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FINAL TECHNICAL REPORT

ON A

STUDY TO VALIDATE THE INTEGRATION OF ADVANCED ENERGY-MANEUVERABILITY THEORY WITH TRADEOFF ANALYSIS

(TITLE UNCLASSIFIED)

Contract F33615-71-C-1564 NEW

Project No. B101

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Convair Aerospace Division
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CONTRACT NO. F33615-71-C-1564
PROJECT NO. B101

JAN 25 1972

Prepared for

Deputy for Development Planning
Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

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GENERAL DYNAMICS
CONVAIR AEROSPACE DIVISION

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FOREWORD

This document is the final technical report on a four-month conceptual design and analysis study of several day-fighter aircraft configurations (F33615-71-C-1564, Project B101). The study was performed by the Convair Aerospace Division of General Dynamics and sponsored by the Deputy for Development Planning (ASD/XRL), Wright-Patterson Air Force Base, Ohio. The contract study covered the period 15 April to 15 August 1971. Mr. Howard K. Gerritzen (ASD/XRL) was the Program Manager. The General Dynamics Project Engineer was Mr. H. J. Hillaker; the Program Study Leader was Mr. D. Lobrecht.

The objectives of the four-month study were (1) to define day-fighter configurations that represent an optimum combination of air-to-air capability (performance and handling qualities) and weight, and (2) to generate data that will permit credible performance tradeoffs and cost analyses to be conducted by the Air Force.

Data presented in the Convair Mid-Term R&D Contract Status Report (FZM-5726, dated 25 June 1971) are included in this final report. The report is submitted in fulfillment of the requirements of Contract Item 0002 in accordance with Exhibit A (DD Form 1423) to the subject contract as specified by Sequence Number A002.

This report contains no classified information extracted from other classified documents, with the exception of F100-PW-100 engine data resulting from the P&WA F-14B/F1-5 engine contract (F33657-70-C-0600). These data are Confidential, Group 4, and carry the NOFORN classification.

UNCLASSIFIED ABSTRACT

A number of air-superiority day-fighter concepts are synthesized so that low unit cost and high transonic maneuverability are paramount. The basic approach used to maximize fighting qualities while minimizing size and cost was to employ only minimum or mission-essential equipment and to optimize only on those capabilities that contribute directly and demonstratably to the visual air-to-air combat environment. The primary configuration tradeoff issues addressed are (1) single-engine versus twin-engine concepts, (2) aircraft size versus performance, and (3) effects of recent technology advancements in aerodynamic design and structural materials. Study results show that visual air-to-air day fighters utilizing current technology can be developed to have superior maneuvering performance, with adequate range and combat fuel allowance, at gross weights less than one-half that of current air-superiority fighters. Single-engine concepts provide greater maneuverability and 5000-pound lower gross weights than twin-engine concepts, when using presently identified engines. The use of smaller engines in the single-engine concepts to further reduce aircraft size results in prohibitive reductions in maneuverability or insufficient mission range. Composite materials can be utilized to increase combat maneuverability significantly. As an example, if it is desired to utilize all of the benefits of composites to increase turning capability (within constraints of equal acceleration capability and equal mission radius), airplane sustained turn rates can be increased over an aluminum airplane by 12 percent with a composite wing and 36 percent with maximum composite usage. Supercritical airfoils used on fixed-wing supersonic aircraft can be utilized to improve transonic capability but at the expense of supersonic capability.

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SECTION 1

INTRODUCTION

(U) The purpose of this study is to define a number of baseline air-superiority day-fighter concepts that are synthesized so that low unit cost and high transonic maneuverability are paramount. Thus, the trend toward achieving high unit effectiveness through sophistication and attendant high unit cost that results in reductions in force levels will be reversed, and the basic need for larger numbers of aircraft with high unit effectiveness will be fulfilled. The basic approach used to maximize fighting qualities, while minimizing size and cost, was to use only minimum or mission-essential equipment and to optimize the design only for those capabilities that contribute directly and demonstratably to the visual air-to-air combat environment. The weight saving from this approach allows a tradeoff for more optimum wing loading and a significant increase in thrust/weight ratio. It is this use of design discipline and emphasis on simplicity that provide the greatest achievements in superior maneuvering performance, higher reliability, reduced maintenance, increased utilization rate, and lower procurement and operating costs.

(U) The principal issue addressed is whether a lightweight fighter can have superior maneuvering performance and still have adequate range and combat fuel allowance. If it can, at less than one-half the weight of current air superiority fighters, it must then be determined whether it can be built for one-half the cost or less. The primary configuration tradeoff issues studied to assess these issues are: (1) single-engine versus twin-engine concepts, (2) aircraft size versus performance capability, and (3) recent technology advancements in aerodynamic design and structural materials versus conventional technology and materials.

1.1 STUDY TASKS

(U) Three different aircraft concepts were designed around two different engines: Concept 1, a single-engine aircraft using the high-thrust F100-PW-100 engine (see Section 3); Concept 2, a single-engine aircraft using a smaller, J101-GE-100 engine (see Section 4); and Concept 3, a twin-engine aircraft using the J101-GE-100 engines (see Section 5).

~~(S)~~ [One aircraft version of the larger, single-engine concept (Concept 1) was designed with a specified wing geometry: wing loading of 60 psf, aspect ratio of 3.0, taper ratio of 0.4, thickness/chord ratio of 4 percent, fixed leading-edge sweep of 35 degrees, straight leading and trailing edges, and manually selectable single-hinge leading-edge high-lift devices (see Section 6). The selected wing used on the Concept 1, 2, and 3 designs is the same except that the taper ratio is .20 and the wing leading edge is faired inboard and rounded at the tips.]

(U) In addition, two new technology developments were evaluated on Concept 1 to identify the potential of application to this type of aircraft. The new developments are advanced transonic aerodynamics (supercritical wing design) and advanced composite materials, which can be utilized to provide a smaller aircraft or significantly enhance transonic maneuverability by allowing greater freedom in optimizing the aerodynamic design. The supercritical wing study is presented in Section 7 and the composite material study in Section 8.

(U) Also, an inlet trade study was accomplished to determine the impact and implications of other fixed- and variable-inlet types for comparison with the basic normal shock inlet (see Section 9).

(U) Other tradeoffs (wing geometry, tail hook, self-sealing fuel tanks, structural criteria, and mission rules) were also conducted during the course of the study. These are presented in Section 10.

1.2 AIRCRAFT DESIGN OBJECTIVES

(U) Certain specific aspects of an aircraft cannot be compromised if a truly superior fighter is to be achieved. The design ground rules, constraints, and performance objectives used in the study are identified below.

1.2.1 Performance

~~(S)~~ Two combat missions, short range and long range, were used for sizing the aircraft. On both missions, the outbound and return legs are optimum speed and altitude, with combat [at 30,000 feet consisting of one acceleration from Mach 0.9 to 1.5, two 360-degree turns at Mach 1.2, and

~~(S)~~ three 360-degree turns at Mach 0.8. (Specific mission rules are presented in Section 3.2.) For the Short-Range Air-Superiority Mission (SRASM), the desired radius of action is not less than 225 n.mi, using internal fuel only. For the Long-Range Air-Superiority Mission (LRASM) the desired radius of action is 750 n.mi, using external fuel for all fuel requirements prior to combat so that combat starts with full internal fuel. A non-refueled ferry range of 2600 n.mi is desired, using external fuel tanks (retained).

(U) Maneuvering performance (energy rate and turn rate) is the essential prerequisite for success in visual air-to-air engagements. Used in defense, it allows the aircraft to counter enemy missile and gun attacks. In offense, it is the means for achieving successful missile or gun-firing position. No predetermined maneuverability goals were specified for the study; however, the objective of the study was to determine the maximum maneuverability that the technology can provide within the constraints of the design problem.

~~(S)~~ No compromises are made for speeds outside the projected air combat arena (Mach 0.6 to 1.6). The placard speed is Mach 1.2 at sea level (no overspeed criteria). Maximum speed at altitude is the maximum attainable with fixed-geometry inlets and with no maneuvering, stability, and tracking qualities required of flight above Mach 1.6.

(U) Special attention has been given to configuration design features that will provide excellent handling qualities, i.e., controllability at all aircraft angles of attack and rotational rates, good tracking qualities, high response rates, no pitch-up characteristics, no post-stall departure, no adverse yaw up to stall, and controllability in stall.

1.2.2 Armament

~~(S)~~ One of the essential features that contributes to fighter excellence is credible, lethal ordnance. The armament consists of guns and usable, reliable, low-cost missiles. Although an improved gun is necessary, this study is based on two 20-mm M-39 guns with 500 rounds of ammunition for weight and space allocations. The aircraft are configured to carry up to four AIM-9X missiles. The design missions are quoted for two AIM-9X missiles onboard, which are considered expended at the end of combat.

(S) In addition to the missile hardpoints, there are three hard points for bomb or fuel-tank carriage. The outboard cruise leg of the Long Range Air Superiority Mission requires two external fuel tanks (300 or 450 gallons depending on the design). For Ferry missions the configurations are capable of carrying two 600-gallon fuel tanks and one 150-gallon centerline tank. FRD [redacted] FRD

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FOIA (b)(1)(b)(3) and 50
USC Section 403,
E.O.13526 SEC. 3.3(b)(2),
(b)(4)
1.4(a)(g)(h)

1.2.3 Crew Station and Escape System

(U) One of the basic requirements of a superior fighter is outstanding visibility. Vision constraints for design are 15 degrees over the nose, 195 degrees vertical, full 360 degrees horizontal, and 40 degrees over the shoulder with minimum restrictions due to seats, ducts, bowframes, wing, etc.

The seat should be optimized for simplicity, low weight, and high visibility. The YANKEE 705 seat is used in this study. The HIAD cockpit does not apply, and the cockpit can be narrower than that described in HIAD. There are no requirements for pressure suits or powered canopy.

1.2.4 Propulsion

(U) Only presently identified engines that have undergone full-scale demonstration, or alternate derivatives utilizing the basic core engines, are considered. The basic single-engine concept is designed around the F100-PW-100 engine, and the twin-engine concept is designed around two smaller J101-GE-100 engines. The tradeoff of size versus performance is accomplished by designing a small single-engine concept around the J101-GE-100 engine for comparison to the larger single-engine concept.

(U) All aircraft designs have fixed, normal-shock inlets; however, trade studies are presented on the effect of other fixed- and variable-geometry inlets.

88th ABW/IPI
FOIA (b)(1)
E.O.13526 SEC. 3.3(b)
(4)
1.4(a)(g)

1.2.5 Structures and Materials

(S) The aircraft are designed for a limit load factor of 6.5g at 80 percent internal fuel weight with two AIM-9X missiles and full ammunition (without external fuel tanks). The limit load factor with external tanks is 3.5g.

(U) The aircraft and landing gear are designed to accept a maximum of 10 fps rate of sink at 40 percent internal fuel, no external stores, and gun empty. No requirement exists for nose wheel steering or special soft-field landing capability.

~~(S)~~ [The placard structural and flutter limit is Mach 1.2 at sea level (full maneuver capability). No overspeed criteria is required. No maneuvering capabilities are required for flight above Mach 1.6. Safe level flight is possible beyond Mach 1.6 up to the maximum-speed thrust limit.]

(U) Conventional aluminum construction is used on the basic designs. A trade study of composite material usage is presented.

(U) There are no requirements for foam or self-sealing fuel tanks in the wings. Fuselage fuel tanks are self-sealing. There are three hard points for external fuel tanks. Inflight refueling capability is provided.

1.2.6 Avionics

~~(S)~~ Only mission-essential avionic equipment needed for a visual day fighter is provided. Items that may be potentially attractive but that have substantial development risks are left for retrofit or growth versions. It is assumed that any functions pilots perform in combat today without strain need not be automated. The avionics equipment for the purposes of this study comprises (1) a fire control system consisting of a snap-shoot gunsight, range-only radar, simplified armament panel, 20-mm gun, and AIM-9X missile provisions; (2) a navigation system consisting of an inertial 3-mph system (lightweight, low-cost, LN-30 type system), TACAN, and ILS (no autopilot requirement); (3) a communication system consisting of a primary UHF radio with direction finding, a back-up UHF radio, and an air-to-ground IFF; and (4) an APR-36 radar warning system and an APX-72 identification system.

SECTION 2

SUMMARY

(U) The specific results of this study show that visual air-to-air day fighters at weights less than one-half of current air-superiority fighters can be developed to have superior maneuvering performance and adequate mission range and combat fuel allowance without the use of advanced technologies. It is the mission-essential/combat-relevant/design-discipline approach to the concept that provides the superior maneuverability necessary to win air battles against future threats. The nature of the concept -- small size and simplicity -- will ensure low procurement and operating costs. Each of the many requirements that could be added to the concept (e.g., sophisticated inlets for better high-Mach capability, higher structural load factor, self-sealing fuel tanks, tail hooks, speed brakes, autopilot, nose wheel steering, etc.) does not by itself add a significant penalty to the aircraft to perform the design mission or markedly reduce its maeuverability; however, taken collectively, they destroy the feasibility of providing a truly superior maneuvering fighter and increase the procurement and operating costs. The greatest achievements are attained by excluding each design criterion and specification that does not contribute directly to winning the air-to-air engagement through superior maneuverability in the primary air battle arena.

(U) A brief summary of each configuration concept and trade study is presented in the following subsections.

2.1 LARGE SINGLE-ENGINE CONCEPT (401B/F100-PW-100)

~~(S)~~ The 401B aircraft (Concept 1) is a single-place, single-engine, fixed-wing design concept utilizing the F100-PW-100 engine and a blended lifting-body configuration (Figures 2.1-1 and 2.1-2). The primary distinguishing features of Configuration 401B are (1) wing/body blending for lift at high angles of attack, and cross-sectional area shaping; (2) mid-wing with thickened wing root; (3) forward engine location with aft fuselage extensions to obtain a balanced airplane with reasonable tail arms; (4) twin vertical tails; (5) bottom, aft normal-shock-inlet location; and (6) bubble canopy.

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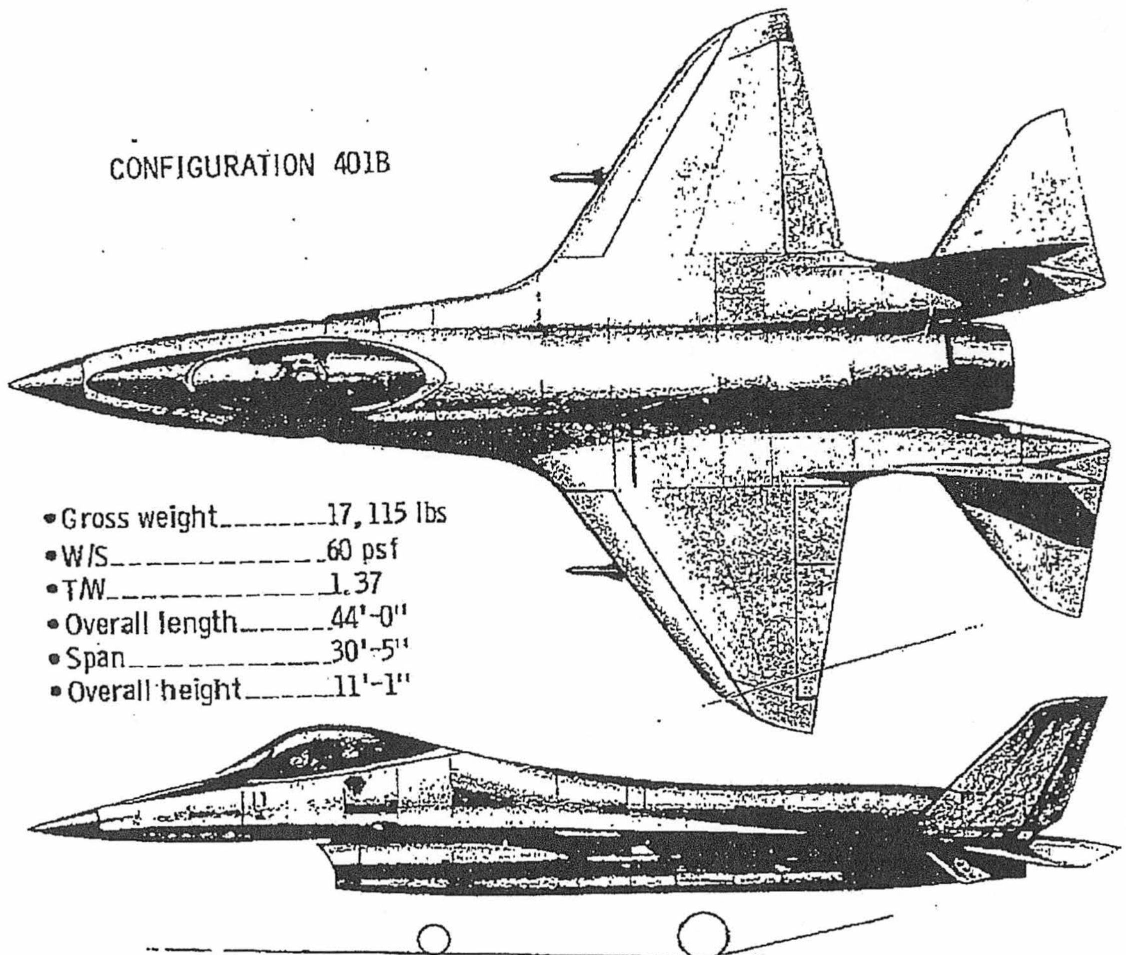

~~(S)~~ Figure 2.1-1 Single-Engine 401B, Top and Side Views (U)

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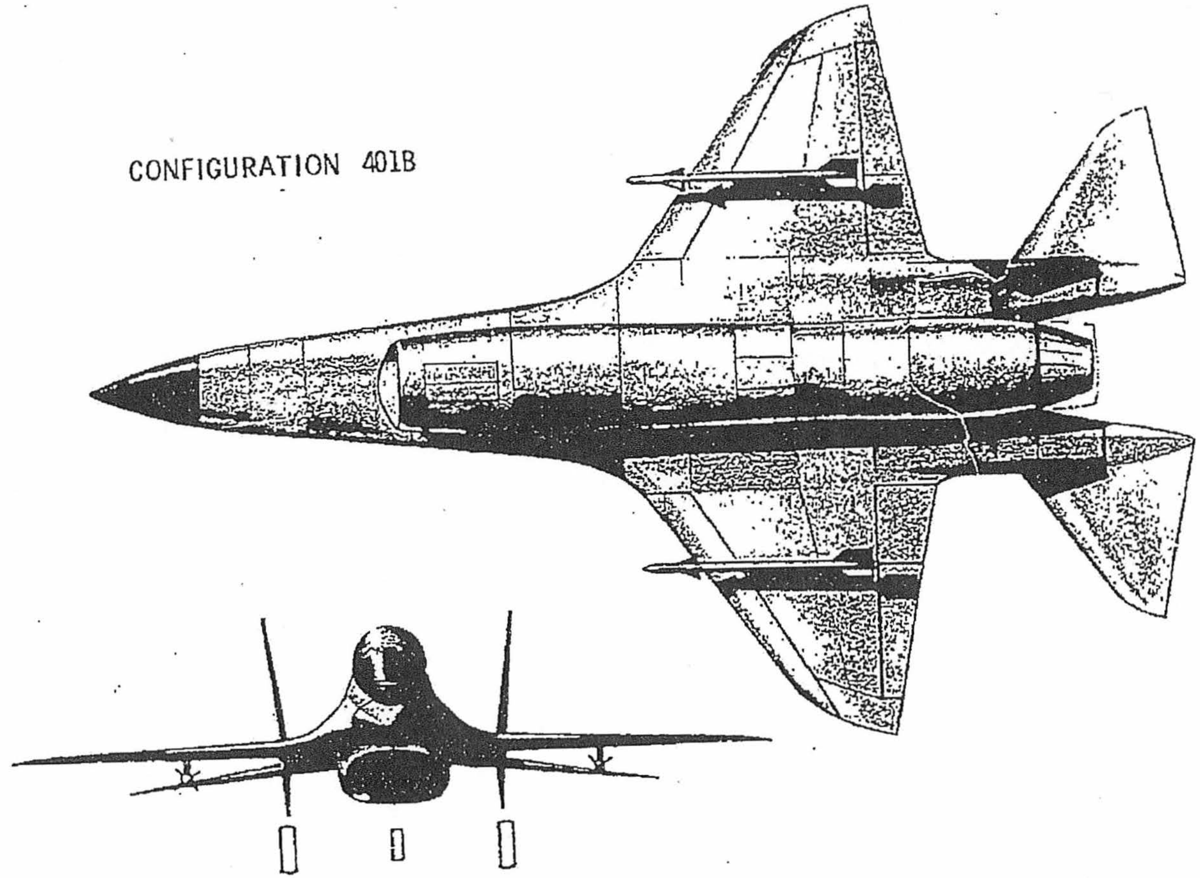

~~(S)~~ Figure 2.1-2 Single-Engine 401B, Bottom and Front Views (U)

~~(S)~~ Gross weight (full-up internal fuel plus mission payload) of the initial design is 16,800 lb. Growth data for aircraft weights of 15,600 lb to 18,000 lb, holding constant wing loading and engine size, were obtained for final sizing of the aircraft. The 23,470-lb rated thrust of the engine provides a thrust/weight ratio spread of 1.5 to 1.3 for the growth curve. The aircraft, when sized to perform the Long-Range Air-Superiority Mission (750 n.mi) and designed with sufficient overload capability to meet the ferry range (2600 n.mi), requires a gross weight of 17,115 lb, which results in a thrust/weight ratio of 1.37. The LRASM requires two 300-gal external fuel tanks for the outbound portion of the mission. The Short-Range Air-Superiority Mission capability, which is performed without external fuel tanks, has a radius of 239 n.mi. The ferry mission requires the use of two 600-gal. fuel tanks and one 150-gal. tank to achieve the desired 2600-n.mi range with tanks retained.

~~(S)~~ If the aircraft were sized for the LRASM only, without the additional overload penalties associated with the ferry objective, the gross weight would be approximately 16,800 lb, with a corresponding thrust/weight ratio of 1.4. Summary mission capabilities of the 17,115-lb version are tabulated below. Detailed design data and rationale, and performance, aerodynamics, handling qualities, weight, and propulsion data are presented in Section 3.

401B MISSION SUMMARY
(17,115-lb A/P)

Mission	Range (n.mi)	Radius (n.mi)	$\dot{\theta}_{M.8}$ (deg/sec)	$\dot{\theta}_{M1.2}$ (deg/sec)	Accel. Time (sec)
LRASM	-	750	9.8	8.1	35.5
SRASM	-	239	10.9	9.1	32.4
Ferry	2614	-	-	-	-

Silhouettes of the 17,115-lb version of 401B are superimposed on equal-scale outlines of the F-4 and MIG-21 aircraft in Figures 2.1-3 and 2.1-4 to show relative sizes.

2.2 SMALL SINGLE-ENGINE CONCEPT (403/J101-GE-100)

~~(S)~~ The 403 aircraft (Concept 2) utilizes the same configuration concept as the 401B except that it is designed around