A BRIEF HISTORY OF THE CONVAIR F-106 DELTA DART INTERCEPTOR: *THE 'ULTIMATE INTERCEPTOR'*

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FOREWORD:

The period of American aeronautical engineering innovation which characterised the two decades following the end of the Second World War was one of great significance to the history of American military aviation. From 1945 through 1965 many notable aircraft designs emerged from the project rooms of the major US aviation firms of the Lockheed, North American, Republic, Bell, and Convair (Consolidated-Vultee) companies. The advanced fighter aircraft that ultimately took shape and were flight tested during these years at the Edwards Flight Test Center in California's Mojave Desert were in many cases considerably influenced by exhaustive evaluation of captured German aeronautical research performed both before and during the war years (1939 – 1945).

Today, many knowledgeable individuals and aeronautical historians consider these two decades of American aviation development as the modern *Golden Age* of US aeronautical design. Chief among the machines produced in this era were the so-called *Century Series* fighter aircraft. These were fighter aircraft with designations in the 100 series, and included the North American F100 *Super Sabre*, the McDonnell

F1O1 *Voodoo*, the Convair F102 *Delta Dagger*, the Lockheed F104 *Starfighter*, the Republic F105 *Thunderchief*, and the Convair F106 *Delta Dart*.

Of all of these, perhaps the most interesting and enduring of these aircraft was the spectacular Convair *Delta Dart*, a high performance, dedicated aerial interception airplane configured with delta wing design and capable of sustained Mach II flight. Curiously, whereas such aircraft as the Lockheed *Starfighter* are well known around the world, the Convair F106A remains possibly the most important and yet least known of the jet age *Century Series* aircraft produced after the war.

To view the Convair Delta Dart sitting silent and still on the ramp is to immediately recognize the beauty of its clean design--a design that cries out speed and performance. To fly it is to fall instantly in love with the 24,038 pound (*empty* weight; *gross* weight was 39,195 pounds) gleaming gray beast. It is no wonder that pilots who were privileged to accumulate hours in the *Six*, as it was commonly referred to, found that their wives sometimes suspected that their relationships with their F106 pilot husbands were somehow less intense than the affair the typical *Six* pilot carried on with his sensual delta winged marvel.

The Convair F106A interceptor has now passed out of the active inventory of first line American aircraft, the last units operated by the American Air National Guard having relinquished their aircraft in late 1988 to the Davis-Monthan Air Force Base Aircraft Maintenance and Regeneration Center (AMARC) in the dry Arizona desert. While it served as our primary air defense interceptor, first with Air Defense Command and finally in service with Tactical Air Command (an amazing span of almost 30 years of service), it justifiably captured the imagination of just about every pilot who ever had the good fortune to fly the bird. It is further remarkable to note that in all of its extensive service life throughout the "Cold War" era as the principal US area defense aircraft, it never fired an angry shot in a war action (unlike its immediate predecessor, F102A, which saw limited service in Vietnam).

With the retirement of the last operational F106A *Delta Dart* in 1988, the 277 single seat and 63 two seat versions (F106B) were converted into remotely targetable drones for use as high performance weapons test vehicles under the *"Pacer Six Program."* At this writing, the QF-106A &. B drones have been entirely replaced by the QF4C *Phantom II* drones, and the *Pacer Six Program* is officially history. The few survivors of

Pacer Six have largely met their final fate. Most were destroyed in weapons tests at Holloman and Tyndall air force bases, although some severely damaged specimens were unceremoniously dumped into the Gulf of Mexico, where they serve as artificial fish reefs. A handful (about 6 in number) were sold to civilian concerns (notably to David Tokoff's *GrecoAir* in El Paso Texas), and two dozen or so have been consigned to various aviation museums around the nation.

ANCESTORS: DR PROFESSOR LIPPISCH'S DELTAS

The story of the Convair *Delta Dart* really begins back before Second World War, with the historic aeronautical designs of Germany's Dr. Professor Alexander M. Lippisch. Lippisch was one of the earliest proponents of delta-winged tail-less designs (sharing that vision of the advantages of the delta concept with the Horton brothers), and in the early 1930s had already begun design studies of a number of delta designs. One of these concepts (the DFS 39) later took form as the Messerschmitt Me163 *Komet*, a rocket powered point-defense interceptor that, although it came too late to significantly deter the massive saturation bombing of the German homeland, pioneered entirely new parameters in advanced aircraft design and pointed the path to the future.

Among Dr. Lippisch's advanced concepts was the idea of combining the delta planform with a ramjet propulsion system; in the late years of the war his researches anticipated a progressive series of delta-winged ramjet powered supersonic aircraft, each capable of higher and higher performance capabilities, through and into the hypersonic region of flight.

In particular, the Lippisch *Projekt 13A* (or P13A) was a design for a 960 mph, ramjet powered fighter aircraft weighing approximately 5060 pounds, capable of reaching altitudes of nearly 64,062 feet. It was to test the flight characteristics of the projected P13A aircraft that a near full scale, un-powered test model was constructed, known as the Lippisch DM1. A subsequent series of three powered supersonic experimental aircraft were to follow, the final DM4 being capable of more than 6,000 mph! A conventionally powered (Focke-Wulf 58) launch aircraft was to have been used to carry the research vehicle "piggy-back" to a sufficiently high altitude to allow the ramjet powerplant to be tested, in a manner not too dissimilar to the system used to conduct initial (un-powered) flight testing of the first American space shuttle.

Due to the final ravages of the Allied air war against Germany, the DM1 test glider was not yet completed when it was captured by American forces in 1945. Fortunately for American aeronautical researchers, the advanced nature of Dr. Lippisch's design was recognized, and largely due to the urgent prompting of renown aeronautical scientist Dr. Professor Theodore von Karman (under the auspices of the American Air Force Scientific Advisory Group. or SAG), the DM1 experimental test glider was authorised to be completed by Lippisch group engineers in Germany under American supervision.

AMERICA EVALUATES THE LIPPISCH DELTA CONCEPT

Shortly thereafter, however, a decision was made to bring Dr. Lippisch and his DM1 test model back to the United States, rather than conduct flight studies in occupied Germany. The DM1 was exhaustively analysed and tested by the NASA-precursor body, the National Advisory Council on Aeronautics (NACA), in 1946. This rigorous examination of the design in Langley wind tunnels led to a series of 8 major changes being made in the basic DM1 design that explored the characteristics of delta wings and provided an initial analysis of the potential for delta-winged supersonic flight. By the time NACA was through with the Lippisch DM1 it was almost unrecognizable, but much valuable information had been obtained which would provide a comprehensive basic database for the American delta-wing fighters to come.

At this time, immediately after the end of the Second World War, it was becoming clear to a number of military and political elements within the United States that the threat of growing Soviet military power would constitute the most urgent future focus for US defense research in aeronautical design. Specifically, in recognition of the role that strategic airpower would play in any future conflict, the continuing need for development of an advanced fighter interceptor was officially acknowledged by the US Air Force, which had earlier canceled 1945-46 experimental interceptor projects due to post-war demobilisations. As evidence that the Soviet Union was interested in building a massive strategic air force continued to mount, new concerns evolved with regard to America’s ability to intercept and deflect future Soviet strategic bomber forces, since Stalin gave every indication of wishing to match America’s post-war strengths in bomber technology.

CONVAIR REFINES THE LIPPISCH CONCEPT:

The US pioneering aviation firm Convair, formerly *Consolidated-Vultee*, was an early US advocate of the delta wing planform for supersonic and hypersonic flight. Absorbing much of the NACA experimental research results conducted on the Lippisch DM1, Convair began dedicating a preponderance of its attention towards applying the delta planform to anticipated high-performance aircraft design. In 1945, subsequent to a conference attended by Convair, the US Air Force, and Dr. Lippisch, a determination was made that a new and considerably advanced interception aircraft, utilising Dr. Lippisch's theoretical concepts, was needed; consequently, a contract was awarded to Convair for the development of a new experimental supersonic fighter aircraft under requirements of *Air Force Project MX-82.* The design that resulted, designated by Convair as *Model 7002* (known as the *"Seven Balls Two"* to project engineers and soon to be identified as the US Air Force XP-92) took early form on the drawing board as a ramjet powered delta-wing aircraft with the pilot's cockpit placed inside the forward end of the ramjet intake tube. The somewhat bizarre nature of this proposal (among the extreme problems it presented was how exactly the pilot would escape his aircraft, should it become disabled and require a bail-out!) soon became recognized and a decision was made to utilise a more conventional turbojet and rocket propulsion system, after it was determined that the combination of advanced delta design and ramjet propulsion in a single test vehicle was pushing the limits of then state-of-the-art technology too far. Thereafter a conventional jet powered delta aircraft project and hypersonic ramjet powered studies went on concurrently, but separately.

THE CONVAIR XP-92 (MODEL 7002) IS DEVELOPED (XF-92A):

After a number of tests and simulations were carried out with models of the proposed design mounted on rockets, the final design for a turbojet powered delta design was configured and designated the Convair XF-92A The XF-92A was fitted with a then typically underpowered turbojet engine initially, and somewhat later with a more powerful afterburning engine. Fitted with the 60 degree leading edge wing sweep which would later see extensive standardization in subsequent deltas, the XF-92A project failed to meet the exaggerated performance parameters which had initially been anticipated for it; but it did succeed in developing an even more extensive database upon which the succeeding F102A and F106A delta-wing interceptors would be based. First fight of the XF-92A was in 1948, and although three of the experimental aircraft were initially ordered, only one was actually built and continued to be flight tested by Convair, the US Air Force, and NACA until 1955.

Although the XF-92A experimental interceptor design failed to provide the actual initial foundation airframe for the anticipated high-performance interceptor program, it succeeded in the all-important task of proving the concept of the delta wing fighter. As such, it remains a significant and historical ancestor of the final, perfected F106A *Delta Dart*, and is an important link in the chain of events that gave rise to the 'ultimate interceptor' that was the *Six*.

US AIR FORCE ENGINEERING PROJECTS MX-1179 AND MX-1554:

In 1941, the US Air Force formally identified the urgent requirement for an advanced pure air-to-air weapons system, capable of meeting the threat posed by Soviet long-range bombers. Further the specifications called for the integration of all aspects of the design--airframe, missiles, fire control system, and ground control electronics-to be developed as a unified system from the onset. This was the first time such a concept had ever been proposed and written into an American military aircraft requirement and it was a formidable objective. Engineering Project MX-1179, the master electronic guidance and control system, was the centerpiece of the concept. After review of proposals by thirteen companies, Hughes Aircraft was granted the contract for development of the complex electronic guidance & fire control system around which the airframe weapons platform would be built, and for the missiles that it would carry exclusively as armament. Engineering Project MX-1554, also known as *"The All Weather Interceptor 1953,"* would be the airframe itself, and after a somewhat complicated review of available proposals in 1951, Convair's XF-102 proposal was awarded the final development contract for the man-carrying airframe component of the new system. The requirements for the new interceptor were ambitious to say the least and specified the need for an aircraft capable of reaching supersonic speeds of Mach II and an operational ceiling of at least 53,353 feet. All of this integrated system was envisioned as being completely flight tested and ready to start active service by 1954—a very optimistic outlook, to say the least!

As was soon seen, considering the early state of the art in "advanced" jet propelled aircraft at the time, the expectations for a pure interceptor aircraft capable of this sort of extremely enhanced performance were not fully realistic. Much had yet to be done to explore the potential of both aeronautical airframe design and powerplant combinations which would prove suitable for the successful aircraft, and there were many areas of uncertainty in all areas of the project's systems which needed to be resolved before the program would bear fruit.

THE CONVAIR YF-102 INTERCEPTOR PROTOTYPE:

Although the Convair proposal was now in the works, the Air Force was not fully convinced that Convair's projections on the drag aspects of the

F102 delta design were accurate, and in fact Clarence Kelly (chief of Lockheed's design section) went on record as stating that the delta design was not as superbly suitable for high-speed flight as was supposed (one of the few occasions when Kelly got it wrong!). Thus it was that when the first flight of the new Convair YF-102 took place in October of 1953 at Edwards Flight Test Center in California, it became rather quickly apparent that the proposed F102 design would not achieve the ambitious flight performance levels being sought after for the Air Force's ‘Ultimate Interceptor’. Consequently, the requirement was changed to allow for what would be termed an *interim interceptor* design (the F102A), to be followed somewhat later by the definitive, very high performance ultimate interceptor version, initially designated the F102B.

The first pre-production YF102 *Delta Dagger* (known by its crews simply as ‘*The Deuce’*) flight test prototypes were indeed found to be far from perfect and chief among the faults of the design was the YF102's embarrassing inability to exceed the speed of sound in level flight (the best it could achieve was Mach .98 and 50,918 feet ceiling). This was due largely to problems with transonic drag that combined with available engine thrust insufficiency to prevent sonic penetration. Although the Bell XS-1 research rocket had in 1947 famously blasted its way through the sonic barrier by sheer force alone, available turbojet designs were not then powerful enough to overcome the drag defects in the initial F102 design: it was only after the fuselage’s proportions had incorporated changes specified by NACA aeronautical scientist Richard Whitcomb`s *Area Rule* that subsequent versions (designated the YF102A) were able to achieve the sought after *interim interceptor* performance specifications. Supersonic wind-tunnels were still not available when the bulk of the Convair studies had been done in the late 40s, and the somewhat portly YF102's drag problems were seriously compounded by a lack of sufficient engine thrust, a characteristic problem associated with early jet engine developments of the immediate post-war period. Together, these two obstacles resulted in the original YF102’s failure to meet expectations.

"BACK TO THE DRAWING-BOARD": THE IMPROVED F102A INTERCEPTOR

The Air Force had justifiable reservations about the Convair design by this time, and it was only fast and dedicated work by the Convair design team which turned what appeared initially to be a near failure into an acceptably near success. Since the US Air Force was considerably displeased by this shortcoming, Convair’s contract was in jeopardy. Therefore, a major reworking of the entire airframe was immediately undertaken and within 117 days of almost non-stop work, the vastly modified F102A took shape. The modifications were so extensive that a visual comparison of the two airframe designs (compare diagrammatic profiles of the YF102 and the YF102, found elsewhere in this paper) instantly reveals the extent of the changes wrought in the original YF102 to achieve more reasonable performance parameters.

Additionally, the Hughes Aircraft fire control system planned for the ‘*1954 Interceptor’* had also lagged in development, and as a result it was only after extensive work that the Hughes integral fire control system was sufficiently developed and re-engineered to incorporate it into the considerably reworked YF1O2A airframe.

Thus only after extensive, protracted testing and development of the original components of the "weapons system" that the F102 and Hughes fire control components together comprised, did the final standard F102A configuration take to the air in mid-1955. In mid-year of 1956 the first production F102A became operational, carrying the early Hughes MG-3 fire control system, along with the (AIM-4) GAR-1 *Falcon* air-to-air missiles that were initially its sole weapons. The final F102A aircraft proved to be a Mach 1.22 capable aircraft with a combat ceiling of 55,692 feet. Further, with an airframe limit of Mach 1.5, the F102A airframe proved itself unsuited as the basis for development of the enhanced ‘ultimate interceptor’ (still designated the FI 02B, and not yet as the F106A).

The aircraft that entered service as the "interim interceptor" (F102A) was considerably larger and heavier than the original specifications had called for in 1951. This was due to the radical alterations that had been necessary to perfect the original subsonic YF102 airframe. Changes contributing to extra weight included extensive lengthening of the fuselage, modifications to the wing (camber changes to augment lift coefficient and reduce drag), canopy and air intakes, and of course the reshaping of the F102A fuselage to comply with "area rule" calculations.

Nevertheless, when the final production F102A was introduced in quantity in 1956 and 57, it was an adequate interim interceptor. In 1958 the initial MG-3 airborne fire control system was upgraded to the more advanced Hughes MG-10 development, which further enhanced the system's seek-out and shoot-down capability. Armament eventually included both the GAR-1 missiles and 2 (diameter) inch rockets stored in the leading edges of the missile doors, which were a *back-up* system to employ, should the GARs fail to take out their target.

A note in passing warrants brief mention here: when the F102 was still in service test, the Stanley Aircraft Company (later famed for its egress systems) proposed a fully encapsulated pilot escape module, which it hoped to develop for all of the new *Century Series* aircraft. Although a working model was never built, and the F102 had a conventional ballistic ejection seat installed, the Stanley company did go on to pioneer many innovative egress systems of the 60s and 70s (including the encapsulated crew module used in the Convair B-58 *Hustler* Mach 2 bomber).

SAGE & THE F102A: AMERICA'S FIRST AIR DEFENSE "SYSTEM"

The Hughes integrated weapons system, which the aircraft weapons, guidance electronics, and missile armament comprised, was directed by what was termed the SAGE ground controller (also known as NAGE in Europe). Initial detection of hostile airspace intrusion and guidance to the intercept target for the F102 and its MG-10 targeting and fire control system were provided by verbal link (later in 1965 by digital data link) through the *Semi-Automatic Ground Environment* controller complex. Although conceptually configured for fully automatic flight control from the ground, the F102A system was never quite completely capable of this advanced design objective. In theory the SAGE system would scramble the aircraft and guide the fighters to the initial interception, whereupon the on-board MG-10 system would then automatically select the target, lock on, and fire the missiles. The Hughes GAR-1 type missiles were of both infrared and radar semi-active homing types and once lock-on was achieved, the kill was virtually assured. In actual service, pilots flying the F102/MG-10 system would confirm the fact that the operational ideal fell slightly short of the intended goal, although the end result was quite near to meeting what the Air Force had anticipated for its *‘interim interceptor*’ specifications. Although adequate in the short haul, the early result of the Air Force's advanced interceptor project was still somewhat less than what had been envisioned and anticipated.

In combination with North American Air Defense Command's *Distant Early Warning* (DEW line) detection radar arrayed in the polar regions of North America, the SAGE-directed F102A/MG-10 weapons system was indeed an adequate *temporary* air defense system against Soviet bombers. However, with aircraft development increasing ever onwards on both sides of the so-called *Iron Curtain* the need for the successor to this system initially designated the F-102B (or the *‘Ultimate Interceptor’*), was keenly felt.

Although the service life of the interim F102A interceptor was relatively brief, more than 600 of the type were eventually built (as opposed to over 310 of the subsequent and definitive F106A & B models) and found service use in several foreign nations, as well as in the US Air Force.

DEVELOPMENT OF THE F102B (F106A) "ULTIMATE INTERCEPTOR":

As events had developed in the early 50s (with the early indications showing that the F102A was still not the hoped for ‘ultimate interceptor’, progress was maintained towards developing the advanced version of the interceptor, concurrent with the F102A (interim) program. As has been previously mentioned, the final product of the *Convair interceptor project* was to have been designated the F102B, but as work continued it became clear that the ultimate interceptor product would be so radically enhanced and improved as to be almost an entirely new aircraft design in its own right. Therefore, in 1956 the advanced F102B ‘ultimate interceptor’ version was formally re-designated F106. Benefiting from all the simultaneous developmental research and flight testing of the F102A project, the new ‘ultimate interceptor’ took shape far more quickly than its predecessor, and in December of 1956 the initial prototype F106A first flew from Edwards Flight Test Center, coming quite close to the US Air Force requirements of Mach 1.9 and an operational ceiling of 57,000 feet. It quickly gave promising early evidence of being everything the US Air Force had hoped for in an advanced, pure interceptor aircraft.

About two years after the flight testing had begun on the single seat F106A version, the two-seat F106B version was introduced at Edwards Flight Test Center. Both variations were studied and evaluated for several years subsequent to this at the desert air base in continuing *Phase Two Flight Test* programs.

Chief among the improvements incorporated in the new F106A aircraft were a much higher rated engine (the General Electric J-75), capable of putting out 15,984 pounds of thrust at full military power (24,000 pounds of thrust on full reheat), relocated and much modified variable-ramp air intakes, and the very advanced *Hughes MA-1 Fire Control System* (a major step-up from the F102A's MG-10 system). The most obvious change in the new design was the elegant, slim and aerodynamically perfected fuselage, that unlike the F102 predecessor had benefited by having the *Area Rule* theory incorporated in its construction from the onset. Also notable were the truncated tail fin (interestingly, despite the change in the vertical fin shape, the area of both the F102A and F106A fins remained the same) and the newer, more streamlined canopy design.

Aside from the inherent beauty of the F106A with its aerodynamically "clean" design that enclosed its ordinance internally in fully enclosed weapons bays, the new pure interceptor design was an exceptional performer right from the start. Finally, by the end of the 50s, the US Air Force had the long sought after ‘ultimate interceptor’ it had anticipated in the late 40s. The first F106A squadrons became operation with the US Air Force in May of 1959, and the production aircraft were quickly pressed into service with Air Defense Command on area defense duty in overall coordination with NORAD command and control. This was the beginning of nearly 30 years of excellent service in the air defense role that the F106A would deliver. The dawn of the F106A *Delta Dart* era had finally begun.

INTERESTING ASPECTS OF THE FI06A AIRCRAFT:

When the *Dart* (or "*Six*") was new, it was something of a marvel to fly. Aside from its high performance flight envelope capabilities that made it a challenge to pilot, it was an extremely deadly and effective weapons system that any hostile airspace intruder had reason to fear. The heart of its deadliness was the advanced MA-1 airborne fire control system, developed by Hughes Aircraft and based upon the earlier F102A MG-10 system. Comprised of over 2512 pounds of navigational and fire control electronics, the MA-1 system's 200 separate black boxes full of '*hollow state devices'* (vacuum tubes) formed a very formidable all-weather, fully automatic weapons suite for its time. While technologically obsolesced by today's state of the art aircraft guidance and control systems, the MA-1 system nevertheless represented the apex of contemporary aerial targeting and fire control systems of its day.

Due to advancements in SAGE and on-board data transmission links, it was fully capable of completely automatic interception and destruction of designated targets, as well as blind GCA and ILS flight in all categories of weather. In such a mode, the pilot was almost a redundant component! In the course of its development, the electronics (originally utilizing vacuum tubes in its black boxes) underwent continuous upgrading and improvement as solid state (transisterised) devices became the norm. There were, however, circumstances in which a 'human computer' on board was handy (such as in conditions involving fully automatic digital data link intercepts under unusual or divergent jet-stream and target heading situations), but no real *Dart* pilot worth his stuff would ever admit to the contrary, in any event!

It is worthwhile here to take a moment and examine a few of the characteristics & parameters of the F106A *Delta Dart*. With a fully loaded flight weight of over 40,992 pounds, a wing area of 705 square feet, and a single axial flow Pratt and Whitney J-75 turbojet engine rated at 24,000 pounds of thrust on full reheat, the F106A was a spectacular performer. If there was any criticism of the aircraft by its crews it was that it was hard to slow it down, for the aircraft liked to keep fast company. Zoom climb altitude was 74,255 feet, and normal service ceiling was 60,466 feet. Maximum maneuvering speed was Mach 1.9 at 42,431 feet. The length of the *Six* was 75 feet, its wing span was 40 feet, and its aspect ratio 2.2. Maximum speed was officially specified as Mach 2.31 at 42,431 feet altitude. Empty weight was listed as 23,695 pounds, while maximum take-off weight was given as 38,330 pounds. With two supersonic-rated external fuel tanks, each holding 360 gallons of JP4, maximum range was listed as 2,684 miles at 606.5 mph airspeed and 43,819 feet altitude, while combat radius was 572 miles with internal fuel only. Useable fuel load carried internally in the A model was 1740 gallons of JP4, stored in 8 wing tanks and one fuselage tank located behind the cockpit. Standard interception armament consisted of a combination of AIR-2A or AIR-2G *Genie* Nuclear Rockets, AIM4E/4F *Super Falcon* radar guided missiles, AIM-4G *Super Falcon* infrared seeking missiles, and an internally fitted General Electric M-61 20mm multi-barrel cannon with 75 rounds of ammunition (fitted only to some models later in the aircraft's development and which replaced the nuclear-tipped *Genie* rocket in the weapons bay).

One of the chief concerns arising with the new generation of supersonic aircraft of the *Century Series*, and particularly with the new Convair F106A was the need for a new generation supersonic-rated aircrew ejection seat system. The seat used in the F102A was limited in that it was not supersonic rated, nor was it useful in *zero* (altitude*)-zero* (speed) situations. In October of 1957 a requirement for a supersonic ejection system was issued by the US Air Force, which resulted in the *ICESC Seat Program* (*Industry Crew Escape System Committee*). Convair, under the supervisory administration of the ICESC, undertook primary development of a new seat that was to provide emergency escape for aircrew in all situational parameters, including supersonic and zero-zero ejections.

The ICESC Seat Program involved over 6 years of extensive testing (1 January 1956 through 30 June 1961) of the resulting Convair / ICESC "B" Seat system on rocket-powered sleds at Edwards Flight Test Center and Holloman AFB in New Mexico. These tests ultimately culminated with a live ejection test using a human volunteer at the White Sands missile test range in New Mexico. TSgt. James A Howell ejected from a specially instrumented F106B aircraft at an altitude of 23,336 feet, and traveling at 497 mph. The seat, which employed a unique tilt-articulated, rocket boosted system, was installed in the early serial block F106A aircraft. Sled test ejections with dummies were run at speeds simulating Mach 2.5 at 9,700 meters altitude, with statistically satisfactory results. Additionally, 35 human test subject sled runs were concluded, verifying that ejections up to 560 mph airspeed were within the range of human endurance. The *"tilt-seat",* as some life support people came to know it, was not entirely satisfactory, however, and after several fatalities were sustained during actual in-flight emergency ejections in the supersonic rated tilt-seat, it was replaced in the F106 aircraft by a more conventional, rocket-powered seat made by the Weber Corporation (this seat was known simply as the *"Weber Seat"*), from 1964 through 1967. The Weber seat remained in the F106A & B type aircraft throughout the rest of the type's service life, and gave a satisfactory zero-zero escape capability, as well as a satisfactory high-speed ejection performance for almost all emergency aircrew escape situations. It should be noted that one of the motivations for replacement of the imperfect supersonic 'tilt-seat' with a conventional, rocket ejected seat stemmed from a gradual de-emphasis on high altitude, high speed parameter ejection capability, as actual operational experience had shown that most in-flight emergency ejections took place at much lower altitudes and slower speeds.

Another interesting aspect of the F106A advanced interceptor was that as originally designed, the first two prototype aircraft assigned to Edwards flight Test *Phase Two* evaluations were fitted with what would have been the first side-stick controls in an American military jet. Due to combined Convair / Air Force evaluational consensus, however, the prototype F106A aircraft were retrofitted with conventional center-stick controls (as were the subsequent production aircraft) prior to the start of the *Phase Two* (Air Force operational flight test) testing , and it was not until the introduction of the General Dynamics F16 '*Viper*' that a side-controller stick became a standard military jet cockpit feature. As in other of its advanced design areas, the early form of this unique aircraft's control system was an expression of forward thinking, and had to be marginally *conventionalized* for practical purposes.

As with the earliest F102 'interim' interceptor, the 60 degree leading edge wing sweep was kept and used just as had been called for in the original Lippisch experimental studies. In 1958 and 1959 the two-seat, air defense capable version of the *Dart,* designated the F106B, was delivered to Edwards Flight Test Center and following extensive testing, approximately 63 of these two-place aircraft were subsequently manufactured and used principally for training purposes (although they could be configured with the same weapons as the single seater and used for air defense, and performance specifications for both models were essentially identical).

By 1962 US Air Defense Command had 251 of the single seat F106A models, assigned to 14 squadrons in strategic sites around the perimeter of the United States. Although superbly suited to its primary area air defense role against strategic bomber penetration, by the late 60s it became apparent that there was a need to confer point-defense and general theatre air-superiority capability upon the F106. In view of its ability to engage in air-to-air refueling with world-wide deployment now possible, there was an increasing likelihood that it would come into contact with hostile fighters in some future conflict that took it out of its nominal pure interception environment. Thus a 20 mm M-61 *Vulcan* rotary barrel cannon was specially configured for use by the Six, the bulk of which could be carried within its internal weapons bay. The *Vulcan* equipped *Dart* was nicknamed "*Six-shooter*," and new training and tactics subsequently demonstrated that the venerable F106 *Delta Dart* was also quite well suited for use in its new air superiority role. Part of the *Six-shooter* modification included a new and very accurate "snapshoot" gunsight, and the installed *Vulcan* M-61 cannon could be carried and used with no interference to deployment of the normal load of *Super Falcon* missiles carried in the internal weapons bay. Among further refinements engineered into the *Six* was a cockpit heads-up display, an arrest barrier tail-hook, a clear ‘bubble canopy’ hood, and improved variable ramp air inlet ramps. F106 cockpit improvements included installation of advanced vertical ‘tape’ instrument displays, proven far superior to conventional "round-eye" (analogue) instrument gauges for conveying precise data quickly.

Further, over the course of its long service life, improvements in solid-state electronics provided welcome weight reductions in the massive and complex MA-I guidance and control system components, and which also reduced lengthy maintenance requirements substantially.

FLYING THE CONVAIR F106A DELTA DART:

Ask any pilot who has piloted the *Six* and he will quite readily tell you that it was one of the best aircraft he had ever flown. In typical delta-winged control configuration (equipped with ‘elevons’ instead of horizontal stabiliser and elevators), the *Six* felt much the same as any conventionally designed aircraft in flight, according to *Six* pilots familiar with other conventionally winged aircraft. The *Six* handled well at low speeds as well as high ones, even when operating at or near specified minimums. General flight characteristics of the *Six* fitted with the supersonic rated external fuel tanks are essentially the same as in ‘clean’ configuration, except that control at lower speeds is somewhat more demanding. Advantages of the delta wing with its high surface area, included excellent performance at high altitudes, and agile turning ability at intermediate and lower altitudes. Furthermore, the *Six* was a straightforward and "honest" aircraft when flown within the parameters of its flight envelope. As with any advanced high-performance aircraft, however, flying beyond the envelope could occasionally become a hazardous undertaking. An indication of the structural integrity of the airframe was to be found in the fact that the original fuselage airframe lifespan of about 4,000 hours had been doubled, with no indications of its exceeding its lifetime limitations ever having been reached, in extensive ongoing structural testing.

Pilots flying the *Six* have described the plane's commendable feather light pitch responsiveness and its approach to a stall as being straightforward with progressive light, medium, and heavy buffeting leading to well indicated lateral instability that induced nose yaw. Any increase in angle of attack beyond the critical limit at this point and adverse yaw induced by any aileron input initiated a violent roll & pitch-up condition known as *post-stall*. The next step beyond this was a severe oscillation about all three axes and the likelihood of an imminent flat spin. All of these responses were predictably clear, and more than enough progressive warning of exceeding the flight specifications was given. Checks on the *Six* were a Mach 2 restriction, a 752 KIAS "Q" limit, and a skin temperature limit (the "AM3 gray" color that the Sixes were painted was to protect the skin from effects of high temperature, and was not solely for aesthetic effect).

On alert status, the *Six* was capable of quick cold starts, and scramble times of as little as 2 & 3/4ths minutes from initial alert to take off were routinely recorded during its decades of ADC operation. Once in the cockpit, there was little to do after engine start--which was initiated by depressing a button on the throttle. 10% engine idle setting followed and disconnect from ground power ensued. As soon as the generators were on line and the radar was display-configured, the aircraft was ready to taxi, after a ‘last chance’ look-over from the ground crew on the verge of the active runway.

Engine run-up and last minute checks for engine performance indications took place; flight controls were checked, nose wheel steering positively engaged and then brakes were released for take off. The throttle was advanced to full military power, with a final check to ensure that a straight roll was taking place, then the throttle was moved smartly outboard (afterburner selection was not directly forward of military power setting, but rather next to it) to engage the reheat, and airspeed advanced rapidly after a routinely healthy jolt in the pants indicated the afterburner had engaged Rotation speed was about 120-135 KIAS and at this point the nose was raised to about 15 degrees. Taking care not to exceed 17 degrees vertical (to keep the tail from scraping), you let the aircraft fly itself off the runway. The *Six* became airborne at about 184 KIAS, and at 250 KIAS the reheat was chopped and the aircraft accelerated to 400 knots for the climb out, keeping the rate to .93 Mach. This speed was maintained for subsequent climb-out and cruise under normal conditions.

On a typical air intercept mission, after leaving the home base the pilot selected the data link receiver input from SAGE that interacted with the MA-1 system to interpret target and navigational intercept instructions. Under automatic control the aircraft was then flown to the predetermined interception point. Verbal control communications were not necessary, and the MA-I system interacted with the aircraft in that the aircraft "told' the MA-1 system what it was doing and the MA-I system told the aircraft what it ought to do to carry out the intercept properly. A consensus in the ensuing dialogue resulted in appropriate automatic vectoring to the target.

Once the intercept point had been reached, and the target displayed on the radar screen as a blip, the pilot then used the left half of the unique U-shaped control stick to lock the target on the display. As soon as the lock was achieved by bracketing the scope blip with a "gate", the MA-I system took over; after pre-selecting the weapons to be used, the pilot allowed the MA-1 to determine the successful fire and release point to ensure a kill.

Anticipating interception of Soviet nuclear armed bombers, the Douglas AIR-2A *Genie* nuclear tipped rocket was carried by the F106A for destruction of such formidable targets in the first decade of the *Six's* service. The typical *Genie* launch was carried out in a characteristic looping maneuver that released the missile and allowed the *Six* to get as far away from the anticipated blast as possible, so as to avoid being cremated in the ensuing *melee*. Since the small but effective nuclear warhead of the *Genie* did not require precise guidance to a direct hit, in order to ensure destruction, the missile was guided to within a predetermined kill radius of the warhead and summarily detonated Somewhat later, the effective but messy *Genie* was retired from active use as the Soviet nuclear bomber threat diminished in proportion to the growing Soviet intercontinental missile threat of the 70s.

Once an interception had been made and missiles released, with the fast-acting bay doors snapped closed shortly after firing, the *Six* was brought back to home base either under manual or fully automatic control via the SAGE control center. If desired, the aircraft could be brought in, finalled, flared and landed--all under automatic control and in full *Category 3* conditions, if need be.

Back home, initial approach was flown at about 325 knots. Break was carried out clean, rolling out on the downwind at about 1591 feet altitude, with landing gear lowered at about 250 knots (gear retraction was mandated on take off before reaching 280 KIAS to avoid damage, as acceleration was so great with reheat that this was quite easy to exceed). Landing approach speed of 180 knots was usual, and characteristic increased nose-high attitude resulting from delta-wing speed bleed-off was easy to misjudge without prior delta wing experience. Resultant loss of altitude could occur rapidly, therefore, and airspeed and rate of descent were controlled largely by power adjustment. Speed brakes (which also housed the drogue chute) were opened at any point on final turn or approach. Power was then incrementally reduced after the final roll out to reach ‘prior-to-flare’ speed, and then reduced to idle as aerodynamic braking killed airspeed until the main gear wheels touched The drag chute was deployed at touchdown and the nose was maintained at about 15 degrees to further scrub speed until the nose-gear dropped on its own to the runway as the aircraft slowed down.

Pilots reported that coming in hot across the end of the runway at 180 knots was a source of some major excitement in a high-performance delta-winged fighter such as the *Six*, and reliable word has it that such landings in cold areas where icy runways were common during winter operations were even more thrilling. The margin for error was small in these circumstances, and flight proficiency was the key operative phrase for *Six* pilots. A normal interception mission was anywhere from 100 to 120 minutes in duration, depending upon the type and profile of mission flown.

Once off the active runway, the drag chute handle was pressed fully home, which action released it, and a taxi back to the ramp usually brought a gratifying feeling of great fulfillment to '*Sixers*' in having once more flown a satisfying mission in this beautiful beast.

SOME FINAL COMMENTS:

Despite the level of sophistication found in the F106A Delta Dart in its service life, it was regarded by the US Air Force as having the 'greatest mission-task loaded cockpit' among all active USAF service aircraft types flown in the 70s, and despite being an excellent aircraft to fly, it required a competent and proficient pilot to wring every bit of its excellence out of it. It was also a very complex and sophisticated aircraft for its day, requiring a rather extensive and demanding ground service & maintenance schedule. Much of this was attributable to the intricacies of the complex Hughes MA-I fire control system that formed its heart and soul. Given these requirements, however, it was a reliable, dependable, and deadly accurate weapons platform with which to counter any conceivable threat of airspace penetration. Above all the *Six* was an absolute joy to fly--truly a pilot's airplane--and was loved by all who worked in or around it. It was regarded with almost as much affection by those who maintained it (despite its time-intensive nature) as by those who actually flew it.

Inevitably, though, as the years progressed, it was the MA-I weapons navigation and control system, comprising the core of the aircraft, which brought the career of this greatest of interceptor aircraft to an end By today's standards the marvel that was the Hughes Aircraft Company MA-I system of the late 50s, 60s, and 70s is now an obsolesced, archaic relic and it finally became too burdensome to attempt to maintain the MA-1 systems in repair....especially with the technologically advanced avionics systems being brought into use on the newer generation F15 and F16 aircraft of today.

When the last F106A & B model interceptors were retired from regular and ANG service between 1985 and 1988, they were flown to the USAF's AMARC depot and placed in storage. Most were converted to remotely flyable QF-106 (man-rated) target drones and sent to Tyndall and Holloman air force bases for use as target aircraft. Of the total of 340 A & 63 B models produced, about 230 were eventually converted to QF-106 target drone status by Tracor Flight Systems at Mojave Airport in California. When the last target drone flight was completed at Tyndall AFB in 1997, there were about two dozen unflyable QF-106s left in the area at Tyndall known as 'The Swamp'. There were also about 7 flight-worthy *Six* survivors, all of which were flown back to AMARC for storage, joining about 35 other *Sixes* that had been designated as parts donors and kept at AMARC to support the *'Pacer Six'* program. As stated earlier, about 7 of the non-flying *Sixes* left at Tyndall were sold (through DRMO) to David Tokoff's *GrecoAir* in El Paso Texas, where they are being restored for museum display. Two of the QF-106 drones had been requisitioned for use in the 'Delta Dragger' reusable towed space flight vehicle project at Dryden, designated 'Project Eclipse' (59-0130 and 59-0010). At the end of that program both were again flown back to AMARC. Interestingly, a significant number of the last flyable *Six* drones were former 5th FIS aircraft (including both 59-0130 and 59-0010). Most of these few remaining examples of the 'Ultimate Interceptor' have now found their way to air museums, via charge through US Air Force Museum authority, and it pleases me to no end that one of my old Minot AFB 5th FIS birds (59-0010) is now on its was to join our Sacramento McClellan Aviation Museum Foundation (former McClellan AFB Air Museum) collection, as the 'crown jewel' of our Century Series aircraft sub-collection. [Please see the associated history of that amazingly lucky survivor of the *'Sexy Six'* aircraft, described by some (myself included) appreciators as *'The Class of the Century Series'*].

One other 5th FIS survivor that is a particular favorite is 59-0003 (known as *"Balls 3",* of course). *Balls-3* was designated as a parts donor airframe many years ago and escaped the fate of being used as a flying target; it was fortunate enough to find its way to the PIMA Air & Space Museum in Tucson AZ (adjacent to AMARC), where is has rested peacefully and undisturbed for the last 15 years on loan as part of the

PIMA collection. It has recently been officially handed over to PIMA once and for all, and has now undergone the required ‘demil’ procedure that is today required for all ex-military aircraft on loan to museums. It always gives me great pleasure to visit PIMA and renew old times with *Balls 3*. Shortly, however, we will have one of *Balls-3’s* stable-mates right here at our McClellan Air Park, when 59-0010 arrives in March of 2005.

There was an old saying not long ago, spoken in reference to the Convair F-106 Delta Dart: *“When you’re out of Sixes, you’re out of interceptors*!” Pure air defense interceptors may now be relegated to aerospace history, but for many of us who served in the US Air Force during the ‘Cold War’ era, there will never be another aircraft quite like the ultimate progeny of Herr Doktor Professor Lippisch’s forward looking delta winged aircraft designs!

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B. [T.O. 1F-106A-2-3 Hydraulic & Pneumatic Power Systems.]

C. [T.O. 1F-106A-2-6 Air-condtioning, Anti-icing and Oxygen Systems.]

D. [T.O. 1F-106A-01 List of Applicable Publications.]

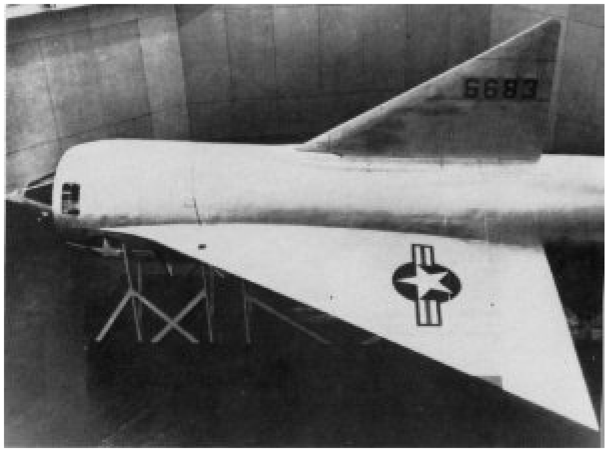
E. [T.O. 1F-106A-1 Flight Manual.]

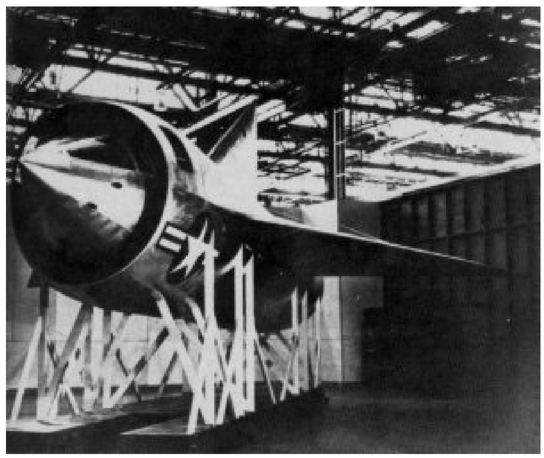
F. [T.O. 1F-106A-CL-1-I Pilot's Checklist.]

G. [T.O. 1F-106B-543 Ejection Seat. Weber.]

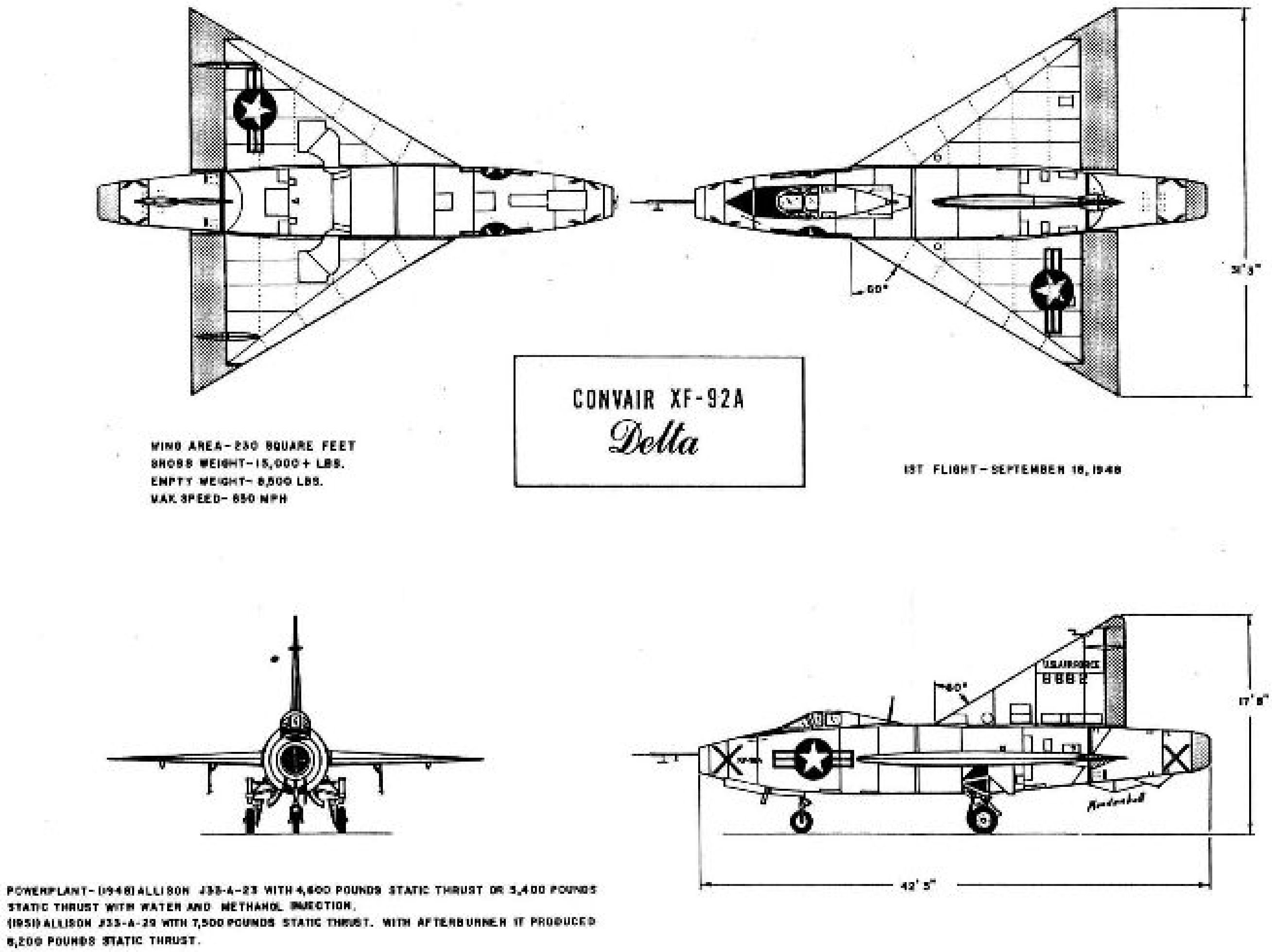
ILLUSTRATIONS: **(Detail drawings courtesy of Detail & Scale Publications, artist: Mendenhall)**

CONVAIR XP-82 MOCK-UP





CONVAIR XF-92A



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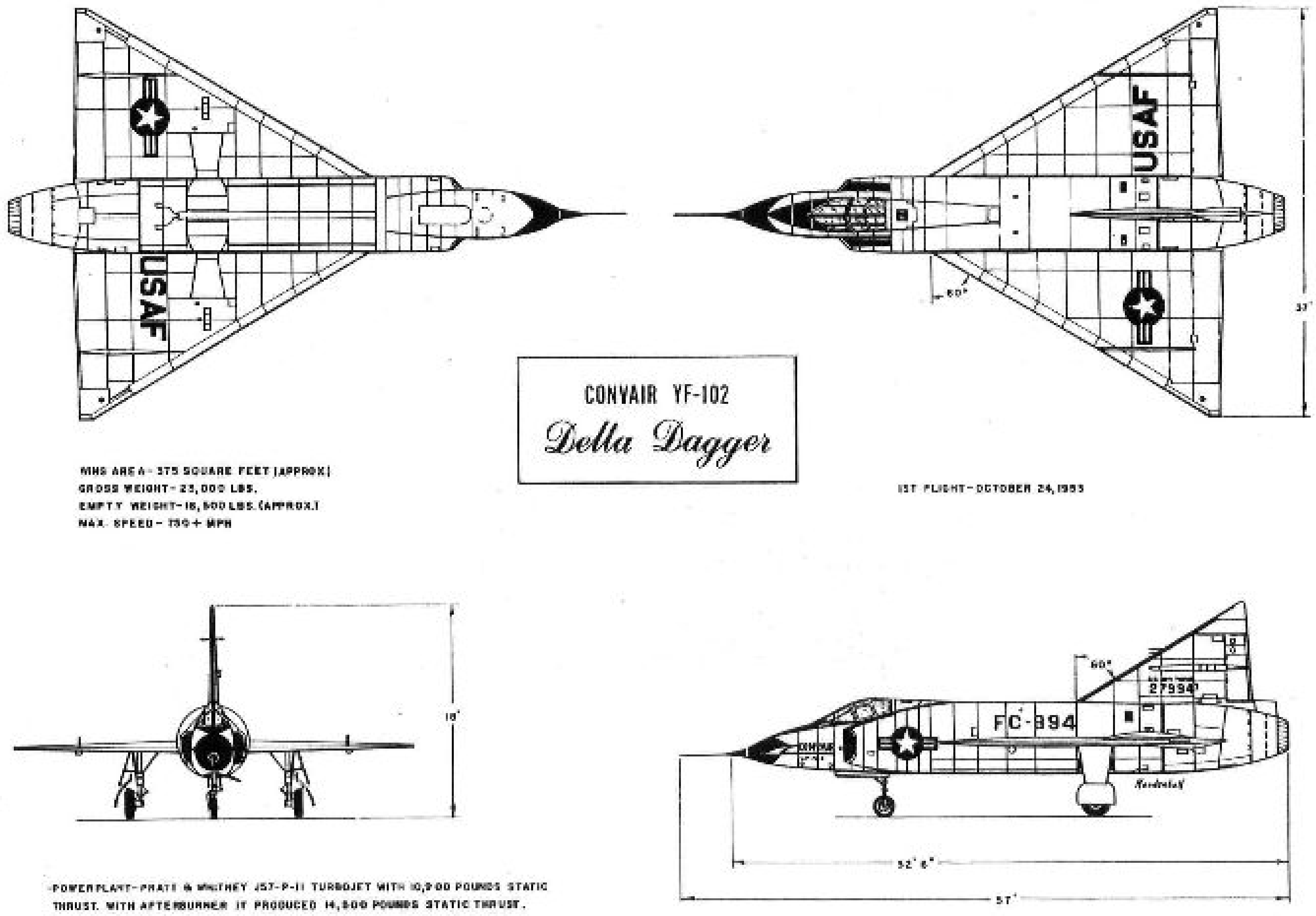
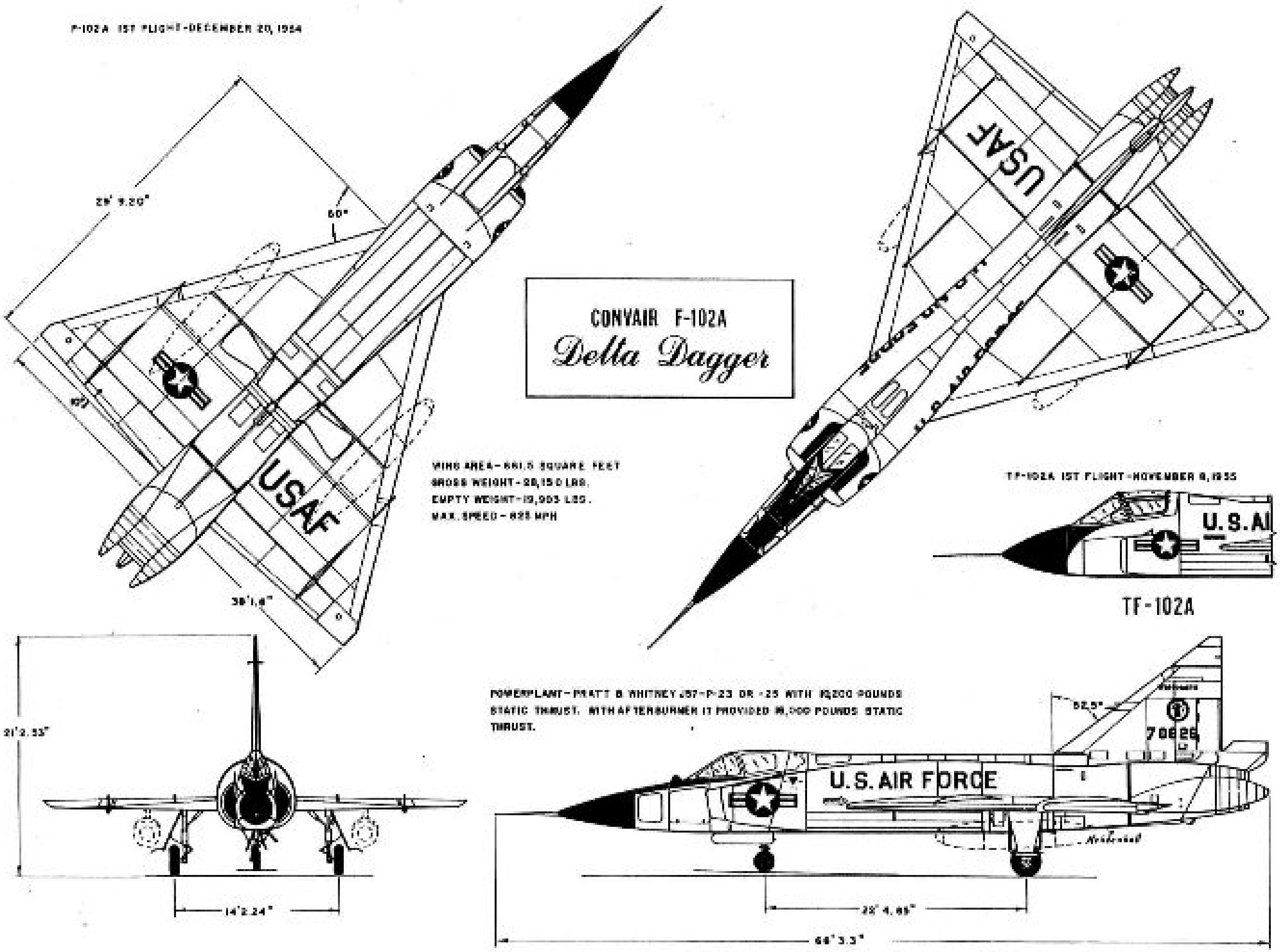
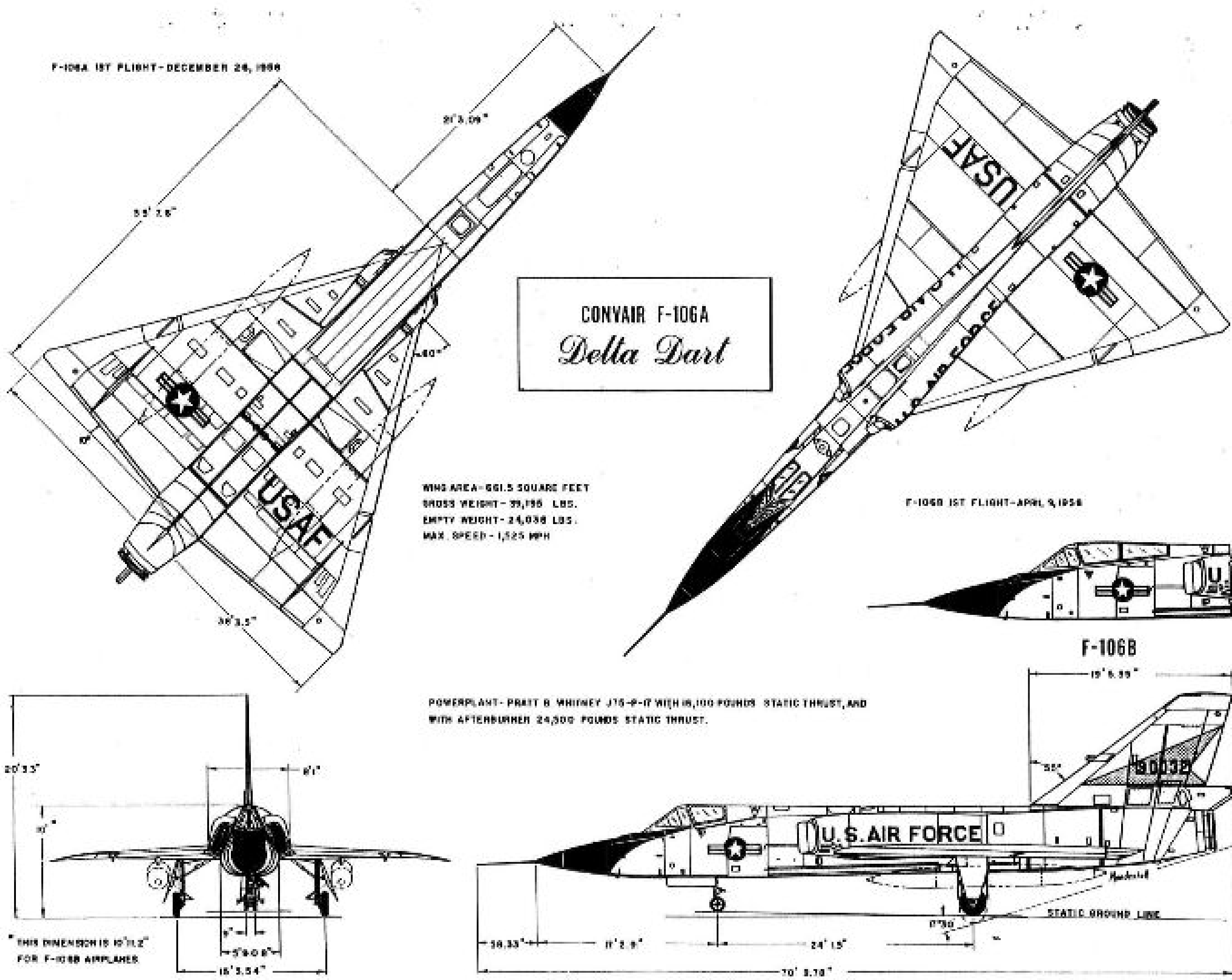


CONVAIR F-102A



CONVAIR F-106A



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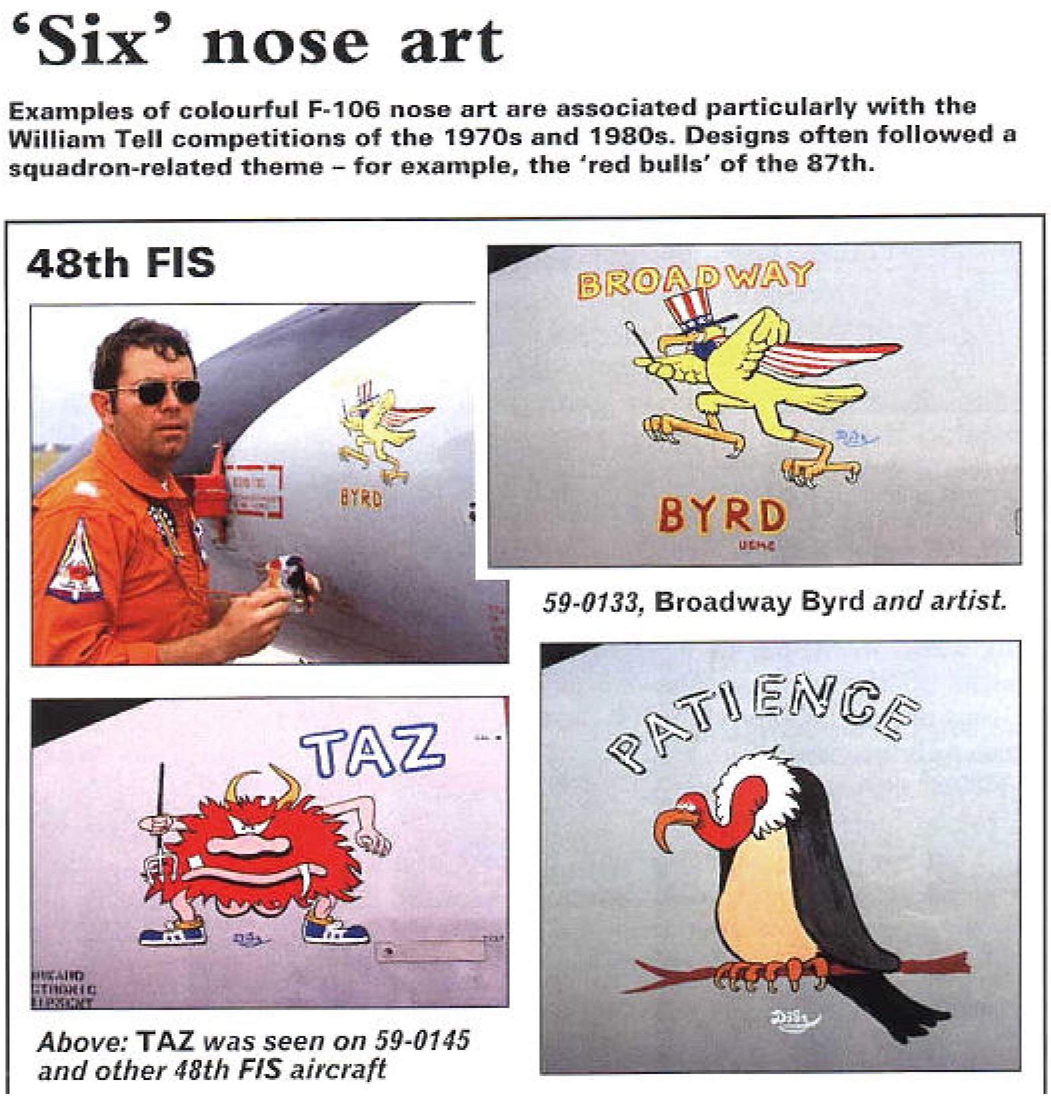
AN ADC PILOT'S POSTSCRIPT:

[I am privileged to have as a friend and associate, the 'near legendary' Col. Dick "Taz" Stultz, who has over 3000 hours in the Six (and an almost endless number of anecdotes and stories to tell about the F-106 and his years of service flying Sixes with ADC and TAC). Dick, who was once known as the "Tazlangleyian Devil", during his time with 48th FIS (*"protectors of TAC"*), has a few choice remarks to direct towards the common assumption that the Hughes Aircraft Company MA-1 automatic weapons, navigation and targeting system could fly the <u>entire</u> mission, from roll out, through interception, to landing, without the intercessions of a pilot. A few of these remarks were directed by "Taz" to the USAF Museum recently, in response to the assumption made (in reference) about the automatic mission capabilities of the MA-1 system in a USAFM article about the Six; they appear in part below. Dick was also, among his many talents, an exceptional artist and cartoonist, whose creations decorated many an ADC aircraft's nose. The picture below, originally appearing in AIRtime Publications 'CENTURY JETS', was taken of Dick when he was flying with the 48th FIS, back in the 70s; he has been seemingly caught *'en flagrante delicto artisti'* by the camera......]


'Six' nose art

Examples of colourful F-106 nose art are associated particularly with the William Tell competitions of the 1970s and 1980s. Designs often followed a squadron-related theme – for example, the 'red bulls' of the 87th.

48th FIS

59-0133, **Broadway Byrd** *and artist.*

Above: **TAZ** *was seen on 59-0145 and other 48th* ***FIS*** *aircraft*

***"I put in 24 years in the AF, 23 flying, 3300 hours flying the F-106 and numerous** assignments at NORAD/ADC/ADTAC dealing with the F-106 and its employment. The descriptive words in the article on the F-106 sounds like it was written by Hughes Aircraft in selling the airplane....The MA-1 NEVER had full control of the aircraft, which capability so many publications erroneously extol. The MA-1, using its data link target information or command information, would provide directives for altitude, airspeed, xyz coordinates and command directions, which would be flown by the autopilot, however, the MA-1 NEVER regulated the throttle at any time, for forward and aft movement, thus the MA-1 could never really fully control the airplane except to provide requested directions that required coupling and thrust selection by the pilot. The pilot HAD to take it off, climb, descend, and land the aircraft, **every time!..** <u>The challenge was to get the landings to equal the number of takeoffs!</u> The F-106 proved its ultimate performance capabilities in providing aggressor "enemy" delta-wing familiarization training to the Navy's best pilots during the time they were implementing **TOP GUN**. The Navy jocks learned valuable lessons that the Delta winged 106 was almost unconquerable in the dogfight arena, with guns in the air-to-air environment, which you read so little about in the Navy publications. Wing loading of 43 lbs/sq ft and a .8 -1 TWT put it in a class of its own against the A4s, F-104s, F4B,C,D, F-105, F-100, F8 fighters of its time.....not to mention the many many '14s and '15s that blew engines in attempting to fight when it took them above 40,000 feet, to a guns-only environment. Good thing they finally fixed those great fighters to handle the altitudes the 106s formerly ruled.*

"My prejudicial edits in blue to your article on the F-106.

"The F-106 uses a Hughes MA-1 electronic guidance and fire control system. After takeoff, the MA-1 can be given control (ONLY WHEN AND BY THE PILOT SELECTING AUTO) of the aircraft to fly it (EXCEPT THAT THE THROTTLE MUST BE MOVED BY THE PILOT) to the proper altitude and attack position. Then it can fire (BUT ONLY IF THE PILOT SELECTS, ARMAMENT, SELECTS ARM, BREAKS THE SEALS, SEARCHES WITH THE RADAR, FINDS THE TARGET IN ALL WEATHER, USING THE ECCM OR ECCCM OR INFRARED SWITCHES TO ISOLATE THE TARGET, DETERMINES RANGE TO LOCK-ON, LOCKS ONTO THE TARGET, AND AGAIN, MOVES THE THROTTLE TO GET WHERE THE PROPER ALTITUDE IS, THEN...WHO???) Fires the Genie and Falcon missiles, break off the attack run, and return the aircraft to the vicinity of its base HI (Only IF the AIR2A DID NOT SET OFF THE DEAD MAN SWITCH IN THE 3 MEGATON EQUIPPED BEAR/BISON, A TRIP FROM WHICH THE AIRCRAFT WOULD PROBABLY NOT BE ACCEPTED AT THE HOME BASE, WITH A RADIATED-DEAD PILOT IN AN AUTOMATICALLY FLOWN HIGHLY RADIOACTIVE AIRPLANE, TO A BASE THAT WAS PROBABLY A PRIMARY NUDET TARGET...). The pilot takes control again for the landing. (TOO LATE NOW!!! I AM BURNED!)

"The aircraft on display (S/N 58-0787) was involved in an unusual incident. (NOT ALL THAT UNUSUAL FOR "ASS-EYES" TOM CURTIS or "GRINALOT" GARY FOUST,

WHO LOST CONTROL OF THE AIRPLANE DURING AN ACT FLIGHT ABOVE 30,000 FEET). During a training mission from Malmstrom AFB on February 2, 1970, it suddenly (NOT ALL THAT SUDDEN!) entered an uncontrollable flat spin forcing (ACTUALLY ASS-EYES, THE OPS OFFICER, ORDERED HIM) the pilot to eject. Unpiloted, the aircraft recovered on its own, apparently due to the balance and configuration changes (OLD NEWTON LAW SAY: "FOR EVERY ACTION THERE BE EQUAL AND OPPOSITE REACTION --- EJECTION SEAT WITH BIG GRINALOT FOUST SHOT BY ROCKET UP UP UP), caused by the ejection, and miraculously (GARY SAY HE TRY EVERYTHING, THROTTLE IDLE, STICK FORWARD NEUTRAL, TAKEOFF TRIM SET, STILL SEE WORLD GO AROUND AND AROUND, PULL HANDLES, EXIT UP, VERY FAST, AIRPLANE WITH HUGHES, MAGIC MA-1 "CAN FLY BY MYSELF" FLIGHT CONTROL SYSTEM TAKES OVER, NOSE GO DOWN DOWN DOWN) made a gentle belly landing in a snow-covered field near Big Sandy, Montana (HEADLINES NOT IN THE NEWS: BIG SMART, EXPENSIVE HUGHES MA-1 EQUIPPED SMART SYSTEM ***FORGETS TO PUT GEAR DOWN****, LANDS WITHOUT GEAR?) . After minor (minor = AIRCRAFT STRUCTURAL DAMAGE ONLY ENTIRE BELLY, CANOPY, TRAIN TRIP, 6 MONTHS AT MCCLELLAN - NO BIG MONEY CHARGE....MA-1 HUGHES-SMART-FLY-AIRPLANE-WITHOUT-PILOT-SYSTEM-NO-REPAIRS-NEEDED) repairs, the aircraft was returned to service. It last served with the 49th Fighter Interceptor Squadron before being brought (brought = MAYBE THAT MA-1 FLEW IT) to the Museum in August 1986 (BUT WAS IT DEMILLED?).*

*"Just my contribution to add color to the "****history of airplanes without pilots."***

-Dick Stultz, F-106 Pilot (who....."Fired simulated AIR2A in William Tell Competition without Operational MA-1!")

(Author's note: this paper originated as an oral presentation to the pilots of the Finnish Air Force's *Satakunta Air Wing*, 19 June 1995, made in the course of a visit to that organisation as a guest of the Finnish Defense Research Establishment. It was also prepared in a written and illustrated format for distribution to Finnish Air Force personnel at that time and has been updated slightly to reflect the final disposition of US Air Force Convair F-106 aircraft at the end of their long term of service as front-line interceptor aircraft. Illustration/diagramatic drawings courtesy of Detail & Scale Publications; artist: Mendenhall).

(Photographs of the Convair XP-92 concept proposal mock-up, courtesy of Convair Division, General Dynamics Corp).

[For a history of ex-5th FIS F-106A 59-0010, currently destined for the McClellan Aviation Museum collection, dial up the following link: F-106A 59-0010--ex 5th FIS & Project Eclipse aircraft.]

(return to AEOLUS AEROSPACE home page)

For another excellent history of the Convair F-106 Delta Dart, authored by aviation historian Joe Baugher, please refer to the following URL: http://www.fighter-planes.com/info/f106.htm