the aircraft's superlative performance - it's high angle-of-attack "nose-up" attitude on the runway giving an impression of the aeroplane leaping skywards. Take-off, usually a noisy affair, was also a spectacular one as the climbing Stratojet left thick trails of smoke from it's eighteen rocket assistors.[4] Fig.11

More importantly for SAC, the B-47 proved to be a charismatic ambassador, providing the Air Force with a modern, advanced and spectacular delivery vehicle for nuclear weapons. John Heskett states that:

> the most vitally important function of industrial design in political terms, ... is it's decisive role in the establishment of military superiority. (Heskett, 1980:p.189).

It was undoubtedly a confidence-booster for America; now that both superpowers had the Bomb, it was important that America have the 'best' means of delivering it - nuclear war was not regarded in the early 50's with the disdain it carries now. Along with the F-86, the B-47 became a symbol of a new optimism and brashness, a vehicle for American technological and ideological supremacy. The American consumer could buy hairdryers that resembled the J47 engines of the Stratojet, or cars that mimiced the F-86 Sabre's air intake. The ostentatiousness of the USAF's aircraft's Bare Metal finish was echoed in the preponderance of chrome and metallic products that were produced during the 1950's. The Department of Defense financed Hollywood movies romanticising the B-47, F-86 and their courageous pilots, and the aircraft took part in massive displays aimed at showing the public (and the Russians) the magnitude of the Air Force's power.[5] Fig.12

> ... three ship formations of Stratojets, separated by about 10,000 feet distance, and travelling at about 300 mph (490 km/h) flew over the reviewing stand in a continuous parade for more than two hours. (Dorr, 1989:p.724).

The global force of 1700 B-47's remained on nuclear alert during the early part of the Cold War, and were

Fig.11: B-47C Stratojet taking off with full rocket-assistance (JATO).

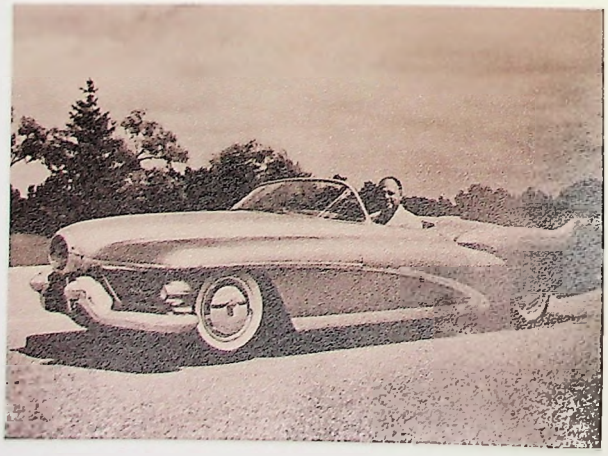


Fig.12: Harley Earl, General Motors' automobile stylist, seated in his 'LeSabre' concept car of 1953. Compare with F-86 Sabre in Fig.4.

undoubtedly a deterrent to war.[6] The last RB-47E's were retired in 1967 after a long and distinguished career.

However, it remains that the B-47 was never used in combat, even in Korea, a war which

> had been judged not worth pressing the nuclear button for (Lewis, 1989:p.91).

Despite it's colossal importance to future aviation, the Stratojet also ushered in an era of over-confidence, overspending and lack of organisation which would provide the Air Force with some less-than-ideal aircraft, aircraft which challenged established perception in speed and altitude performance. The North American F-86 Sabre and Boeing B-47 Stratojet introduced an era of unprecedented innovation in aviation, combining advanced technology with novel and original approaches to design problems.

The years around the turn of the decade (1945-1952) saw the start of an economic boom that would last for almost 15 years and raise public morale and expectation to exalted levels. Investment in defense during the Korean War and the explosion of the H-Bomb in 1952 placed aerospace companies on the crest of a wave, and finance was readily available for development and research. The years during and after Korea saw a 'brave new approach' to the design of fast jets. The results, the much vaunted 'Century Series' fighters, were somewhat inconsistent as answers to military problems, yet resoundingly successful in their long-term effects on aeroplane design (See Dorr, 1989:p.1375).

The story started in October 1947, when test pilot Charles 'Chuck' Yeager piloted his Bell X-1A rocketplane to Mach 1,05, faster than the speed of sound[7], to become the first man to break through the 'sound barrier'. Research programs undertaken by the USAF, the National Advisory Council for Aeronautics (NACA) and the Navy

pushed the frontiers of performance ever further on: swept wings, delta wings and even straight wings were tested with various combinations of jet and rocket propulsion. It was a matter of considerable prestige: the British had been planning supersonic flight programs of their own, and only Government cancellation of their M52 aeroplane prevented them from challenging American assaults on performance landmarks.

The American Government, of course, provided much money for research and development, the goal being supersonic military aeroplanes within years of Yeager's flight. North American's F-100, successor to the F-86 was the first American military aircraft capable of level flight at supersonic speed. Based quite closely on the F-86, it featured a powerful J57 turbojet, swept wings and more refined aerodynamics. It marked the birth of the Century series, and although it did not embody any major advances in technology, it proved to be a solid and reliable design. The next aircraft in the series, the McDonnell F-101 Voodoo had a much more convoluted development, fraught with delays, changes of the Air Force policy and downright incompetence of Air Force officials in decision-making. Originally conceived as an escort fighter for the giant B-36, the Voodoo (then designated XP-88) would combine high speed and altitude capability. The XP-88 was powered by two miserably primitive Westinghouse J34 turbojets, and like it's competitor the Lockheed XP-90 was hopelessly short on performance. Fig.13 Fig.14

The Air Force was suitably disappointed, and even with the installation of afterburning[8] (another British idea) on the engines, neither design lived up to expectation. The flight of the XB-47 in December 1947 rendered both aircraft quite obsolete - neither escort fighter had a hope of staying with the sprightly Stratojet. By 1950, the XF-90A was dropped and the Voodoo announced as competition winner, despite it's obsolescence (See Patton, 1988:pp.10-18)[9] .

Fig.13(above): North American F-100 Super Sabre. Note bold U.S. AIR FORCE legend.

Fig.14(below): McDonnell XP-88 and (bottom), Lockheed XP-90. Note dramatic dart-like form of the Lockheed design. The XP-88 was finally ordered as the F-101 Voodoo.

This was not the end of the story, however. Air Force officials still felt the need for an escort or 'penetration' fighter, and the Voodoo was resurrected again as the F-101 before being cancelled again immediately after it's first flight. It might be said that the Air Force's conduct was detrimental to the aircraft industry - McDonnell had invested much capital in the Voodoo program. However, McDonnell used the opportunity to try out new types of air intake, tailplane configuration and new aluminium alloys which combined strength and lightness. The Voodoo finally received a production order from Tactical Air Command for service as a tactical fighter and Air Defense Command as an interim interceptor.

It could be said that mismanagement was to blame for the lack of decisiveness on the Voodoo program. So much money was available for aerospace development that finance was seen as the answer to all problems. The Voodoo program displayed how Air Force chiefs were blind to the fact that there was no real 'need' for a penetration fighter. That the Voodoo survived in other roles is surely a tribute to the versatility of McDonnell's design.

While the Voodoo was quite a conventional aeroplane, it's successor in the interceptor role most certainly was not. The XF-102 Delta Dagger was a radically new concept employing a futuristic-looking tailless 'Delta' wing which combined the high speed advantages of sweepback with the controlability of a straight trailing edge. Delta wings have large wing area, giving high lift characteristics and long chord giving high structural stability, enabling a thin, low drag, wing. (Kermode, 1987:p.200).

The Delta Dagger had a convoluted development history, originating from a 'Generalised Bomber Study', GEBO I,which commenced in late 1946. Convair created

> thousands of design proposals and studies (Lowe, 1983:p.196).

many of which employed the Delta wing. Inspiration for the

Delta came from the work of pioneering German aerodynamicist Alexander M. Lippisch and the result of this research was the dramatic XF-92A fighter prototype, later offered as the XF-102 supersonic interceptor. Despite employing a powerful reheated J57 twin-spool turbojet, however, the XF-102 ran out of pace at Mach 0,74, some 40% short of expectations.[10] Not attributable to lack of power, designers had to reconsider the design of the aeroplane itself. The F-102 only became a viable combat aircraft with the adoption of 'area rule' in the shape of the fuselage. Fig.15 Fig.16

Area rule was devised by celebrated NACA aerodynamicist Richard T. Whitcombe, and, put simply, it means that

> the area of cross-section should increase gradually to a maximum, then decrease gradually. (Kermode, 1987:p.332).

In practice, the extra cross-sectional area created by the wings must be compensated for by slimming down of the fuselage in plan view, creating the characteristic "coke bottle" shape when viewed from above. This important discovery was revolutionary: the area-ruled F-102A smashed through the sound barrier on it's first flight in 1954. Production was ordered, and the F-102 and F-106 (a heavily modified interceptor) gave excellent service with TAC and ADF. (See Peacock, 1986: pp.198-206).

The F-106 had a purposeful and influential appearance. It's Delta wings became the definite formation for high speed flight and it's sleek appearance was accentuated by the chisel-shaped windshield. Importantly, the F-102/106 made the Delta wing acceptable, and such aircraft as Concorde depended on Delta wing technology developed by Convair. The futuristic appearance of the Delta Dart gained popular enthusiasm and many of the science fiction books and movies of the mid 1950's displayed spacecraft, rockets and even hand weapons with 'Delta wings' while automobiles sprouted vulgarly Fig.17

Fig.15: Convair XF-92A.

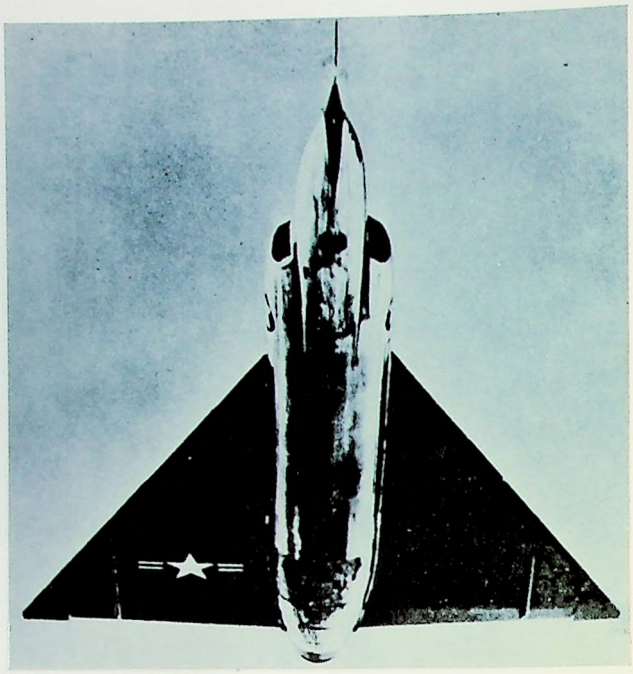


Fig.16(below): Convair F-102A Delta Dagger. Note 'waisting' of the fuselage- a feature of area-rule.

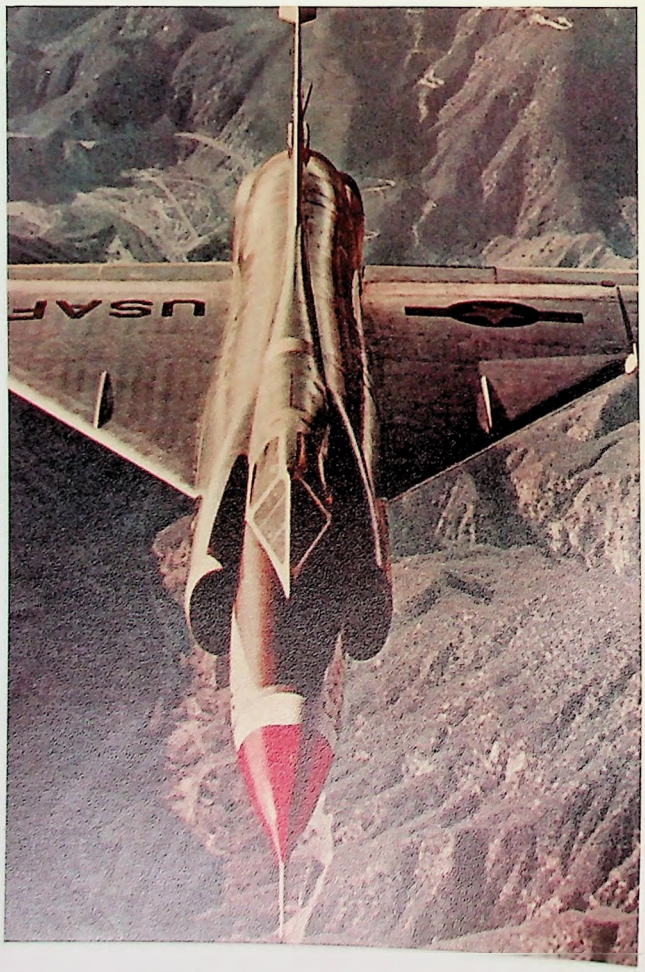


Fig. 17: Convair F-106 Delta Dart. Although superficially similar to the F-102A, the F-106 was a completely new aircraft with Mach 2,4 performance.

Fig.17A: Four Lockheed F-104C Starfighters.Note extremely long and pointed fuselage, stubby wings and wing-mounted fuel-tanks.

Fig.18A: 1957 spaceflight journal showing a rocket proposal with delta wings. Such a design was shown to be impractical, but spacecraft in science-fiction continued to use delta wings until the mid-sixties.

decorated Delta-shaped fins on their flanks. Fig.18A

Despite the import and influence of the Delta Dagger and Delta Dart, one aircraft above all others in the Century Series represented the Eisenhower vision of American supremacy and the gullibility of his military staff. As we have seen, the B-47 Stratojet's dramatic appearance was as much part of it's importance to the Air Force as it's abilities. It represented a huge step-forward and gave the American's "one up" on the Soviets, so vital in the days of Cold Wars and witch hunts. Like the automobiles that transported American teenagers in the 50's, the F-104 Starfighter was quite ostentatious and rather more an aesthetic than military success. A Fig.18,19 product of Kelly Johnson's 'Skunk Works', the Star-fighter was conceived as an extremely simple aircraft, based loosely on the experimental Douglas X-3 Stiletto and employing a needle-like fuselage, blade-thin wings and eventually a powerful J79-GE-3 reheated turbojet. The result was astonishing acceleration and speed and a ceiling in excess of 60,000 feet. First appearing in 1954, the Starfighter was the very embodiment of it's performance: the extremely attentuated and pointed form of the fuselage offered very low frontal area, while the wings were so thin that the trailing edges had to be covered to protect mechanics from injury[11]. The engine was mounted near the aircraft's centre-of-gravity which at high speed also became centre-of-pressure. Armed with cannon and the latest rocket-powered Ford Sidewinder missiles, the F-104 seemed to be the answer to the fighter pilot's dreams. (See Dorr, Alberts, 1989:p.1633).

Unfortunately, the F-104 did not make a successful fighter. Although it's aforementioned attributes were desirable in a fighter, manœuverability, range and warning radar were absolute necessities and were never part of the Lockheed design brief. The Starfighter was purchased as answer to one set of parameters: the Air Force was so impressed by the F-104's dramatic appearance and super-

lative speed that it completely ignored some of the others. So it was that the Starfighter went to war in Vietnam during the sixties, proving itself quite ineffective with it's short range and poor manoeuverability[12] .

History has treated the Starfighter well, and it remains very much as vivid an icon of the fifties as the Cadillac or James Dean. Brash and arrogant in it's Bare Metal finish and colourful graphics, it functioned as something of a sex symbol for the Air Force, it's charisma outshining it's shortcomings. In Tom Wolfe's book The Right Stuff , Chuck Yeager's attempt to capture the world altitude record in a Starfighter is given a suitably romantic treatment:

> He's slammed back in his seat again. The nose pitches up 70 degrees. The g-forces start rising. The desert starts falling away. He's going straight up into the indigo.
> (Wolfe, 1979: p.354).

Fig. 20

Somewhat more notorious than the Starfighter was comtemporary bomber the Convair B-58A Hustler, developed from the aforementioned XF-92 at the same time as the Delta Dagger. It represented an attempt at recapturing prestige for America. Martin's XB-51, a radical design with fuselage mounted engines, could not satisfy tactical bomber specifications and the British English Electric Canberra was chosen instead, to be licence-built in the U.S.A. as the Martin B-57[13] . This must have proven quite a blow to U.S. pride, and it should have provided the struggling British aircraft industry with a much needed boost. As it happened, numerous papers from the British Government effectively killed off the British aircraft industry - a blow from which it has never really recovered.

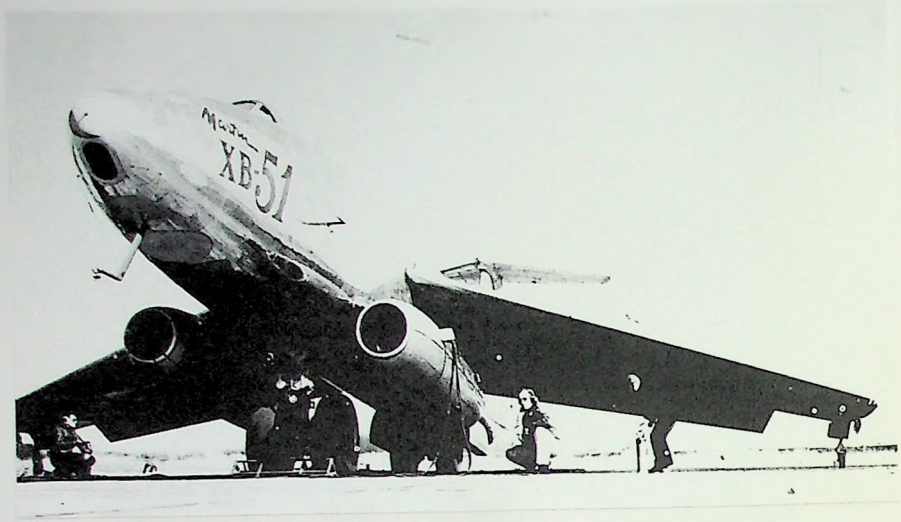
Fig.20A

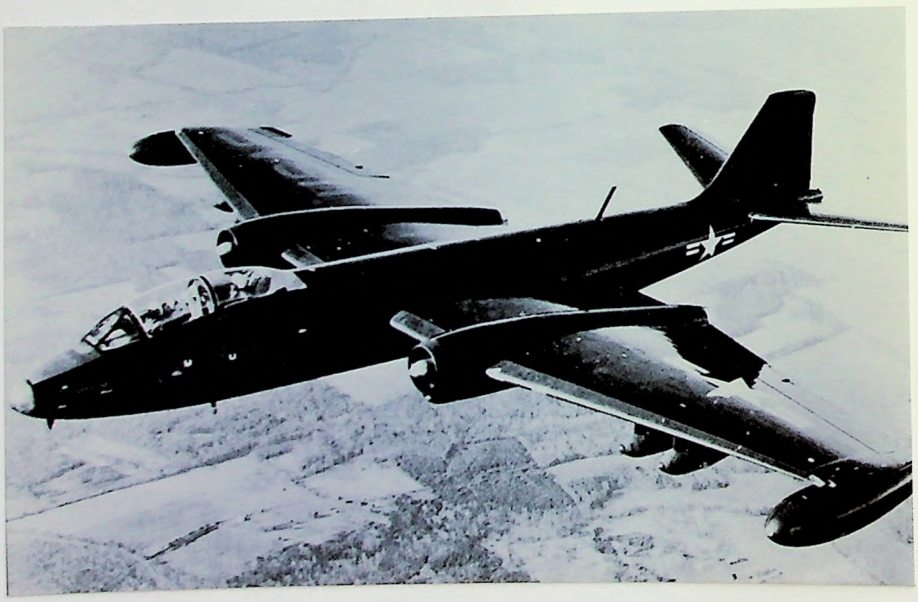
Fig. 21

In the meantime, the Air Force pressed ahead with finance for GEBO II, and Convair's work on a radical design with swept forward wings and Martin's on the tri-jet Delta winged 'XB-68'. The final design, the XB-58, was produced by Convair and was revolutionary in

Fig.19: Front-view of Starfighter showing low frontal area and blade-thin wings.

Fig.20: 'He's going straight up into the indigo'.





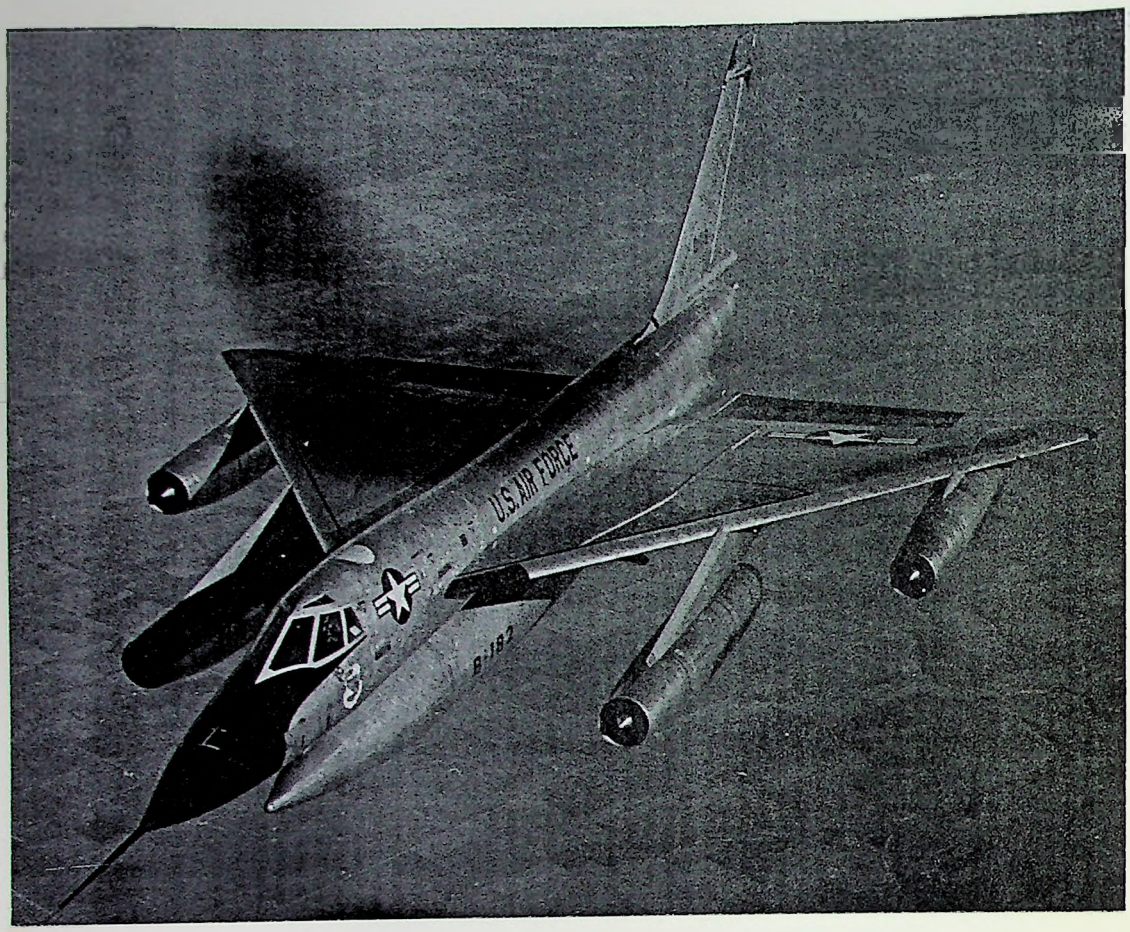
Figs.20A&21: Martin's unsuccessful XB-51 featured engines radically mounted to the fuselage (top), but the tactically-superior B-57 Canberra, designed in Britain, was chosen for production (bottom).

almost every respect. A very large aircraft, it incorporated a tailless Delta wing with conical camber, area-ruled fuselage and four very powerful J79-GE-5 engines, themselves extremely complex, mounted beneath the wings as stress relievers as on the B-47[14]. The fuel load and weaponry were carried in a huge pod slung beneath the fuselage. It looked more spectacular and space-age than even the Delta Dart. (See Lowe, 1983: pp.196-197). Fig.22,23

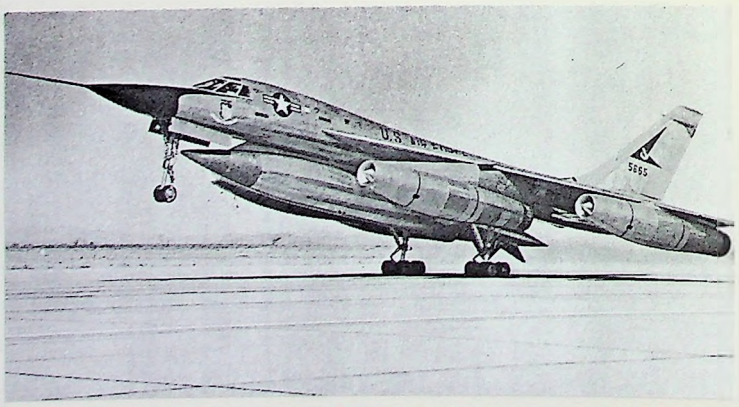
First flying on 11 November 1956, the Hustler performed almost flawlessly, and none of the new features incorporated in the design gave cause for concern, except the engines which required comprehensive maintenance. It finally entered service on 15 August 1960 as the B-58A, undeniably one of the most visually impressive aeroplanes ever built and just as much a vision of the future as the Stratojet of a decade earlier had been. In it's aluminium finish, the gleaming Hustler seemed the very embodiment of supersonic flight, and it could deliver consistently in combat trials.

Why then was the Hustler withdrawn after only nine years service? Unlike the Starfighter, the Hustler was an extremely capable aircraft, capable of Mach 2,2 at over 60,000 feet, putting it well beyond the reach of contemporary Russian fighters. It smashed 19 official World Absolute records in a publicity program planned by SAC breaking transatlantic and transcontinental milestones and capturing all of the prestigious international trophies: the Bleriot, the Thompson, the Mackay, the Harmon and the Bendix. (See Lowe, 1983:p.202).

By the late 1950's, however, the political scene had changed quite radically. Public opinion on nuclear warfare had altered as scientists made horribly apparent how terrifying the effects of nuclear war could be. At a price of $30 million per airframe,[15] the USAF could no longer justify operation of an aircraft which cost so much to procure and maintain. The Hustler was the last aircraft of the Bare Metal era.



Figs.22&23: The dramatic Convair B-58A Hustler, showing it's delta wings, area-ruled fuselage and streamlined pod housing weapons and fuel.



If one aircraft can be said to mark the change from post-war 'Bare Metal' to the troubled Vietnam era, it is the Boeing B-52 Stratofortress, a design with it's roots in the 1940's and a service life that continues in the 1990's.

The B-52 was, like the B-47 that preceded it, almost solely a product of Boeing thinking and planning and, apart from some SAC 'pressure' on engine manufacturers Pratt & Whitney, devoid of interference from the Department of Defense or anybody else. Boeing was given almost free rein with the design of the B-52 based on considerable experience gained during the B-47 program. Jeffrey E. Ethell summarized it thus:

> Senior officers were still permitted to exercise vision, imagination and leadership. Congress had not yet intruded so pervasively into the innermost details of aircraft procurement, and the public was able to countenance without apologies the purchase of a weapons system which promised a clear armed superiority over potential enemies. (Ethell, Christy, 1985:p.49).

In this favourable climate, an aircraft as challenging as the B-52 could be given full attention by engineers and designers at Boeing without self-appointed defense experts from Washington. Such a climate proved very receptive to the Starfighter and Hustler, as we have already seen, and the B-52 was born of a similar philosophy to these aeroplanes; namely that it must be better than the 'enemy' at all costs![1]

Unlike the Starfighter and Hustler however, the B-52 was a relatively conventional aeroplane by the standards of the early fifties. During the war, Boeing had been preoccupied by production of the B-17 and B-29 bombers, and was already committed to the medium bomber program that would give birth to the Stratojet. It was left to Convair to produce SAC's 'global' bomber, the B-36.

As we have seen, the B-36, even in it's final B-36J configuration, was an old fashioned idea, and formidable

though it's size and range were, it could never be any match for the new generation of jet-powered MiG fighters already flying in the Soviet Union. Much more important was the introduction of the B-47 Stratojet - with six engines and swept wings it could leave most fighters standing and left the B-36 like a relic from the dinosaur age.

So it was that Boeing's heavy bomber proposal, Type 474, took shape, a swept-wing design with turboprop engines. Designer Edward Wells dropped the turboprops in favour of six J40 turbojet engines and submitted his proposals to SAC as the XB-55. However, before the proposal could be approved, Wells and his team had come up with an even more impressive solution. "Pete" Warden, SAC Chief of Bomber Development, had been urging Pratt & Whitney to speed up development of the still-secret YJ-57 engine, a twin-spool turbojet. With a certain amount of confidence, he met with Boeing personnel in Dayton, Ohio in 1948 and suggested that Wells and his team work to a swept wing, jet-powered concept similar to, but much larger than, the B-47.

Much legend surrounds what happened the following weekend [2]. Wells called Warden on Friday, 26 October 1948 and told him that their new proposal would be ready on the following Monday. The thirty-three page proposal outlined the design parameters for the new bomber, based on experience with the B-47 and a mere three years later, the prototype XB-52 Stratofortress was rolled out. It had a long, slim low drag fuselage and a low drag tandem cockpit [3]. The eight Pratt & Whitney J57 engines hung in four twin nacelles beneath the wings, acting as dampers as on the B-47. The undercarriage was of tried and tested bicycle design, with $\pm$ 20° adjustment for dealing with crosswinds when landing or taking off. The bomber possessed huge load carrying ability and range and although Convair presented the B-36-based YB-60 as competition, there seemed little doubting that the B-52

Fig.24

represented the future of the U.S. strategic nuclear deterrent.

Despite the B-52's competence, it's future was never certain during the late 1950's, as SAC instigated a series of proposals aimed at providing a successor to the Stratofortress. That SAC failed in this regard is due to a number of factors: the excellence of the B-52 in it's role, a lessening of the defense budget available to the Air Force and changing public opinion with regard to nuclear weapons and nuclear war. It would be the last high altitude long-range bomber using gravity-fall nuclear weapons to enter full service.

From 1955 on, SAC envisaged a three-part nuclear deterrant: a 'strategic triad' of Boeing B-52 nuclear bomber, General Dynamics (Convair) Atlas [4] and Martin Titan [5] intercontinental ballistic missiles (ICBM's). From a purely military point of view, however, a bomber which took hours to fly to it's target was something of an out of date concept by the end of the fifties [6]. Comprehensive stockpiling of nuclear missiles began in earnest in 1957, and development of two nuclear cruise missiles, the North American Navaho (SM-64) and Northrop SM-62 Snark was well underway. Anyway, by 1960 a new acronym entered SAC vocabulary: MAD or Mutually Assured Destruction, a considerable deterrent in the sense that both sides in a global nuclear war faced almost complete annihilation. The U.S. 'boasted' of it's capacity to wipe out Soviet 'defenses' many times over, and despite Khrushchev's claim that 'we are not a bloodthirsty people', the Russians soon acquired overkill capacity too. However, as Peter Lewis points out

> There was one flaw in the logical perfection of the balance of terror which began to trouble the public mind. If you want to be sure of having deterred the enemy, you have to fire first. (Lewis, 1989:p.91).

Consequently, weapons aimed at enemy bases were useless since enemy missiles would already be on their way.

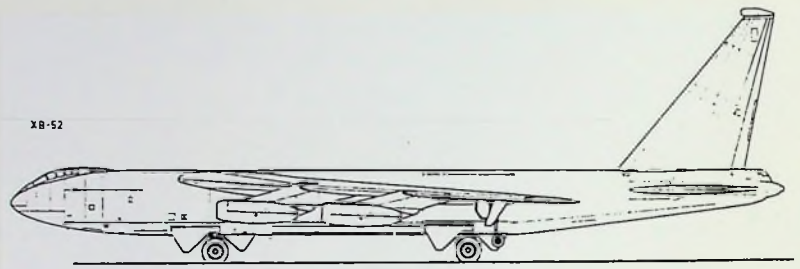
> The alternative is massive retaliation by missiles aimed at the enemy's cities, which will stay put. (Lewis, 1989:p.91).

Combined with the effects of nuclear fallout, a phenomenon first described in the late fifties, the prospect of Mutually Assured Destruction served to undermine public confidence in war tactics which guaranteed no winners. Smaller military nations such as France and Britain spent vast sums of money acquiring nuclear capability in an effort to be part of the 'nuclear club'. A series of 'false alarms' necessitated the hasty recall of SAC bomber fleets already on their way - a 'hot line' was installed between Moscow and Washington in 1963. (Lewis, 1989:p.94).

In contrary to this escalation of the Arms Race, public opinion was shifting towards disarmament and the movement was gaining considerable support from ex-nuclear scientists, Russian and American alike. People became informed of the hazards of nuclear war, and terms such as fallout and radiation poisoning entered the popular vocabulary. President Eisenhower changed position - in 1955 he claimed that nuclear testing was harmless, by August 1958 popular opinion had swayed him toward suspension of nuclear weapon testing.

America's $12 billion defense budget of 1958 was causing serious problems, with public confidence in the program failing. Rising economies such as Germany and Japan concentrated their efforts on consumerism, not on obsolete nuclear weapons. In 1959, Khrushchev and Eisenhower mutually admitted that the Arms Race was a farce [7], and the American President urged suspension of nuclear stockpiling when leaving office in 1960. Despite this, the Arms Race continued for nearly 20 years.

In this climate, the Air Force and it's B-52's were no longer seen as figureheads of the American Way. The change in public attitudes corresponded with the end of the Bare Metal era, and colour schemes reverted to sombre green and brown 'camouflage' - propaganda movies from



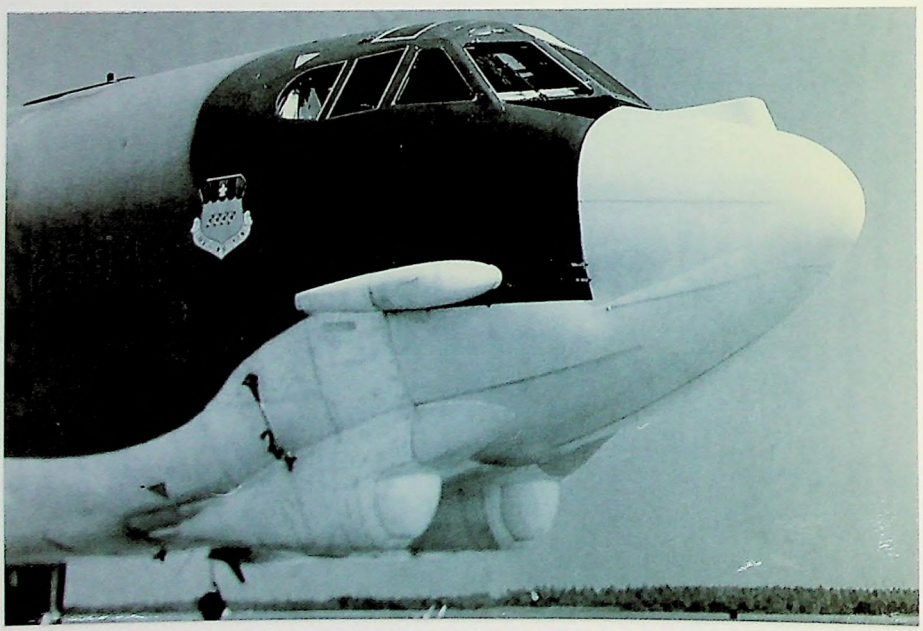


Fig.24(top): Boeing XB-52 Stratofortress with tandem cockpit layout.

Fig.25(above): Close-up view of B-52G nose showing fairings for FLIR and LLLTV optical sensors.

Hollywood gave way to Kubrick's 'Dr. Strangelove'[8], a terrifying satire on the Arms Race. (Lewis, 1989:p.92).

So it was that the B-52 soldiered on throughout the first half of the 1960's, proving extremely adaptable and capable. New weapons such as standoff nuclear cruise missiles could be carried on the Stratofortress, as well as many types of nuclear and conventional bombs. The final variant of the Stratofortress, the B-52H, was a vastly improved aeroplane with new TF33 turbofan engines giving much more power at greater efficiency[9]. With pilots on board, bombers could be recalled in the event of a false alarm, something that was impossible with the ICBM and nuclear cruise missiles.

The designation 'B-52' is perhaps the most famous of all military designations, having given birth to a rock group and a bouffant hairstyle of the late fifties. It's angular lines and sheer bulk made it something of a potency symbol, and dark colour schemes employed since the sixties are in keeping with the macho, military-man image. Nowadays, 200 B-52G and B-52H Stratofortresses remain in nuclear strike capability, adapted to low-level strike mission after an expensive modification program during the seventies. With the installation of high technology mission aids including television and infrared, the Stratofortress has sprouted bumps and bulges accentuating this aggressive image. Fig.25

It is worthwhile examining briefly the nature of Air Force graphics as applied to the B-52 as another illustration of the changes taking place during the early sixties. Bare Metal Stratofortresses were gleaming, confident machines, and the 'U.S. Air Force' legend grew greatly in size from the original B-52A's to the later B-52F's. At around the same time, the lower surfaces of the aircraft were painted in reflective white to protect the skin of the aeroplane from the flash of a nuclear explosion. SAC badges were always prominently displayed on the B-52's nose, while the Air Force insignia appeared Fig.26,27

Figs.26&27: Note enlargement in SAC badge and U.S. AIR FORCE legend apparent from earlier 1954 B-52A(top) and 1958 B-52D (above). B-52D also has white underbelly.

behind the wing's trailing edge.

In the early sixties, B-52's gained their first 'camouflaged' colour schemes of two-tone green and brown. The anti-flash white was retained until 1965, when it was changed to black for raids in Vietnam, supposedly lessening visibility. By now, the insignia had shrunk to 40% it's previous size, and the U.S. Air Force legend had disappeared altogether. The use of stencilled lettering helped popularise that typeface as a 'military' image after Vietnam. To a large extent, remaining G and H Stratofortresses retained these schemes, although colourful badges reappeared during the 1980's. Fig. 28

The turn of the decade, 1957-63 was a busy one for the USAF, and with some models including the B-52 and even B-58 beginning to look a little outdated, the pressure was on to find answers to problems that didn't really need solving. It was hardly surprising that few of these projects received much public support or confidence.

Fig.28: B-52G Stratofortress in dark colour scheme in use since the Vietnam War. Graphics are hardly visible, but the aircraft retains a white underbelly.

For the most part, the USAF inventory of the 1960s and 1970s was made up of aircraft and missiles developed during that very productive post-war era from 1945 to 1960. The new McDonnell Douglas F-4 Phantom, holder of the official absolute speed record, served as principal fighter/interceptor with support provided by Century-series Starfighters and Delta Darts[1]. The B-52 stood alone as principal strategic bomber with the B-58 in the nuclear strike role and some RB47's serving with strategic reconnaissance squadrons.

The period of post-war affluence in America was reaching a zenith, and this undoubtedly helped the huge growth in air travel that came with the jet airliner. Boeing 707's and Douglas DC-8's could traverse the Atlantic Ocean in six hours or the continent in five, and new air routes across the world were opening monthly. By 1958, orders for airliners were streaming in from the world's major operators, and such manufacturers as McDonnell Douglas, Boeing and North American found themselves in a prosperous position. The Air Force and SAC recognised this and embarked on a series of very expensive contracts aimed at giving their fleets a high-technology profile.

As we have seen, ICBM's had stolen much of the strategic bomber's thunder and the public could hardly have sanctioned an expensive replacement for the competent Stratofortress. Still, North American were issued Weapons System contract WS-104 for development of a revolutionary rocket-powered pilotless cruise missile, the Navaho and WS-110A for a Chemically Propelled Bomber (CPB)[2]. The Navaho needed new guidance and propulsion systems as well as new structural techniques to make the project feasible, and North American built the innovative X-10 recoverable test vehicle to try out these new systems. By 1957, the system had been perfected at a cost of $691 million to the tax-payer, and the X-10 was performing feats

Fig.29

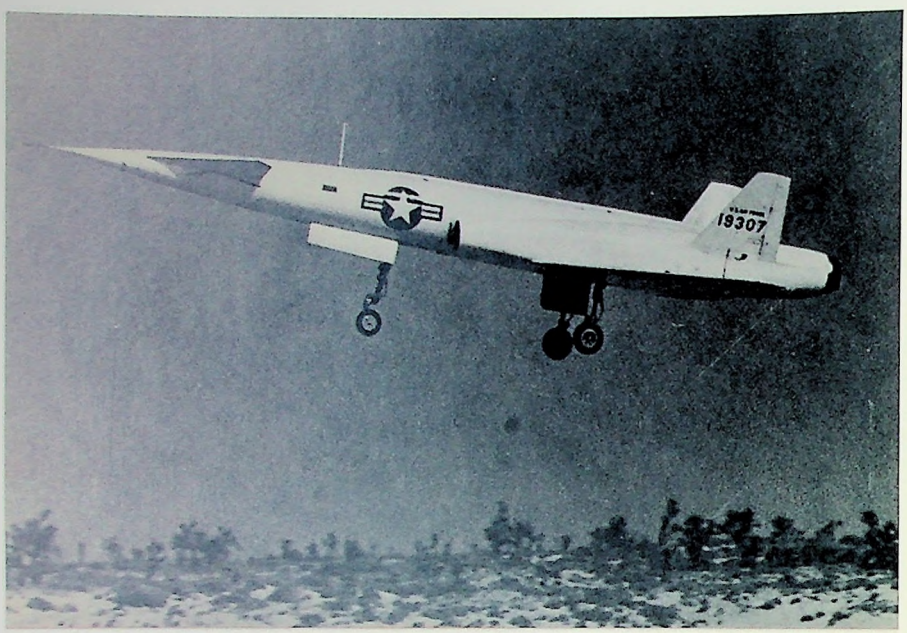


Fig.29: North American X-10 pilotless research vehicle used in conjunction with the SM-64 Navaho cruise missile programme, cancelled in 1959. Compare configuration with Valkyrie shown in Figs.30-31.

previously thought unattainable - with pinpoint accuracy and control. However, with the first presentation of the XB-70 CPB in July 1959, the SM-64 Navaho was cancelled. Justification for this horrendously expensive apparent dead end was two-fold. Firstly, the SM-64 provided much needed research for the bomber, which was to travel at the same Mach 3 speeds, as well as use honeycomb-sandwich construction techniques for incredible strength, lightness and heat performance. The XB-70 adopted the same 'canard' (tail first) layout as the Navaho. Secondly, the Rocketdyne motor used by the Navaho served as the basis for the rocket engines that powered the American space program to the Moon in 1969. (See Yenne, 1985:pp.175-185).

Still, the Air Force's cancellation of the Navaho in favour of another high altitude bomber can hardly be justified. The Russians were already known to have developed ground-to-air missiles (SAMS) capable of shooting down any aircraft flying at high altitude, even an aircraft travelling at three times the speed of sound.

The shooting down of Gary Power's U-2 spyplane over Russia in 1960 brought home the vulnerability of high-altitude insurgence, and the hostile policital atmosphere made the future of the XB-70 bleak before it had even flown. Nonetheless, the Air Force ordered three (later two) XB-70A prototypes on 4 October 1961. By January 1962, with production of the prototypes well under way, the plans for adoption of the XB-70A (known as 'Valkyrie') had effectively been dropped, and despite plans for reconnaissance RS-70 versions of the aircraft, the B-70 program was officially cancelled in February 1964.

Nevertheless, both XB70A prototypes were completed and conducted an extensive and expensive research program with the National Aeronautics and Space Administration (NASA). The new aeroplane was rolled out to an awestruck group of onlookers on 21 September 1964. It was a truly colossal aeroplane, superlative in almost every respect. Fig.30

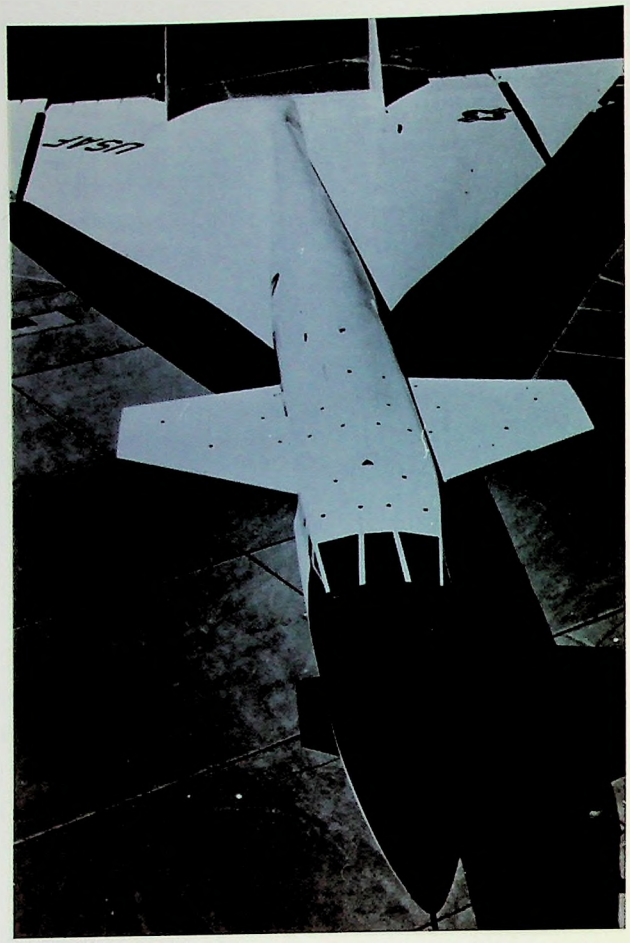
At the time, it was the heaviest, most powerful, longest ranged, highest flying, most costly and second fastest aircraft ever produced*. It's wing was a huge Delta with tips that folded down at 65 degrees to trap the supersonic shock wave and provide 'compression lift', a new principle devised by NASA engineers Alfred J. Eggers and Clarence A. Syventson[3]. An extremely efficient method of producing lift at high speed, it gave the Valkyrie capability of sustaining Mach 3 for long periods with the awesome power of it's six General Electric YJ93-GE-3 engines. Gleaming in it's white paint, a long snake-like fuselage grew from the wing's upper surface, giving Valkyrie a graceful, swanlike appearance. Fig.31

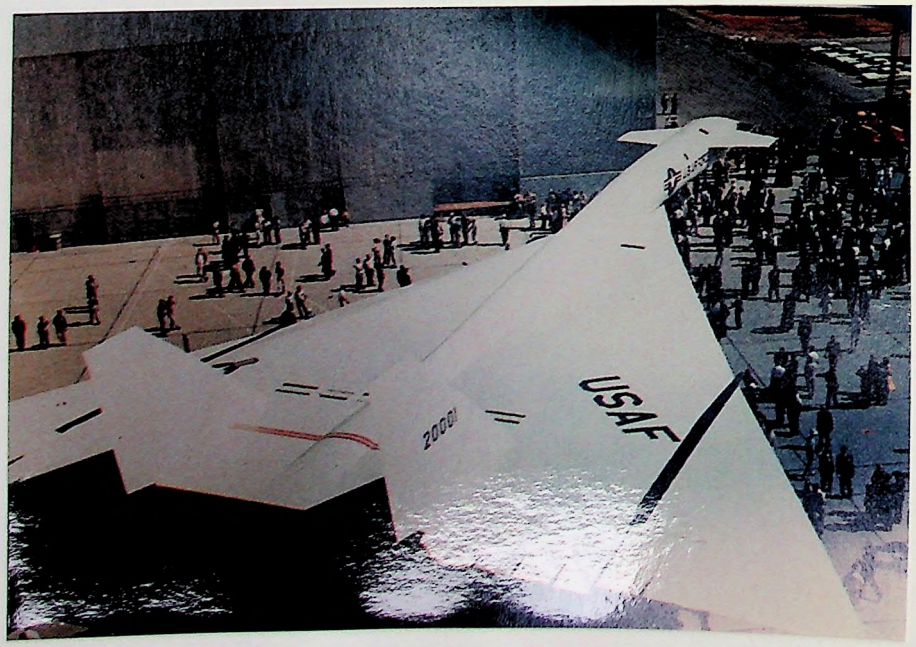
The XB-70 performed almost faultlessly for two years, culminating in a thirty-three minute flight at Mach 3,08 by prototype No.2 on 19 May 1966. It was to be the aeroplane's swansong - on 8 June 1966 the No.2 Valkyrie was lost in a mid-air collision with an F-104C during a publicity 'shoot' organised by engine makers General Electric.

This event effectively ended the high-profile image of the Air Force. 'No more publicity' became the battle cry for SAC, and the crash of the Valkyrie corresponded very closely with the painting of the last Bare Metal Stratofortresses in sinister camouflaged schemes. U-2 spyplanes, hitherto Bare Metal, were painted black, an appropriate finish for such a secret and mysterious aeroplane with such secret missions. The Pentagon attitude to 'the Media' has been unhealthy since, and all testing and flying is carried out in the utmost secrecy even to-day. The last ride of the Valkyrie symbolised the death of Bare Metal optimism and reckless spending, and it was left to the space program to restore public confidence in the American aerospace industry.

* only Lockheed's YF-12A was faster.

Figs.30&31:
North American XB-70A Valkyrie. Note huge size and swan-like appearance.





The positive legacy of the XB-70A was the mass of data obtained during NASA's research program, data on high speed flight and the nature of the upper atmosphere. The Valkyrie's contribution to the U.S. Supersonic Transport (SST) and Shuttle Transport System (STS) programs was incalculable, and much of the initial research from the Navaho era went towards investigations for new materials and production techniques. The use of stainless steel and honeycomb-sandwich was pioneered by the Navaho and Valkyrie, as was a special new support system needed for escape at Mach 3. It is likely that Lockheed were kept informed of North American's research during the design stages of their A-12/F-12 program, the most secret ever undertaken by the U.S.A.F. Funded by the CIA, the A-12 was designed to be a single seat spyplane and although it remained "in service" until 1969, very little else is known about it, and only one photograph was ever released [4]. However, much more is known about the YF-12A and it's reconnaissance derivative, the SR-71A. Based around two revolutionary YJ58 turbo-ramhets developed by Pratt & Whitney, the new aircraft required new techniques of manufacture and advanced aerodynamics, just like the Valkyrie [5]. Pioneering the use of titanium as a structural metal the YF-12A also needed special new fuel, with a performance range from sea-level right up to the 100,000 ft. ceiling expected of the new interceptor. (See O'Leary, 1986:pp.147-151).

The YF-12A first flew on 7 August 1963, and was of truly dramatic appearance. The fuselage had almost vanished, blending as it did with the wing which was of double-Delta layout. The wing started at the nose, and flowed back to the rear of the plane, interrupted only by the huge nacelles housing the Pratt & Whitney JT11D-20B engines (the J58 designation was changed). Two all-moving slab tailplanes provided lateral control. Fig.32

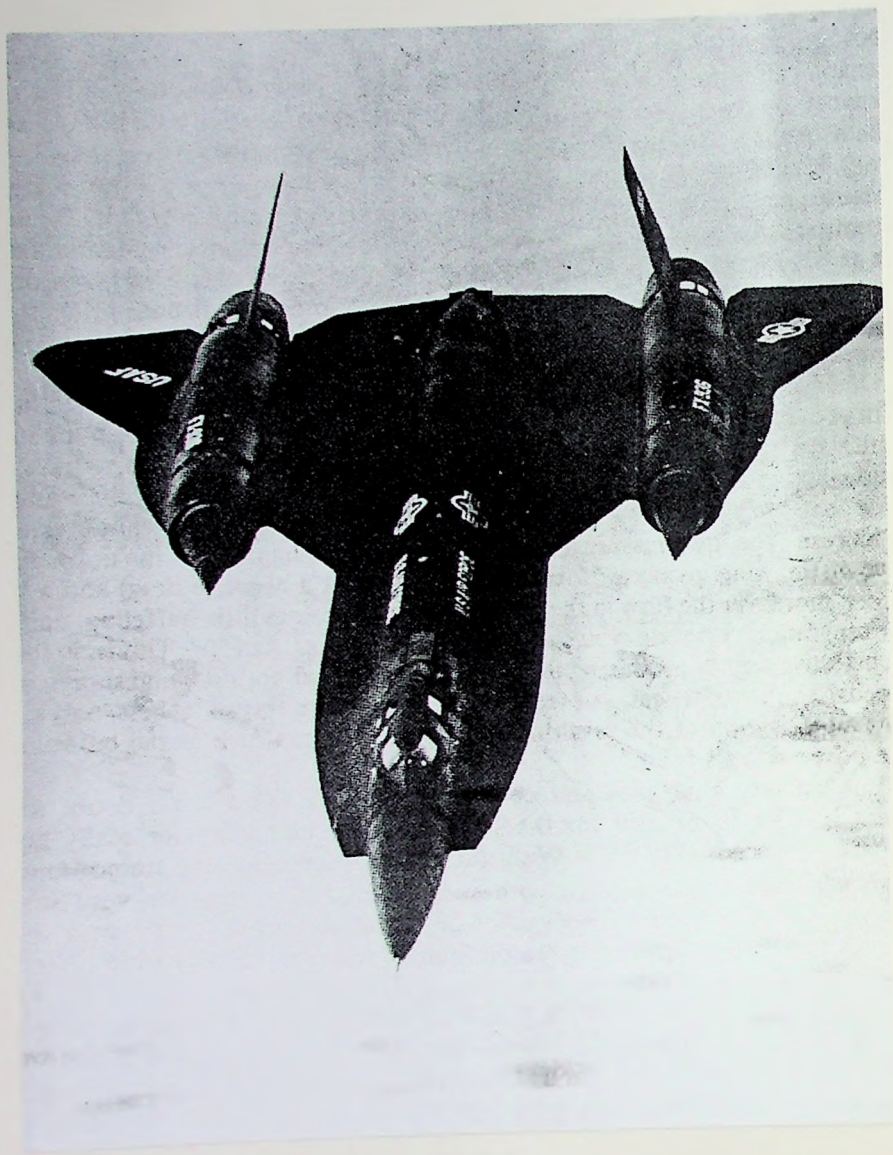


Fig.32: Lockheed YF-12A interceptor. Although never produced as an interceptor, the YF-12A remained flying until 1979, having been designed in the late fifties.

Originally coloured in grey and white, the YF-12A soon gained an all-over black colour scheme in keeping with it's secret specification and sinister mission. In 1964 the reconnaissance version, SR-71A, was added to the inventory, differing from the YF-12A in the redesign of it's nose - it did not require a radome. Fig. 33

The YF-12A/SR-71A, known as 'Blackbird', is surely the most dramatic evocation of speed ever realised. From it's small frontal area to it's sweeping lines and the almost disproportionate size of it's engines, the Blackbird conveys a vivid sense of dynamism. It has become a splendid ambassador for the USAF, being the most recognisable form with the most dramatic performance. The Blackbird also conferred something of a 'cult status' upon the man responsible for it's development, Kelly Johnson. As we have seen, Johnson's team at Burbank, California had already created America's first operational jet, the Shooting Star, and it's most spectacular fighter, the Starfighter. His Lockheed U-2, an ultra-high altitude spyplane, was an expression of simplicity with a very clean fuselage and extremely long thin wings. Like Jack Northrop, Johnson was something of a visionary, but has been recognised and accoladed for his work, unlike the unlucky Northrop who retired, frustrated, in 1952. The Blackbird was the ultimate expression of Johnson's romantic vision. (See Convair, 1985:p.165). Fig.34

The SR-71A remained in service long after orbital satellites rendered it's mission obsolete, finally retiring as late as January 1990. The reason for this is a valid one: from the mid-1970's the Air Force had been regaining lost ground as a new generation of teenagers grew up with the new generation of fighters and bombers. The SR-71A, with it's exaggeratedly ostentatious appearance became the figurehead for this new openness, ironic considering it's 20 year service life. Like the B-58A Hustler of thirty

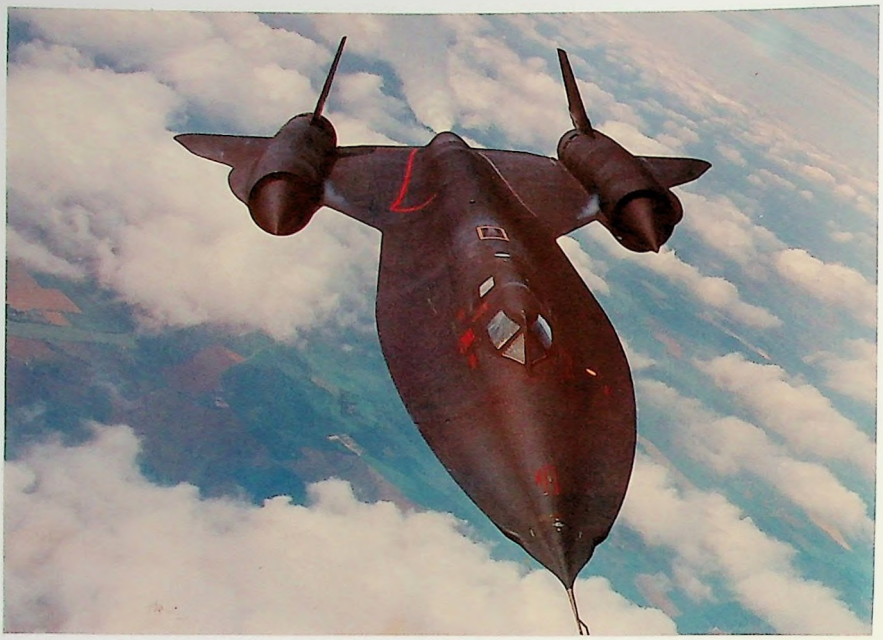


Fig.33: The sweeping lines of the Lockheed SR-71A Blackbird.

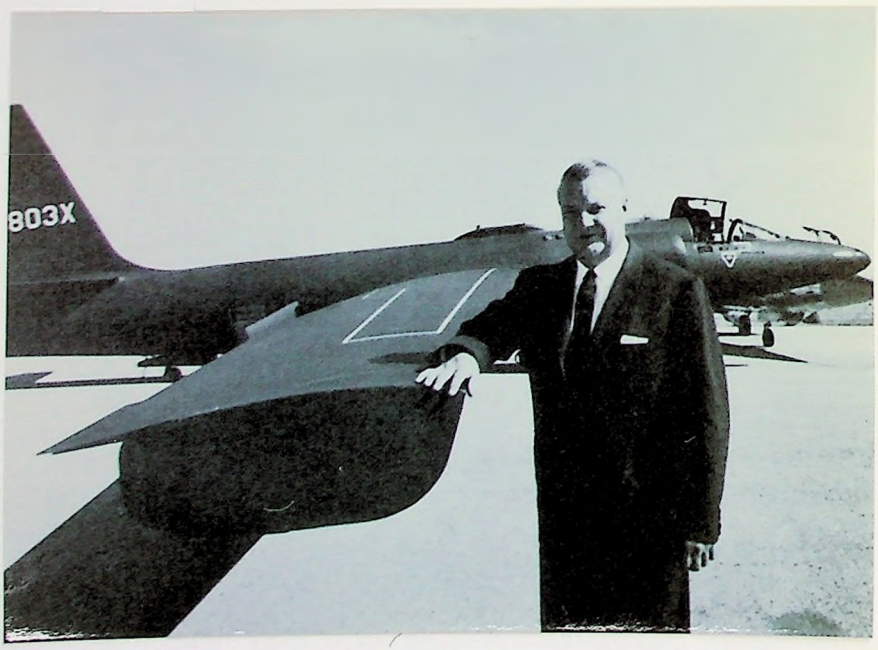


Fig.34: Clarence L. Johnsnon pictured with the highly-secret Lockheed U-2 spyplane. The U-2 was an extremely high-flying aircraft with a huge wingspan.

years earlier, by the late 80's, the Blackbird held most world speed and altitude records for aeroplanes.

It's greatest achievements were in the fields of research however, and it's pioneering use of ramjet technology and titanium structure will prove invaluable with the development of the hypersonic spaceplanes planned for the turn of the century.

Although Blackbird was the fastest regular aeroplane in it's time, it is worth mentioning briefly the North American X-15, a rocket-powered bullet of an aircraft that drew to a close the speed and altitude research program started with the Bell X-1 in 1947. This program was most influential in verifying and testing new theories that would eventually filter through to regular military service aeroplanes, such as swept wings (Douglas D558-II), blade-thin straight wings (Douglas X-3) and newer, more revolutionary theories like variable sweep (Bell X-5). Fig.35

The X-15 was planned to be the ultimate speed/altitude research aircraft, operating at the very edge of the atmosphere and providing data on heat, stability and control problems with re-entry vehicles. The achievements of the X-15 are somewhat forgotten to-day - most publicity in the 50s /early 60s period centred around the Mercury space program, a program which itself benefitted enormously from X-15 research (See Yenne, 1985:pp.102-103).

Rocket-powered and launched from beneath an NB-52A, North American's design was chosen over submissions from Bell, Republic and Douglas, despite their commitment to the Navaho and Valkyrie weapons systems contracts. Constructed from stainless steel and titanium, the X-15 was first powered by two Reaction Motors XLR 11 rocket motors and later by a single Thiokol XLR 99. All test flights were made from Edwards AFB, California (formerly Muroc Dry Lake), and each flight followed a ballistic trajectory for about 275 miles. The program commenced on 10 March 1959 and ended 199 flights later on 24 October 1968.

The X-15's exploits remained largely unknown to the public; both the media and citizen alike were more interested in the 'Mercury Seven' astronauts and the new space race; Yuri Gagarin of the Soviet Union became the first man in space in 1961 and the pressure was on for America to follow suit. Initial American tests involved use of chimpanzees, leading to disapproval from Air Force test pilots from whose ranks a number of the astronauts had been drawn; Chuck Yeager commenting that

> he'd be damned if he was going to step into some Spam can with chimpanzee-shit all over the seat. (Chant, 1990:p.2324).

Nonetheless, X-15 test pilots were awarded astronaut's wings for flights over 50 miles high; Major Robert White reached 314,750 feet on 17 July 1962, just over a year after Alan Shepard had become America's first man in space. With President John F. Kennedy's anncunced goal of having a man on the moon by the end of the decade, emphasis was well and truly shifted to the Gemini and Apollo space programs. The X-15's last benchmark was set on 3 October 1967 when Captain William Knight took his X-15A-2 to 4,534 mph or Mach 6,72, a figure which remains unchallenged. Fig. 36

The legacy of the X-15 extended far beyond the space program:

> The rocket aircraft was showing scientists how the human body behaved at stratospheric altitudes and hypersonic speeds. It was telling engineers how to design rocket engines and fuels. It told aerodynamicists how aircraft should be designed to fly faster and higher than ever. It's contribution to biomedical science was almost incalculable. (Chant, 1990:p.2325).

New materials such as the Emerson Electric T-500 coating which protected the X-15 at hypersonic speeds led to the development of Teflon, now familiar on non-stick

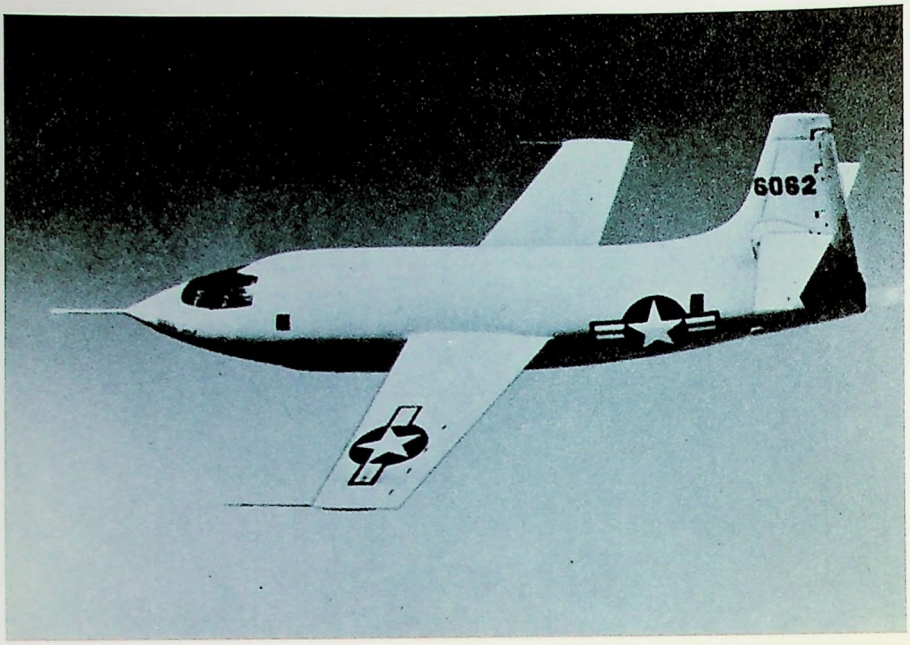
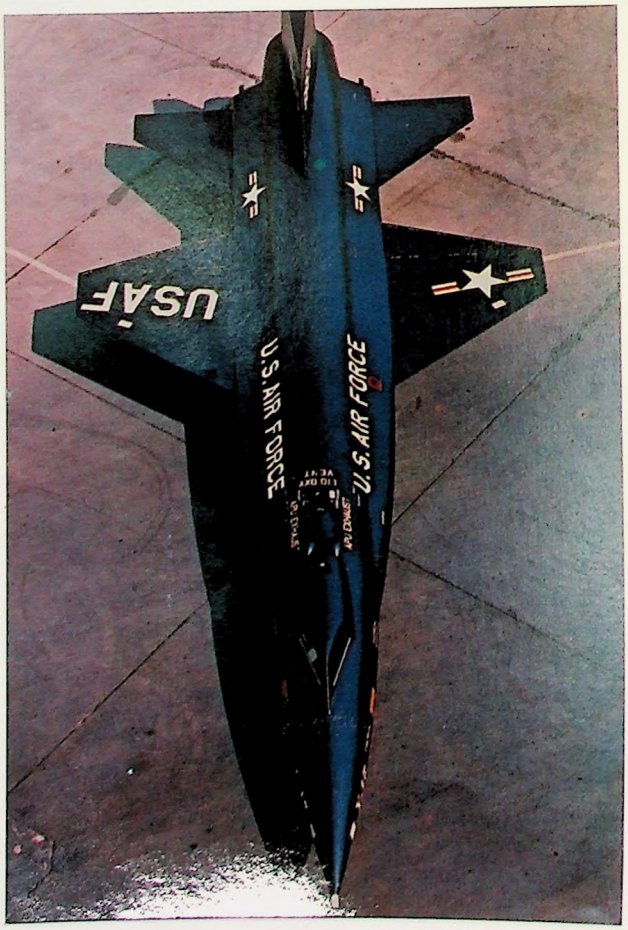


Fig.35: The Bell X-1A, first through the sound-barrier.

Fig.36: North American X-15A, capable of over six times the speed of sound. It last flew in 1968.



frying pans and frictionless bearings. It is a most familiar example of aerospace science benefitting the common man, a practice which became profligate after the Apollo moonlanding program. (See Chant, 1989:p.2327).

Interest in the space program lasted into the early 70's until the last moon landing by Apollo XVII. Following the ending of the Vietnam war, an Air Force laboured with being seen as a symbol of all that was bad about the American Way began a restructuring process involving the procurement of up-to-date aircraft and weapons. When Ronald W. Reagan came to power in 1980, a new macho approach to the Armed Forces and foreign policy ushered in an era of spending and production which may in time rival that of the post war period[6] .

SUMMARY AND CONCLUSIONS.

This thesis has shown two principal conflicting views that exist when trying to analyse the significance of American aeroplane design of the period 1944-1965. On the one hand aircraft historians tend to overlook the practical and political implications of the aircraft, while on the other hand, political commentators discuss military procurement purely in terms of policy and economics. So, aeroplanes such as the B-36 tend to be praised by aviation writers for their technical achievements and spectacle without consideration of the aircraft's strategic obsolescence, while in the case of political writers, the converse tends to be true, as illustrated in Chapters 2 and 3.

During the course of research, however, it became apparent that each aircraft represented a step in a learning process, a process which pushed the limits of available technology to their furthest. The spectacular successes of the 1950 s such as the Starfighter, while betraying certain military shortcomings explored new areas of performance and handling, and provided splendid ambassadors for the Air Force in terms of consolidating public confidence and enthusiasm in the U.S.A.F. (Chapter 2).

However, the politics of military procurement during the fifties and early sixties are much more sinister. The first major post-war acquisition, the B-36, was a misfit in it's role, designed for massed raids on German cities yet expected to fly alone to isolated Soviet targets defended by sprightly jet-powered fighters. The B-36 was the genesis of the 'larger, faster, higher' philosophy and thus generally excellent aircraft like the Convair F-102 were ear-marked as 'interim', to be replaced by improved aeroplanes as soon as the latter became available. Although not pre-planned obsolescence, the military became obsessed with replacing basically good aircraft with new ones that offered little significant advantage. The tax payers, as shown in Chapter 4 with the B-52, had little objection toward procurement of 'new, improved' types;

not only was anti-Communist feeling at fever pitch, but people had grown used to the idea of replacing their automobiles annually, trading them in for the 'new, improved' model.

For the aircraft industry the result was colossal growth, as military money funded refinement and development of new aerodynamic theory, wing configurations and powerplant technology, as described in Chapters 2 and 4. Much of this research was channelled into development of pioneering jet-powered airliners such as the Boeing 707 which ultimately made air travel accessible to the masses and swift trans-Atlantic and transcontinental flights a reality. In this respect, the Boeing B-47 Stratojet dictated the form of every large jet aeroplane for the rest of the century, from Boeing's own types to aircraft from Lockheed, McDonnell Douglas and most European manufacturers.

The aircraft also became symbols of their political age. President Eisenhower had a military background, with a robust approach to military policy. Aircraft such as the B-52 Stratofortress not only performed missions of extreme military importance (nuclear deterrent), but also symbolised this robustness; the Stratofortress was physically large and dominating with an angular masculine form and a brash Bare Metal finish. The SAC badge and U.S. AIR FORCE legend were displayed prominently on the aircraft for all to see, and the media joined in by deifying the bombers' courageous pilots.

As pointed out in Chapter 3, the scene changed dramatically at the turn of the decade. With the mass-stockpiling of nuclear missiles, the frightening prospect of a Mutually Assured Destruction prompted a change in public opinion and in the light of horrifying revelations on the possible results of nuclear war, opinion of military policy became increasingly hostile. The Space Programme became the new champion for the American Way and the figurehead for technological supremacy. High technology,

high profile programmes like the Navaho and unfortunate Valkyrie were cancelled as the military could no longer justify such expenditure on such a scale. Lack of planning in evidence with the procurement of the Starfighter shown in Chapter 3, finally came to a summit with the pursuing of the Valkyrie programme. In effect, the Department of Defense learned it's lesson and the next really significant new aircraft, the F-15 and F-16 fighters of the mid 1970's displayed an all-around competence never possessed by the Starfighter.

Of course, this has a corollary effect. In the cases of the Stratojet and Valkyrie, shown in Chapters 2 and 4, no such advances in technology could have taken place without liberal financing. Now that defense budgets have become more constrained, aeroplanes get better and better within fixed configurations rather than risking new, unproven, ones. The Stratojet is an example of a risk that paid off, the Flying Wing of one that did not.

It seems likely that the aeroplane will remain the most conspicuous item in the military inventory, representing high levels of technological progress and excellence. It is also likely that a dichotomy will continue to exist in the analysis of such aircraft: their scientific progress will be praised while the justifyiability of their expense will be questioned.

In summing up, the designs of the 1950's and early 1960's were made possible by a number of factors; firstly, a huge amount of money was available to aircraft manufacturers for research and development of new theories and aeroplane types - this led to some very specialised aircraft with limited military potential - secondly, the American public could 'countenance without apologies' (Ethell, 1985:p.41) new weapons systems which seemed to offer a clear superiority over the Soviet Union - thus it was that some excellent aircraft such as the Stratofortress were born - and thirdly, the aircraft manufacturers themselves were enthusiastic about producing aeorplanes that

could be used in the development of a design for the lucrative civil market - the Boeing 707 is a prime case-in-point.

The results of this work were some designs with limited growth potential that nevertheless, in their supreme evocation of speed and excitement, were figure-heads for military and civil America alike. Some excellent designs outlived expensive replacement attempts, or disappeared due to short-sighted policy changes. This period is likely to influence the development of aviation for decades to come.

FOOTNOTES

CHAPTER I.

1. Alexander De Seversky is an ex-Air Force commander who wrote several 'inside stories' on the wartime and immediate post-war Air Force. Reference from YENNE, Bill, The history of the U.S. Air Force .

2. Other early jets included the German F9F-2 Panther, McDonnell F2H-2 Banshee and Republic F-84.

3. ASPECT RATIO : Ratio of wingspan/chord. Chord is defined as the length of a line joining leading edge to trailing edge of a wing (Kermode).

4. The Messerschmitt Me262 was the first jet-powered fighter to enter service anywhere - it entered service with the Luftwaffe in early 1944.

5. Contemporary accounts gave a 14:1 kill ratio in favour of the F-86. Grossly exaggerated, presumably for propaganda purposes, Dorr suggests a more realistic 4:1 ratio. This is still very convincing.

6. John Knudsen Northrop (1895-1981) was a pioneer of all metal aircraft construction, and was responsible for the Lockheed Vega monoplane of 1929.

7. The rotation of the propellers provided stability against a tendancy for the flying wing to "sideslip". Vertical surfaces helped reduce this tendency.

8. 'WAR OF THE WORLDS' (Byron Haskin, 1953, U.S.).

> Vivid, frightening adaptation of H.G. Well's story about a Martian invasion. Dramatically sound and filled with dazzling, Oscar-winning special effects; superior sci-fi.
> (Matlin, 1989, p.1213).

The YB-49 made a cameo appearance on U.S. Air Force stock footage as a nuclear bomber. It's attempts to defeat the Martians failed.

9. The Northrop B-2A is a strategic nuclear bomber incorporating 'Stealth' technology - making it next to invisible on radar and heat detection equipment. The

B-2 was rolled out in November 1988 and completed two test flights during 1989.

CHAPTER 2.

1. Now the United States Air Force Museum, Dayton, Ohio.
2. Most engines had a useful service life of less than 100 hours.
3. See Burnet, 1979, Chapter 7.
4. These rocket-assistors, fitted to many types in the post-war era, were incorrectly designated JATO (Jet Assisted Take Off). They were in fact pure rockets.
5. One famous movie starred James Stewart as a B-47 Stratojet pilot with the dilemma of having to chose between a happy family life and a career in SAC. I don't recall how it ended up.
6. Up to 300 Stratojets were in the air at any one time, 24 hours a day (Dorr, 1989,p.720).
7. The sound 'barrier' had been thought unbreachable, and numerous test pilots American and British, were lost when losing control of their aircraft approaching Mach 1. At the time, the Americans called it "the sonic wall". 'Not being an engineer, Yeager didn't believe the "barrier" existed' (Wolfe, 1979,p.52).
8. Afterburning or reheat involves re-ignition of the engine's exhaust gases while still in the jet pipe. Although it provides much increased thrust, it has a voracious appetite for fuel.
9. Patton's article, 'Long Range Longshots', appeared in Wings magazine and contained an in-depth look at the escort fighters competition. (See bibliography).
10. A 'twin-spool' turbojet involved two compression stages instead of one (single spool).

11. Bob Alberts, a former F-104 pilot, claimed:

> The wings were advertised as being razor sharp. They said you could cut steak with it! If you've ever been next to a 104, you know they're not that sharp, but it was good publicity.
> (Dorr, Alberts, 1989, p.1634).

12. It's tiny wings, while not inhibiting high speeds, had too small an area to be effective at low speed during tight manoeuvering. This led to a high accident rate with Starfighters.

13. Ironically, the fuselage-mounted engine became a standard for British airliners, such as the BAC-III and Vickers VC-10. Boeing also copied the layout for their 727.

14. The General Electric J79 featured variable-incidence startor vanes which could be adjusted to suit the airflow through the engine at differing speeds. A variable shock cone ensured that passage of air was always subsonic even at Mach 2.

15. 1960 U.S. dollars.

CHAPTER 3.

1. By now, the Russian Tupolev Tu-20 'Bear' had entered service as their first strategic bomber. Turboprop powered, it was somewhat less capable than the Stratofortress. It also remains in limited service, largely replaced by more modern Tu-95 and Tu-125 bombers.

2. Namely, that the B-52 was designed from start to finish in one weekend! This is, of course, nonsense, although Boeing's design team did lay down the parameters for the B-52's specification based on B-47 Stratojet experience.

3. This revised to side-by-side seating for the B-52A, for reasons of crew co-ordination. Very successful in this respect, most aeroplanes with pilot/co-pilot flight crew now employ side-by-side seating.

4. Designated SM-65.

5. Designated SM-68.

6. An ICBM could reach targets in less than half an hour.

7. 'According to Khrushchev Remembers, (the conversation) went like this:

Eisenhower : How do you decide military funds?

Khrushchev : How do you?

Eisenhower : My military leaders say "We need such and such". I say "Sorry, we don't have the funds. They say "The Soviet Union has already allocated for such a programme, so we shall fall behind"... So I give in. That's how they ring the money out of me. How is it with you?

Khrushchev : Just the same'

(Lewis, 1989,p.105).

8. Dr. Strangelove (Or how I learned to stop worrying and love the Bomb). (Stanley Kubrick, 1963,GB). Peter Sellers, George C. Scott.

> Perhaps Kubrick's most perfectly realised film, simply because his cynical vision of the progress of technology and human stupidity is wedded with comedy, in this case Terry Southern's sparkling script in which the world comes to an end thanks to a mad U.S. general's paranoia about women and commies ... the result is scary, hilarious and nightmarishly beautiful, far more effective in it's portrayal of insanity and call for disarmament than any number of worthy anti-nuke documentaries.
> (The "Time Out" Film Guide, 1989,p.159).

9. The B-52H first flew on 31 August 1958

CHAPTER 4.

1. The Phantom first flew in May 1958 with a Navy designation XF4H-1. Disputed over as the first all-missile fighter, it fought off stiff competition from the Vought XF8U-3 (Crusader III). Originally designated F-110A, and thus being an unofficial member of the Century series, the Phantom proved to be an outstandingly successful and capable design, setting

standard for nearly 20 years. (See Dorr, 1989, pp.1375, 1396-1403).

2. The 'chemical' was to be a new boron-based fuel, much more volatile than carbon-based fuels. Extremely problematic, this 'zip' fuel was terminated from the XB-70 programme in August 1959 (See Chant, 1985,p.4267).

3. Eggers was said to have discovered the principle whilst mowing his lawn.

4. See O'Leary, U.S. Sky Spies , 1986,p.147.

5. A ramjet requires forward movement to allow air to pass through the combustion area. Since the aeroplane must be moving forwards to provide thrust, the YJ58 was a turbo ramjet, allowing the aircraft to gain speed under it's own power.

6. The Ford and Carter administrations were quite frustrating for the Air Force: Gerald R. Ford had to contend with the aftermath of the Watergate scandal, while Jimmy Carter's administration sought world peace and arms reduction. Carter cancelled the North American Rockwell B-1A in 1977, approving instead a refurbishment plan for the B-52 fleet. President Reagan reintroduced the aeroplane as the B-1B in 1984.

WORKS CONSULTED

1. ALLAN, Chris, Fast Jets 2, London, 1987
2. ANDERTON, David, Jet Bombers, London, 1976
3. BAYLEY, Stephen, GARNER, Philippe, SUDJIC, Deyan, Twenthieth Century style and design, London, 1986
4. BURNET, Charles, Three centuries to Concorde, London, 1979
5. CONRAN, Terence, The Conran directory of design, London, 1985
6. DURE, Neville, Sound Barrier, London, 1955
7. ETHELL, Jeffrey L., CHRISTY, Joe. B-52 Stratogortress, London, 1984
8. FEININGER, Andreas, Industrial America 1940-1960, New York, 1981
9. Flight, pub. Time Life Libraries Inc., New York, 1973
10. FORTY, Adrian, Objects of desire, London, 1986
11. FRANCILLON, Rene J., LEWIS. Peter, B-52, London, 1988
12. GOLDBERG, Alfred, A history of the U.S. Air Force, New York, 1957
13. GREEN, William, The aircraft of the world (1953), London, 1953
14. GREEN, William, The aircraft of the world (1955), London, 1955
15. GUNSTON, Bill, Early supersonic fighters of the West, London, 1979
16. HESKETT, John, Industrial Design, New York, 1980
17. JONES, Lloyd S., U.S. bombers 1928-1980 (3rd ed.), Flabrook, Ca., 1980
18. KENNA, Rudolph, Somethin' Else, Glascow, 1989
19. KERMODE, A.C., Mechanics of flight (9th ed.), Harlow, 1987
20. LEWIS, Peter, The fifties, London, 1989
21. MALLAN, Lloyd, Secrets of spaceflight, Greenwich, Conn., 1957

22. MALLAN, Lloyd, Man into space,
Greenwich, Conn., 1960

23. MATLIN, Leonard, T.V. movies and video guide,
New York, 1989

24. MILLER, Jay, The "X" planes; X-1 to X-29,
New York, 1984

25. MONDEY, David, Pictorial history of the U.S. Air Force,
London, 1977

26. O'LEARY, Michael, U.S. Sky spies since W.W.I.,
Poole, 1986

27. PEACOCK, Lindsay T., Strategic Air Command,
London, 1981

28. REED, Arthur, BAC Lightning,
London, 1979

29. SGARLATO, Nico, Aircraft of the U.S.A.F.,
London, 1978

30. Strategic Air Command, (ed. Norman Polman),
Cambridge, 1980

31. TAYLOR, Michael J. H., Military prototypes of the 1950s (Warbirds 18),
London, 1983

32. TAYLOR, J. W. R., Warplanes of the world,
London, 1960

33. TAYLOR, J. W. R., TAYLOR, M. J. H., MONDEY, David,
The Guinness book of air facts and feats,
Enfeld, 1973

34. 'Time Out' film guide, The, pub. Tony Elliot,
London, 1989

35. U.S. civil and military aircraft for 1958,
pub. R. Longo & Co.,
Los Angeles, 1958

36. WOLFE, Tom, The Right Stuff,
New York, 1979

37. WOOD, Derek, Jame's world aircraft recognition handbook (2nd ed.),
London, 1982

38. YENNE, Bill, The history of the U.S. Air Force,
Twickenham, 1984

39. YENNE, Bill, The encyclopaedia of U.S. spacecraft,
Twickenham, 1985

JOURNALS

1. BRAYBROOK, Roy M., 'Fighter design philosophy' Air International, Jan. 1976, 15-21
2. BROOKESMITH, Peter, 'USAF fast jets', Take Off 12, 1988, 340-344
3. BROWN, David, 'Home of the right stuff', Air International, Oct. 1985, 196-201
4. CHANT, Chris, 'Manned X-planes' Take Off 89, 1990, 2496-2500
5. DORR, Robert F., 'The American Nuclear bomber' (Parts 1-4), Take Off 23-26, 1988, 696-785
6. DORR, Robert F., 'The Mig Killers' (Parts 1-4), Take Off 48-51, 1989, 1340-1431
7. DORR, Robert F., ALBERTS, Bob, 'Flying the zip', Take Off 59, 1989, 1633-1641
8. DORR, Robert F., 'The black bullet', Take Off 83, 1990, 2322-2327
9. GUNSTON, Bill, 'Lockheed SR-71 "Blackbird", Warplanes 3, 1985, 46-55
10. GUNSTON, Bill, 'Convair's shattered dream', Take Off 84, 1990, 2340-2347
11. MACKNIGHT, Nigel, 'The Missile', Spaceflight News, Mar. 1990, 6-15
12. MASON, Francis K., 'Valkyrie: The doomed dream', Aircraft 214, 1985, 4265-4271
13. O'LEARY, Michael, 'Delta Dart stand-down', Military Airpower, Aug/Sept. 1988, 44-49
14. PALMER, Trisha, 'Early strategic missiles'
    BISHOP, Chris, 'Dawn of the ICBM'
    CHANT, Chris, 'Wings or rockets'
    DRURY, Ian, Warmachine 85, 1985, 1681-1700.
15. PALMER, Trisha, BISHOP, Chris, CHANT, Chris, 'Post-war bombers, Warmachine 17, 1983, 321-340

16. PALMER, Tricha, 'Postwar jet fighters',
BISHOP, Chris, 'Sabre over Korea',
LAKE, John, 'Air defence in the 1950s',
CHANT, Chris 'U.S. Air Force, Part I', Warmachine 45, 1984, 881-902

17. PATTON, Pat, 'Long range longshots', Wings, Oct. 1988, 10-21, 52-55

18. PEACOCK, Lindsay, 'Last of the Century fighters', Air International, Oct. 1986, 198-206

19. WARWICK, Graham, 'Fighters- Improving the breed', Flight, 7 Nov. 1981, 1369-1375

20. WARWICK, Graham, 'F-18 into service', Flight, 28 Nov. 1981, 1613-1616

FILMS

1. Dr. Strangelove (or how I learned to stop worrying and love the Bomb,
dir. Stanley KUBRICK, 1963, Great Britain,
Peter Sellers, George C. Scott.

2. Right Stuff, The,
dir. Philip KAUFMANN, 1983, U.S.A.,
Sam Shepard, Scott Glenn, Ed. Harris.

3. War of the Worlds,
dir. Byron HASKIN, 1953, U.S.A.,
Gene Barry, Les Tramayne.

TELEVISION

"Reaching for the Skies' (8 programmes),
series producer: Ivan RENDALL, B.B.C., 1988.